Air Handling System Control Applications

SECTION OF ENGINEERING MANUAL OF AUTOMATIC CONTROL 77-1100

Contents

INTRODUCTION

This section describes control applications for air handling systems commonly found in commercial buildings. The basic processes such as heating, cooling, humidification, dehumidification, and ventilation are presented individually then combined into typical air handling systems. A discussion covering requirements for effective control is also included to provide guidelines for the design of the actual air handling systems with the related controls. Examples are based upon digital control systems. These digital control strategies may not be practical with other forms of control, and may not be possible with all digital controllers or by all digital controller programmers.

Also throughout the section, dashed lines indicate interlocked links and solid lines functional relationships between control items.

Psychrometric aspects are included for most applications. They are shown in abbreviated form. Unabridged copies of ASHRAE Psychrometric Charts No. 1 and No. 2 are included at the end of this section for reference. For further understanding of the basics of psychrometric charts refer to the Psychrometric Chart Fundamentals section.

For additional detailed information on air handling systems, refer to the ASHRAE 1996 HVAC Systems and Equipment Handbook.

ABBREVIATIONS

The following abbreviations are used throughout this section in the text and drawings. Refer to Definitions in the Control Fundamentals section and the Psychrometric Chart Fundamentals section for further details.

AHU — Air Handling Unit
BCMS — Building Control Management System
cfm — Cubic feet per minute
DB — Dry Bulb
DDC — Direct Digital Control
DP — Dew Point
EA — Exhaust Air
EPID — Enhanced PID
F — Fahrenheit
IAQ — Indoor Air Quality
MA — Mixed Air
MAT — Mixed Air Temperature
N.C.[1] — Normally Closed
N.O.[2] — Normally Open
OA — Outdoor Air
OAT — Outdoor Air Temperature
P — Proportional
PI — Proportional-Integral
PID — Proportional-Integral-Derivative
RA — Return Air
RAT — Return Air Temperature
RH — Relative Humidity
SA — Supply Air
VAV — Variable Air Volume
WB — Wet Bulb

1 Applies to valves and dampers that are actuated to fail in the closed position in the event of loss of motive force.
2 Applies to valves and dampers that are actuated to fail in the open position in the event of loss of motive force.

REQUIREMENTS FOR EFFECTIVE CONTROL

Effective control system performance requires careful design of the mechanical system and selection of components. Consideration needs to be given to the following by the mechanical system designer and the control engineer:

1. PROPERLY DESIGN DISTRIBUTION SYSTEM TO DELIVER AIR TO THE SPACE.
   a. Extend ductwork to all parts of the space.
   b. Insulate ductwork if it runs through a space where the temperature is considerably different from that of the air within the duct or if the space dew point is likely to be above the supply air temperature.
   c. Locate outlets only where the air in the duct is well mixed.
   d. Locate RA grilles where they will aid in distribution and eliminate short circuiting of the supply air.

2. PROPERLY SELECT DIFFUSERS AT OUTLETS TO THE SPACE.
   a. Do not have low ceiling diffusers blow directly downward.
   b. Use several small diffusers rather than one large one.

3. PROPERLY SIZE AND SELECT HEATING COILS.
   a. Size coils to meet their maximum loads. Avoid oversized coils for best control.
   b. Use multiple inline coils where the required temperature rise is high.
   c. Select coils for even distribution of the heating medium at light loads to prevent surface temperature gradients and accompanying stratification.
   d. Furnish preheat coils with a maximum temperature rise of 30 to 35 degrees.
   e. Provided multiple low-temperature controls to protect large coils. Provide one for every twenty square feet of coil face area with the element location favoring where cold air is more likely to be.

4. PROPERLY SIZE AND SELECT COOLING AND REFRIGERATION EQUIPMENT.
   a. Consider dividing the cooling capacity among several coils.
   b. Consider some form of reheat if dehumidification is required.
   c. Prevent short cycling of compressors under light load by:
      1) Installing multiple compressors where large capacity sequencing is needed.
      2) Providing means of loading and unloading a compressor under light load.
      3) Sizing the refrigeration equipment accurately.
      4) Providing minimum on and off time delays.
      5) Providing a hot gas bypass.

5. CONSIDER SEPARATE MECHANICAL SYSTEMS FOR AREAS IF THEIR HEATING OR COOLING LOADS DIFFER GREATLY FROM THE OTHER AREAS.

6. ELIMINATE STRATIFICATION IN THE DUCTS.
   a. Use mixing chambers or other mechanical devices where mixing is critical.
   b. Use the system fan to mix the air. A single inlet fan mixes air more effectively than a double inlet fan.
   c. Arrange steam coils so that the supply header is on the longest dimension if possible.

   NOTE: No one of these methods provides a complete answer to the stratification problem. They should be used in combination where needed.

7. PROVIDE PHYSICAL ARRANGEMENT OF SYSTEM COMPONENTS TO PERMIT SUITABLE LOCATION OF SENSING ELEMENTS.
   a. Furnish sufficient spacing between coils to permit installation of sensing elements.
   b. Provide ductwork downstream from a coil or other components to allow placement of the sensing element in an unstratified mixture of exiting air.

8. PROPERLY LOCATE THE SENSING ELEMENT.
   a. Locate sensing elements where they will measure the variables they are intended to control.
   b. Locate space sensing elements on an interior wall where they can measure a condition representative of the whole space.

   NOTE: Space sensing elements can sometimes be located in the RA duct as close to the space as possible if another suitable location cannot be found.

   c. Locate duct sensing elements in an unstratified air mixture.
   d. Locate air pressure and flow pick-up elements away from immediate fan discharges and provide with capacity tanks where necessary to eliminate surges and pulsations.

e. Locate humidifier leaving air humidity sensors no less than eight and no more than thirty feet downstream of the humidifier.

9. CONSIDER THE PHYSICAL ARRANGEMENT OF HUMIDITY SYSTEM COMPONENTS.
   a. Locate humidifiers downstream from a source of heat.
   b. Locate reheat coils downstream from cooling coils.
   c. Provide unlined ductwork downstream of humidifiers, and straight for a minimum of ten feet.

10. PROPERLY SIZE AND SELECT THE CONTROL VALVES.
   a. Do not oversize modulating control valves. Refer to the Valve Selection and Sizing section.
   b. Select control valves that position properly upon HVAC shutdown and upon loss of motive force. (Refer to Table 1.)

11. PROVIDE THE AIR HANDLING SYSTEM WITH LOW TEMPERATURE PROTECTION WHERE FREEZING TEMPERATURES ARE POSSIBLE.
   a. For steam coils, give consideration to:
      1) Providing vertical tubes.
      2) Pitching coils properly to the trap.
      3) Providing vacuum breakers.
      4) Providing traps of proper type, size, and location.
      5) Providing adequate drip and cooling legs.
      6) Locating steam valve at high point.
      7) Providing face and bypass type coils.
   b. For hot and chilled water coils, give consideration to:
      1) Providing coil pumps to assure flow through coils during periods of subfreezing temperature.
      2) Using antifreeze solutions.
      3) Operating all water pumps when OA is below 35°F.
      4) Draining idle coils and lines.
   c. For control applications, give consideration to:
      1) Providing low temperature limit controllers for all systems to enable one or a combination of the following:

         NOTE: Ensure that temperature sensing elements are exposed to coldest portion of airstream.

         a) Opening valves to provide full flow to coils.
         b) Starting pumps.
         c) Closing OA dampers.
         d) Starting fan to circulate RA.
         e) Stopping fan if 100 percent OA system.
         f) Initiating low temperature alarms.
         g) Stopping fan if steam is not present.
      2) Providing failure alarms for pump, coils, and other heating systems components.

12. ALLOW AIR HANDLING AND CONTROL SYSTEM DESIGN TO PROVIDE ENERGY CONSERVATION.
   a. Use space sensors, rather than OA sensors, to determine reset schedules. For example, use the damper signal from space PI control loops to reset multizone unit hot and cold deck temperature controller setpoints.
   b. Do not permit air handlers to introduce OA to a building area which is unoccupied or during the warm-up period unless required for night purge or IAQ.
   c. Use PID control where elimination of control offset conserves energy or increases comfort.

13. PROVIDE HVAC VENTILATION SEQUENCES THAT COMPLY WITH CURRENT IAQ CODES AND STANDARDS.

14. NETWORK DIGITAL CONTROLS FOR BUILDING-WIDE ENERGY AND COST PERFORMANCE.
   a. Share points such as OA temperature among controllers.
   b. Have chiller strategies address fan system demands.
   c. Have pumping system strategies address control valve demands.
   d. Have fan system strategies address space terminal unit demands.

15. SEE THAT CONTROL SYSTEM DESIGNERS FULLY UNDERSTAND THE COMPLETE BUILDING HVAC SYSTEM.

   Refer to HVAC system components manufacturers recommendations for application requirements and guidelines.

16. HARD-WIRE SAFETIES IF HAND-OFF-AUTO SWITCHES ARE PROVIDED
   a. Hard-wire all temperature low limit, fire, and pressure safeties if the system can be easily operated manually. In cases where a PC operator monitoring station is provided, the safeties are also usually monitored by the local digital controller.
   b. If override switches are not provided, and system operation is always dependent upon the digital control system, safeties may be wired to the digital controller for control and monitoring, thus saving duplicate wiring.
   c. The real value of the safeties is achieved by proper mounting, testing, and maintenance of such devices.

17. PLACE CONTROL VALVES ON THE LEAVING SIDE OF WATER COILS.

    Control valves on the leaving side of water coils leaves pressure in the coil when the valve is closed, thus aiding in eliminating air through the air vent on the leaving side of the coil, and also prevents the possibility of air being induced into the system through the vent if the pump produces a negative pressure in the coil return line.

18. CONSIDER THE ABILITY OF THE HVAC SYSTEM OPERATOR TO UNDERSTAND THE SYSTEM WHEN DESIGNING GRAPHICS FOR THE OPERATOR INTERFACE.

APPLICATIONS-GENERAL

The following applications are presented in a DDC format using notation from the Symbols in this section. In some cases the degree and complexity of control shown is not practical in other forms of control.

Suggested microprocessor data points are shown as they could appear on a color graphic display of a PC operator workstation. In some cases data points, other than those required for control and operation, are shown to help an operator understand the loading and performance of the HVAC system and related control loops. If a PC station is not required, the data points required for control and operation should still be specified for the operator by listing the points or including a graphic sketch.

Values, setpoints, gains, timings, etc. shown in these examples are general, and actual values should be determined on a project-to-project basis.

The following applications were selected for this section on Air Handling System Control Applications. Caution should be used in simply combining any of these applications together as a control solution for a more complex system. Application variations may be required depending on the heating, cooling, and pumping configurations, the building use and occupants, the ability of control vendors and related control systems, the ability of local operating and maintenance persons, codes, and weather.

Lines connecting inputs, outputs, values, and control functions have been added to aid in understanding. In many cases these lines would create unacceptable clutter on an actual system graphic display. Graphic display and management function (alarms, records, etc.) concepts are discussed further in the Building Management System Fundamentals section.

Although the control solutions presented are good general recommendations, other solutions are acceptable, and in some cases, may better depending on the job objectives.

VALVE AND DAMPER SELECTION

Pneumatic valve and damper actuators are shown in these examples. If actuators are electric, certain ones need not be spring return unless a specific reason exists. Table 1 outlines general actuator selection. The table indicates actuator positioning desired on system shutdown and loss of motive force.

Table 1. Valve and Damper Actuator Selection Guide.

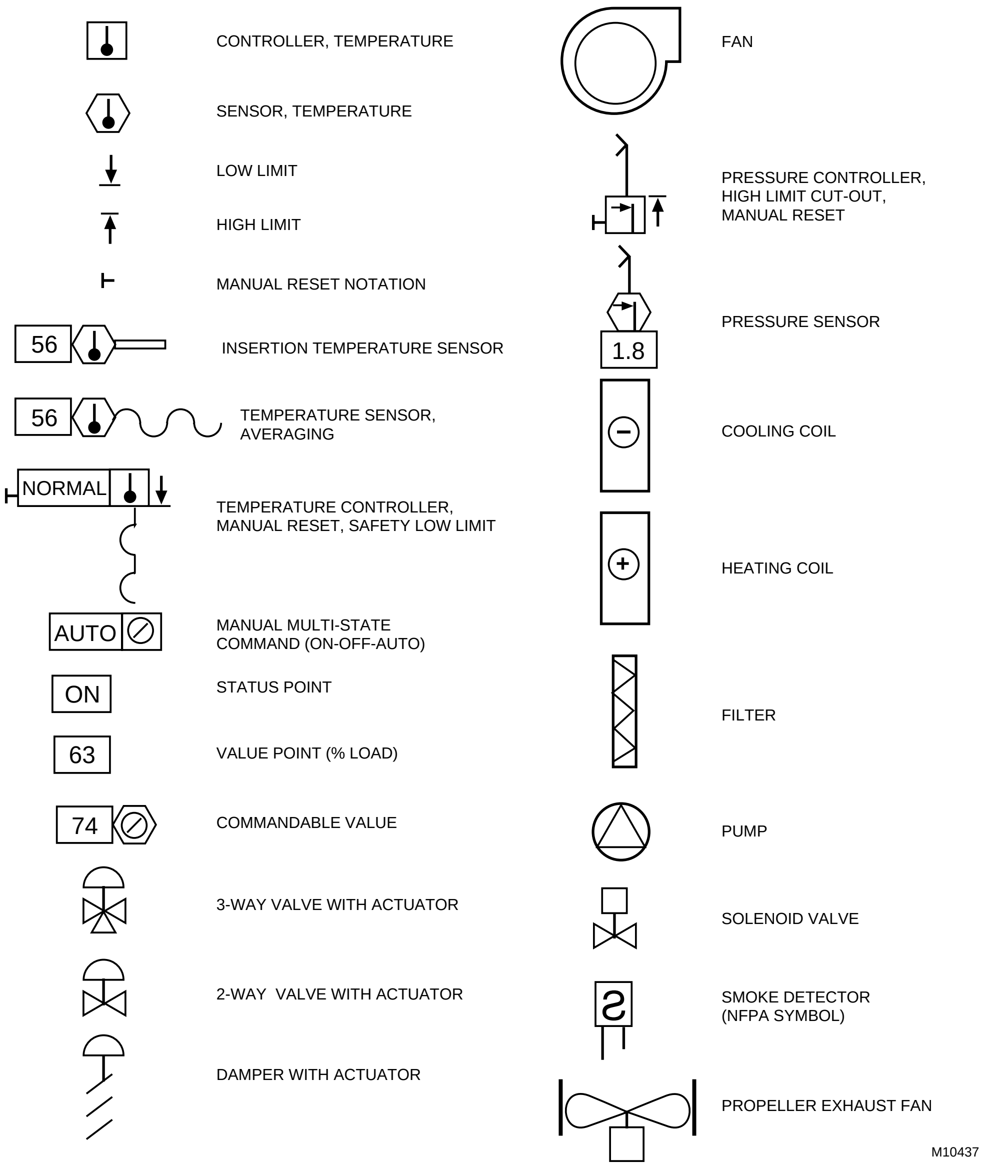
<table>
<tr><th rowspan="2">Actuator Application</th><th colspan="2">Pneumatic Actuators</th><th colspan="2">Electric Actuators</th></tr>
<tr><th>System Shutdown</th><th>Loss of Air</th><th>System Shutdown</th><th>Loss of Electricity</th></tr>
<tr><td colspan="5">Dampers</td></tr>
<tr><td>Outdoor air</td><td rowspan="2">Closes</td><td rowspan="2">Closes</td><td rowspan="2">Closes</td><td rowspan="2">Closes</td></tr>
<tr><td>Relief air (to outdoor)</td></tr>
<tr><td>Return air</td><td>Opens</td><td>Opens</td><td>Opens</td><td>Opens[1]</td></tr>
<tr><td>VAV fan inlet vanes</td><td>Closes</td><td>Closes</td><td>Closes</td><td>Closes</td></tr>
<tr><td>VAV box</td><td>Owner Perference</td><td rowspan="2">Opens</td><td>Owner Perference</td><td>Owner Perference</td></tr>
<tr><td>Multizone hot deck, cold areas</td><td>Opens</td><td>Opens</td><td>Opens</td></tr>
<tr><td>Multizone hot deck, hot areas</td><td>Closes</td><td>Closes</td><td>Closes</td><td>Closes</td></tr>
<tr><td colspan="5">Valves</td></tr>
<tr><td>AHU chilled water</td><td rowspan="2">Closes</td><td rowspan="5">Opens</td><td rowspan="2">Closes</td><td rowspan="2">Stays same</td></tr>
<tr><td>Terminal reheat</td></tr>
<tr><td>Preheat in OA below 35F</td><td>Opens[2]</td><td>Opens[2]</td><td rowspan="2">Opens</td></tr>
<tr><td>Preheat in OA above 35F</td><td>Closes</td><td>Closes</td></tr>
<tr><td>Other hot water</td><td rowspan="2">Closes[2]</td><td rowspan="2">Closes[2]</td><td>Stays same</td></tr>
<tr><td>AHU steam heating</td><td rowspan="2">Closes</td><td rowspan="2">Closes</td></tr>
<tr><td>Steam humidifier</td><td>Closes</td><td>Closes</td></tr>
</table>

1 Return air dampers need no springs if the associated fan is delayed upon start-up to allow the RA damper to properly position to assure that the fan does not start with both RA and OA dampers closed.

2 If a duct temperature sensor is located near a hot water or steam coil, leaving the coil under control (with a setpoint of 80°F to 100°F) during equipment shutdown can provide added freeze alarm protection. If variable flow hot water pumping is provided and a duct low temperature control senses freezing conditions, hot water valves may be positioned approximately 25% open if a temperature sensor is not available.

SYMBOLS

The following symbols are used in the system schematics following. These symbols denote the nature of the device, such as a thermometer for temperature sensing.

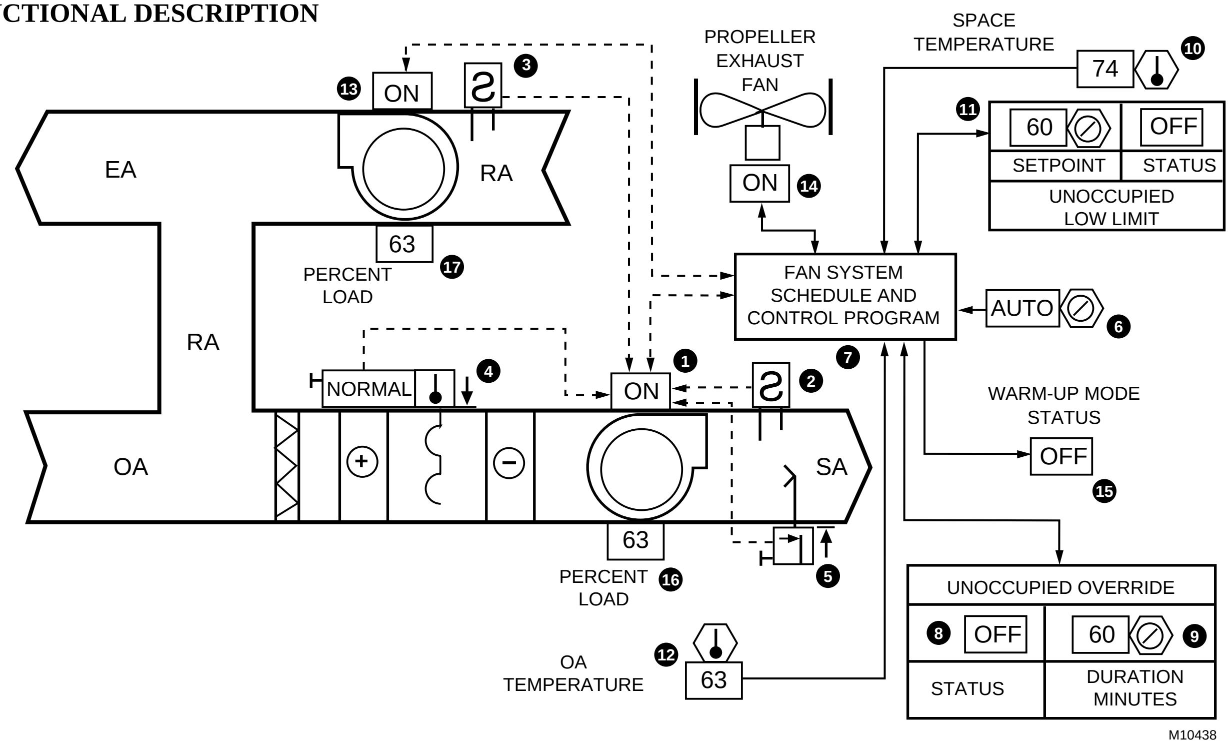


VENTILATION CONTROL PROCESSES

The following applications show various ways of controlling ventilation in an air conditioning system.

FAN SYSTEM START-STOP CONTROL

FUNCTIONAL DESCRIPTION



Item No.	Function
1	Supply fan starts and enables return fan start and system controls.
2	SA smoke detector stops supply fan when smoke detected.
3	RA smoke detector stops supply fan when smoke detected.
4	Controller stops fan when low temperature detected.
5	SA high static pressure control stops fan when unsafe pressure exists.
6	Automatic fan system control subject to commandable ON-OFF-AUTO software point.
7	Control program turns supply, return, and exhaust fan on and off dependent upon optimized time schedule, unoccupied space temperatures, and occupant override requests.
8	Occupant override switch provides after hours operation when pressed.
9	Duration of operation for override request.
10	Space temperature (perimeter zone) inputs to optimum start-stop, unoccupied purge, and low limit programs.
11	Setpoint at which unoccupied low-limit program executes.
12	OA temperature input to optimum start-stop program.
13	Return fan operation enables exhaust fan control program.
14	Exhaust fan status (operator information).
15	Warm-up mode status (operator information).
16	Supply fan load (VAV type systems-operator information).
17	Return fan load (VAV type systems-operator information).

FEATURES

1. Smoke, low temperature, and high static pressure safety shutdown (hard-wired).
2. Optimized start-stop control of supply, return, and exhaust fans.
3. Proof of operation interlocking and alarming on supply and return fans.
4. Software on-off-auto system command.
5. Zero ventilation/exhaust during preoccupancy operational periods.
6. May be modified for night purge and prepurge operation.
7. After-hours operation function; duration is operator adjustable.
8. Positions valves and dampers properly during off modes.
9. Night low temperature operation.
10. See Smoke Management Fundamentals section for smoke control considerations.

CONDITIONS FOR SUCCESSFUL OPERATION

1. See REQUIREMENTS FOR EFFECTIVE CONTROL.
2. Proper hardware and software interlocks with heating, cooling and terminal equipment.
3. To protect the AHU housing and ductwork, the high pressure cutout must be hard-wired and located with a minimum of tubing to prevent delays of operation. Modulating limit control is not recommended since the problem causing the high pressure is rarely a control loop malfunction, but a physical one (smoke damper slamming shut, sensor tubing cut or failed, vane actuator linkage failure, etc.).

LIMITATIONS

1. Heating and cooling equipment must be available to operate.
2. On large 100% OA systems and systems where OA and RA dampers both close upon fan shutdown, dampers should be enabled prior to fan start, and the fan should start only after damper end switches prove dampers are in safe positions.

SPECIFICATIONS

Air handling system shall be under program control, subject to SA and RA smoke detectors, SA high pressure cutout, and heating coil leaving air low-temperature limit control; and shall be subject to system software on-off-auto function.

Supply fan shall be started and stopped by an optimum start-stop seven day time schedule program, an unoccupied low space temperature limit program, or by an occupant via push button request. The push button shall be integral with the space temperature sensor. Any push button request shall provide sixty minutes (operator adjustable) of full system operation.

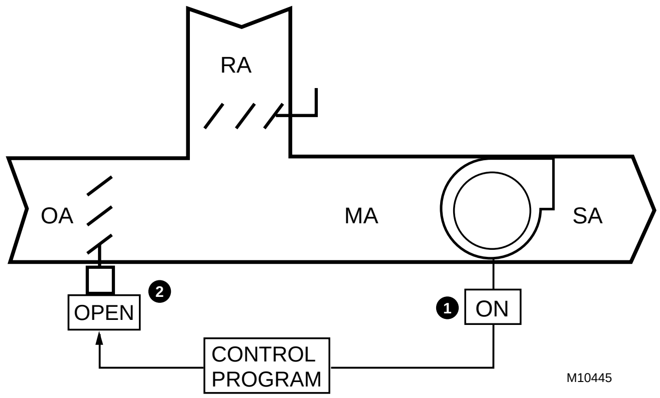
Return fan shall operate anytime the supply fan proves flow (via a current sensing relay).

The exhaust fan shall operate during scheduled occupancy periods and during occupant requested after-hour periods anytime the return fan proves flow.

Heating/cooling plant (based upon fan system demands), temperature, humidity, pressure, and ventilation controls shall be enabled to operate anytime the fan system operates. Unless otherwise specified, during fan off periods, N.O. heating and cooling valves shall position closed, N.C. steam valves shall position closed, N.C. humidifier valves shall position closed, N.C. outdoor and relief dampers shall position closed, and N.O. RA dampers shall position open.

FIXED QUANTITY OF OUTDOOR AIR CONTROL

Functional Description



Item No.	Function
1	Control system energizes when fan is turned on.
2	Damper opens on fan startup, closes on fan shutdown.

FEATURES

1. A fixed quantity of OA is admitted when the fan is operating.
2. This system is composed of a minimum of ventilation and control equipment.

CONDITIONS FOR SUCCESSFUL OPERATION

1. The system provides the desired proportions of OA and RA (a manual RA damper, shown, is usually required).
2. The system is designed so that coils are not subject to freezing.

LIMITATIONS

The MA temperature varies as a function of OA temperature. The equation is:

$$MAT = \frac{OA\ (cfm)}{Total\ (cfm)}(OAT - RAT)$$

or:

$$MAT = (RAT \times \%RA) + (OAT \times \%OA)$$

Example, calculate the mixed air temperature of a 10,000 cfm fan with 25% OA at 5°F. RA is 75°F.

$$MAT = 75 + \frac{2500}{10{,}000}(5 - 75) = 57.5°F$$

or:

$$MAT = (75 \times 0.75) + (5 \times 0.25) = 57.5°F$$

SPECIFICATIONS

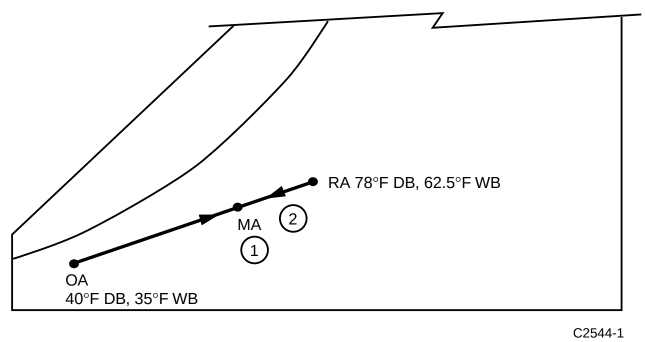
The operation of the OA damper shall be two-position. The OA damper shall open when the fan is on and close when the fan is off.

PSYCHROMETRIC ASPECTS

The proportions of OA and RA admitted are constant at all OA temperatures.

In the following chart it is assumed that:

1. One-third OA and two-thirds RA are admitted.
2. RA condition is 78°F DB and 62.5°F WB.
3. OA condition is 40°F DB and 35°F WB.
4. MAT = (2/3 x 78) + (1/3 x 40) = 65.3°F.

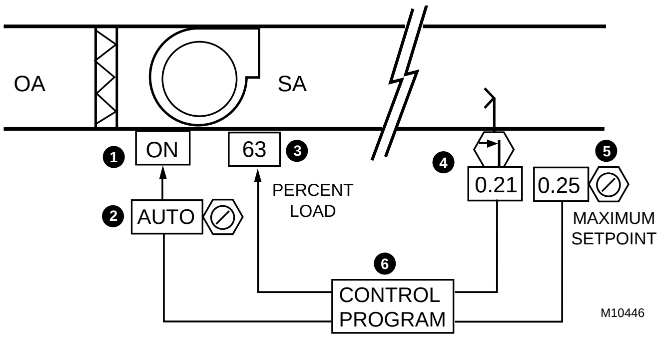


The following results are obtained:

Item No.	Explanation
1	MA condition at 40°F DB OA condition.
2	As OA temperature rises, the MA temperature moves to the right of the initial MA temperature.

OUTDOOR AIR FAN CONTROL FOR MULTIPLE AHU'S

Functional Description



Item No.	Function
1,2	Fan runs under building system control, subject to software on-off-auto function.
3-5	Fan loads to maintain duct static pressure setpoint. Static pressure setpoint varied by AHU OA damper positions to maintain minimum pressure to satisfy all operating AHU fan OA damper positions.
6	Control program coordinates fan start-stop and loading.

FEATURES

1. OA fan provides minimum OA for multiple AHUs, which are usually stacked one above the other in a tall building. Each AHU has a minimum airflow OA damper and airflow station.
2. Duct pressure (and fan loading) optimized to satisfy AHU with greatest demand.
3. Pressure increased during night purge and ventilation prepurge modes to accelerate cycles.
4. OA filter reduces AHU filter burden, reduces OA fan maintenance, reduces air flow station maintenance, and prevents OA airflow from dropping as filter loads.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Control network, software, and programming advises OA fan of AHU damper demands.
2. The system is designed so that coils are not subject to freezing conditions.

SPECIFICATIONS

The OA fan shall start anytime any AHU operates in the occupied, night purge, or prepurge mode, subject to a software on-off-auto function.

The OA fan loading shall be under EPID (see Control Fundamentals section) control with a start value of 25% and a ramp duration of 250 seconds.

NOTE: EPID was selected (and designed specifically) for this type of application because of the start-up nature of VAV fans. The problem is the large PID error signal (the difference between the actual duct pressure and duct pressure setpoint) that exists at the start moment. At startup the duct pressure is zero and the setpoint of the VAV supply fans is usually over one inch of water, at which point the proportional element of PID calls for heavy loading, and the integral element adds to that. Over half the time the real fan start-up load is minimal since the building is not warm and the VAV boxes start at or near their minimum airflow setpoint. It is therefore very predictable that the fan will accelerate rapidly, the duct pressure will rise rapidly (and, with PID, will overshoot), and unsafe conditions may occur.

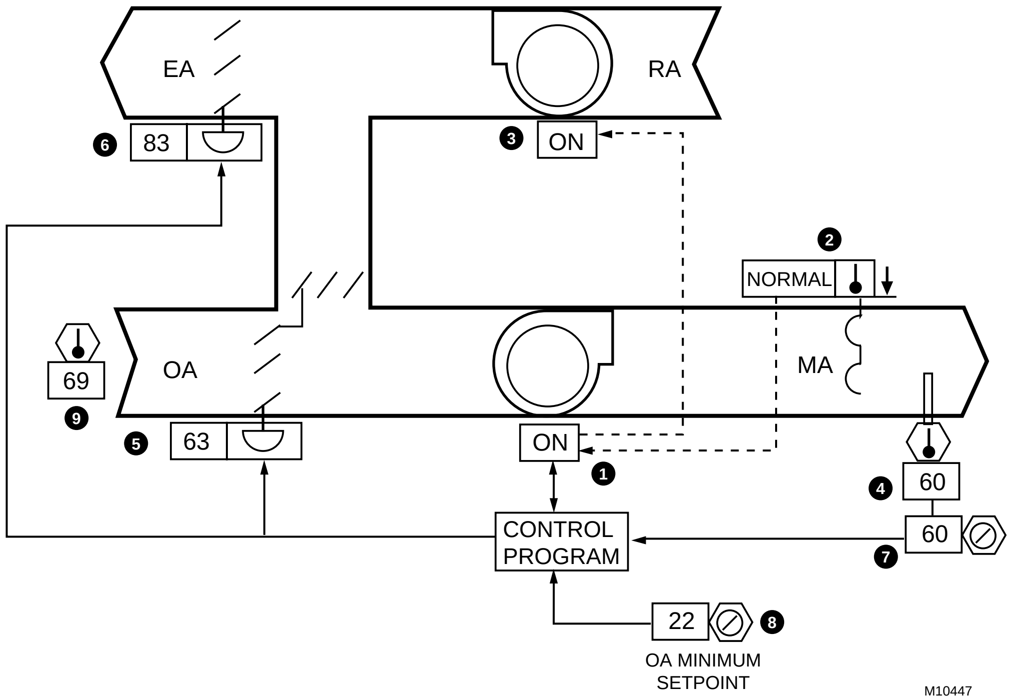
Recognizing this, EPID starts the fan at a minimum loading, senses the error, and ramps the error slowly and linearly into PID control usually over a 30 to 90 second period (adjustable to any value). Thus the fan loads quickly to 20 or 25%, then loads slowly thereafter. As the error is fed into PID, the fan loads to remove the error (and does remove it as it is received), and the setpoint is reached in a very orderly and controlled manner with no overshoot. During startup, EPID control runs the motor at a speed high enough to prevent overheating and to reach a load level to prove operation to any monitoring BMCS; however, the speed is lower than that necessary to meet the VAV boxes minimum airflow demand.

With pneumatic proportional control, branch line restrictors are often placed in the air line to the inlet vane actuator (or to the variable fan drive transducer line) to slow this loading (a check valve can be installed around the restrictor such that unloading is instantaneous). PI control, can have "integral windup", which accumulates during times that a P error is allowed to exist. The integral wind-up raises the P setpoint so the fan starts with full capacity and can overpressure the supply ducts. The restricted branch line allows the branch signal to increase slowly.

Anytime all AHUs operating in the occupied mode have OA dampers less than 80% open, the OA fan duct static pressure setpoint shall be decremented at the rate of 0.1 inches of water every 60 seconds. Anytime any AHU is operating in the occupied mode and the OA damper is full open, the OA fan duct static pressure setpoint shall be incremented at the rate of 0.1 inches of water every 60 seconds up to a maximum value. The decementing and incrementing values shall be verified during commissioning. Anytime any AHU operates in the night purge or prepurge modes, the OA fan duct static pressure setpoint shall be equal to the maximum setpoint.

MIXED AIR CONTROL

Functional Description



Item No.	Function
1-3	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
4	MA temperature maintained by modulating mixing dampers.
5,6	OA and EA dampers close and RA damper opens when fan is off, and modulate for temperature control when fan is on.
7	Setpoint for MA temperature control.
8	Damper control and setpoint for minimum ventilation damper position. NOTE: This is not 22% OA or OA damper open 22%, it is the control program output value necessary to position the OA damper such that the design OA airflow is maintained.
9	OA temperature, operator information.

FEATURES

1. The proper proportions of OA and RA, above minimum OA setting, are admitted to prevent the MA temperature from dropping below the desired MA temperature.
2. A minimum quantity of OA, determined by the setting of the minimum position signal is assured at all times.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Adequate mixing of OA and RA, which may be obtained using a special mixing chamber.
2. The temperature sensor is located where the air is thoroughly mixed. The discharge of the fan in a blow-through system usually provides adequate mixing.

LIMITATIONS

1. If the manual positioning value is set to admit a large quantity of OA, and the OA temperature falls below the temperature at which MA temperature controls require only minimum OA, a source of heat may be necessary to maintain the MA temperature.
2. During periods of high OA temperature, 100% OA may be undesirable.

SPECIFICATIONS

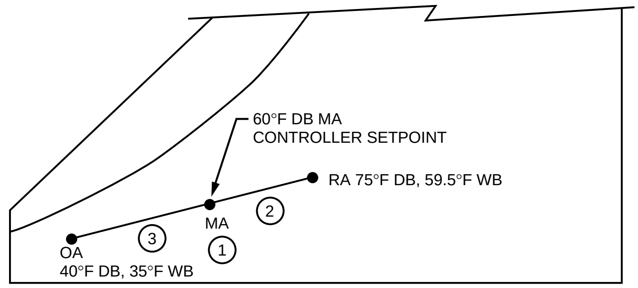
See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, the OA, EA, and RA dampers shall be modulated by an MA PID control loop to satisfy the MA temperature setpoint down to a minimum ventilation position.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. The manual positioning value is set for one-third minimum OA.
2. RA condition is 75°F DB and 59.5°F WB.
3. OA condition is 40°F DB and 35°F WB.
4. The MA controller is set at 60°F.
5. The desired MA temperature can be maintained until the OA temperature falls below the temperature at which only minimum OA is admitted and until the OA is greater than 60°F.



The following results are obtained:

Item No.	Explanation
1	As OA temperature varies between 30°F and 60°F, the MA condition lies on the 60°F DB line.
2	As OA temperature rises above 60°F DB, 100 percent OA is admitted, and the MA condition will lie to the right of the 60°F DB line.
3	As OA temperatures fall below 30°F DB, one-third OA (set by the manual positioning switch) is admitted, and the MA condition will lie to the left of the 60°F DB line.

ECONOMIZER CYCLE DECISION

Where 100% outdoor air economizer cycles are included with air handling systems, the decision of when to switch to the economizer mode is usually made automatically based upon the following criteria:

— The outdoor air conditions.
— The return air conditions or assumed conditions.
— The size and geographical location of the AHU.
— Cost.
— The users ability to understand control strategy and maintain the humidity sensors.

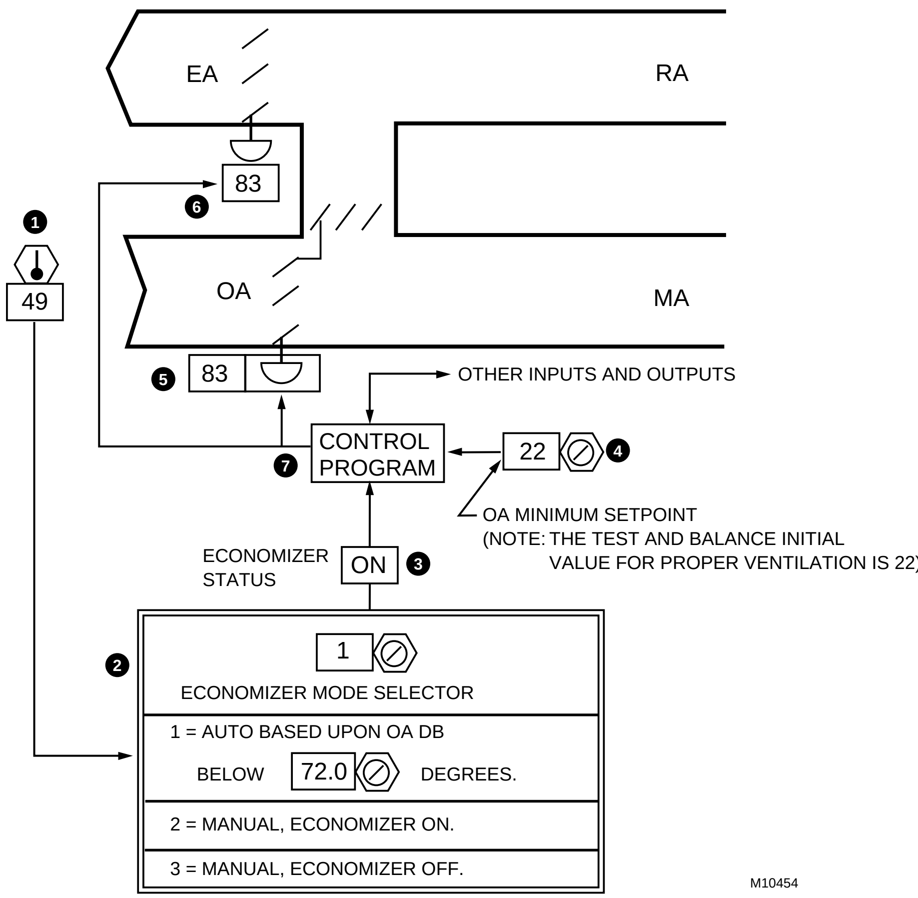
The economizer decision does not enable or disable chiller periods of operation. Chillers are generally enabled anytime chilled water valves open. At economizer changeover, the OA (containing less heat than the RA) is intended to reduce the load on the cooling coil until no chilled water is required.

The OA sensors should generally be located at least six feet above the ground in the shade (North side) in a perforated enclosure away from exhausts.

Following are several popular strategies with guidelines of when each is appropriate.

ECONOMIZER CYCLE DECISION—OUTDOOR AIR DRY BULB CONTROL

Functional Description



Item No.	Function
1	OA sensor senses OA temperature.
2	Economizer decision mode selector, including OA temperature setpoint below which the economizer decision is invoked, and command options.
3	Economizer decision status (operator information).
4	Setpoint for minimum OA damper position.
5	Actuator positions OA and RA dampers.
6	Actuator positions EA dampers.
7	Control program coordinates occupancy, temperature, smoke, and ventilation controls.

FEATURES

1. Outdoor air is used for cooling (or to supplement the chilled water system) anytime the OA temperature is below the economizer setpoint.
2. Stable, accurate, simple, electronic OA temperature sensor makes reliable economizer decision.
3. Economizer decision may be global and broadcast over the digital system network to other AHU systems.
4. Operator options for overriding the basic decision.
5. The test-and-balance minimum OA damper position initial value is provided as text. If the operator adjusts the minimum OA damper value, there is no longer a point of reference as to what it should be without this note.

CONDITIONS FOR SUCCESSFUL OPERATION

Local weather data analysis needed to determine the optimum changeover setpoint. The analysis need only consider data when the OA is between approximately 60°F and 78°F, and during the occupancy period.

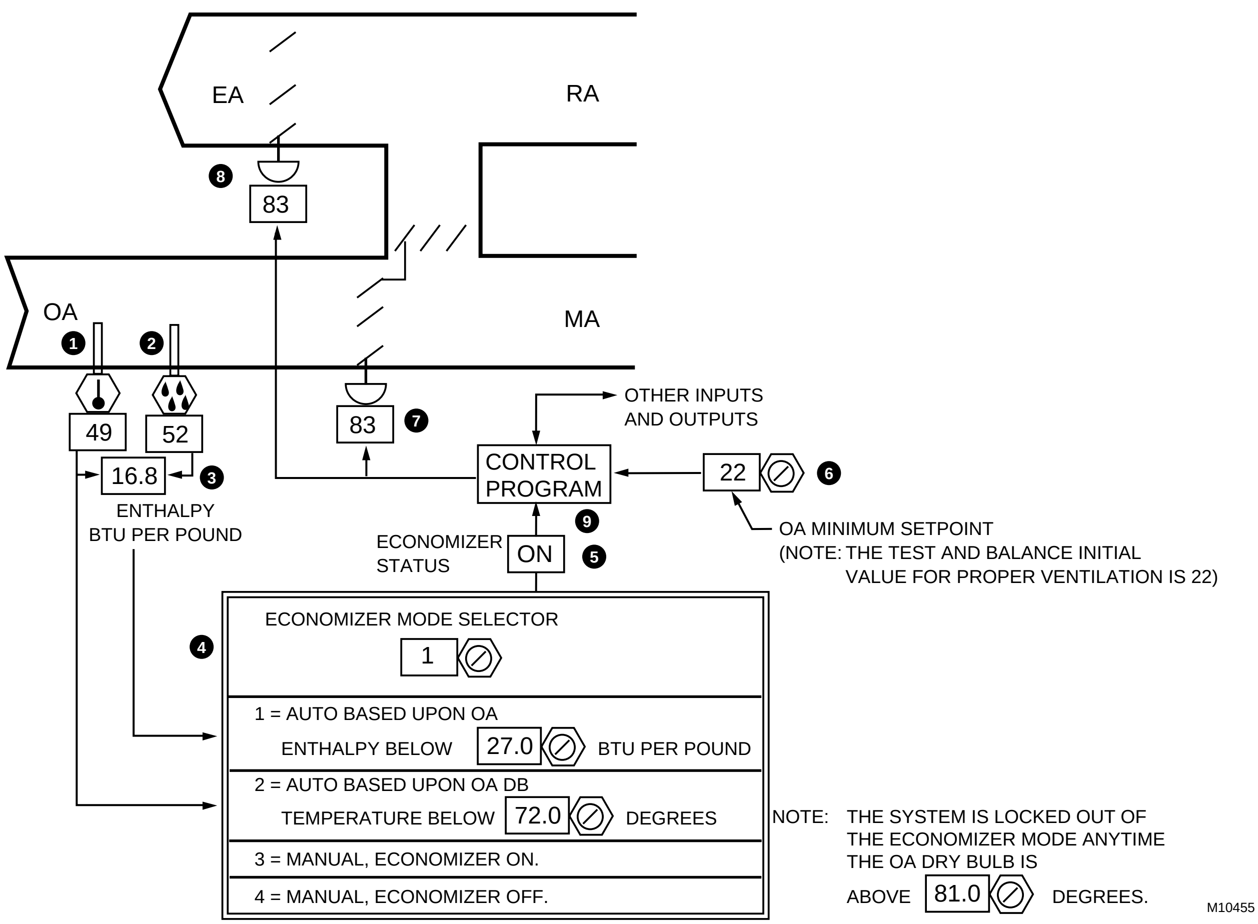
NOTE: The dry bulb economizer decision is best on small systems (where the cost of a good humidity sensor cannot be justified), where maintenance cannot be relied upon, or where there are not frequent wide variations in OA RH during the decision window (when the OA is between approximately 60°F and 78°F).

SPECIFICATIONS

A global economizer function shall be provided to switch all AHUs from OA cooling to minimum OA based upon an OA temperature setpoint. Software shall also be provided to allow the user to override the decision from being based upon OA dry bulb (with an appropriate commandable setpoint), to manually lock the system into or out of the economizer mode.

ECONOMIZER CYCLE DECISION—OUTDOOR AIR ENTHALPY CONTROL

Functional Description



Item No.	Function
1	Sensor senses OA temperature.
2	Sensor senses OA humidity.
3	OA enthalpy calculated from OA temperature and humidity.
4	Economizer mode decision selector, including OA enthalpy setpoint below which the economizer decision is invoked, and command schedule.
5	Economizer decision status (operator information).
6	Setpoint for minimum OA damper position.
7	Actuator positions OA and RA dampers.
8	Actuator positions EA dampers.
9	Control program coordinates occupancy, temperature, smoke, and ventilation controls.

FEATURES

1. Outdoor air is used for cooling (or to supplement the chilled water system) anytime the OA enthalpy is below the economizer setpoint.
2. OA enthalpy considers total heat and will take advantage of warm dry low enthalpy OA and will block out cool moist OA, thus saving more energy than a dry-bulb based economizer loop.
3. Economizer decision should be global and broadcast over the digital system network to other AHU systems.
4. Operator options for overriding the basic decision and for selecting OA DB economizer changeover during periods of humidity sensor maintenance or failure..
5. The test-and-balance minimum OA damper positioned value is provided as text. If the operator adjusts the minimum OA damper value, there is no longer a point of reference as to what it should be without this note.

CONDITIONS FOR SUCCESSFUL OPERATION

1. A high quality RH sensor with at least 3% accuracy should be selected.
2. Periodic maintenance of the humidity sensor is provided.
3. An estimate of the typical return air enthalpy is needed to determine the optimum changeover setpoint.

NOTE: This OA enthalpy changeover decision is generally recommended unless the system falls into the range where OA dry bulb or OA/RA enthalpy comparison should be considered.

LIMITATIONS

A high dry-bulb limit setpoint should be included to prevent the enthalpy decision from bringing in air too warm for the chilled water coil to cool down.

SPECIFICATIONS

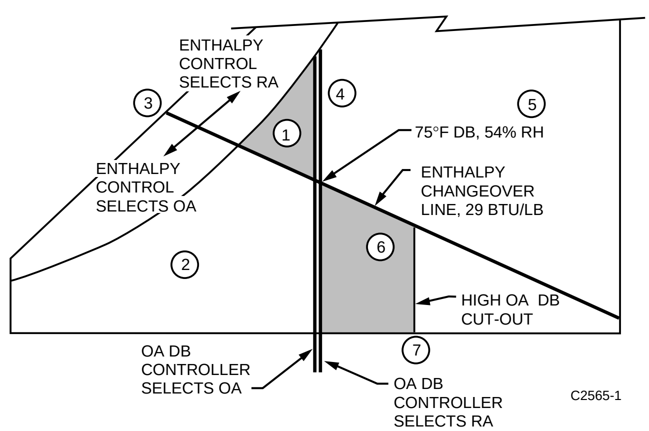
A global economizer program function shall be provided to switch all AHUs from OA cooling to minimum OA based upon an OA enthalpy calculation setpoint, except the system shall be locked out of the economizer mode anytime the OA DB is higher than 81°F. Software shall also be provided to allow the user to switch, with an appropriate commandable setpoint, the decision to be based upon OA dry bulb or to lock the system into or out of the economizer mode.

NOTE: The preceding graphic is an example of a major benefit of digital control systems. This graphic implies several enhancements over a simple economizer decision. It gives the user four economizer control software selectable options; an automatic OA enthalpy based economizer decision, an automatic OA dry bulb based economizer decision (for use if the OA RH sensor is bad), a manual economizer ON command (for use if the chiller plant is not ready to run for any reason), and a manual economizer OFF command (for use if the outdoor air is poor or a sensor malfunctions in the summer).

This enhanced scheme has the same program inputs (OA temperature, OA humidity) and the same output (the economizer decision status) as a basic OA enthalpy decision program. The enhancements are all software. After initial development and testing of the program (including the graphic development) this program can be cataloged, selected, and subsequently loaded on other projects for no appreciable additional cost over the basic program.

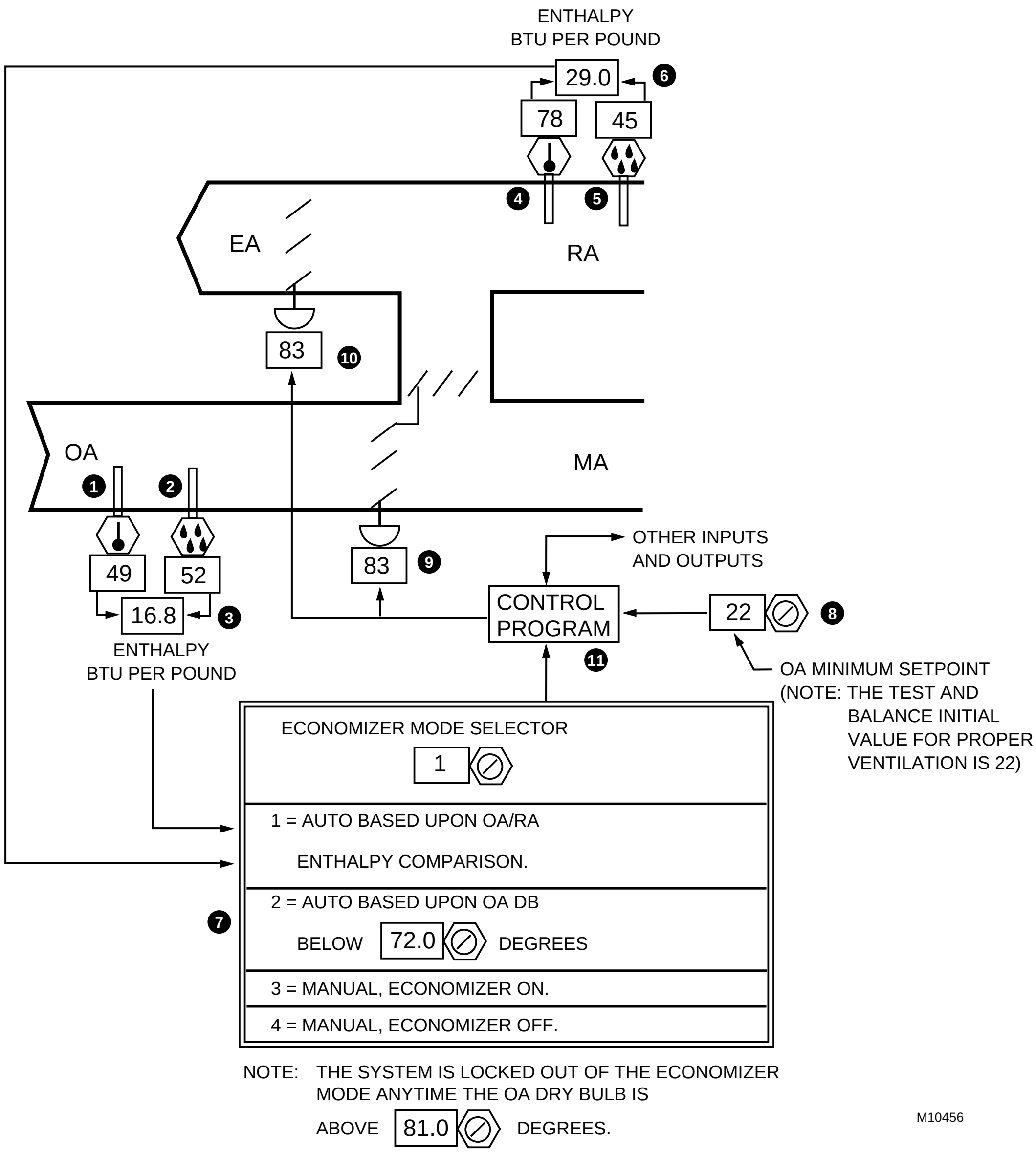
PSYCHROMETRIC ASPECTS

1. The following chart shows a comparison between an OA enthalpy and an OA DB economizer decision. For comparison, the enthalpy changeover setpoint is 29 Btu per pound of dry air (Line 3), and the dry bulb setpoint is 75°F (Line 4).
2. If the changeover decision is based upon enthalpy, the system will be in the economizer mode anytime the outdoor air lies in the area below Line 3 and to the left of Line 6.
3. If the changeover decision is based upon dry bulb temperature, the system will be in the economizer mode anytime the outdoor air lies to the left of Line 4.
4. Area 1 contains high enthalpy, low temperature air that would be used for free cooling if the decision was based upon OA dry bulb. This excess enthalpy would burden the chiller unnecessarily.
5. Area 6 contains low enthalpy, high temperature air that would be not used for free cooling if the decision was based upon OA dry bulb. This low enthalpy would reduce the chiller load.
6. Line 3 represents the dry bulb value, to the right of which the cooling coil could not handle the sensible load, no matter how dry the air is. This is the high temperature economizer cutout line used with the enthalpy and OA/RA enthalpy comparison economizer decision.



ECONOMIZER CYCLE DECISION—OUTDOOR AIR/RETURN AIR ENTHALPY COMPARISON

Functional Description



Item No.	Function
1	Sensor senses OA temperature.
2	Sensor senses OA humidity.
3	OA enthalpy calculated from OA temperature and humidity.
4	Sensor senses RA temperature.
5	Sensor senses RA humidity.
6	RA enthalpy calculated from OA temperature and humidity.
7	Economizer mode selector and command schedule.
8	Setpoint for minimum OA damper position.
9	Actuator positions OA and RA dampers.
10	Actuator positions EA dampers.
11	Control program coordinates occupancy, temperature, smoke control, and ventilation controls.

FEATURES

1. Outdoor air is used for cooling (or to supplement the chilled water system) anytime the OA enthalpy is less than the RA enthalpy.
2. Enthalpy considers total heat and will consider variations in OA and RA moisture content, thus saving more energy than dry-bulb based and OA enthalpy economizer loops.
3. The OA enthalpy calculation should be global and broadcast over the digital system network to other AHU systems.
4. Operator options for overriding the basic decision and for reverting to an OA DB economizer decision.
5. The test-and-balance minimum OA damper position value is provided as text. If the operator adjusts the minimum OA damper value, there is no longer a point of reference as to what it should be without this note.

CONDITIONS FOR SUCCESSFUL OPERATION

1. High quality RH sensors with at least 3% accuracy and long term stability should be selected.
2. Periodic maintenance of the humidity sensors is provided.
3. In some cases, only certain AHUs (which have varying latent loads) need RA enthalpy sensors and calculations, and others will be perform satisfactorily with OA enthalpy only. If RA moisture varies similarly on several AHUs, a single comparison and decision may be globally shared among them.

NOTE: The OA/RA enthalpy comparison decision is best on systems where the return air experiences wide swings in humidity when the OA temperatures are between approximately 60°F and 80°F. The size of the AHU should also be considered since savings will vary with fan airflow.

SPECIFICATIONS

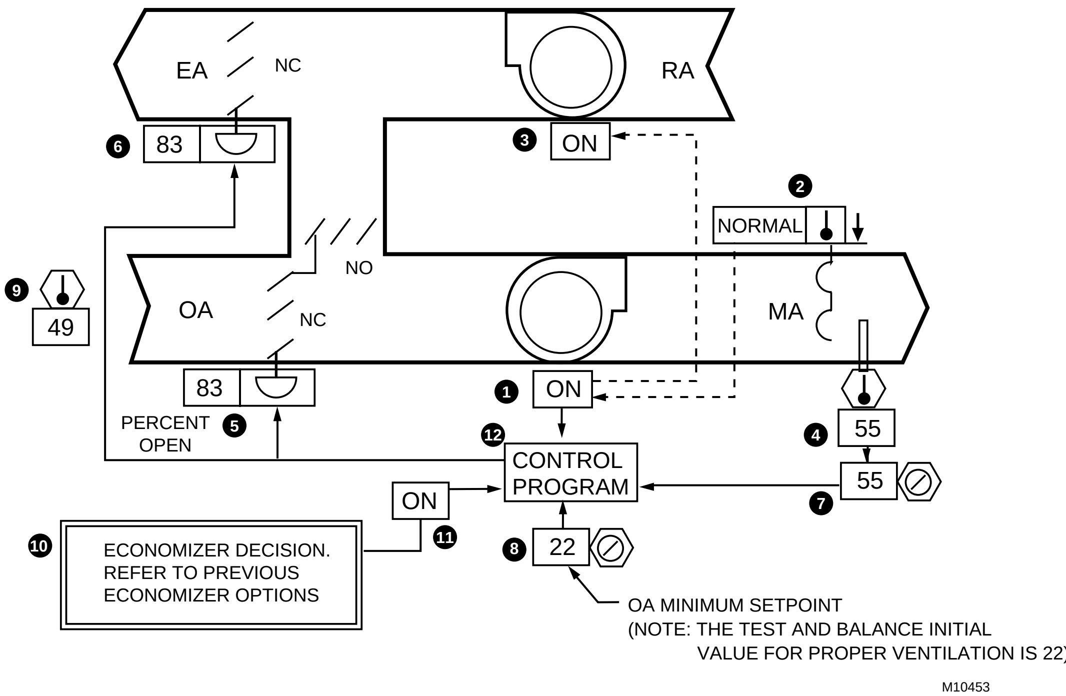
An economizer decision function shall be provided to switch the AHU from OA cooling to minimum OA based upon an OA/RA enthalpy calculation and comparison. Anytime the OA enthalpy is below the RA enthalpy, the system shall switch to the economizer mode, except the system shall be locked out of the economizer mode anytime the OA DB is higher than 81°F. Software shall also be provided to allow the user to switch the economizer mode to an OA dry bulb base (with an appropriate commandable setpoint), or to lock the system into or out of the economizer mode.

ECONOMIZER CYCLE DECISION—OUTDOOR AIR/RETURN AIR DRY BULB TEMPERATURE COMPARISON

This rarely used economizer decision is similar to the enthalpy comparison but considers dry bulb temperatures only. This scheme is best on small systems if return air temperatures vary significantly when the OA temperatures are between approximately 60°F and 80°F.

MIXED AIR CONTROL WITH ECONOMIZER CYCLE (VENTILATION SYSTEM ONLY)

Functional Description



Item No.	Function
1-3	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
4	MA temperature maintained by modulating mixing dampers.
5,6	OA and EA dampers close and RA damper opens when fan is off and modulate for temperature control when fan is on.
7	Setpoint for MA temperature control.
8	Setpoint value for minimum ventilation damper position.
9	Determines when OA is suitable to assist in cooling.
10	Control program coordinates MA, minimum ventilation, and economizer control of mixing dampers.

FEATURES

1. The proper proportions of OA and RA are admitted to maintain the desired MA temperature during economizer operation periods.
2. A minimum quantity of OA, determined by the software adjustable setpoint value, is assured at all times.
3. The OA economizer changeover program returns the OA damper to the minimum position when OA is not suitable.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Adequate mixing of OA and RA. Mixing may be obtained using a special mixing chamber. The temperature sensor should be in the fan discharge when possible. The fan in a blow-through system usually provides adequate mixing.
2. An MA averaging element sensor is used on draw-through units.

LIMITATIONS

If the manual positioning value is set to admit a large quantity of OA and the OA temperature falls below the temperature at which only minimum OA is required for MA temperature control, a source of heat is necessary to maintain the MA temperature.

SPECIFICATIONS

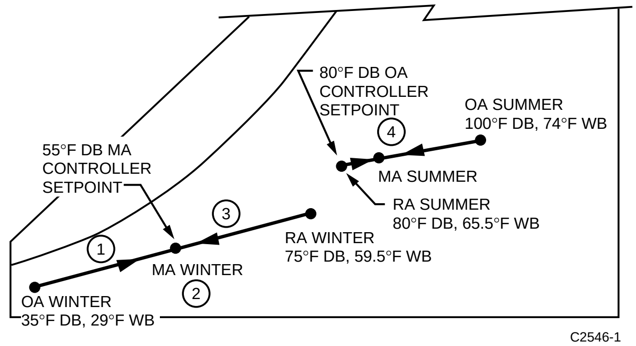
See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, the OA, exhaust, and RA dampers shall position to a minimum ventilation position and shall be further modulated by an MA PID control loop to maintain the MA temperature setpoint. Anytime the OA conditions rise above the economizer setpoint, the MA temperature control shall be disabled.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. The manual positioning setpoint value provides 25 percent minimum OA.
2. The MA controller is set at 55°F.
3. The OA controller closes the OA damper to the minimum position when OA temperature is 80°F.
4. RA condition is 75°F DB and 59.5°F WB for winter; 80°F DB and 66.5°F WB for summer.
5. OA condition is 35°F DB and 29°F WB for winter; 100°F DB and 74°F WB for summer.
6. Other components exist in the complete system which hold the RA at the desired condition.
7. The desired MA temperature can be maintained during economizer periods until the OA temperature falls below the temperature at which only minimum OA is admitted if the OA is less than 55°F.

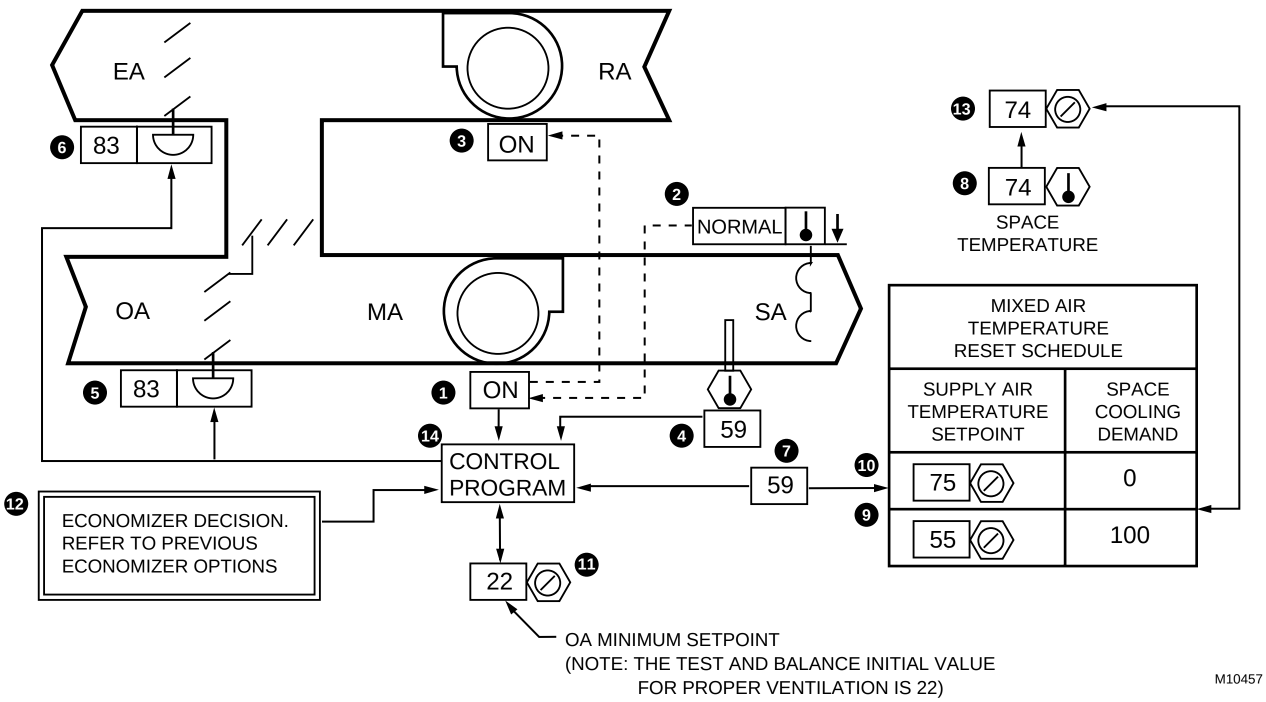


The following results are obtained:

Item No.	Explanation
1	At OA temperatures below -5°F DB (25 percent OA set by manual positioning setpoint value), the MA condition lies to the left of the 55°F DB line.
2	As the OA temperature varies between –5°F and 55°F, MA conditions lie on the 55°F DB line.
3	As the OA temperature varies between 55°F and 75°F, 100 percent OA is admitted and the MA lies in the area between 55°F and 75°F DB.
4	As the OA temperature rises above 80°F DB, the system operates on 25 percent OA and the MA temperature varies from 95°F to 85°F DB.

ECONOMIZER CYCLE CONTROL OF SPACE TEMPERATURE WITH SUPPLY AIR TEMPERATURE SETPOINT RESET

Functional Description



Item No.	Function
1-3	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
4	SA temperature maintained by modulating mixing dampers.
5,6	OA and EA dampers close and RA damper opens when fan is off and modulate for ventilation and temperature control when fan is on.
7	Setpoint for SA temperature control.
8	Space temperature demand resets SA temperature setpoint.
9,10	Calculates SA temperature setpoint (7) based upon space temperature cooling demand.
11	Setpoint value for minimum ventilation damper position.
12	Determines when OA is suitable to assist in cooling.
13	Space temperature setpoint and PID function. PID output (0 - 100) inputs to reset schedule.
14	Control program coordinates space temperature, SA temperature, minimum ventilation, fan interlock, and economizer control of mixing dampers.

FEATURES

1. The system admits only the minimum quantity of OA required for ventilation when the OA is unsuitable for cooling assistance.
2. During intermediate weather the system admits OA for cooling to satisfy the space temperature demands, subject to SA temperature schedule setpoints.
3. A minimum quantity of OA, determined by the software adjustable setpoint value, is assured at all times.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Adequate mixing of OA and RA. Mixing may be obtained using a special mixing chamber. The temperature sensor should be in the fan discharge when possible. The fan in a blow-through system usually provides adequate mixing.
2. A satisfactory schedule of all settings must be determined.

LIMITATIONS

If the manual positioning value is set to admit a large quantity of OA and the OA temperature falls below the temperature at which only minimum OA is required for SA temperature control, a source of heat is necessary to maintain the SA temperature.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, the OA, exhaust, and RA dampers shall position to a minimum ventilation position and shall be further modulated by an SA PID control loop to maintain the SA temperature setpoint. The SA temperature setpoint shall be varied from no less than 55°F to no more than 75°F as the space temperature PID loop cooling demand varies from 100 to 0%. Anytime the economizer program is invoked, the SA temperature control shall be enabled.

PSYCHROMETRIC ASPECTS

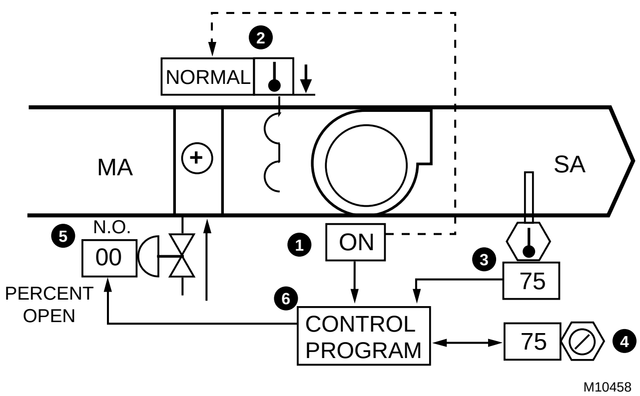
For the psychrometric aspects of this application, refer to MIXED AIR CONTROL WITH ECONOMIZER CYCLE. The psychrometric aspects of the two applications are the same.

HEATING CONTROL PROCESSES

The following applications show various ways to control heating in an air conditioning system.

CONTROL FROM SUPPLY AIR

Functional Description



Item No.	Function
1-2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3,5	SA temperature maintained by modulating the hot water valve.
4	Setpoint for SA temperature control.
6	Control program coordinates temperature control and fan interlock.

FEATURES

1. Air is discharged at a minimum temperature.
2. Valve opens upon loss of motive force (electricity or compressed air) and closes upon fan shutdown.

CONDITIONS FOR SUCCESSFUL OPERATION

1. A multiple inline coil arrangement should be used if a high temperature rise is required.
2. Heating medium and flow must be available.

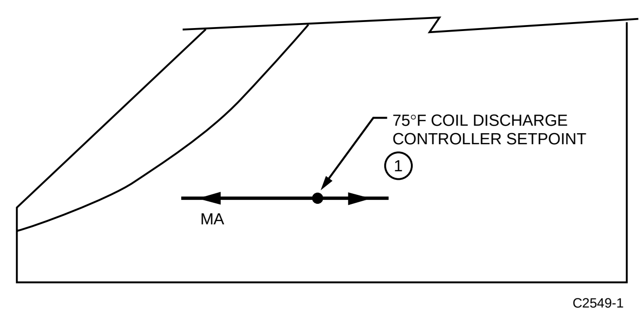
SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, the hot water valve shall be modulated by an SA PID control loop to maintain the SA temperature setpoint. The hot water valve shall close upon fan shutdown and open upon loss of motive force.

PSYCHROMETRIC ASPECTS

1. The SA temperature remains constant until the entering air temperature exceeds the desired SA temperature.
2. In the following chart it is assumed that the SA PID control loop is set at 75°F.

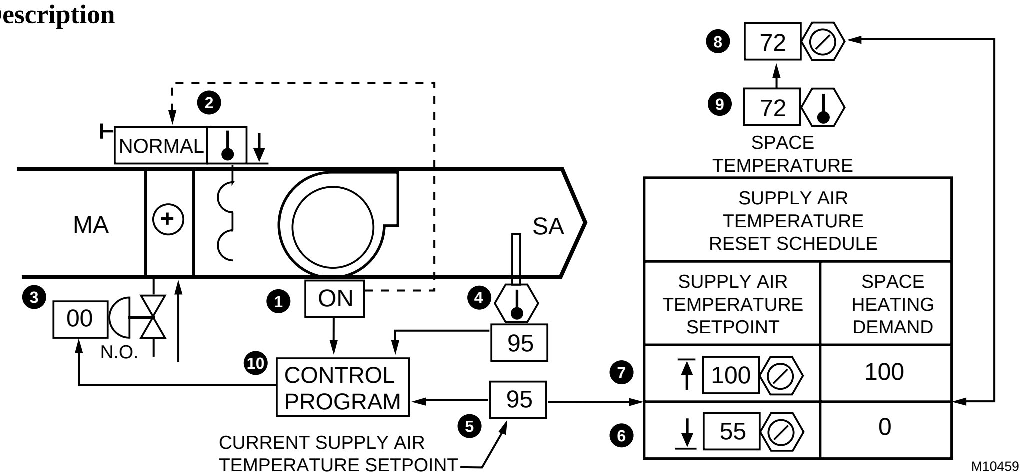


The following results are obtained:

Item No.	Explanation
1	Coil discharge is 75°F DB until MA exceeds 75°F DB, above which the coil valve is closed, no heat is added, and SA condition is equal to MA.

CONTROL FROM SPACE WITH SUPPLY TEMPERATURE RESET

Functional Description



Item No.	Function
1-2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3	Hot water valve modulates heating medium.
4,5	SA temperature controlled to maintain setpoint.
6,7	SA temperature setpoint determined by space heating load.
8,9	Space temperature is compared to space temperature setpoint to determine SA temperature setpoint.
10	Control program coordinates temperature control and fan interlock.

FEATURES

1. Air is supplied at a temperature necessary to make up the sensible heat loss in the space.
2. The SA temperature will not fall below a desired minimum or rise above a desired maximum (unless heating coil entering air rises).

CONDITIONS FOR SUCCESSFUL OPERATION

A multiple inline coil arrangement if a high temperature rise is required.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

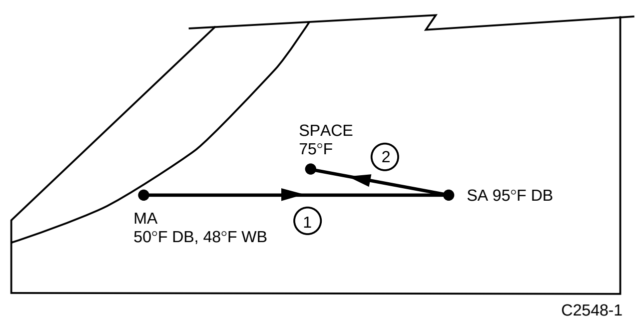
1. Anytime the supply fan runs, the hot water valve shall be modulated by an SA PID control loop to maintain the SA temperature setpoint. The SA temperature setpoint shall be reset from no lower than 55°F to no greater than 100°F as the space temperature PID demand for heating varies from 0% to 100%.
2. The N.O. hot water valve shall close upon fan shutdown.

PSYCHROMETRIC ASPECTS

The supply condition of the air depends on the condition of the entering air and the temperature rise needed to satisfy the space heating requirements.

In the following chart it is assumed that:

1. The space temperature control loop is set at 75°F.
2. MA condition is 50°F DB and 48°F WB.
3. A space heating load exists which is large enough to require 95°F DB SA to meet the design condition heat loss.

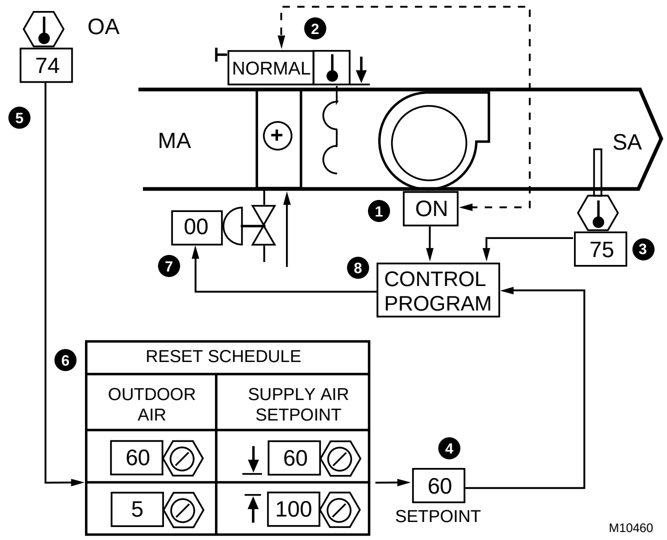


The following results are obtained:

Item No.	Explanation
1	The heating of the MA to the supply temperature occurs along a line of constant moisture content.
2	Space air picks up moisture from the occupants and contents of the space.

OUTDOOR AIR TEMPERATURE RESET OF SUPPLY AIR TEMPERATURE

Functional Description



Item No.	Function
1,2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3,4	SA temperature setpoint, as adjusted by reset schedule, maintained by modulating hot water valve.
5,6	OA temperature resets the SA temperature setpoint according to a reset schedule.
7	Hot water valve modulates flow, opens upon loss of motive force, and closes upon fan shutdown.
8	Control program coordinates SA temperature, valve, and fan interlock control.

FEATURES

The SA temperature rises as the OA temperature falls according to a predetermined reset schedule.

CONDITIONS FOR SUCCESSFUL OPERATION

Use multiple inline coil arrangement should be used if a high temperature rise is required.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

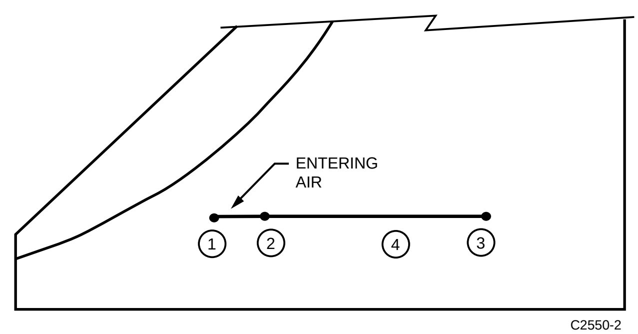
Anytime the supply fan runs, heating control shall be enabled. A SA PID control loop shall modulate the hot water valve to maintain the SA temperature setpoint. The SA temperature setpoint shall be reset from 60°F to 100°F as the OA temperature varies from 60°F to 5°F.

PSYCHROMETRIC ASPECTS

The SA condition depends on the entering air condition and the temperature rise needed to satisfy the space heating requirements.

In the following chart it is assumed that:

1. The MA system is set to maintain 60°F DB MA temperature.
2. The OA temperature reset controller increases the setpoint of the discharge PID control loop linearly from 60°F to 100°F DB as OA temperature falls from 60°F to 5°F DB.

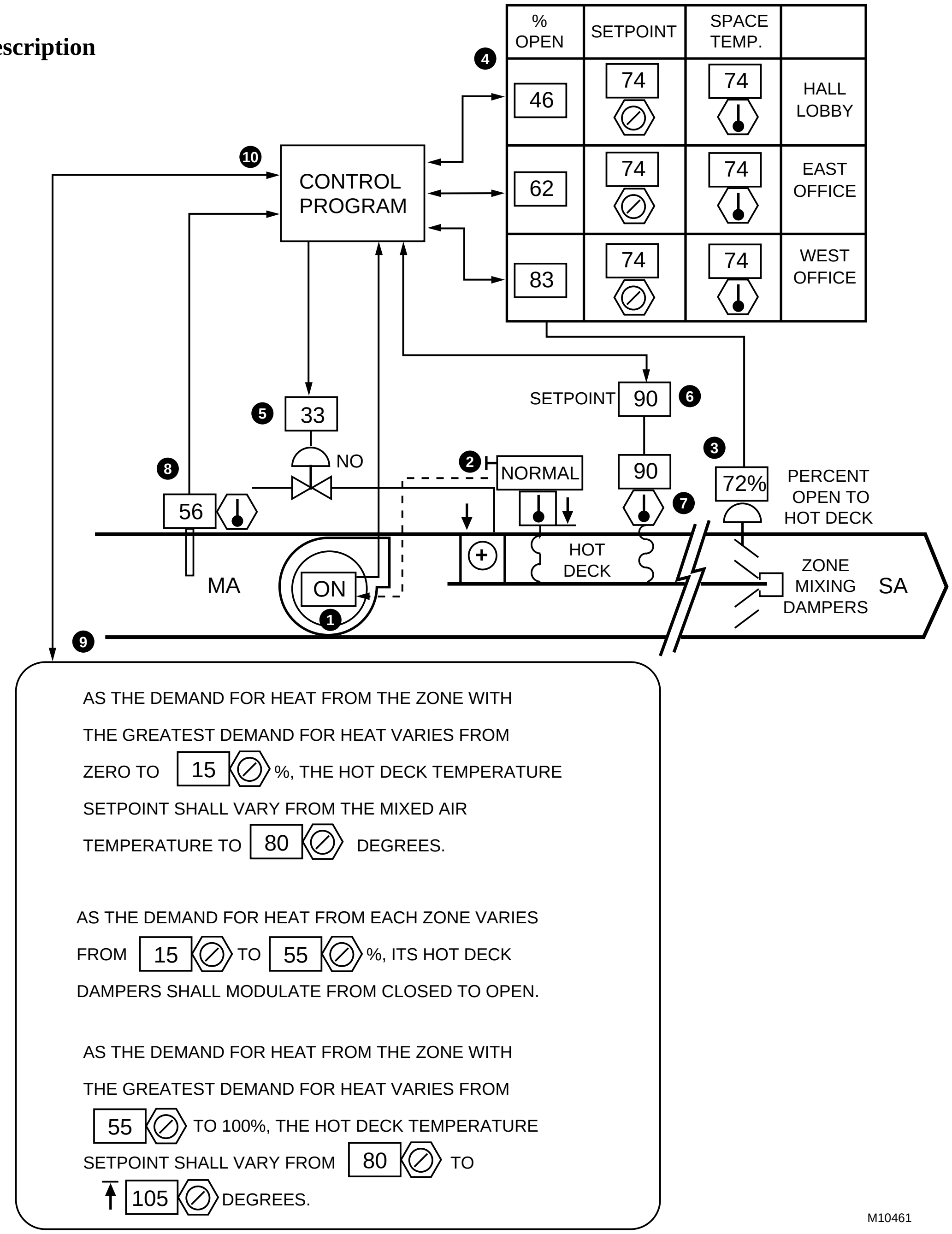


The following results are obtained:

Item No.	Explanation
1	MA temperature.
2	SA at the beginning of the reset schedule.
3	SA heated to 100°F at outdoor design temperature.
4	Between 0°F and 60°F OA temperature, SA temperatures are between points 2 and 3.

SPACE TEMPERATURE CONTROL OF ZONE MIXING DAMPERS AND RESET OF HOT DECK TEMPERATURE

Functional Description



Item No.	Function
1-2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3-4	Zone mixing dampers modulate to maintain zone temperature setpoint.
5-7	Hot water valve modulates to maintain hot deck temperature setpoint.
8	MA temperature determines hot deck reset schedule start point.
9	Dynamic graphic sequence display permits the operator to adjust program setpoints. Program adjusts hot deck temperature based upon operator inputs.
10	Control program coordinates load reset, temperature, and fan interlock programs.

FEATURES

1. A motorized zone mixing damper and space temperature PID control loop for each zone provides zone control.
2. A single coil or group of coils in the hot deck furnishes heat for the entire system.
3. The hot deck temperature is reset by the zone with greatest load which provides efficient control when used in conjunction with a cold deck coil/control.
4. A reasonably constant volume of air is delivered to each room or zone.
5. A dynamic sequence-of-operation graphic display. This not only clearly explains the sequence but also allows easy program modification.

NOTE: Except for low-leakage OA dampers, measurable leakage usually exists through "closed" dampers. Given this leakage, as the zone heat demand increases from zero to 15%, the hot deck temperature setpoint is raised from the mixed air temperature to 80°F before any zone damper movement. Zone heating demand from 15 to 50% then modulates the zone dampers from zero to 100% open to the 80°F hot deck. Further zone heating demand from 50 to 100% raises the hot deck temperature setpoint from 80°F to the upper limit of 105°F. A major objective of this strategy is to minimize heat leakage to zones requiring no heat.

CONDITIONS FOR SUCCESSFUL OPERATION

1. A hot water coil on units having full flow at all times provides uniform hot deck temperatures. This can be accomplished with a three-way valve and coil pump. Resetting hot water temperature also helps.
2. All zones are connected to load the reset program to satisfy total load requirements. In large systems good practice dictates connecting only selected diverse zone loads. Zones that may be allowed to go out of control (storage rooms, etc.) should not be connected to the load reset program.
3. Each zone duct should have a balancing damper following the mixing dampers to ensure design volume to each zone.
   NOTE: See the Microprocessor-Based/DDC Fundamentals section for a description of the load reset program.

LIMITATIONS

1. If only selected zones are connected to the load reset program, the load requirements of unconnected zones may not be satisfied.
2. Reduced steam flow may cause temperature gradients across the face of the coil.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, heating control shall be enabled.

Each zone mixing damper shall be modulated to maintain zone space temperature setpoint. The hot water valve shall be modulated to maintain the hot deck temperature setpoint.

The hot deck temperature setpoint shall be reset from the MA temperature to 80°F as the heating demand from the zone with the greatest heating demand varies from 0 to 15%.

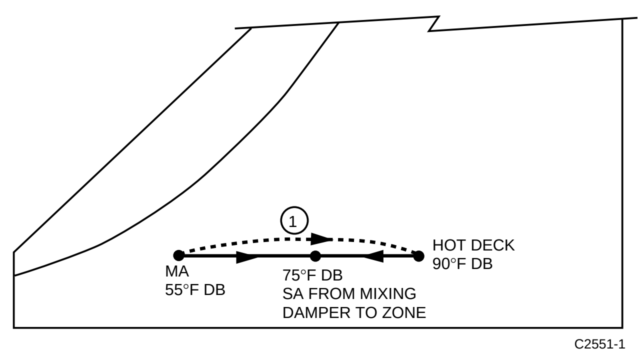
Zone mixing dampers shall modulate from 0 to 100% open to the hot deck as their respective zone demands for heating vary from 15 to 55%.

The hot deck temperature setpoint shall be reset from 80°F to 105 °F as the heating demand from the zone with the greatest heating demand varies from 55 to 100%.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. MA temperature is 55°F DB.
2. The zone with the greatest heating load requires a hot deck temperature of 90°F DB.
3. The zone depicted requires 75°F DB SA to meet its load.



Item No.	Explanation
1	Heating of MA to the hot deck temperature occurs along a line of constant moisture content. Individual zones obtain any needed SA temperature along this line with the coldest zone controlling the hot deck temperature and getting 100 percent hot deck air.

PREHEAT CONTROL PROCESSES

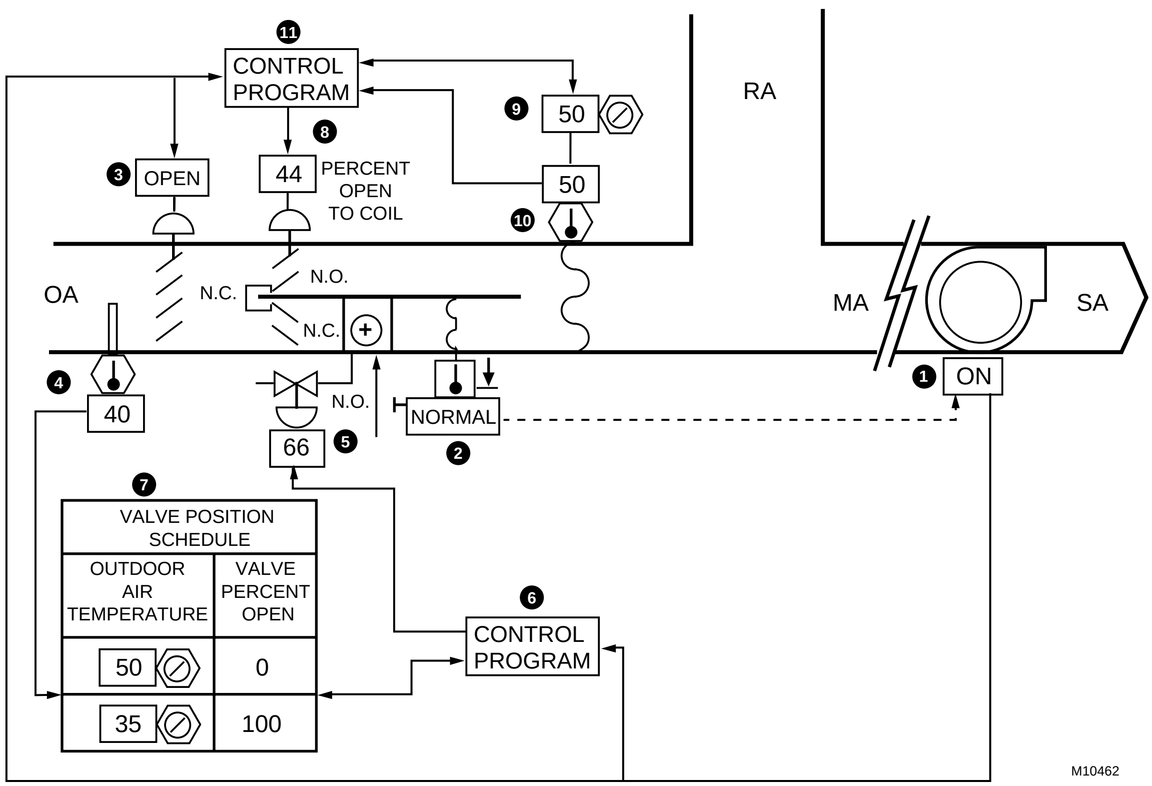
The preheat process heats the air in preparation for subsequent conditioning. Preheat is sometimes necessary when high percentages of low temperature OA must be handled by the system. Considerations before a preheat component is installed in an air conditioning system are:

1. Preheat coils are often exposed to subfreezing temperatures. Provision to prevent freezing the coils must be made.
2. Accurate sizing of preheat coils is important. They should be sized so it is possible to allow OA for cooling yet not overheat the space.

In most of the following illustrations, preheat is shown in the OA preceding the mixing of OA and RA. In complete HVAC systems, the final preheat coil leaving air temperature setpoint should be dictated by demands for heating or cooling.

PREHEAT CONTROL WITH FACE AND BYPASS DAMPERS

Functional Description



Item No.	Function
1-2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3	OA damper opens on fan startup, closes upon fan shutdown (in some cases the OA damper may be part of a mixed air system).
4	OA temperature determines valve position.
5	Valve controls heating medium flow to coil.
6	Control program coordinates fan interlock and valve control.
7	Valve position determined by OA temperature.
8-10	Face-and-bypass dampers controlled to maintain face-and-bypass leaving air temperature setpoint.
11	Control program coordinates fan interlock and face-and-bypass damper control.

FEATURES

1. Preheat coil conditions large quantities of low temperature OA before it enters the system.
2. Bypass damper controls temperature of air leaving the face-and-bypass section without endangering the preheat coil which operates in full valve open mode during freezing conditions.
3. Upon fan shutdown, valve controls at 100°F leaving air temperature in freezing weather and positions closed upon fan shutdown in non-freezing weather.

CAUTION: If steam (or very hot water) valves position full open during off periods, air temperatures may melt fire damper linkages.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Preheat coil sized to raise a maximum quantity of OA from outdoor design temperature to 50°F.
2. Averaging element sensor positioned in face-and bypass air to sense average air temperature.
3. Bypass air well mixed with face (and return) air prior to entering down-stream water coils (additional low temperature controls may be required for down-stream water coils).
4. On large 100% OA systems the OA damper opens prior to fan start up to protect ducting from collapse.
5. The setpoint of air leaving the preheat section is usually dictated by the downstream AHU temperature controls.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, heating control shall be enabled, and the OA dampers shall open for ventilation requirements.

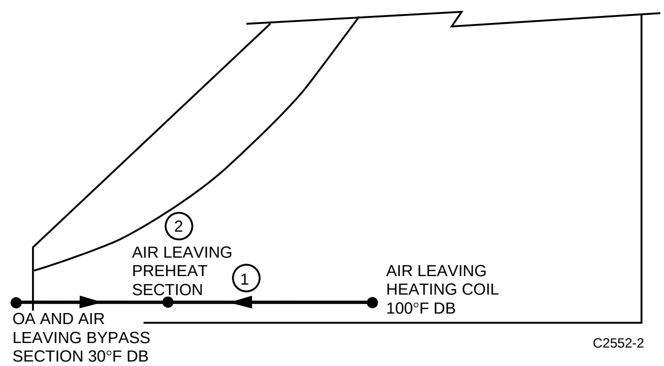
The heating coil valve shall open upon loss of actuator motive force, shall close upon fan shutdown if the OA temperature is above 35°F, and shall control to maintain 100°F leaving air temperature upon fan shutdown if the OA temperature is below 35°F.

The heating coil valve shall position from 0 to 100% open as the OA temperature varies from 50°F to 35°F. The face-and-bypass dampers shall modulate to maintain an average face-and-bypass leaving air temperature of 50°F.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. The coil has a 50 Fahrenheit degree temperature rise with full air flow 0°F air and a 70 Fahrenheit degree temperature rise with reduced air flow as in the example.
2. The coil water flow modulates from closed to open as OA temperature drops from 50°F to 35°F.
3. OA temperature is 30°F DB.

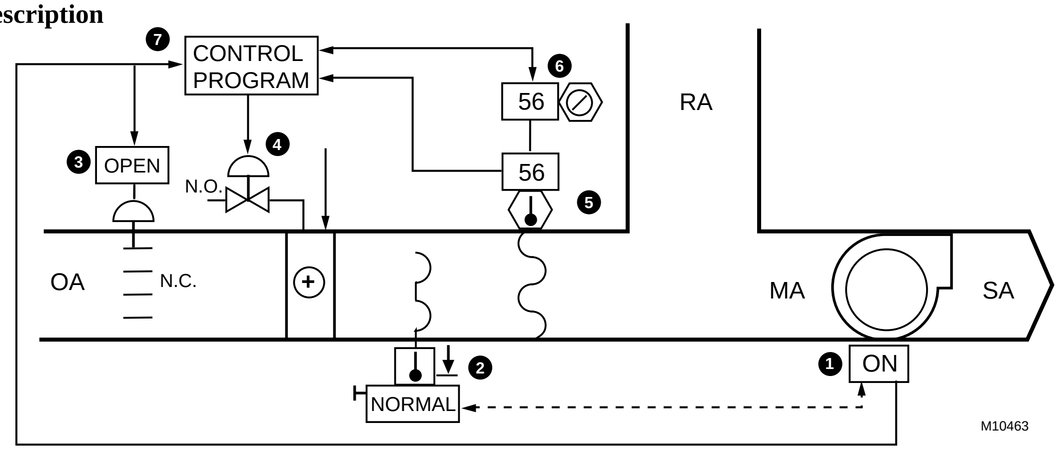


The following results are obtained:

Item No.	Explanation
1	Heating of OA occurs along a line of constant moisture content from 30°F to 100°F.
2	The PID control loop maintains the temperature of the preheat section leaving air.

CONTROL FROM PREHEAT LEAVING AIR

Functional Description



Item No.	Function
1-2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3	OA damper opens on fan startup, closes upon fan shutdown.
4-6	Heating valve modulates to maintain heating coil leaving air temperature setpoint.
7	Control program coordinates fan interlock and valve control.

FEATURES

1. A preheat coil conditions large quantities of low temperature OA before it enters the system.
2. A fixed amount of OA for ventilation is delivered whenever the fan is on.

CONDITION FOR SUCCESSFUL OPERATION

1. The temperature is limited to a value low enough to have the coil valve full open at freezing temperatures.
2. Water temperature reset and/or a recirculating pump is very helpful in keeping high flow at varying OA temperatures. If a large temperature rise is required, use an arrangement of multiple inline coils.
3. The control network sends a command to start the hot water system anytime the hot water valve is not closed.

NOTE: If a variable flow hot water system exists, it may be preferable to have the hot water valve position to approximately 25% open (rather than full open) upon fan shutdown in freezing weather. This saves pump energy and often prevents the need for multiple pumps.

LIMITATIONS

If too high a temperature rise is used, the valve may short cycle or slow down the water in the coil and allow the coil to freeze.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, heating control shall be enabled, and the OA dampers shall open for ventilation requirements. The heating coil valve shall be modulated by a PID control loop to maintain the coil leaving air temperature setpoint.

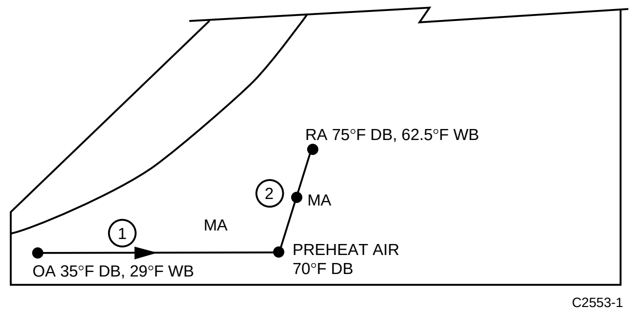
The heating coil valve shall open upon loss of actuator motive force, shall close upon fan shutdown if the OA temperature is above 35°F, and shall control at a leaving air temperature setpoint of 100°F upon fan shutdown if the OA temperature is below 35°F.

PSYCHROMETRIC ASPECTS

The coil discharge and MA conditions can be distributed over considerable area on the psychrometric chart depending on the entering air condition and the temperature rise through the coil.

In the following chart it is assumed that:

1. The preheat coil has a 35 degree Fahrenheit temperature rise.
2. The preheat coil valve modulates to maintain leaving air temperature.
3. RA condition is 75°F DB and 62.5°F WB.
4. The MA is composed of 50 percent preheated air and 50 percent RA.
5. OA condition is 35°F DB and 29°F WB (design).

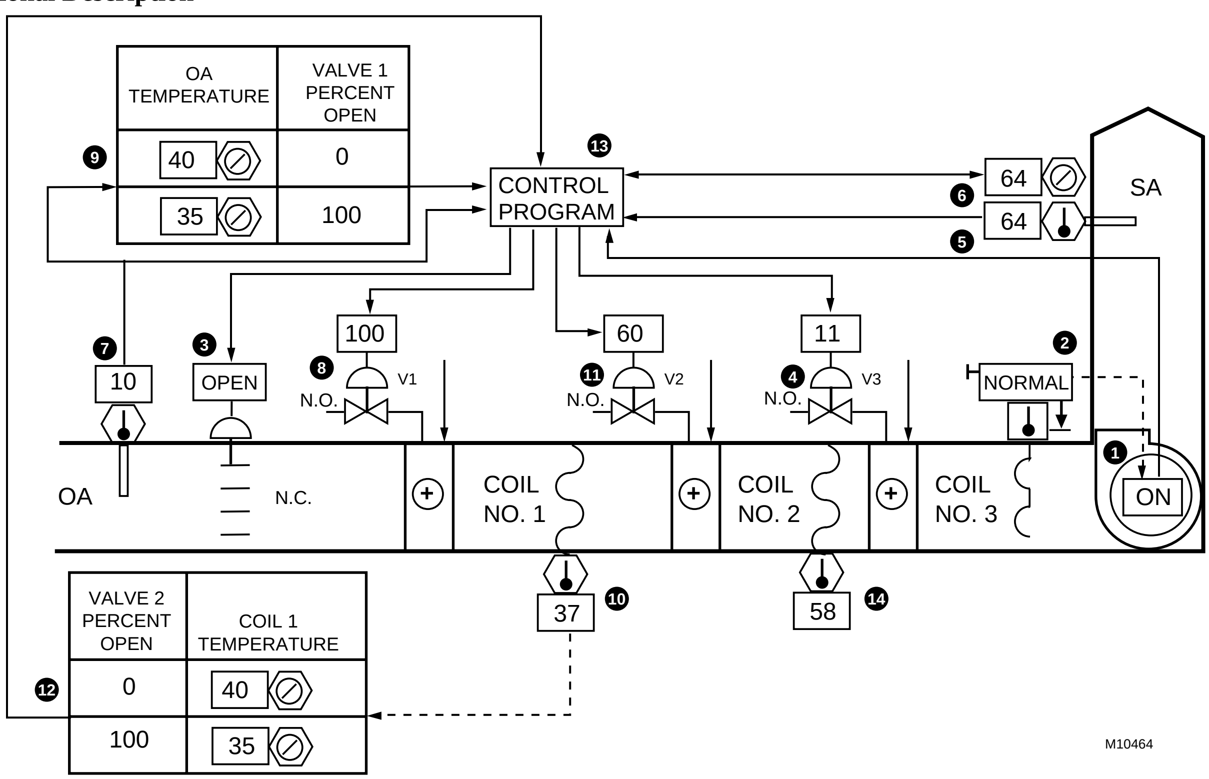


The following results are obtained:

Item No.	Explanation
1	Heating of OA occurs along a line of constant moisture content from 35°F to 70°F.
2	This condition represents the mixing of preheated air and RA supplied to the system.

MULTIPLE COIL CONTROL FROM OUTDOOR AND SUPPLY AIR

Functional Description



Item No.	Function
1,2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3	OA damper opens when fan runs.
4-6	Supply air PID control loop modulates the coil #3 valve to maintain constant supply temperature.
7-9	Coil #1 is under open loop control by OA temperature.
10-12	Coil #2 is under open loop control by coil #1 leaving air temperature.
13	Control program coordinates temperature, ventilation, and fan interlock control.
14	Coil #2 leaving air temperature is for operator information (unless alarm monitoring is desired).

FEATURES

1. The multiple inline coil system heats below-freezing air with little danger of freezing the coils or overheating the space.
2. The supply temperature is constant (or may be dictated by other HVAC controls).
3. In this sequence, individual Coil 1 and 2 Valves are opened fully just before freezing air enters to prevent freezing.
4. The low temperature control (Item 2) is intended to protect the coils from freezing due to the loss of heat. Low temperature controls cannot be installed in the leaving air of Coils 1 and 2 because leaving air temperatures below freezing may be normal. If water flow is lost through Coils 1 or 2, they could freeze without detection by the low temperature control (Item 2). Differential temperature (software) monitor points across Coils 1 and 2 could be added to detect the loss of heating. If a Building Management System is included, the monitor could be two-stage to send an alarm warning message if the coil entering air temperature is less than 32°F and the differential temperature is less than 22 Fahrenheit degrees, and shut the system down if the differential temperature is less than 18 Fahrenheit degrees. If the hot water temperature is reset, or if the design OA temperature is less than 0°F, the two differential temperature alarm values should increase as the coil entering air temperature decreases. Temperature sensors in the coils leaving water may also detect freezing danger. The numbers “22” and “18” are arbitrary and must be carefully determined if protection is to be achieved.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Heating Coils 1 and 2 should provide approximately the same temperature rise and keep the air entering Coil 3 above freezing. Do not oversized any of the coils . The rise for Coils 1 & 2 (which are full open at 35°F entering air temperature) should be selected to produce no more than the maximum leaving air temperature that can be tolerated.
2. Coil 3 should be sized for the balance of the heating load.
3. Follow good piping practices to avoid freezing steam coils.
4. On large systems, fan start signal should open the OA damper, and a damper end switch should start the fan (to prevent the ductwork from collapsing before the damper can open).

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL**.**

Anytime the supply fan runs, heating control shall be enabled and the OA dampers shall open for ventilation requirements.

The heating Coil 1 valve shall open upon loss of actuator motive force, shall close upon fan shutdown if the OA temperature is above 35°F, and shall open upon fan shutdown if the OA temperature is below 35°F. Heating Coils 2 and 3 valves shall open upon loss of actuator motive force and shall close upon fan shutdown.

The Heating Coil Valve 3 shall be modulated by a PID control loop to maintain the leaving air temperature setpoint.

The valve to Coil No. 1 (nearest entering air) shall position from 0% to 100% open as the OA temperature varies from 40°F to 35°F.

The valve to Coil No. 2 shall position from 0% to 100% open as the air temperature leaving Coil 1 varies from 40°F to 35°F.

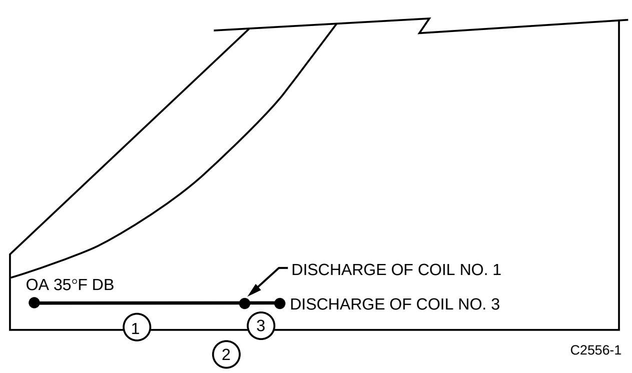
OPTIONAL: Anytime the Coil 1 valve is full open and the Coil 1 air differential temperature is less than a Value V1, an alarm message shall be issued. Anytime the Coil 1 valve is full open and the Coil 1 air differential temperature is less than a Value V2, the fan system shall shut down until manually reset. The Value V1 shall vary from 20 to 24 as the OA temperature varies from 30°F to -10°F. Value V2 shall equal V1 minus 4. A similar monitor and alarm function shall be provided for Coil 2.

PSYCHROMETRIC ASPECTS

This application is of greatest use in a 100 percent OA system. The SA conditions can lie anywhere along the line of the desired DA dry-bulb temperature.

In the following chart it is assumed that:

1. The system handles 100 percent OA.
2. The supply air PID control loop is set at 70°F.
3. Design OA temperature is –20°F.
4. Temperature rises through coils: Coil 1 = 30 Fahrenheit degrees; Coil 2 = 30 Fahrenheit degrees; Coil 3 = as required for the balance of the heating load.
5. OA temperature is 35°F DB.

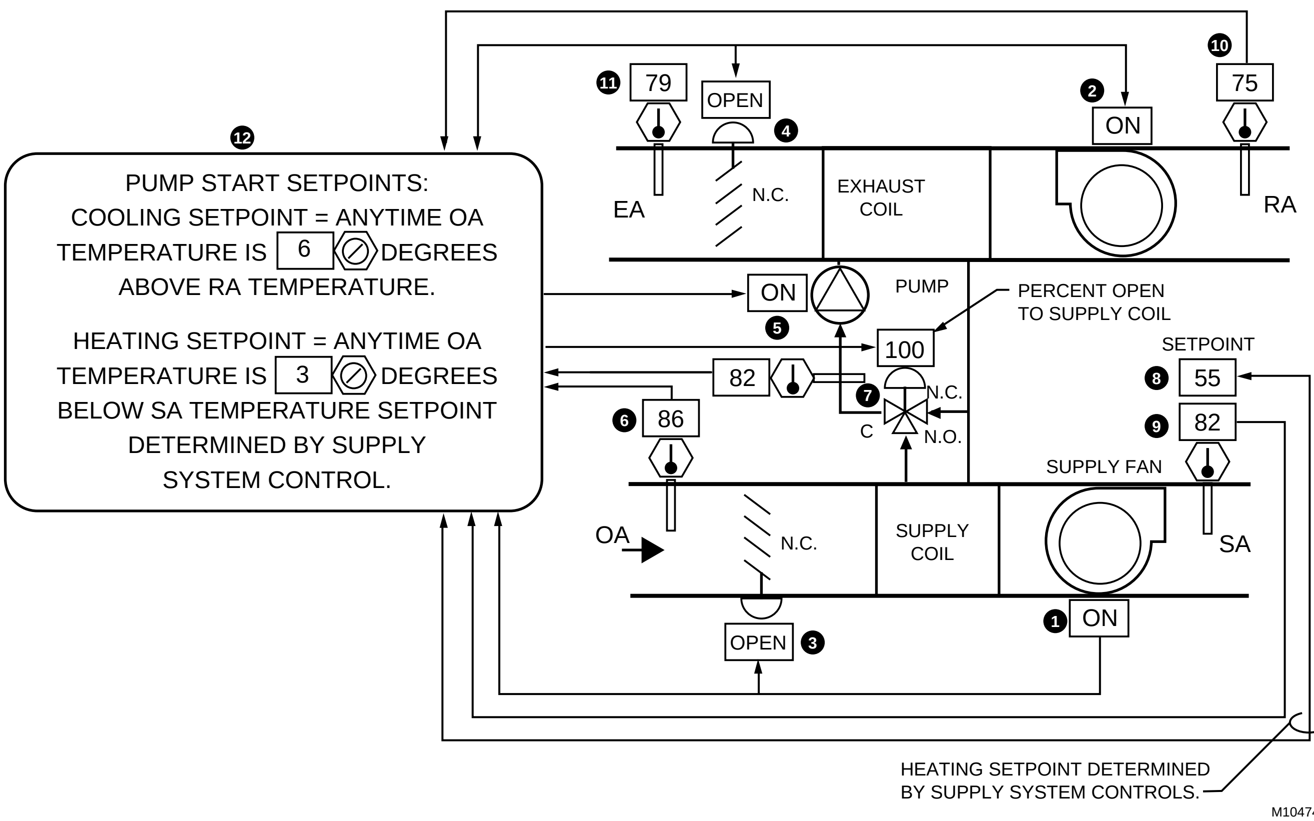


The following results are obtained:

Item No.	Explanation
1	Coil No. 1 is providing 100 percent capacity raising the entering air from 35°F to 65°F.
2	Coil No. 2 valve is closed.
3	Coil No. 3 is modulating and provides a 5°F temperature rise to the desired supply temperature.

YEAR-ROUND HEAT RECOVERY PREHEAT SYSTEM CONTROL

Functional Description



Item No.	Function
1,2	Fans start and enable pump control upon HVAC demand for ventilation (See FAN SYSTEM START-STOP CONTROL).
3,4	Dampers close upon fan shutdown.
5	Pump runs when temperature conditions are suitable for beneficial results.
6,10	The OA and RA temperature difference determines when pump operation is beneficial.
7	Mixing valve prevents too much RA heat from being transferred such that the SA temperature exceeds that demanded by the HVAC control system. Mixing valve also keeps water entering the exhaust coil from dropping below freezing to prevent the coil from frosting.
8,9	HVAC system SA temperature setpoint determines valve position in winter.
11	Operator information.
12	Dynamic graphic sequence display permits the operator to adjust program setpoints.

FEATURES

1. Use of the heat recovery system makes it energy efficient to use 100 percent OA by transferring heat from RA to supply air during heating operation and transferring cooling from RA to supply air during cooling operation.
2. This system can be used to preheat air for an MA system or as a 100% OA system.

CONDITIONS FOR SUCCESSFUL OPERATION

1. A non-freezing medium should be circulated between coils.
2. Heat recovery pump should be shut down during periods when low OA and RA differentials exist and when the HVAC system demands for free cooling are not exceeded by cool OA.
3. Improved control under heating light load conditions may be obtained with an SA PI control loop and a three-way valve. Since the exhaust temperature is never low enough to satisfy the cooling demand, the valve should not bypass the coil during cooling operation.
4. Entering air to each coil may require filtration to keep heat transfer coefficients high.
5. Building exhaust must be centralized.
6. If, after heat recovery, the SA is still below setpoint, a heat exchanger may be added to increase water temperature to the supply coil.

   NOTE: This reduces the recovery system efficiency by lowering the differential temperature between the water and OA.

SPECIFICATIONS

OA and exhaust fans shall start, their OA dampers open, and the water flow and temperature controls shall be enabled anytime the HVAC system requires OA.

In the cooling season, the recirculating pump shall run with full flow in the coils anytime the OA temperature is greater than six degrees above the RA temperature.

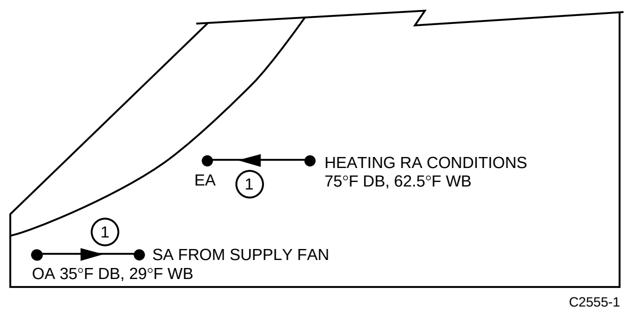
In the heating season, the recirculating pump shall run anytime the OA temperature is less than three degrees below the supply fan SA temperature setpoint.

A pump inlet mixing valve shall be modulated during heating operation if necessary to prevent the supply fan DA temperature from rising above it's setpoint (determined by the HVAC system demands). The mixing valve shall also modulate to prevent the exhaust coil entering water temperature from falling below 32°F to prevent the coil from frosting.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. The three-way valve is full open to the coil because the exhaust air heat does not exceed the supply coil heat requirements.
2. The heat recovery pump is operating.
3. Heating RA condition is 75°F DB and 62.5°F WB.
4. OA temperature is 35°F DB and 29°F WB.



The following results are obtained:

Item No.	Explanation
1	Temperature rise of the SA coil and temperature drop of the EA coil are a function of system design, flow rates, and component efficiency. A 15 Fahrenheit degree rise is shown as an example.

HUMIDIFICATION CONTROL PROCESS

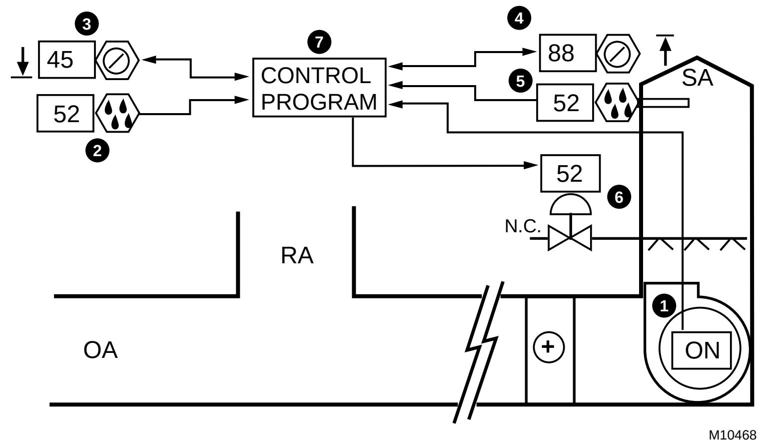
Humidification is a process of adding moisture to air. The most commonly used humidifier type is the steam jet. Humidifier requirements vary; check manufacturers recommendations.

Although steam jet humidifiers are depicted, other modulating types control similarly. On-off humidifiers require a differential in addition to a setpoint.

Generally, humidifiers should be locked off during periods of mechanical cooling.

CONTROL OF MODULATING HUMIDIFIER

Functional Description



Item No.	Function
1	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
2,3	Space humidity PI control modulates the humidifier to maintain the minimum space relative humidity setpoint.
4,5	Humidifier leaving air humidity high limit proportional control modulates humidifier off, if necessary, to prevent relative humidity from exceeding the setpoint.
6	Humidifier is off whenever the fan is off.
7	Control program coordinates digital control loops and fan interlock.

FEATURES

1. Moisture is added with only a slight increase in dry bulb temperature (steam humidifier).
2. Humidification is turned off when the fan is stopped to prevent accumulation of moisture in the ducts.
3. Duct humidity high-limit keeps air below saturation moisture-condensing point.

CONDITIONS FOR SUCCESSFUL OPERATION

1. The steam pressure to the valve is kept at a constant value between 5 and 12 psig.
2. The air passing through the humidifier is warm enough to absorb the required amount of moisture. The best humidifier location is after a heating coil.
3. The high-limit humidistat is set relatively high, about 90 percent relative humidity.
4. If the digital controller is in a network and the OA temperature value is available, the comfort humidification system is disabled when the OA temperature is above a summer value (65°F).
5. Check recommended applications for specific humidifier furnished.
6. Where humidifiers have a separate steam jacket, a separate valve may be added to shut down the jacket steam during prolonged off periods to minimize heat loss. The jacket keeps the humidifier hot so when humidification is required, the humidifying steam does not condense inside the humidifier and enter the duct as water.

SPECIFICATIONS

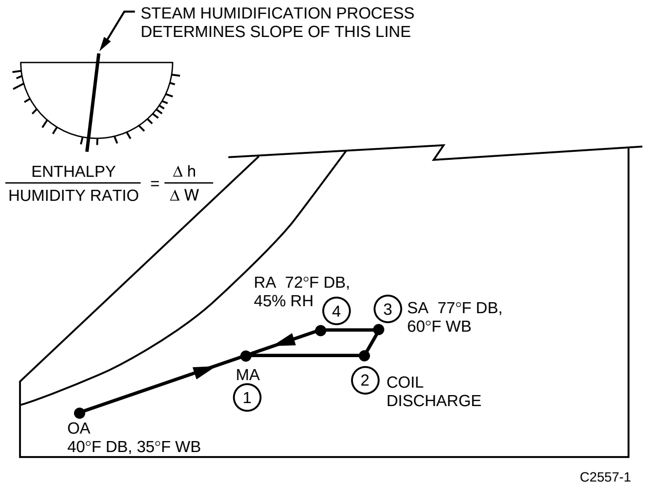
1. The humidifier shall be modulated by a space humidity PI control loop to maintain the humidity setpoint.
2. A humidifier leaving air humidity high limit control loop shall disable the humidifier if the humidity rises above the high-limit setpoint.
3. The humidifier shall be off upon loss of actuator motive force and when the fan is off.

PSYCHROMETRIC ASPECTS

The steam humidification process is almost isothermal.

In the following chart it is assumed that:

1. Space conditions are 72°F and 45% RH.
2. Mixed air (entering the heating coil) is 60°F and 42°F DP.
3. Additional moisture required to maintain space conditions is 0.0014 lbs per lb of dry air.



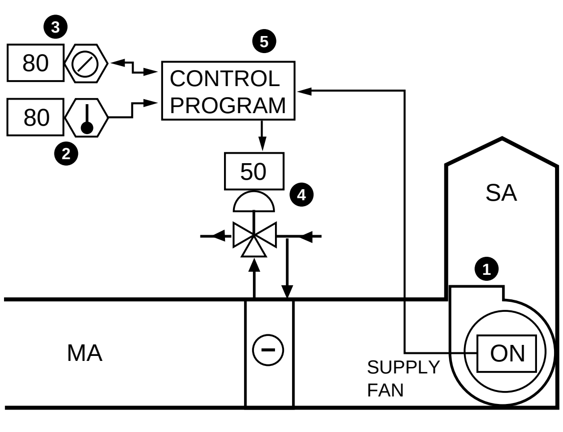
Item No.	Explanation
1	RA and dry OA mix and enter a heating coil.
2	Heating coil leaving air; air gains sensible heat.
3	Humidifier leaving air; air gains mostly latent heat.
4	RA; cooled via heat loss and humidity reduced.

COOLING CONTROL PROCESSES

The following are common control arrangements for cooling.

CONTROL OF MODULATING CHILLED WATER COIL THREE-WAY VALVE

Functional Description



Item No.	Function
1	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
2, 3	Space temperature PID control loop modulates the three-way valve to maintain space temperature setpoint.
4	Chilled water valve directs flow through or around coil as needed to furnish proper amount of cooling.
5	Control program coordinates temperature control and fan status.

FEATURES

1. Chilled water is supplied to the coil at a constant temperature and varying volume.
2. A reasonably constant flow is maintained through the entire piping system.

CONDITION FOR SUCCESSFUL OPERATION

The water must be supplied at a reasonably constant pressure.

LIMITATIONS

Modulating water flow through a constant air volume chilled water coil usually causes a rise in space RH because the coil leaving water temperature rises significantly.

SPECIFICATIONS

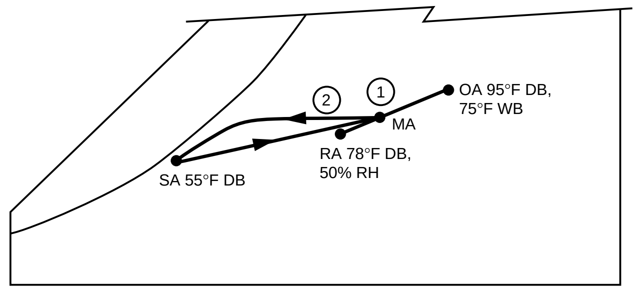
The flow of chilled water through the cooling coil shall be controlled by a three-way valve modulated by a space temperature PI control loop. The valve shall close to the coil upon fan shutdown and open to the coil upon loss of actuator motive force.

PSYCHROMETRIC ASPECTS

The temperature, and often moisture content, of leaving air increases as the sensible cooling load lightens.

In the following chart it is assumed that:

1. Desired space and RA condition is 78°F DB and 50% RH (65°F WB).
2. Design OA temperature is 95°F DB and 75°F WB.
3. Air entering the system is from the ECONOMIZER CYCLE DECISION application. This system operates on 35 percent OA during the cooling cycle.
4. Coil discharge temperature is 55°F.



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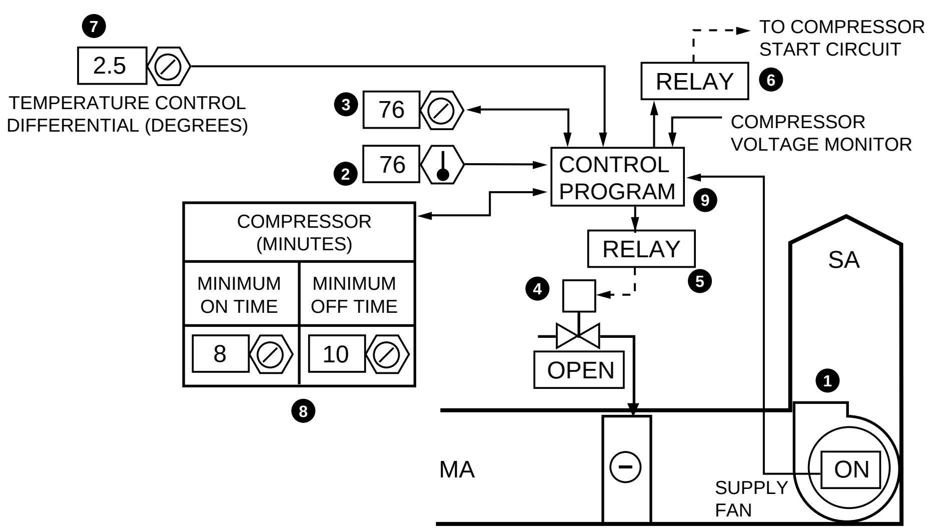
The following results are obtained:

Item No.	Explanation
1	Mixed air temperature at cooling design condition.
2	Air entering the coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.

NOTE: Condition of coil leaving air will change with the cooling load in the space. As the cooling load decreases, the three-way valve will provide less chilled water flow to the coil and the discharge air temperature will rise (approximately along Line 2).

TWO-POSITION CONTROL OF DIRECT EXPANSION COIL SYSTEM

Functional Description



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Item No.	Function
1	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
2	Space temperature inputs to control program.
3	Setpoint determines refrigerant on mode.
4	Refrigerant solenoid valve closes when fan is off.
5	Relay controls liquid line solenoid valve.
6	Relay enables compressor start control system.
7	Temperature differential determines compressor off mode.
8	Compressor minimum on and minimum off times prevent short cycling.
9	Control program coordinates cooling, safety, and fan interlock control.

FEATURES

1. The refrigerant liquid line solenoid valve is closed and the compressor cannot be energized when the supply fan is off.
2. Software time delays for compressor protection.

CONDITIONS FOR SUCCESSFUL OPERATION

The differential timers are set wide enough and the software timers are set high enough to prevent short cycling of the compressor under light load.

LIMITATIONS

1. Direct expansion coils are difficult to control from leaving air due to the large and rapid temperature drop when energized.
2. Compressor operating and safety controls must be incorporated into the control system.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

The DX control system shall be enabled anytime the fan operates.

Cooling system shall be cycled by a temperature control loop with a 2.5 degree (adjustable) differential to maintain the space temperature setpoint. When the system is commanded on by the control program, it shall remain on at least eight minutes, and when it is commanded off (or drops off during power interruptions) it shall remain off at least ten minutes.

On a rise in space temperature to the setpoint, the refrigerant liquid line valve shall open and a relay shall enable the compressor to start under it's controls.

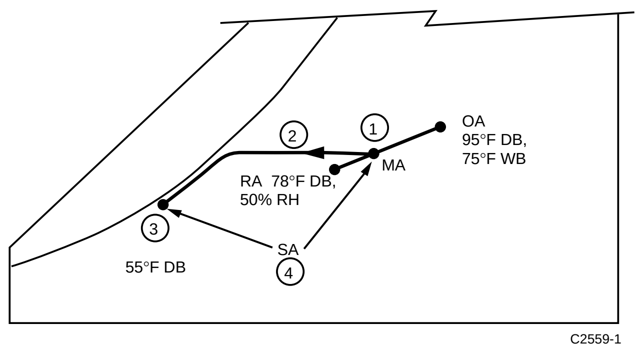
When the space temperature drops to a value equal to the space temperature setpoint minus a differential, the liquid line solenoid valve shall close, and the compressor shall continue to operate until shut down by it's low-pressure cutout. Refrigerant system control and interlock wiring shall be as recommended by the compressor manufacturer.

PSYCHROMETRIC ASPECTS

With on-off control, either cooled air or mixed air is supplied into the space.

In the following chart it is assumed that:

1. Desired space and RA condition is 78°F DB and 50% RH (65°F WB).
2. Design OA temperature is 95°F DB and 75°F WB.
3. Air entering the system is from the ECONOMIZER CYCLE DECISION application. The system operates on a minimum of 35 percent OA during the cooling cycle.
4. Coil leaving air temperature is 55°F.

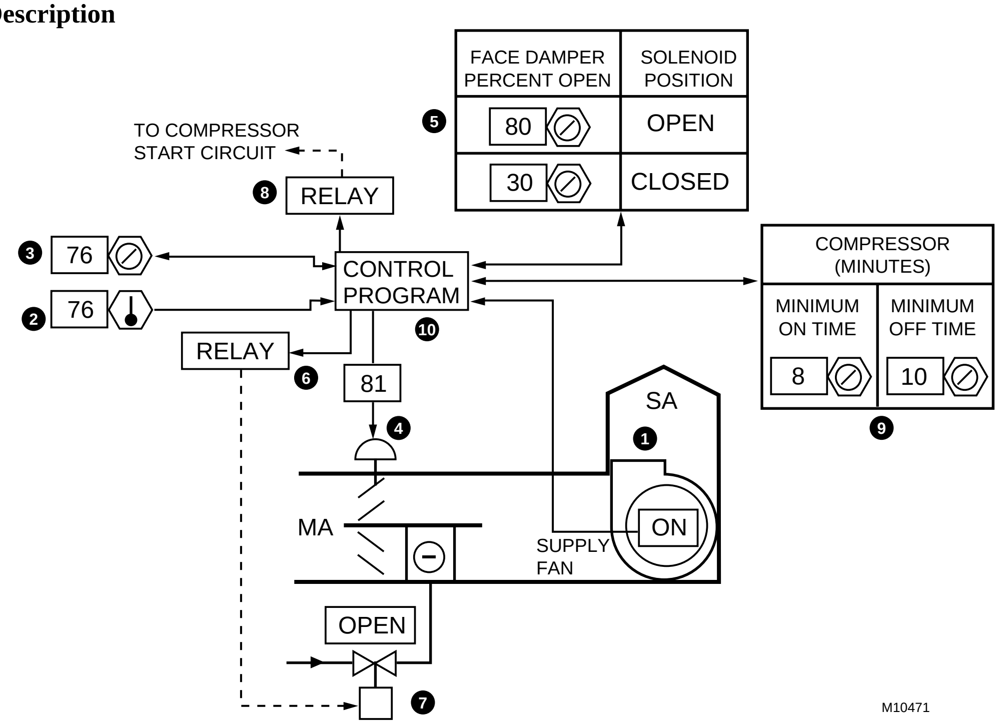


The following results are obtained:

Item No.	Explanation
1	Mixed air temperature at cooling design condition.
2	Air entering the coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3	When the space thermostat has the DX cooling energized, coil leaving air is at this value.
4	Air supplied to the space will alternate between Point 1 and Point 3 as determined by the space thermostat.

TWO-POSITION CONTROL OF DIRECT EXPANSION COIL SYSTEM—MODULATING FACE AND BYPASS DAMPER

Functional Description



Item No.	Function
1	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
2,3	Space temperature sensor inputs to PID control loop to maintain setpoint.
4	Face and bypass damper modulates for cooling control.
5	Damper position determines compressor mode.
6,7	Refrigerant liquid line solenoid valve cycles for cooling.
8	Relay energizes compressor.
9	Timers protect compressor from short cycling.
10	Control program coordinates temperature, compressor, and fan interlock control.

FEATURES

1. The proportions of air passing through and around the coil are varied by modulating face and bypass dampers.
2. Lowering air velocity through the coil lowers the moisture content of air leaving the coil, thus producing lower space RH than systems that only cycle the refrigeration at a constant air volume.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Capacity control of refrigeration provided to avoid icing under light load.

LIMITATIONS

1. Direct expansion coils are difficult to control from SA due to the large and rapid temperature drop when energized.
2. Compressor operating and safety controls must be incorporated into the control system.
3. The system may be controlled from SA if necessary, but only if the sensor is located far enough downstream of the coil to ensure complete mixing of the air and software timers are provided to prevent compressor short cycling. Hot gas bypass may be required.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

The DX control system shall be enabled anytime the fan operates.

Space temperature PI control loop shall modulate DX coil face and bypass dampers to maintain setpoint.

Anytime the face damper modulates up to 80% open, the refrigerant valve shall open and a relay shall enable the compressor to start under compressor controls. When the compressor system is commanded on, it shall remain on at least eight minutes and when it is commanded off (or drops off during power interruptions) it shall remain off at least ten minutes.

Anytime the face damper modulates down to 30% open, the refrigerant valve shall close and the compressor relay shall open.

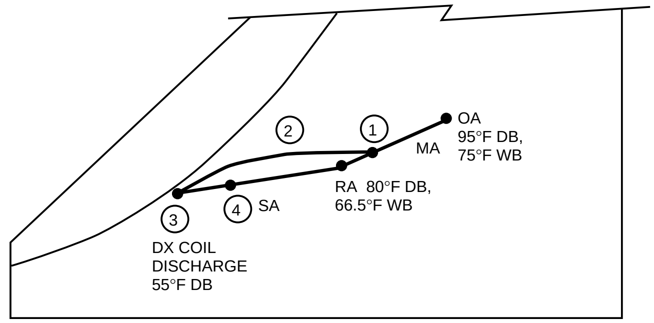
When the solenoid valve is closed, the compressor shall continue to operate until shut down by it's low-pressure cutout.

PSYCHROMETRIC ASPECTS

Cooled air from the coil is mixed with bypass air to provide the necessary DA temperature.

In the following chart it is assumed that:

1. Desired RA condition is 80°F DB and 50% RH (66.5°F WB).
2. Design OA condition is 95°F DB and 75°F WB.
3. Air entering the system is from the ECONOMIZER CYCLE DECISION application. The system operates on 25 percent OA during the cooling cycle.
4. Coil leaving air temperature is 55°F.



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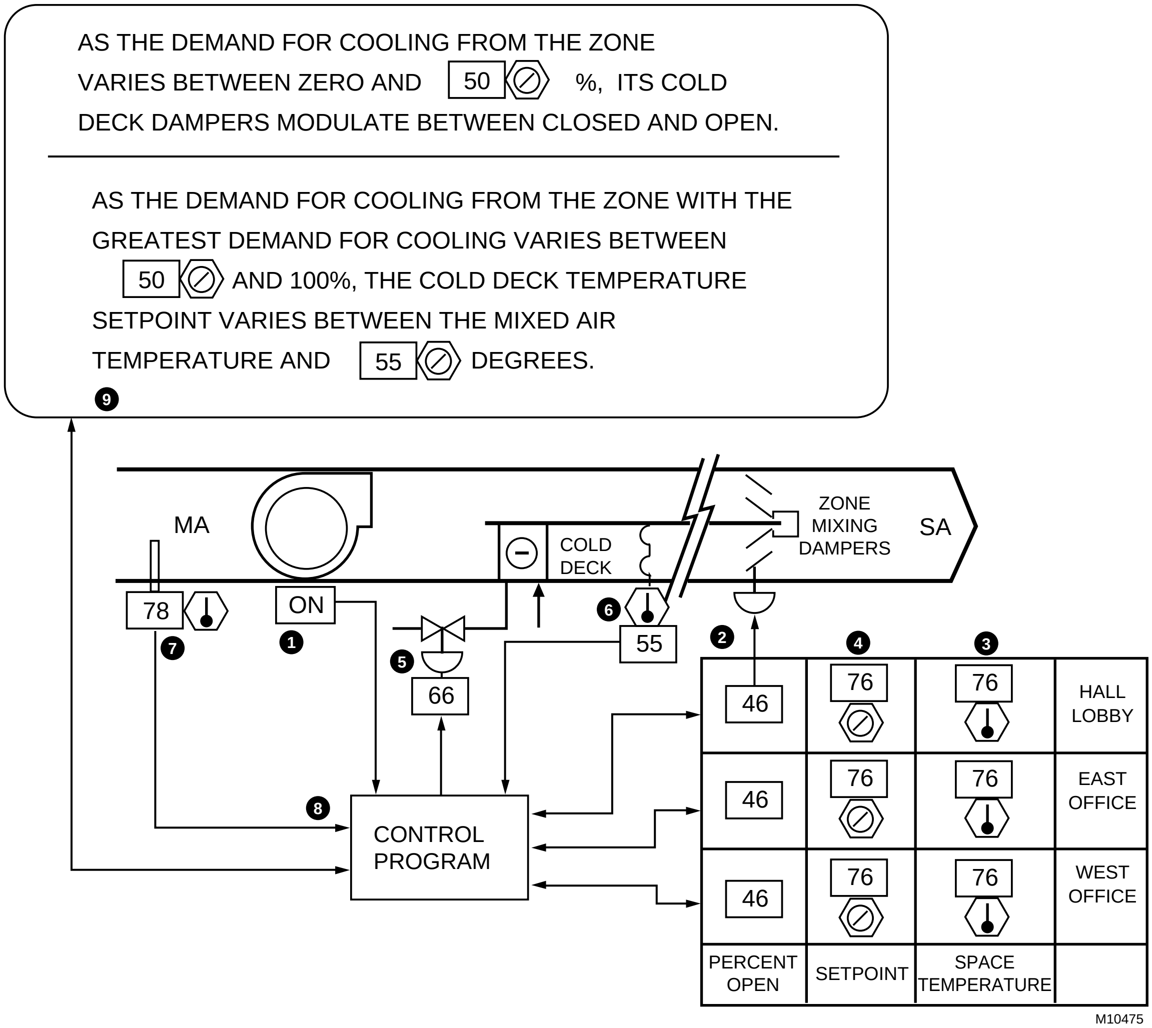
The following results are obtained:

Item No.	Explanation
1	Mixed air temperature at cooling design enters the cooling system.
2	Air enters the coil and is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3	When the space thermostat calls for DX cooling to be energized and the face damper greater is than 30% open, air leaving the DX coil is at this value.
4	Supply air will vary between Point 3 and Point 1 as the space thermostat positions the face and bypass dampers.

COLD DECK SYSTEM WITH ZONE DAMPER CONTROL

Functional Description



Item No.	Function
1	Control system energizes when fan is turned on **(**See FAN SYSTEM START-STOP CONTROL**)**.
2-4	Zone mixing dampers modulate to maintain space temperature setpoint.
5,6	Chilled water valve modulates to maintain cold deck temperature setpoint.
7	Mixed air temperature determines cold deck temperature setpoint at zero cooling load.
8	Control program coordinates zone demand, temperature, and fan interlock control.
9	Dynamic graphic sequence display permits the operator to adjust program setpoints.

FEATURES

1. A mixing damper and temperature sensor for each zone provides individual zone control. (Three zones shown).
2. A single cooling coil or group of coils furnishes cooling for the entire system.
3. A constant volume of air is delivered to each zone.
4. Cold deck temperature is maintained just low enough to satisfy the zone requiring the greatest amount of cooling which provides efficient operation when used in conjunction with a hot deck coil/control multizone system.

CONDITIONS FOR SUCCESSFUL OPERATION

1. All zones are connected to load analyzer program to satisfy total load requirements. In larger systems only selected diverse zone loads are connected. Zones that may be allowed to go out of control (storage rooms, etc.) should not be connected to the load analyzer program.
2. Each zone duct has a balancing damper following the mixing dampers to ensure design volume to each zone.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, cooling control shall be enabled.

Each zone cold deck mixing damper shall be modulated to maintain zone space temperature setpoint.

The chilled water valve shall be modulated to maintain the cold deck temperature setpoint.

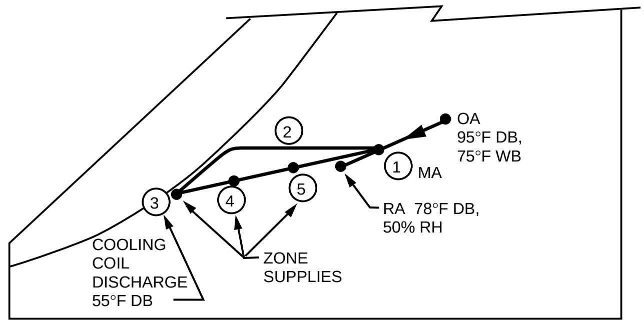
Zone mixing dampers shall modulate from 0 to 100% open to the cold deck as their respective zone demands for cooling vary from zero to 50%.

The cold deck temperature setpoint shall be reset from the mixed air temperature to 55°F as the cooling demand from the zone with the greatest cooling demand varies from 50 to 100%.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. RA condition is 78°F DB and 50% RH (65°F WB).
2. Design OA condition is 95°F DB and 75°F WB.
3. Air entering the system is from the ECONOMIZER CYCLE DECISION application. The system operates on 35 percent OA during the cooling cycle.
4. One zone is calling for full cooling.
5. Other zones require partial cooling.
6. Coil leaving air temperature is 55°F.



C2561-2

The following results are obtained:

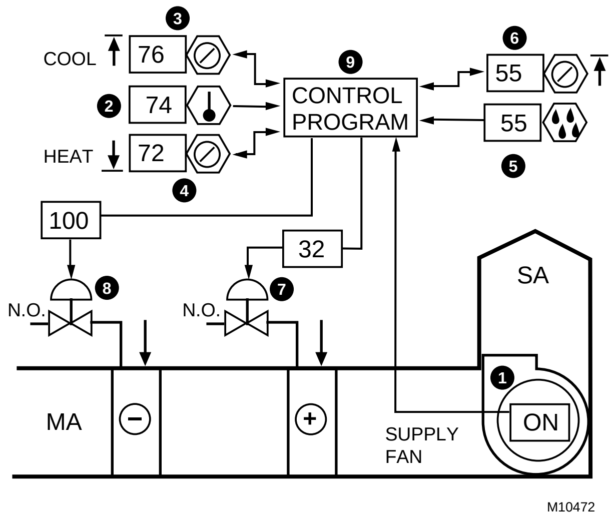
Item No.	Explanation
1	Mixed air temperature at cooling design condition.
2	Air entering the coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3	This condition represents the air leaving the cold deck and air supplied to the zone calling for full cooling.
4	This condition represents the SA to a zone with partial call for cooling. Both cooling and bypass dampers are partially open.
5	This condition represents the SA to a zone with a partial call for cooling but less than that at Point 4.

DEHUMIDIFICATION CONTROL PROCESSES

The following applications show various methods of controlling dehumidification in air conditioning systems.

DIRECT EXPANSION OR WATER COIL SYSTEM CONTROL

Functional Description



Item No.	Function
1	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL**).**
2-4	Space temperature PI control loops have heat and cool setpoints with deadband.
5,6	Space humidity sensor and setpoint enable dehumidification.
7,8	Heating and cooling valves position for heat, cool, and dehumidify cycles. The valves close when the fan is off.
9	Control program coordinates cooling, heating, dehumidifying, and fan and hot water interlock control.

FEATURES

1. This application uses two-position control of a direct expansion or chilled water coil for dehumidification.
2. This application controls both space temperature (with a dead band) and dehumidification.
3. Dehumidification cycle is disabled if hot water flow is not available.
4. Heating setpoint raised slightly during dehumidification cycle to reduce cooling (dehumidifying) energy.

CONDITIONS FOR SUCCESSFUL OPERATION

1. If a chilled water coil is used, the water supply is cold enough to produce the lowest required dew point.
2. The cooling coil valve should be two-position controlled for the dehumidification cycle for quick and maximum dehumidification. A space RH differential is required for two-position control, such as dehumidification on a rise to 60% RH and off on a drop to 55% RH. Modulating dehumidification control of a chilled water valve, which delays moisture removal until the chilled water flow gets high enough to cause condensation, is also satisfactory.
3. Hot water flow is available for reheat or the space will get very cold and humid during periods when dehumidification is demanded and the cooling load is light.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

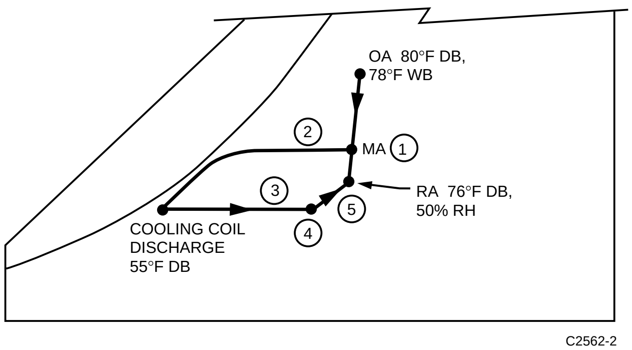
1. Anytime the supply fan runs, control system shall be enabled.
2. The chilled water valve and hot water valve shall be modulated as required to maintain their separate heating and cooling space temperature setpoints.
3. Anytime the space relative humidity rises above it’s setpoint, the cooling valve shall position full open for maximum dehumidification. In this mode, the heating space temperature setpoint shall be midpoint between the heating and cooling setpoints, and the hot water valve shall be modulated to prevent the dehumidification cycle from overcooling the space.
4. The dehumidification cycle shall be disabled anytime there is no hot water flow or temperature.

PSYCHROMETRIC ASPECTS

In comfort air conditioning, dehumidification is typically required when the OA is cool and moist and the solar load is too low to demand enough cooling for dehumidification. The space relative humidity is maintained at or below a desired value, depending on the moisture content of the air entering the cooling coil.

In the following chart it is assumed that:

1. Desired space condition is 76°F DB and a maximum of 50% RH.
2. OA condition is 80°F DB and 78°F WB.
3. Air entering the system is from the ECONOMIZER CYCLE DECISION application. The system operates on 25 percent OA during the cooling cycle.
4. Cooling coil leaving air temperature is 55°F.

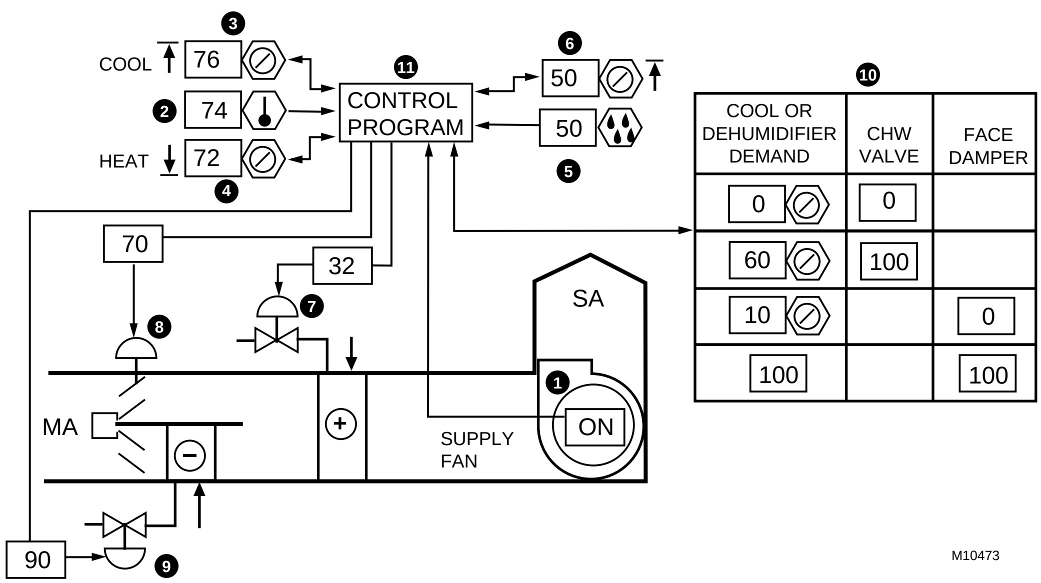


The following results are obtained:

Item No.	Explanation
1	Mixed air temperature at cooling design condition.
2	Air entering the cooling coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3	The final leaving air temperature necessary to satisfy space requirements will be maintained by reheating along a constant moisture line.
4	Heating coil discharge.
5	This process line represents the increase in temperature and humidity that occurs due to the sensible and latent heat gains in the space.

WATER COIL FACE AND BYPASS SYSTEM CONTROL

Functional Description



Item No.	Function
1	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
2-4	Space temperature PI control loops have heat and cool setpoints with deadband.
5,6	Space humidity sensor and setpoint enable dehumidification.
7-9	Heating and cooling valves and face and bypass dampers position for heating, cooling, and dehumidifying cycles.
10	Stages chilled water and face-and-bypass damper loading.
11	Control program coordinates cooling, heating, dehumidifying, and fan and hot water interlock control.

FEATURES

1. Better dehumidification by having the chilled water flow sequence slightly ahead of the face damper opening to keep a low dew point temperature.
2. This application controls heating, cooling (with a dead band), and dehumidification.

CONDITIONS FOR SUCCESSFUL OPERATION

1. If a chilled water coil is used, the water supply is cold enough to produce the lowest required dew point.
2. To prevent frosting the coil under light load, if direct expansion coil is used, proper valve cut-in, staging, and cut-out settings related to the face and bypass damper position are determined.
3. Hot water flow is available for reheat or the space will get very cold and humid during periods when dehumidification is demanded and the cooling load is light.
4. During some chilled water coil loadings, the coil leaving water temperature may drop quite low. If this is undesirable to the chiller plant, a coil leaving air temperature low limit PID loop will reduce the effects.
5. If a DX coil is used, the liquid line solenoid valve is staged with the damper position and software timers are provided to prevent frosting the coil and to prevent short cycling the refrigeration system.

NOTE: The balance of this discussion is for a chilled water coil system.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, the control system shall be enabled.

The hot water valve shall be modulated as required to maintain the heating space temperature setpoint. Anytime the chilled water valve is full open, because of a demand for dehumidification, the actual heating space temperature setpoint shall be midpoint between the heating and cooling setpoints.

As the space temperature cooling PI loop or the space humidity high limit PI loop demand (whichever demand is greater) for cooling varies from 0 to 60 percent, the chilled water valve shall position from closed to open. As the space temperature or the humidity PI loop demand (whichever demand is greater) for cooling varies from 10 to 100 percent demand the face and bypass dampers shall position from closed to open to the coil face.

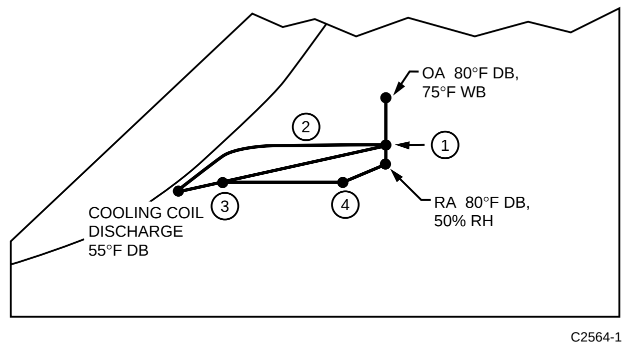
The dehumidification cycle shall be disabled anytime the hot water pump is off or the hot water temperature is inadequate.

PSYCHROMETRIC ASPECTS

The space relative humidity is maintained at or below a desired value depending on the moisture content of the air entering the coil.

In the following chart it is assumed that:

1. Chilled water (not DX) is used
2. Desired space condition is 80°F DB and 50% RH.
3. Outdoor air condition is 80°F DB and 75°F WB.
4. Air entering the system is from the MIXED AIR CONTROL WITH ECONOMIZER CYCLE application. The system operates on 25 percent outdoor air during the cooling cycle.
5. Cooling coil leaving air temperature is 55°F.



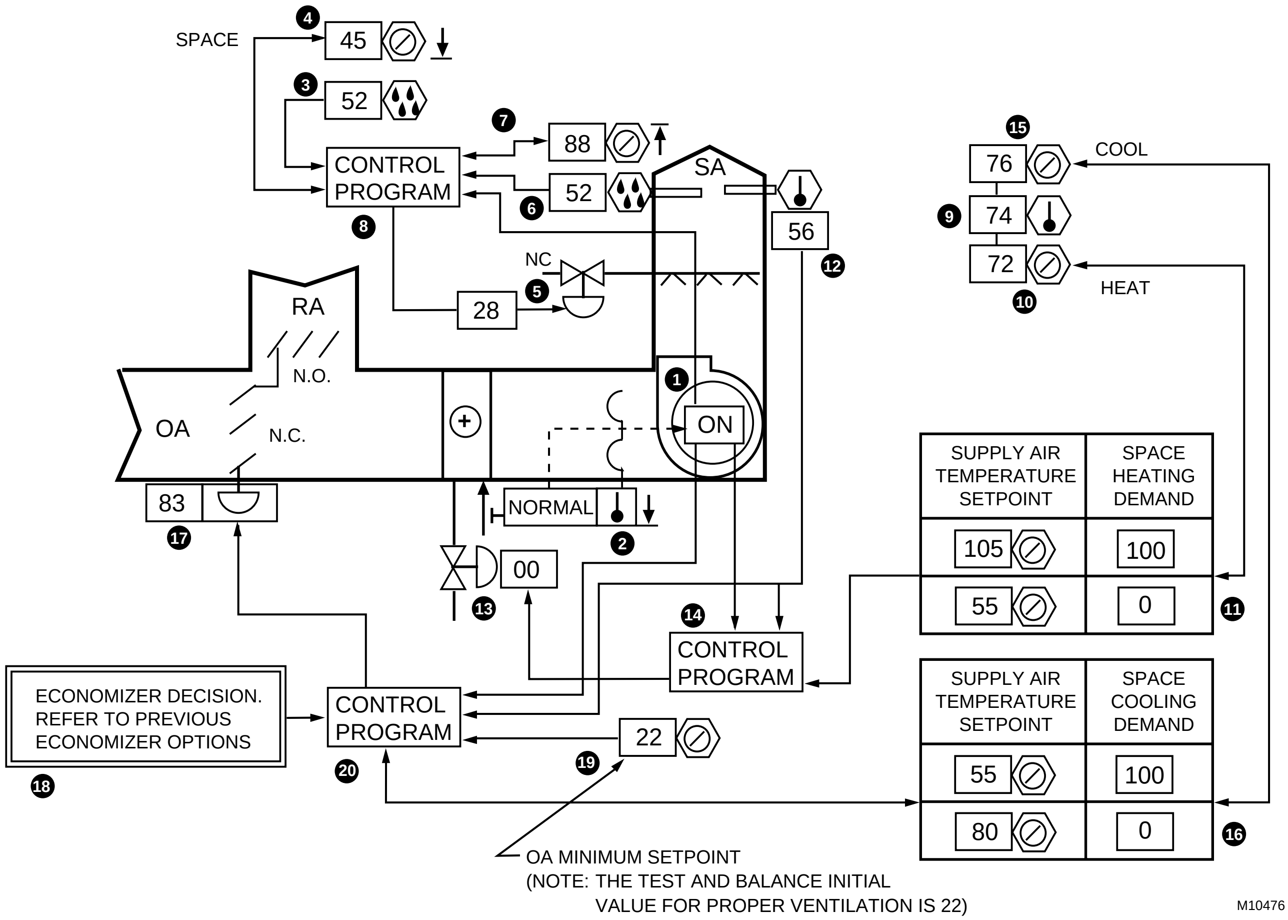
The following results are obtained:

Item No.	Explanation
1	Mixed air temperature.
2	Air entering the cooling coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3	This point represents air entering the heating coil which is a mixture of cooling coil leaving air through the face damper and the mixed air through the bypass damper. If the cooling or dehumidification load decreases, air entering the heating coil will move toward the mixed air condition. If the cooling or dehumidification load increases, air entering the heating coil will move toward the cooling coil leaving air condition.
4	As the cooling sensible load decreases, the heating coil valve will open and Point 4 moves on a constant moisture line from Point 3.

HEATING SYSTEM CONTROL PROCESS

SPACE CONTROL OF HEATING, ECONOMIZER (FREE COOLING), AND HUMIDIFICATION

Functional Description



Item No.	Function
1,2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3-5	Space humidity PI loop controls humidifier valve if space humidity falls to setpoint.
6,7	SA humidity high limit PI loop throttles humidifier valve if duct humidity rises above setpoint.
8	Control program coordinates space and humidifier leaving air humidity control and fan interlock.
9-11	Space temperature heating PI loop inputs to SA temperature heating reset schedule.
12	SA temperature PI loop inputs to heating and mixed air control programs.
13	Hot water valve modulates to maintain SA temperature setpoint.
14	Control program coordinates space and SA heating control and fan interlock.
15,16	Space temperature cooling PI loop inputs to SA temperature cooling reset schedule.
17	Mixing dampers modulate to maintain SA temperature setpoint.
18	Economizer decision program determines when OA is suitable to assist with cooling demand.
19	Mixing dampers minimum ventilation value.
20	Control program coordinates space and supply cooling control, ventilation control, and fan interlock.

FEATURES

1. The outdoor air quantity is modulated from a minimum to take advantage of free cooling based on space temperature demand.
2. The SA temperature will not fall below a set minimum.
3. Air is supplied at the temperature necessary to make up the sensible heat loss of the space.
4. Space relative humidity is maintained at a minimum value by a space humidity controller controlling the humidifier.
5. Separate setpoints for heating and cooling.

CONDITIONS FOR SUCCESSFUL OPERATION

See FAN SYSTEM START-STOP CONTROL.

1. An appropriate schedule of settings.
2. The low temperature limit controller located to respond to the lowest temperature in the duct.

LIMITATIONS

This application used in applications that do not require mechanical cooling.

SPECIFICATIONS

Anytime the supply fan runs, control system shall be enabled.

Anytime the space relative humidity drops below the setpoint, the space humidity PI loop shall modulate the humidifier, subject to an SA humidity high limit override set at 88%.

As the space heating load varies from 0 to 100%, the SA heating PI loop setpoint shall be reset from 55°F to 105°F. The hot water valve shall be modulated as required to maintain the SA temperature setpoint.

Anytime the fan runs, the mixing dampers shall position to a minimum ventilation setting.

As the space cooling load varies from 0 to 100%, the SA cooling PI loop setpoint shall be reset from 80°F to 55°F. The outdoor and return (and relief if applicable) air dampers shall be modulated as required to maintain the SA temperature setpoint.

Cooling damper control shall be returned to minimum position anytime the economizer mode is disabled.

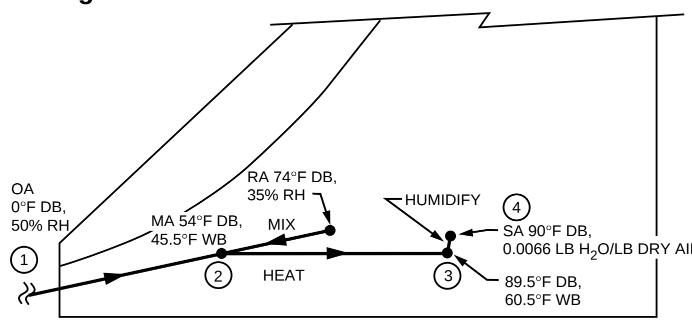
Separate space heating and cooling setpoints shall be provided.

PSYCHROMETRIC ASPECTS

In the following charts it is assumed that:

1. Design outdoor air condition is 0°F DB and 50 percent relative humidity.
2. SA condition at design load is 90°F DB and 0.0066 pound of moisture per pound of dry air.
3. Light load outdoor air condition is 55°F DB and 52.5°F WB.
4. SA condition at light load is 75°F DB and 0.0066 pound of moisture per pound of dry air.
5. Minimum outdoor air is 25 percent.
6. RA condition is 74°F DB and 35% RH.

Design Load

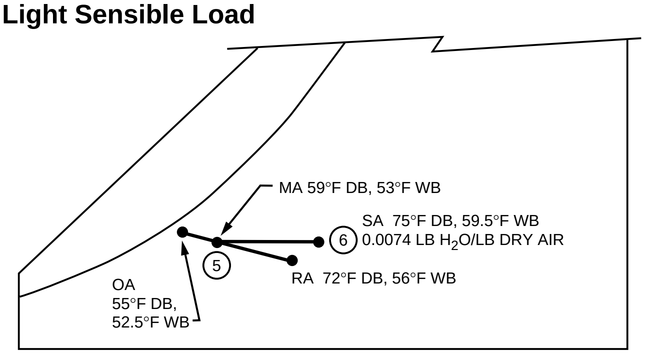


DESIGN LOAD

The following results are obtained:

Item No.	Explanation
1	Design outdoor air condition is 0°F DB and 50 percent relative humidity.
2	Mixed air condition is 54°F DB and 45.5°F WB.
3	Heated air condition is 89.5°F DB and 60.5°F WB.
4	SA condition is 90°F DB and 0.0066 pound of moisture per pound of dry air.

Light Sensible Load



LIGHT SENSITIVE LOAD

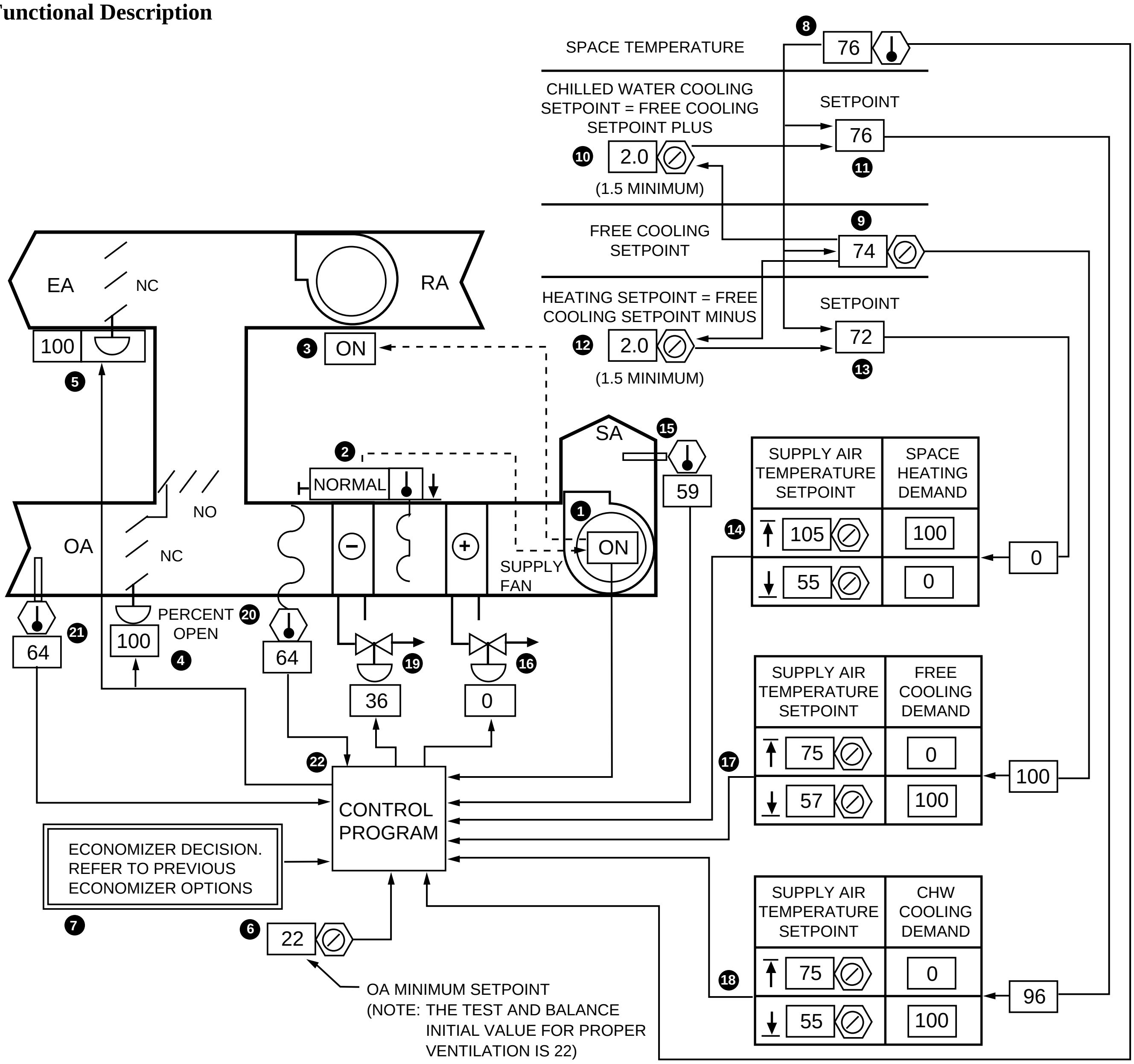
The following results are obtained:

Item No.	Explanation
5	Mixed air condition is 59°F DB and 53°F WB.
6	SA condition is 75°F DB, and 0.0074 pound of moisture per pound of dry air.

YEAR-ROUND SYSTEM CONTROL PROCESSES

HEATING, COOLING, AND ECONOMIZER

Functional Description



Item No.	Function
1-3	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
4-6	Mixing dampers modulate to maintain minimum ventilation value and free cooling SA temperature setpoint.
7	Economizer enables free cooling when OA is appropriate.
8	Space temperature dictates heat and cool demands.
9-13	Free cooling setpoint and heat/cool deadband values determine the SA temperature setpoint for hot and chilled water control setpoints. Software has a minimum 1.5 Fahrenheit degree heating and cooling deadband.
14	Heat demand varies SA temperature setpoint.
15,16	Hot water valve modulates to maintain SA

	temperature setpoint.
17	Free cooling demand varies SA temperature setpoint.
18	Chilled water cooling demand varies SA temperature setpoint.
19	Chilled water valve modulates to maintain SA temperature cooling setpoint.
20	MA temperature sensor for operator information.
21	OA temperature sensor for operator information.
22	Control program coordinates space and supply cooling, heating, and ventilation control, and fan interlock.

FEATURES

1. Use of space control resetting SA temperature control adds stability. The MA sensor is required to prevent freeze-up if the free cooling setpoint is lowered in freezing weather.
2. SA temperature is maintained only as high or low as required to meet space requirements.
3. Free cooling cycle selection determined by the economizer control program to minimize load on mechanical cooling system.
4. Optimum comfort temperature provided during free cooling cycle with energy conserving deadbands for heating and cooling.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Sensor locations must be selected to measure representative air conditions.
2. SA temperature control loops should provide PID control to assure stability with minimum offset.

NOTE: In cold climates this unit would most often have the heating coil ahead of the cooling coil and the low temperature switch after the heating coil. Control would not change. In the configuration shown, it would be possible to add a dehumidification cycle with reheat (software) at a later time.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, control system shall be enabled, and mixing dampers shall position to minimum ventilation position during scheduled occupancy periods.

Anytime the economizer decision program determines that OA is suitable to assist in cooling, the temperature controls shall be enabled to override the dampers minimum ventilation position for free cooling as required.

The space temperature shall have a free cooling PID loop setpoint selected to provide optimum occupant comfort temperature. The space temperature shall have a chilled water cooling PID loop setpoint adjustable to no lower than 1.5 degrees (minimum) above the free cooling setpoint. The space temperature shall have a heating PID loop setpoint adjustable to no higher than 1.5 degrees (minimum) below the free cooling setpoint.

As the space heating load varies from 100 to 0%, an SA heating PID control loop setpoint shall vary from 105°F to 55°F. The hot water valve shall modulate to maintain the heating SA temperature setpoint, except that anytime the space temperature is greater than one degree above the free cooling space temperature setpoint, the hot water valve control PID setpoint shall be 52.5°F.

As the space free cooling load varies from 0 to 100%, an SA free cooling PID control loop setpoint shall vary from 75°F to 57°F. The mixing dampers shall modulate to maintain the free cooling SA temperature setpoint.

As the space chilled water cooling load varies from 0 to 100%, an SA chilled water cooling PID control loop setpoint shall vary from 75°F to 55°F. The chilled water valve shall modulate to maintain this cooling SA temperature setpoint.

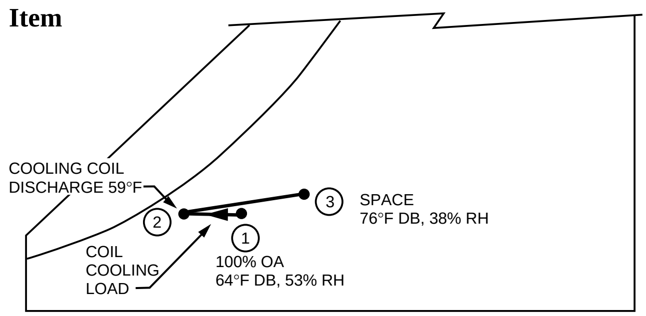
PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. OA condition is 64°F and 53% RH.
2. System is in the economizer mode.

The following results are obtained:

Item



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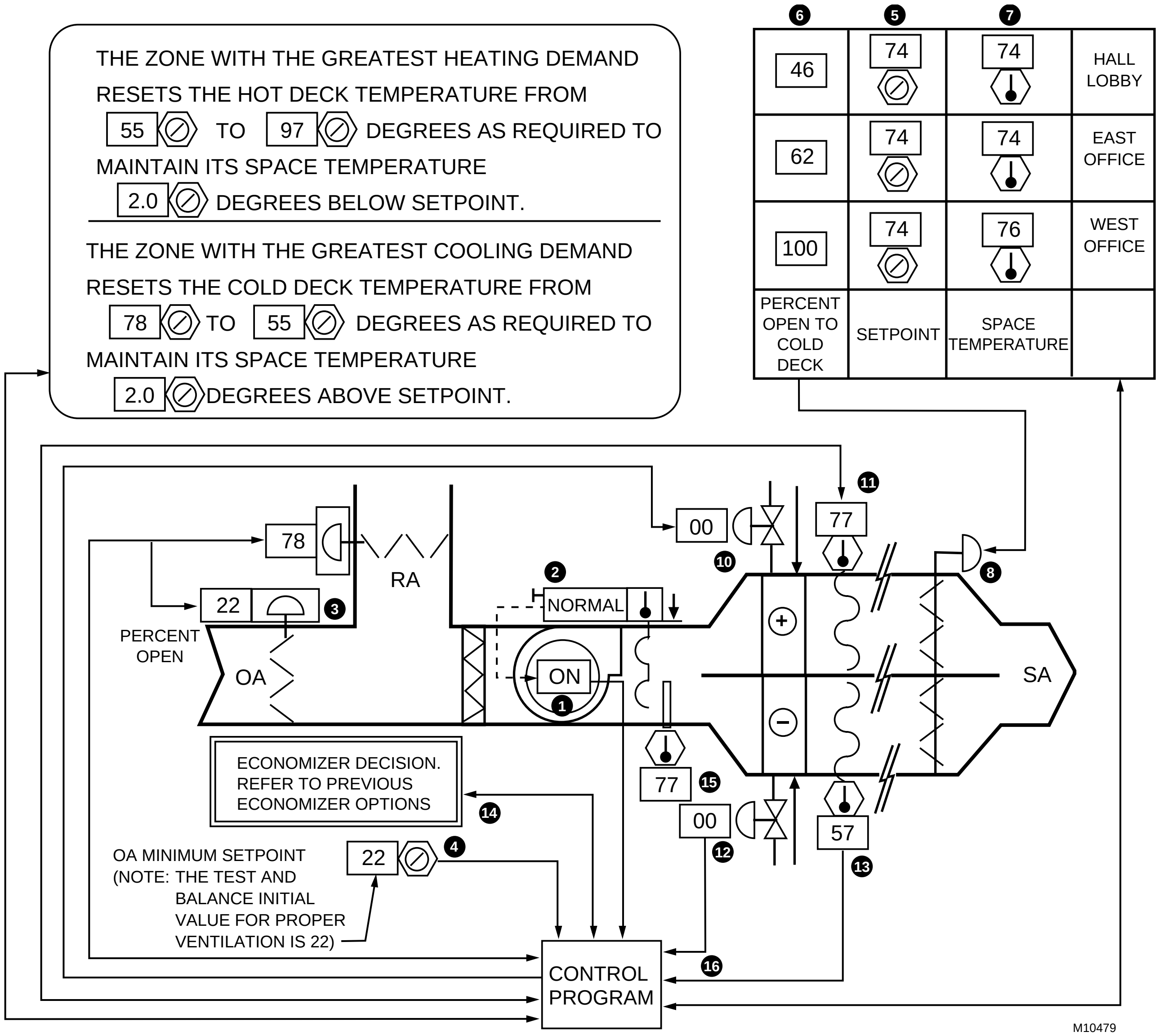
No.	Explanation
1	100% economizer air is entering the cooling coil.
2	The chilled water coil cools the entering air to its 59°F setpoint (removing little moisture because the water flow is low and the OA moisture content is not high).
3	Space temperature is 76°F and 38% RH.

MULTIZONE UNIT

Functional Description



Item No.	Function
1,2	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
3,4	Mixing dampers position to minimum position during occupied fan operation and modulate for cooling.
5-8	Zone mixing dampers modulate to maintain space temperature setpoint.
9	Zone with greatest cooling demand determines cold deck temperature setpoint, and zone with greatest heating demand determines hot deck temperature setpoint.
10,11	Hot deck valve modulated to maintain hot deck temperature setpoint.
12,13	Cold deck valve modulated to maintain cold deck temperature setpoint.
14	Economizer enables free cooling when OA is suitable.
15	Fan leaving air temperature for operator information.
16	Control program coordinates cooling, heating, ventilation, and fan interlock control.

FEATURES

1. This application uses zone control of heating and cooling.
2. Deck temperatures dictated by zones with greatest heating and cooling demand and with a deadband.

CONDITIONS FOR SUCCESSFUL OPERATION

All zones should be connected to load analyzer program to satisfy total load requirements. However, in larger systems it may be good practice to connect only selected diverse zone loads. Zones that may be allowed to go out of control (storage rooms, etc.) should not be connected to the load analyzer program.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, control system shall be enabled, and mixing dampers shall position to minimum ventilation position during scheduled occupancy periods.

Each zone space temperature PI loop shall modulate its zone mixing dampers to maintain its space temperature setpoint.

The zone with the greatest temperature deviation below setpoint shall reset the hot deck temperature setpoint from 55°F to 97°F as required to maintain the zone space temperature 2 degrees below setpoint.

The zone with the greatest temperature deviation above setpoint shall reset the cold deck temperature setpoint from 78°F to 55°F as required to maintain the zone space temperature 2 degrees above setpoint.

The hot deck PID loop shall modulate the hot deck hot water valve to maintain the hot deck temperature setpoint.

The cold deck PID loop shall modulate the OA/RA mixing dampers in sequence with the cold deck chilled water valve to maintain the cold deck temperature setpoint.

Anytime the economizer decision program determines that OA is unsuitable to assist in cooling, the OA/RA mixing dampers shall be returned to their minimum ventilation position.

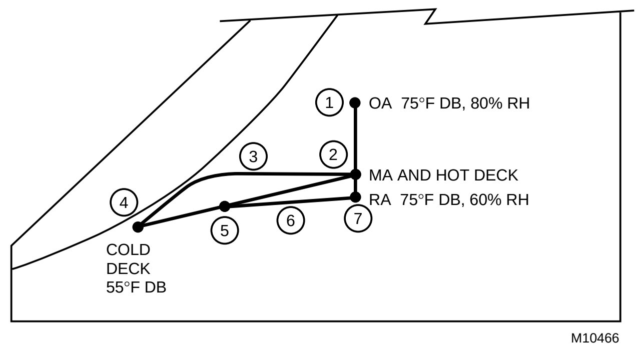
PSYCHROMETRIC ASPECTS

In the summer, zone space temperature is maintained by mixing air from the hot deck with cold deck air (the temperature of which is dictated by the zone with the greatest demand for cooling). The zone with the greatest demand for cooling gets 100% cold deck air.

In the winter, zone space temperature is maintained by mixing air from the cold deck with hot deck air (the temperature of which is dictated by the zone with the greatest demand for heating). The zone with the greatest demand for heating gets 100% hot deck air. The zone with the greatest demand for cooling (assuming a zone space temperature rises two degrees above setpoint and demands cooling) gets 100% cold deck air and dictates the cold deck temperature maintained via the economizer cycle.

In the following chart it is assumed that:

1. Desired space condition is 75°F DB.
2. Outdoor air condition is 75°F DB and 80% RH.
3. The mixed air is 25 percent outdoor air during the cooling cycle.
4. Coil leaving air temperature is 55°F (at least one zone demands full cooling).

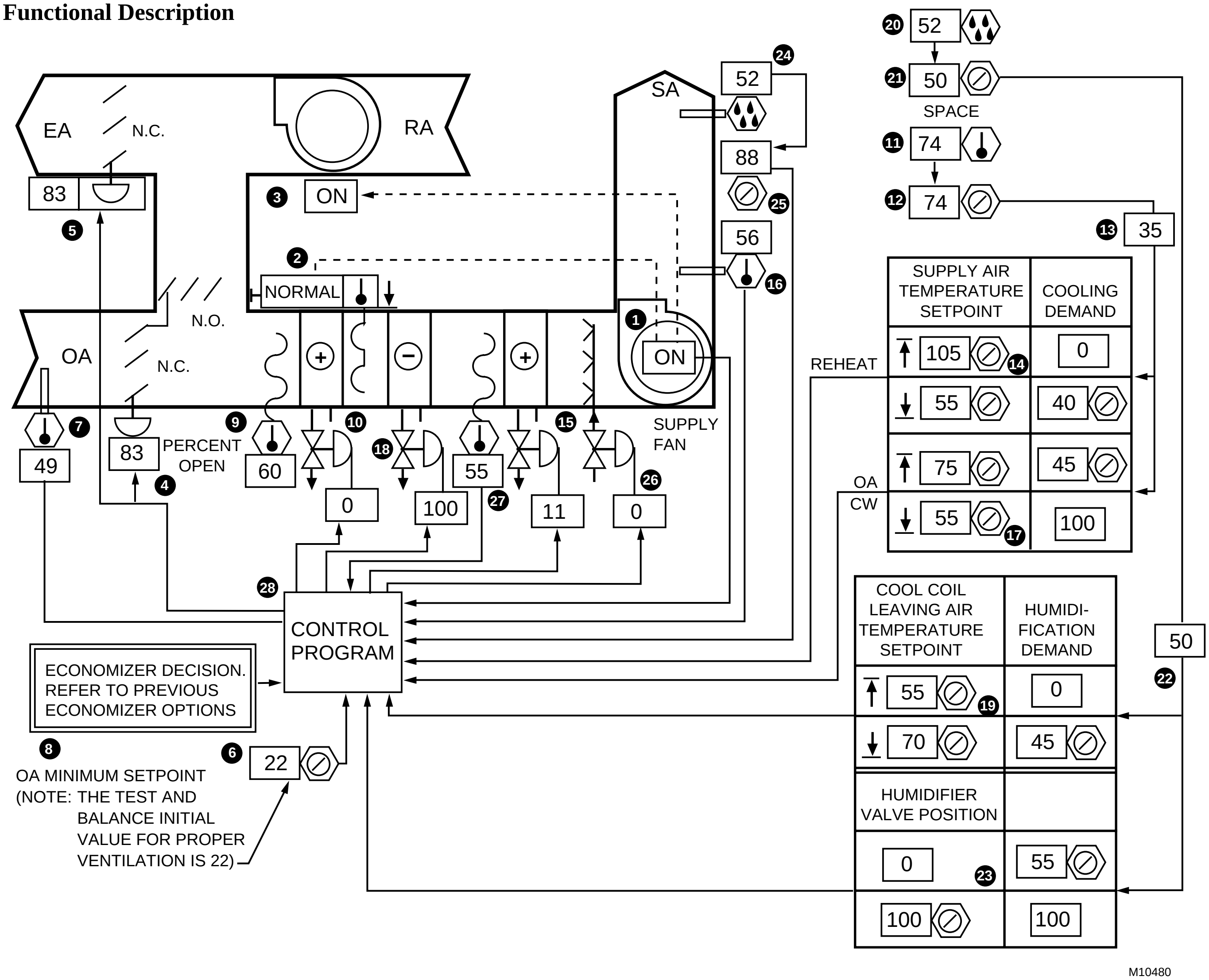


The following results are obtained:

Item No.	Explanation
1	OA temperature at example time.
2	Mixed air is 25% OA and 75% RA. This is also the hot deck air, assuming no zone temperature has dropped two degrees and demanded heating.
3	This line represents the cooling process of the cold deck air. The zone demanding the most cooling dictates how far the process goes from Point 2 to Point 4.
4	55°F DB is the minimum cold deck setpoint set up in the program, set by a zone requiring full cooling.
5	Discharge air to a zone requiring half cold deck air and half mixed air.
6	The space cooling process line.
7	Return air is 75°F DB and 60% RH (humidity rises because humidity is high outdoors and only partial supply airflow is dehumidified).

HEATING, COOLING, HUMIDIFICATION, AND DEHUMIDIFICATION CONTROL WITHOUT DEADBANDS

Functional Description



Item No.	Function
1-3	Control system energizes when fan is turned on (See FAN SYSTEM START-STOP CONTROL).
4-6	Manual positioning value determines minimum ventilation mixing damper position.
7	Operator information, outdoor air temperature.
8	Economizer enables free cooling when OA is suitable.
9	Operator information, MA temperature.
10,27	Heating coil valve modulates to keep reheat coil entering air from getting too low.
11-16	Space temperature PI loop resets setpoint of reheat coil SA PI loop to maintain constant space temperature.
17,18	Chilled water valve modulates in sequence with mixing dampers as required to maintain SA PI setpoint.
19	Chilled water coil leaving air temperature lowered if required for dehumidification.
20-26	Space humidity PI control loop modulates humidifier valve to maintain space relative humidity, subject to an SA high limit humidity PI loop.
27	Control program coordinates ventilation, heating, cooling, humidification, dehumidification, and fan interlocks.

FEATURES

1. The system admits outdoor air for cooling based upon the economizer decision.
2. Space relative humidity is maintained by controlling both humidification and dehumidification.
3. Reheat prevents subcooling on dehumidification cycle.
4. Constant temperature and humidity control. (Do not use this where deadband temperature or humidity control is acceptable.)

CONDITIONS FOR SUCCESSFUL OPERATION

1. Heating is available during dehumidification cycle.

SPECIFICATIONS

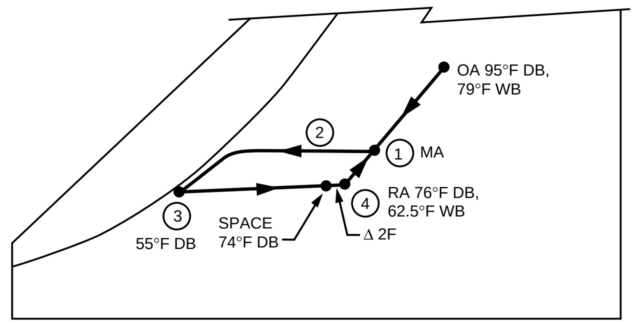
See FAN SYSTEM START-STOP CONTROL.

1. Anytime the supply fan runs, control system shall be enabled, and mixing dampers shall position to minimum ventilation position during scheduled occupancy periods.
2. Anytime the economizer decision program determines that OA is suitable to assist in cooling, the OA/RA mixing dampers shall be under control of the SA PI loop.
3. The space humidity PI loop shall modulate the humidifier, subject to a humidifier leaving air high limit humidity PI loop setpoint, to maintain the space humidity PI loop setpoint. Humidifying control shall be disabled anytime the chilled water valve is modulating or the fan is off.
4. The space humidity PI loop shall override the temperature controls to modulate the chilled water valve open for dehumidification if required to maintain the space humidity PI loop setpoint. The dehumidifying control loop shall be disabled anytime there is no hot water flow or temperature.
5. As the SA PI cooling demand varies from 100 to 45%, the cooling SA PI loop setpoint shall vary from 55°F to 75°F.
6. As the SA PI cooling demand varies from 40 to 0%, the reheat coil hot water valve SA PI loop setpoint (chilled water and economizer) shall vary from 52°F to 105°F.
7. The heating coil hot water valve shall modulate to prevent the cooling coil leaving air temperature from dropping below 52°F.

PSYCHROMETRIC ASPECTS

For cooling conditions it is assumed that:

1. Design outdoor air condition is 95°F DB and 79°F WB.
2. RA condition is 76°F DB and 65°F WB.
3. System operates on 25 percent minimum outdoor air.
4. Space temperature setpoint is set at 74°F.
5. Space humidity control is set at 50 percent.
6. Coil leaving air temperature is at 55°F.



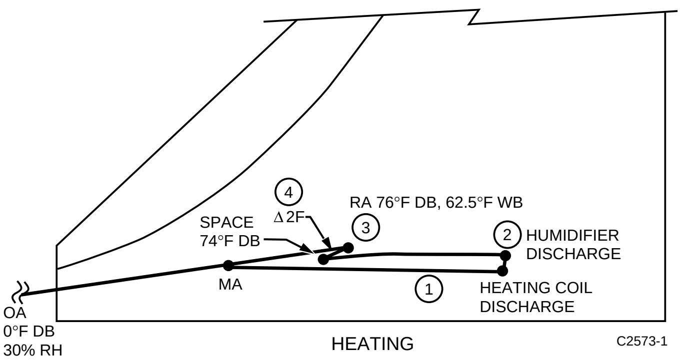
COOLING

The following results are obtained:

Item No.	Explanation
1	Mixed air temperature at cooling design condition.
2	Air entering the coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3	Cooling coil leaving air temperature will be as low as required to satisfy either the space temperature controller or the space humidity controller whichever is calling for the greatest cooling. If dehumidification cools discharge temperature below setpoint, the heating coil provides reheat.
4	The space temperature is 74°F DB and the RA temperature is 76°F DB. The 2°F DB rise is an example of sensible cooling load which may occur in ceiling, space, and RA ducts. The rise will be a function of system, building, and lighting arrangement.

For heating conditions it is assumed that:

1. Design outdoor air condition is 0°F DB and 30 percent relative humidity.
2. RA condition is 76°F DB and 56°F WB.
3. System operates on 25 percent minimum outdoor air.
4. Space temperature is set at 74°F.
5. Space humidification control is set at 50 percent.

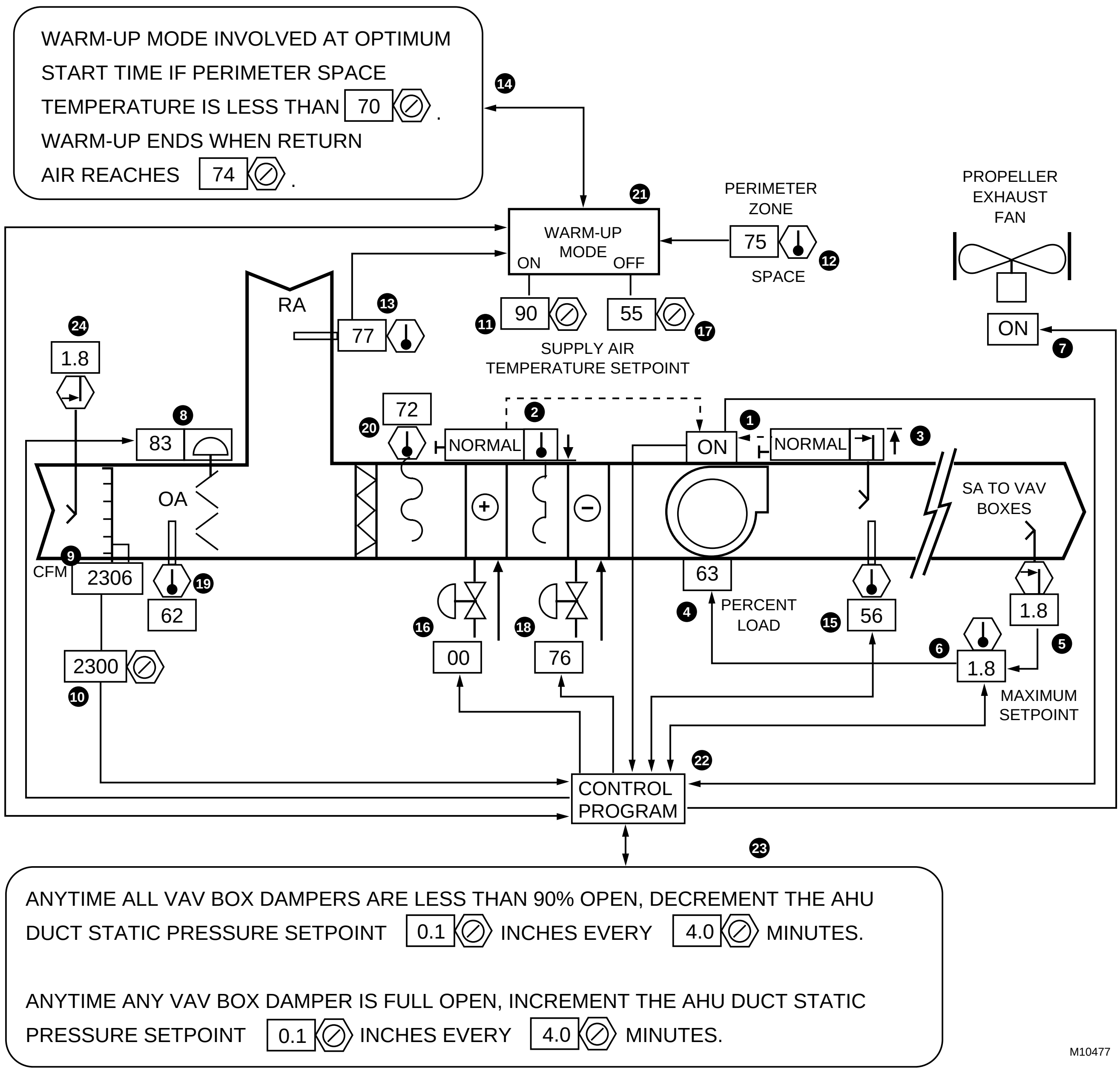


The following results are obtained:

Item No.	Explanation
1	Heating coil leaving air temperature will be as high as required to satisfy the space temperature controller.
2	Humidification will be provided to satisfy space humidification requirements.
3	The space heating and humidifying load varies with people and weather.
4	The 2°F DB RA rise is discussed in the cooling example.

VAV AHU, WATER-SIDE ECONOMIZER, OA AIRFLOW CONTROL

Functional Description



Item No.	Function
1-3	Control system energizes when supply fan is turned on (See FAN SYSTEM START-STOP CONTROL).
4-6	Supply fan loads to maintain duct static pressure.
7-10	During occupied periods, exhaust fan runs and OA airflow is controlled.
11-14	When perimeter temperature is low at startup, SA temperature setpoint is warm until RA temperature rises.
15-16	Heating valve maintains SA temperature setpoint during warm-up.
17-18	Cooling valve maintains SA temperature setpoint during occupied periods.
19-20	OA and MA temperatures are operator information.

21 SA temperature setpoint switches from cooling to heating value during warm-up modes.
22 Control program coordinates temperature control, ventilation, and fan interlock.
23 Control program optimizes duct pressure setpoint.
24 OA shaft static pressure point shared from OA fan control system for this graphic (not a physical point as shown) and provided here for operator information.

NOTE: This system is often found on each floor of a building, and often includes an outdoor air fan (preferably with filtration to protect the AHU OA air flow elements) and shaft, and a water-side economizer. The water-side economizer provides chilled water year round (in cold weather the cooling tower provides chilled water via heat exchangers without the need for the chillers). Dual equal sized chillers and boilers (non-redundant) are assumed.

FEATURES

1. Supplies constant temperature variable volume (energy conserving) air to VAV boxes.
2. Provides constant airflow of OA with varying supply airflow.
3. Provides 100% RA during warm-up periods (preoccupancy purge may be required for IAQ).
4. Perimeter boxes provide space heat when required during occupied periods.
5. AHU provides heating during warm-up periods, and when OA temperature effects cause low SA temperatures. If boxes have electric heat and the AHU hot water is from lower cost gas/oil-sourced heat, box heaters may be disabled during warm-up periods.
6. Duct static pressure setpoint is lowered anytime all VAV box dampers are less than 90% open (If this strategy is used, the duct static pressure pickup need not be at the end of the longest run, but may be at any location where the air is not too turbulent. The maximum setpoint is higher than if the pickup had been at the end of the run because of the pickup location).
7. Reduced fan airflow is provided during warm-up, night purge, and cool-down periods to reduce fan energy, which varies with the cube of the fan airflow.
8. Reduced fan airflow and staged AHU startup during cool-down periods requires only one chiller and keeps the chiller pull-down ahead of the AHU cooling demands such that AHUs get cold (not cool) water for effective cooling and dehumidification, and allows the chiller to operate at an efficient loading (less than 100%).

CONDITIONS FOR SUCCESSFUL OPERATION

1. Airflow element and transducer must be kept clean and calibrated.
2. OA fan must provide adequate OA shaft pressure. Alternatively, if there is no OA fan, the OA airflow setpoint may be maintained by modulating the RA damper which would have to be added.
3. A controller network and adequate software and programming provided to support communication between the box controllers and the fan controller to allow static pressure reset and to position the box dampers properly during night purge, warm-up, and cool-down periods.
4. If any VAV box whose damper position is a program input can never satisfy its space cooling demand for any reason (and its damper is always open), the duct static pressure reset program will not lower the duct static pressure setpoint. The duct static pressure reset program works best when there are no more than thirty monitored VAV boxes per fan system (with great quantities of boxes, it is likely that at least one box damper will always be full open).
   For example, if an interior zone is always under a full cooling load, static pressure reset will not occur unless that zone (and similar zones) is oversized. The oversized zone would then throttle back when the building is at full load when the duct static pressure is at design.
5. All AHUs must be near the same normal occupancy schedule or the cool-down start-up specification edited.
6. Boiler, chiller, pumping system, and OA fan controls carefully networked into the AHU control schemes to assure smooth and efficient building operations.
7. All specified values and setpoints are tuned to specific project requirements.

SPECIFICATIONS

NOTE: A set of 16 similar sized AHUs are assumed.

See FAN SYSTEM START-STOP CONTROL.

Anytime any AHU starts in the optimum start cool-down mode, three to four AHUs shall start and the remaining AHUs shall stage on at five minute intervals (unless they similarly start under their optimum start programs). Any time any AHU operates in the night purge, warm-up, or cool-down modes of operation, all associated perimeter VAV boxes shall operate at 60% of their maximum airflow setpoint, and all associated interior VAV boxes shall operate at 25% of their maximum airflow setpoint, unless the OA temperature is less than 15°F in which case the perimeter VAV boxes shall operate at their maximum airflow setpoint.

During unoccupied periods, anytime the top floor west zone perimeter space temperature is greater than 77°F and the OA temperature is less than 72°F and the OA dew point is less than 60°F, the night purge program shall start. When the night purge program starts, AHUs 9 through 16 (provided their west zone space temperatures are greater than 74.5°F) shall start, and the OA and exhaust fans shall start. When an AHU runs in the night purge mode, its OA damper shall position full open. When the OA fan runs in the night purge mode, its duct static pressure setpoint shall be reset to a value 50% above the normal maximum setpoint. AHU fans running in the night purge mode shall stop when their noted space temperature drops to 74.5°F.

Anytime the night purge program runs for one minute and any of AHUs 9 through 16 are off, AHU's 8 through 1 shall start respectively on a one-for-one basis (provided their west zone space temperatures are greater than 74.5°F). Anytime all fans shut down in the night purge mode, the night purge program mode shall end.

Anytime the supply fan runs, the return fan shall start and the control system shall be enabled. Also, anytime the supply fan runs during scheduled occupancy periods the exhaust fan shall start.

At the scheduled occupancy time, each AHU OA damper control loop shall be enabled under EPID control with a start value of 50 and a ramp duration of 400 seconds. Each AHU OA damper shall modulate to maintain its OA airflow setpoint.

The supply fan loading shall be under EPID control with a start value of 20% and ramp duration of 150 seconds. The supply fan shall load to maintain the duct static pressure setpoint.

The SA temperature shall be under EPID control with a start value of 50% (at which point the hot and chilled water valves are both closed) and a ramp duration of 120 seconds. The hot and chilled water valves shall be modulated in sequence to maintain the SA temperature setpoint.

Anytime the optimum start perimeter zone space temperature sensor is less than 70°F at start-up time, the SA temperature setpoint shall be 90°F until the RA temperature rises to 74°F, at which time the SA temperature setpoint shall be lowered to 55°F. The EPID shall be invoked at the switching of the setpoint to 55°F with a start value of 50 and a ramp duration of 180 seconds.

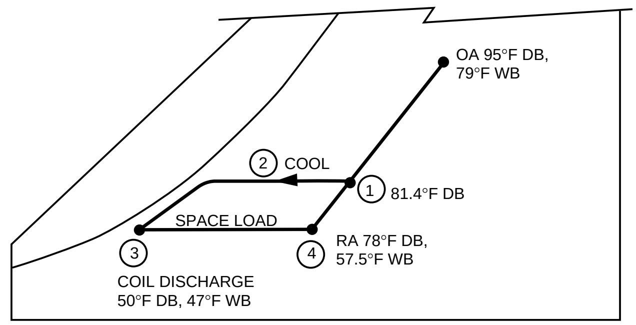
EXPLANATION:

With VAV fan systems, operation during unoccupied periods should be based on minimum energy cost (not minimum on-time). Ideally, for a dual chiller building, the VAV box airflow would be regulated to run one chiller at its most efficient operating point. At this point the AHU fan would draw a small portion of its full-load amperage, good dehumidification would occur, and pumping energy may be reduced. In the night purge mode of operation, the objective is to supply a maximum amount of OA to the AHUs, and to direct it to the warm areas of the building. Reducing the AHU airflow and increasing the OA airflow should result in the supply airflow being a significant proportion OA. If IAQ requirements dictate a prepurge cycle, this operational mode should suffice then also, but would be staged by time rather than temperature.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

1. Outdoor air condition is 95°F DB and 79°F WB.
2. RA condition is 78°F DB and 57.5°F WB.
3. Coil leaving air temperature 50°F.
4. 80% RA.

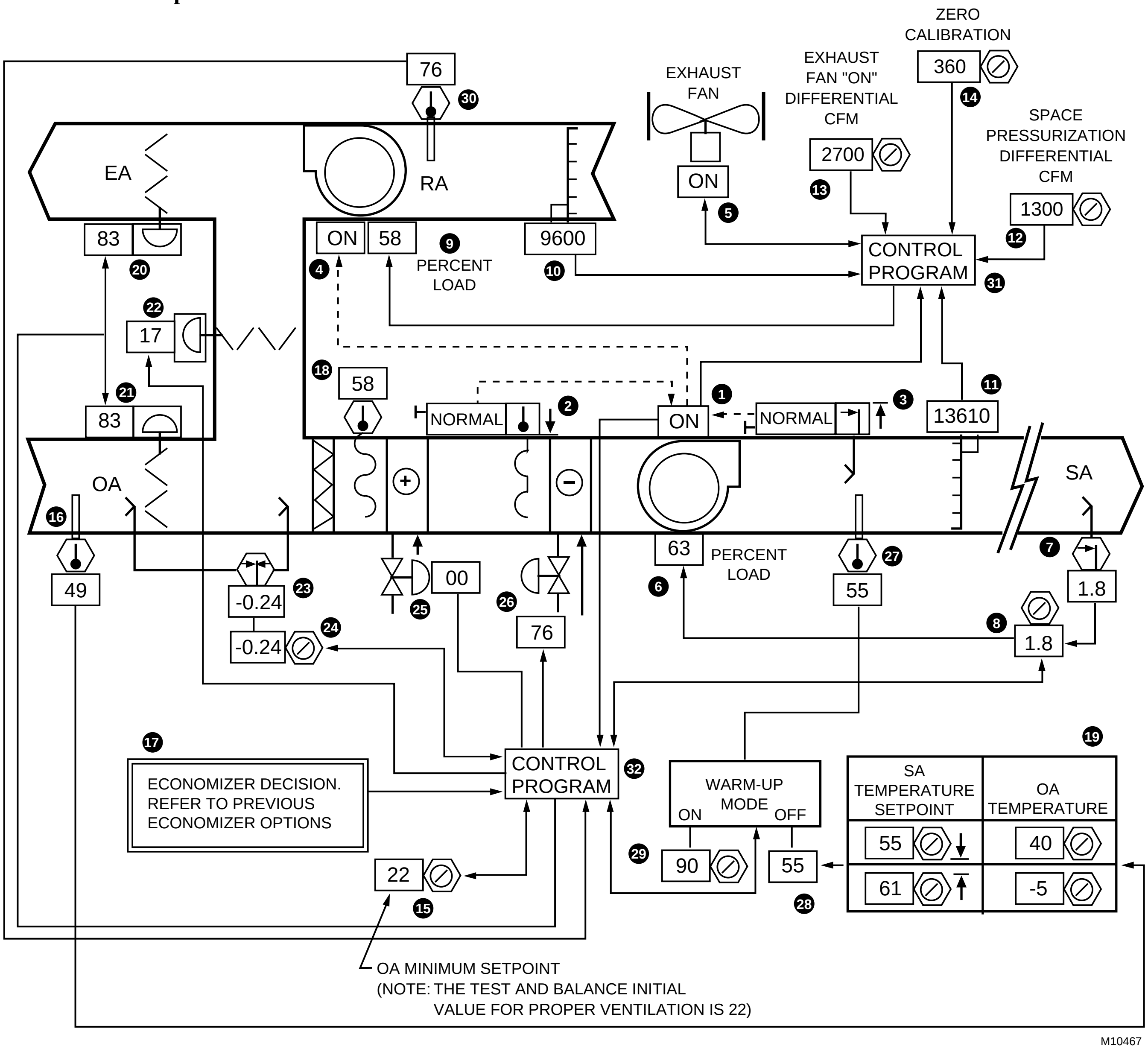


The following results are obtained:

Item No.	Explanation
1	RA mixes with 20 percent (minimum position) outdoor air to obtain mixed air condition.
2	Air entering the coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3	Mixed air is cooled and dehumidified by cooling coil to obtain cooling coil leaving air condition.
4	Reheat coils and/or space internal load heats air to 78°F DB and 57.5°F WB.

VAV AHU WITH RETURN FAN AND FLOW TRACKING CONTROL

Functional Description



Item No.	Function
1-5	Control system energizes when supply fan is turned on (See FAN SYSTEM START-STOP CONTROL).
6-8	Supply fan loads to maintain duct static pressure at the end of the longest run.
9-14	Return fan loads to track supply airflow minus exhaust airflow minus airflow for pressurization.
15	Manual positioning value determines minimum summer ventilation mixing damper position. This position is fixed for the OA and relief air dampers; but is a minimum position for the return air damper, the value of which will be overridden to maintain a constant mixing box negative static pressure and thus a constant OA airflow.
16	OA determines SA temperature setpoint.
17	Economizer enables free cooling when OA is suitable.

18	Mixed air temperature is for operator information.
19	SA temperature setpoint is reset based upon OA temperature.
20-22	Mixing dampers modulate for free cooling.
23,24	Mixing box static pressure maintained constant during noneconomizer mode by modulation of the RA damper during minimum ventilation periods to maintain constant OA airflow.
25-27	Hot water valve, mixing dampers, and chilled water valve modulated in sequence to maintain SA temperature setpoint.
28,29	SA temperature setpoint switches from cooling to heating value during warm-up modes.
30	RA temperature determines end of warm-up mode.
32	Control program coordinates return fan airflow setpoint, loading, exhaust fan control, and fan interlock.
33	Control program coordinates temperature control of mixing dampers, control valves, and fan interlock.

FEATURES

1. The system admits outdoor air for cooling based upon the economizer program decision.
2. Supplies constant temperature variable volume (energy conserving) air to VAV boxes during cooling mode.
3. Provides constant airflow of OA in summer with varying supply airflow.
4. Return fan airflow varies with supply fan airflow dependent upon exhaust and pressurization requirements.
5. Provides 100% RA during warm-up periods.
6. Perimeter boxes provide heat when required.
7. SA temperature setpoint is reset based upon OA temperature.

NOTE: This function has no hardware cost. The setpoint parameters are easily adjusted and can be nulled by setting the -5°F OA SA setpoint the same as the 40°F OA SA setpoint.

CONDITIONS FOR SUCCESSFUL OPERATION

1. Skilled HVAC technicians required for pressure and volumetric setup.
2. Test and balance OA damper minimum position value and mixing box static pressure setpoint value.
3. OA and RA dampers maintained and provided with proper actuators (with positioners if pneumatic).
4. Airflow elements and transducers kept clean and calibrated.

SPECIFICATIONS

See FAN SYSTEM START-STOP CONTROL.

Anytime the supply fan runs, the return fan shall start and the control system shall be enabled. Also, anytime the supply fan runs during scheduled occupancy periods, mixing dampers shall position to minimum ventilation position and the exhaust fan shall start.

Anytime the economizer mode is enabled, the temperature controls shall be enabled to override the AHU mixing dampers minimum ventilation setpoint for free cooling as required.

During non-economizer occupied periods the RA damper shall be modulated to maintain a constant mixing box negative static pressure.

The supply fan loading shall be under EPID control with a start value of 20% and ramp duration of 150 seconds. The supply fan shall load to provide design static pressure at the end of the longest duct.

The return fan loading shall be dependent upon the supply fan airflow. When in the recirculating mode, the return fan airflow setpoint shall equal the supply fan airflow plus a positive or negative value for calibration (of flow elements and transducers) so as to provide a neutral space static pressure. Anytime the OA dampers are not closed completely, the return fan airflow setpoint shall equal the supply fan airflow minus a value necessary to maintain a slightly positive (0.05 in. wc) space static pressure. Anytime the exhaust fan operates, the return fan airflow setpoint shall be further reduced by additional airflow value equal to the exhaust airflow (this exhaust value shall be determined by observing the space static pressure as the exhaust fan starts and stops).

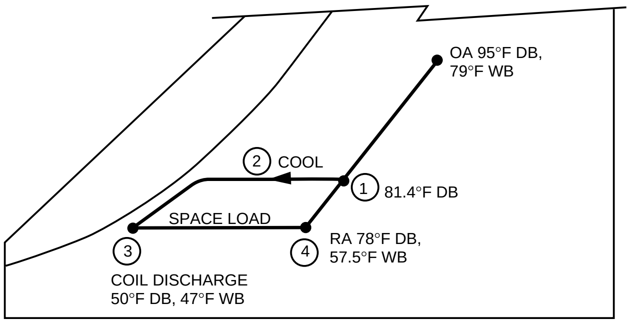
The SA temperature shall be under EPID control with a start value of 33 (at which point the hot and chilled water valves are closed and the mixing damper override signal is zero) and a ramp duration of 120 seconds. The hot and chilled water valves and the mixing dampers shall be modulated in sequence to maintain the SA temperature setpoint.

Anytime the optimum start perimeter zone space temperature sensor is less than 70°F at startup time, the SA temperature setpoint shall be 90°F until the RA temperature rises to 74°F, at which time the SA temperature setpoint shall be lowered to the cooling SA setpoint. The SA EPID shall be invoked at the switching of the setpoint to cooling with a start value of 33 and a ramp duration of 180 seconds. The cooling SA setpoint shall rise from 55°F to 61°F as the OA temperature drops from 40°F to -5°F.

PSYCHROMETRIC ASPECTS

In the following chart it is assumed that:

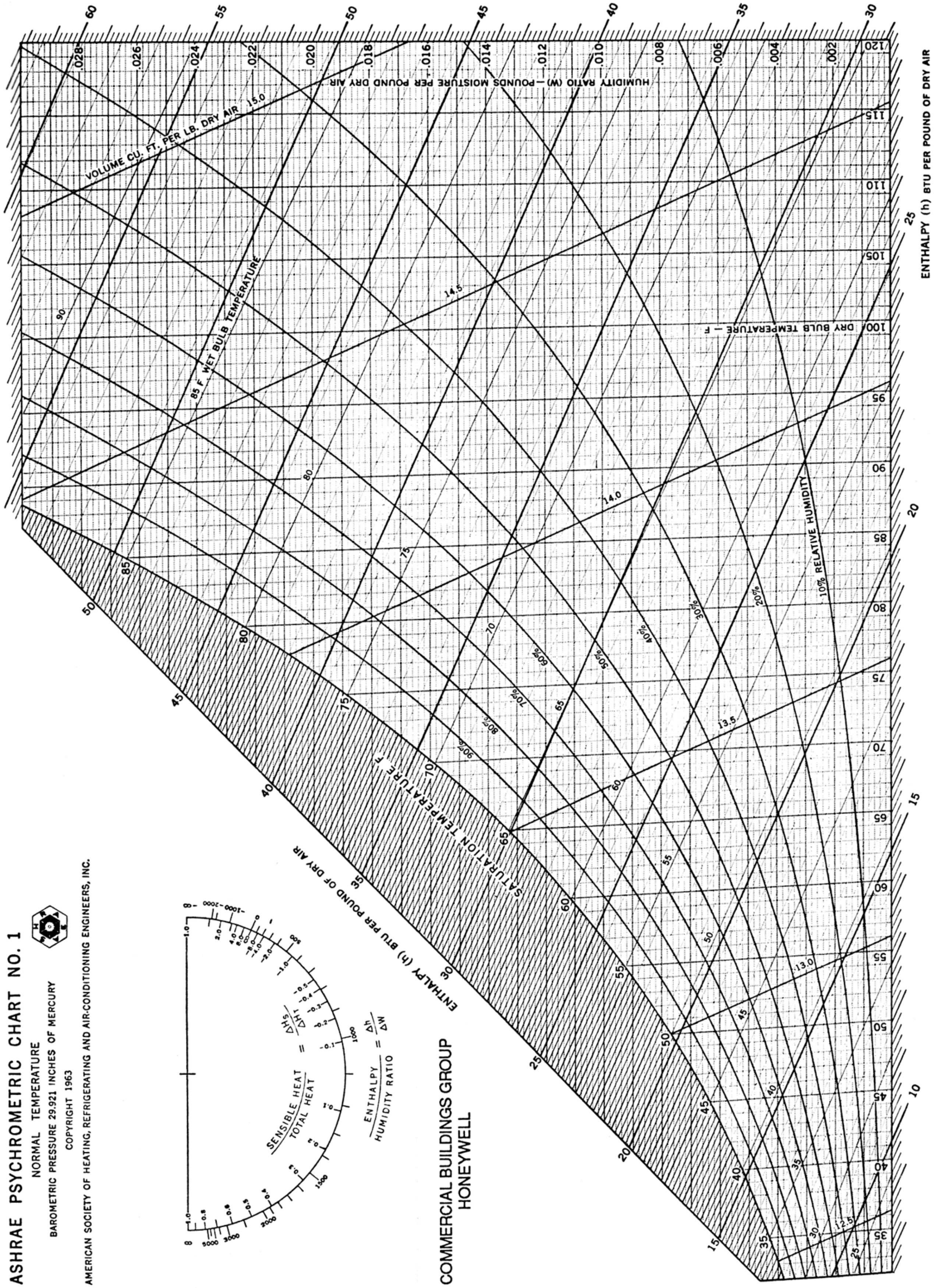
1. Outdoor air condition is 95°F DB and 79°F WB.
2. RA condition is 75°F DB and 57.5°F WB.
3. Coil leaving air temperature 50°F.
4. 80% OA.



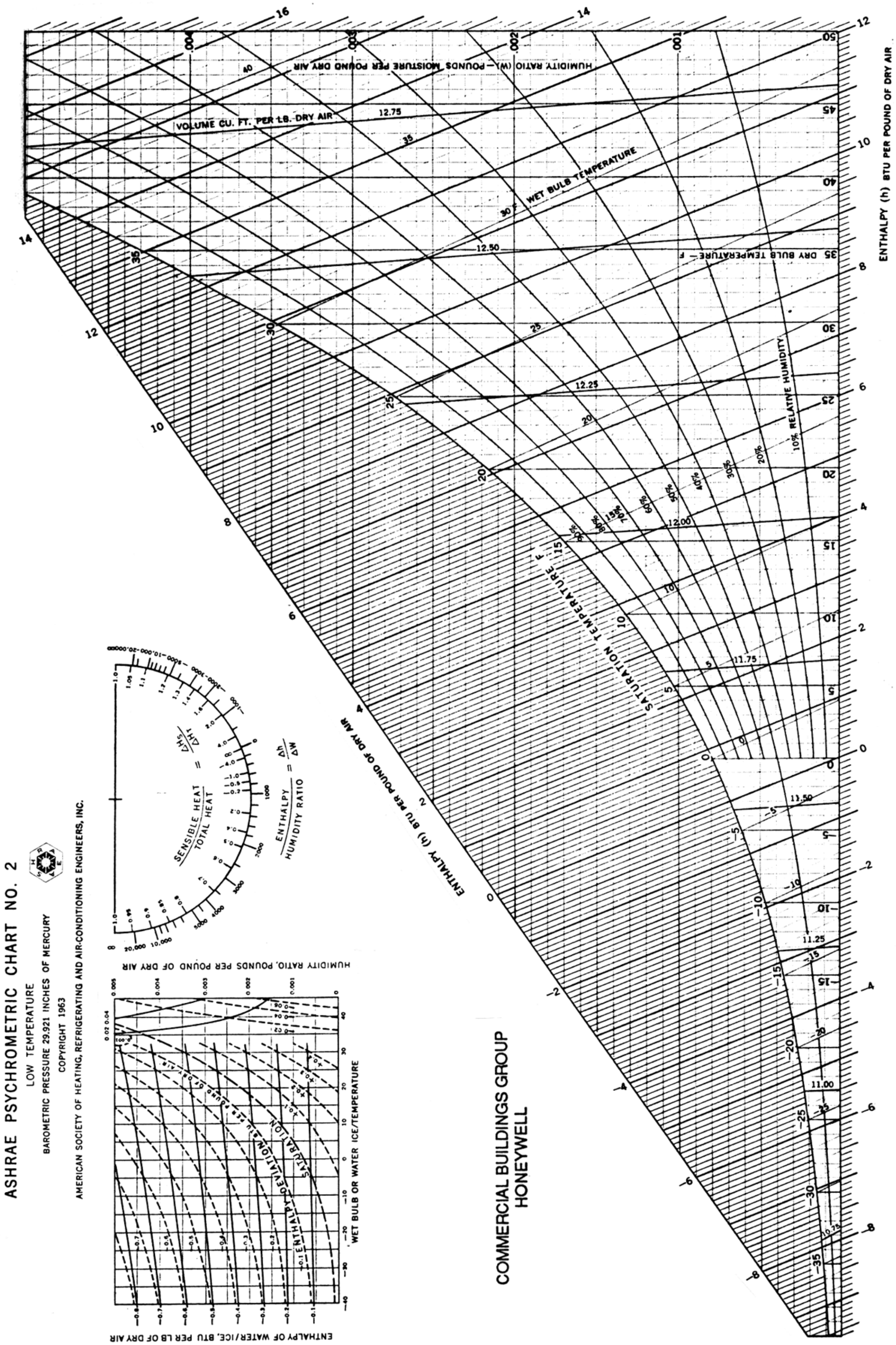
The following results are obtained:

Item No.	Explanation
1.	RA mixes with 20 percent (minimum position) outdoor air to obtain mixed air condition.
2.	Air entering the coil is cooled along a line of constant moisture content until saturation is approached. Near saturation the moisture content is reduced as the air is cooled. This process involves both latent and sensible cooling.
3.	Mixed air is cooled and dehumidified by cooling coil to obtain cooling coil leaving air condition.
4.	Reheat coils and/or space heats air to 75°F DB and 57.5°F WB.

ASHRAE PSYCHROMETRIC CHARTS



ASHRAE Psychrometric Chart No. 1.



ASHRAE Psychrometric Chart No. 2.

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