Duct Diagnostics: What's Wrong with this System

Smarter Buildings: Smarter Business Residential Conference
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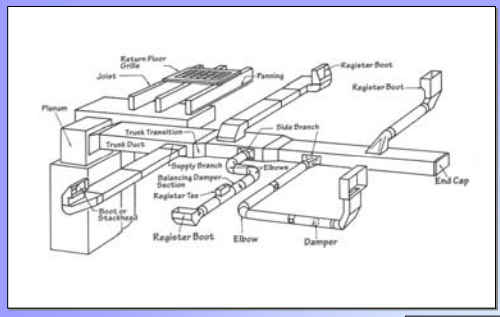
Topics Addressed in Session

- Ductwork sizing discussion.
- Ductwork Specification: Consortium for Energy Efficiency (CEE).
- Tools for duct design and commissioning.
- Some duct installation details.
- Analysis of existing ductwork.
- Ductwork trouble-shooting.

Some Basics of Duct Design and Installation

Ducted Distribution



Good Ducts Start With Good Design

- Design - yeah, right! What constitutes design is usually a mix of after-thought, what happens to be on the truck at the moment, and the need for speed.

Duct Design Objective

- Duct delivery system provides year-around comfort with:
  - Efficiency,
  - Little noise,
  - No hazards to occupants,
  - Little maintenance.

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Low Noise Levels are Important

7

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A Well Designed Duct System

- Properly balanced.
- Look good.
- Be inexpensive to install.
- Help create a comfortable environment.
- Be very quiet while air handler is operating.
- Be economical to operate.
  - Proper insulation, tight ducts, no pressure imbalance.
- Be healthy for occupants (e.g., from pressure imbalances).
- Be easy to maintain.

Page 3

8

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Duct Design Rules

- Place air handler in central location.
- Plan for symmetrical duct system.
- Keep duct runs short.
- Support ducts properly.
- Use minimum number of fittings.
- Keep aspect ratio low.
- Select registers properly.
- Install return in each room having a working door.
- Etc.

Page 4

9

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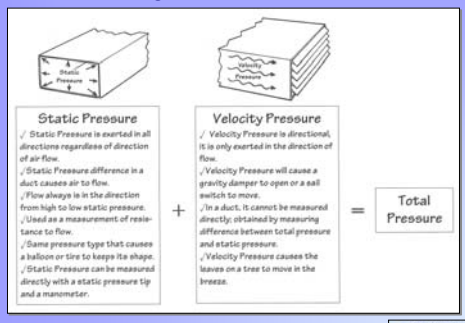
Duct System Pressures



Page 5

10

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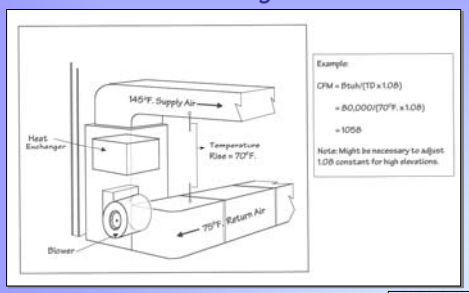
Measuring Temperature Rise & Calculating CFM



Page 6

11

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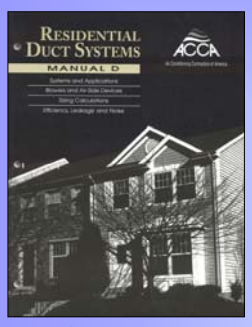
Design Standard is *Manual D*



Available from
ACCA
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Pages 47 and 35 - 49

12

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Manual D Procedure

- Calculate DHL/DCL (*Manual J*, ACCA).
- Select blower (*Manual S*, ACCA & Man. Data).
- Determine External Static Pressure (ESP) from manufacturer's data.
- Determine device pressure losses (DPL) that are added to distribution system.
- Determine Available Static Pressure (ASP).
  - ASP = ESP – DPL (Equal to about 0.2" WG, limits of range are 0.10" to 0.35" WG).

Pages 7 - 11 13

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Manual D Procedure (con.)

- Plan location of registers and grilles (*Manual T*).
- Determine the greatest Total Effective Length (TEL) value for the duct system, supply and return sides. Include measured length and fitting equivalent length.
- Calculate Friction Rate design value (FR).
  - FR = (ASP x 100)/TEL, or use friction chart.
  - Friction rate should be between 0.06" and 0.18" WG/100 feet of duct.

Pages 7 - 11 14

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Manual D Procedure (con.)

- Calculate heating and cooling airflow factors.
  - HF = (blower CFM)/(Design heating load)
  - CF – (blower CFM)/(Sensible cooling design load)
- Calculate CFM for each register (room).
  - Room CFM = HF or CF x Room DHL
- Size branch ducts and trunks with use of duct calculator or friction chart.
- Check velocity.
- Select registers and grilles (*Manual T*, ACCA).
- Balance system with branch balancing dampers.

Pages 7 - 11 15

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Ductwork Specification 1

Quick Reference for HVAC Installation Specification
Ducts and Air Handlers

Section/Specification Element	Specification Element	Potential Benefits	Verification Test or Method
5. Ducts and Air Handlers			
5.1 Duct Location	- All ducts should be located within the conditioned spaces whenever possible. - No ducts in exterior wall cavities. - Always install ducts, don't use building cavities. - No panned floor joints. - Don't use crawl spaces as plenums.	- Reduces conduction and air-leakage losses.	- Visual inspection.
5.2 Duct System Design	- Use *Residential Duct System, Manual D*, 1995 edition or later.	- If ducts are not sized large enough to permit adequate airflow, system efficiency can be adversely affected.	- *Residential Duct System, Manual D*, 1995 edition or later.
5.3 Allowable Duct Leakage, New Air Distribution Systems	- 25 CFM of leakage for every 400 CFM of measured airflow, or - The sum of supply and return leakage divided by air handler fan flow shall be a maximum of 6%.	- Can save 15% in energy costs per year for new systems.	- Tasks for Ensuring Proper Air Handler Airflow – 3.13 and 4.9. - Total Duct Leakage and Percentage Duct Leakage Test – 5.13.1.
5.3 Allowable Duct Leakage, Existing Air Distribution Systems	- 40 CFM of leakage for every 400 CFM of measured airflow, or - The sum of supply and return leakage divided by air handler fan flow shall be a maximum of 10%.	- Can save 10% in energy costs per year for existing systems.	- Tasks for Ensuring Proper Air Handler Airflow – 3.13 and 4.9. - Total Duct Leakage and Percentage Duct Leakage Test – 5.13.1.
5.4 Duct Sealing Materials and Methods	- Refer to *Duct Installation and Sealing Specification.*	- Use of the proper materials and methods extends the life of the ducted system, retaining duct efficiency.	- Visual inspection.
5.5 Insulation, New and Existing Installations	- Follow insulation manufacturer's recommendations. - Refer to *Duct Installation and Sealing Specification*	- Duct insulation slows heat transfer, making the ducted distribution network more efficient.	- Visual inspection.
5.5.2 Insulation, New Installations	- No insulation required for ducts in conditioned spaces, except to prevent condensation. - In unconditioned spaces a minimum R-value of 6 is required. - Ducts located on the exterior of building require a minimum R-value of 8.	- Duct insulation slows heat transfer, making the ducted distribution network more efficient.	- Visual inspection.
5.5.3 Insulation, Existing Installations	- No insulation required for ducts in conditioned spaces, except to prevent condensation. - In unconditioned spaces a minimum R-value of 6 is required. – Parts of ductwork that are not accessible do not require insulation. – If ducts are already insulated to R-4 or greater, no additional insulation is needed. - Ducts located on the exterior of building require a minimum R-value of 8.	- Duct insulation slows heat transfer, making the ducted distribution network more efficient.	- Visual inspection.

Page 16 16

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Ductwork Specification 2

Quick Reference for HVAC Installation Specification
Ducts and Air Handlers (continued)

Section/Specification Element	Specification Element	Potential Benefits	Verification Test or Method
5. Ducts and Air Handlers (continued)			
5.6 Room Pressure Imbalances	- While air handler is operating and house is closed up, pressure differences between 1) closed room and the outdoors and 2) the main body of the house with all the interior doors closed should be no more than 0.01 inches water gauge (5 Pascals), positive or negative.	- High-pressure differences between spaces in a house and the outdoors can increase air leakage to and from the outdoors. Decreasing these pressures can save energy. - Room depressurization may cause hazardous back drafting of combustion gases.	- Room Pressure Imbalances Test – 5.14.1.
5.7 Selection and Location of Supply Registers	- At least one supply-air register should be installed in each conditioned room. - Each register should be able to handle the required heating and cooling CFM and air velocity. - Maximum velocity of 700 feet per minute. - Select for proper throw, drop, and spread.	- Proper selection and placement of supply-air registers can increase occupant comfort.	- Visual inspection.
5.8 Selection and Location of Return Grilles	- Return-air grilles should be located to provide pressure-balanced air circulation during air handler operation. - Max. velocity of 500 feet per minute.	- The proper placement of return-air grilles minimized indoor pressure imbalances during air handler operation, thereby conserving energy lost due to forces air leakage.	- Visual inspection.
5.9 Duct Support	- Ducts should be supported so as to prevent dislocation or damage. - Refer to *Duct Installation and Sealing Specification.*	- Supporting ducts in a proper and durable fashion helps maintain duct system efficiency.	- Visual inspection.
5.10 Volume Dampers	- Supply branch ducts should be equipped with volume dampers to allow for manual balancing of distribution airflow. - After installation, the ducted system should be properly balanced.	- A properly balanced duct system increases occupant comfort and reduces occupant complaints.	- Visual inspection.
5.11 Access for Installation and Maintenance	- Adequate clearance should be provided on all sides of the equipment to allow for easy access for periodic maintenance. - All doors leading from the mechanical room to the outdoors should be large enough to allow easy passage of equipment.	- Adequate clearance for the maintenance of important equipment components allows the equipment to be serviced properly and regularly, thereby ensuring the maintenance of maximum equipment efficiency.	- Visual inspection.
5.12 Maintenance Items	- Inspect the following items at servicing: - Filters, - Duct obstructions and debris, - Duct leaks and disconnections, - Volume dampers, - Duct balancing, - Duct insulation, and - Room pressure imbalances.	- Proper maintenance of the forced-air distribution system will help retain system efficiency.	- Visual inspection.

Page 17 17

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Tools for Duct Design & Testing

Page 18 18

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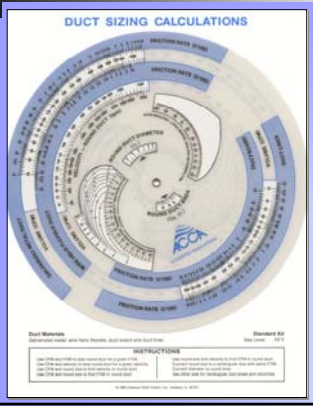

Duct Calculator

From ACCA

19

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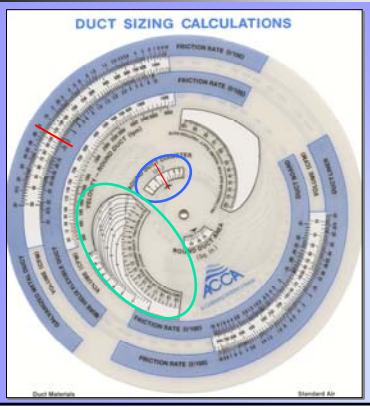

Duct Calculator

From ACCA

20

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Duct Blower

The Energy Conservatory Duct Blaster™

21

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Digital Manometer

22

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Duct Leakage Testing

- If you don't test, you don't know.
- Duct leakage testing is essential to producing comfort and efficiency.

23

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Blower Door

A blower door is often needed for duct leakage testing.

24

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Pressure Pan & Flowbox

25

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Measuring Air Flow

- The volumetric capture bag.
- AKA the garbage bag.
- Works by timing how long it takes to fill a known volume with air.

26

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Page 19

27

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Some Duct Installation Details

28

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Try to Keep Duct Inside

- Inside vs. outside the air and thermal barrier of the house.
- If the ducts are outside, more work is required to make them efficient.

29

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Do not use duct tape on ducts!

But, it's really good for many other needs.

30

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Ducts Should Be Permanently Tight

- Mechanical Fastening
- Sealed with Mastic

Pay attention to gores

31

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Love that Duct Mastic

32

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Provide Ability to Adjust Airflow

- If duct are large enough, airflow can be adjusted to met individual comfort levels or differences in heating and cooling loads

Balancing damper handle

33

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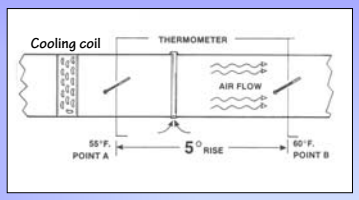
Temperature Measurements

Simple temperature readings can help locate leaks or loss of cooling or heating energy in a ducted system.



Cooling season

Page 20

34

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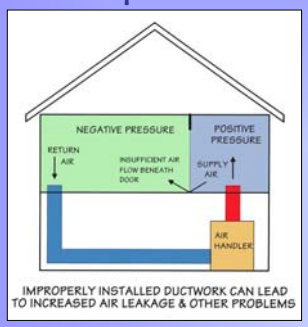
Impact of an Air Handler



What happens to air leakage as a result of the closed bedroom door?

What if a return is installed in the basement return trunk?

What if the supply trunk leaks to the outdoors?

Page 21

35

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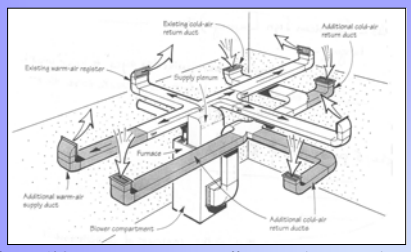
Multiple Returns are Essential

- Return air paths are critical to a good duct system.
- A closed door can serve as an air distribution damper!!

36

Return Side Retrofit



For a furnace/AC to operate at maximum efficiency and capacity, the volume-carrying capacity of the return air must equal that of the supply air. However, many residential systems are undersized on the return side, causing pressure imbalances and discomfort. To balance the return and supply sides, additional return grilles and ductwork might have to be added.

Source: Journal of Light Construction, 2/94, page 49

Page 22

37

Analysis of Existing Ductwork

38

Analysis of Existing Ductwork 1

- Interview occupants about thermal comfort of existing system.
  - Ask such things as:
    - Uncomfortable rooms.
    - Excessive noise.
    - Frequent cycling of air handler blower.

Pages 23 - 26

39

Analysis of Existing Ductwork 2

- Inspect air handler and ductwork for such things as:
  - Anticipator setting.
  - Duct leakage.
  - Restricted returns.
  - Panned floor joists.
  - Ducts in unconditioned spaces.
  - Balancing dampers.

Pages 23 - 26

40

Analysis of Existing Ductwork 3

- Do technical appraisal of duct system and equipment:
  - Temperature rise.
  - Static pressure measurements.
  - Blower CFM.

Pages 23 - 26

41

Analysis of Existing Ductwork 4

- Do pressure testing of existing system:
  - Room-to-room pressures.
  - Duct leakage testing
    - Blower door.
    - Duct blower.

Pages 23 - 26

42

Analysis of Existing Ductwork 5

- Determine strategies for duct repair:
  - Write down possible problems.
  - Check trouble-shooting list.
  - Determine required alterations to furnace/AC and ductwork.
  - Decide on consumer education strategies.

Now, Perform the Work!

Duct Trouble-Shooting Tables

Ductwork Troubleshooting 1

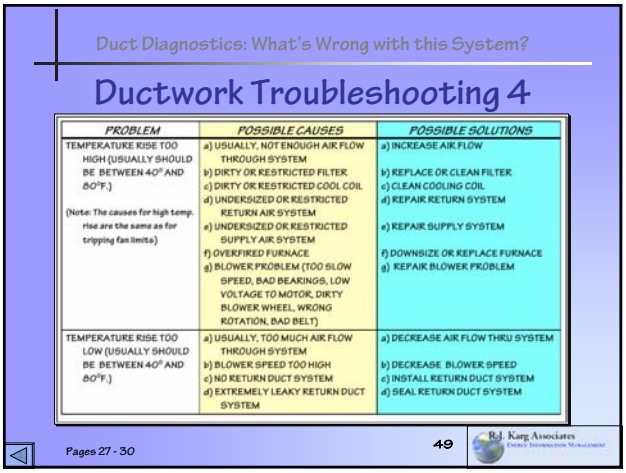
PROBLEM	POSSIBLE CAUSES	POSSIBLE SOLUTIONS
INADEQUATE SUPPLY AIR	a) CLOSED BALANCING DAMPER b) SLIPPING FAN BELT c) LOW FAN SPEED d) DIRTY FAN BLADES e) INCORRECT FAN ROTATION f) DIRTY OR CLOGGED FILTER g) CLOGGED HEAT EXCHANGER h) CLOGGED COOLING COIL i) RESTRICTED RETURN(S) j) UNDERSIZED DUCTWORK k) EXCESSIVE DUCT LEAKAGE l) EXCESSIVE FRICTION AND/OR TOTAL EFFECTIVE LENGTH (TEL)	a) ADJUST BALANCING DAMPER b) REPAIR FAN BELT c) INCREASE FAN SPEED d) TAKE FAN TO CAR WASH e) CORRECT FAN ROTATION f) CHANGE OR CLEAN FILTER g) CLEAN HEAT EXCHANGER h) CLEAN COOLING COIL i) CLEAR RETURN(S) j) UPSIZE DUCTWORK k) SEAL DUCTS l) REDUCE FRICTION (FITTINGS, BENDS, SIZE, ROUGHNESS)
INSUFFICIENT HEATING/COOLING	ALL JUST ABOVE, AND ... a) THERMOSTAT TOO LOW/HIGH b) THERMOSTAT EXPOSED TO HEAT/COOL c) THERMOSTAT IN BAD LOCATION d) BAD THERMOSTAT CALIBRATION e) DIRTY FILTER f) FAN SPEED TOO LOW g) ANTICIPATOR SET TOO LOW (HEATING) h) FURNACE/AC UNDERSIZED i) UNINSULATED TRUNK OR BRANCH j) CFM SET FOR SEA LEVEL	a) RAISE/LOWER SETTING b) REMOVE HEAT/COOL SOURCE c) RELOCATE THERMOSTAT d) RECALIBRATE OR REPLACE e) CLEAN OR REPLACE FILTER f) INCREASE FAN SPEED g) ADJUST ANTICIPATOR h) INCREASE FURNACE/AC OUTPUT i) INSULATE DUCTWORK j) CORRECT CFM FOR ELEVATION

Ductwork Troubleshooting 2

PROBLEM	POSSIBLE CAUSES	POSSIBLE SOLUTIONS
TOO MUCH HEAT/COOL	a) THERMOSTAT SET TOO HIGH/LOW b) BAD THERMOSTAT CALIBRATION c) THERMOSTAT IN DRAFT d) GAS VALVE STUCK OPEN (HEAT) e) ANTICIPATOR SET TOO HIGH (HEAT) f) OPEN BALANCING DAMPER g) DUCTWORK OVERSIZED	a) LOWER/RAISE SETTING b) RECALIBRATE OR REPLACE c) RELOCATE THERMOSTAT d) REPLACE VALVE e) ADJUST ANTICIPATOR f) ADJUST BALANCING DAMPER g) DOWNSIZE DUCTWORK
ROOM STUFFINESS	a) REDUCED AIR FLOW	a) SEE JUST BELOW...
INADEQUATE RETURN AIR	a) LINT BUILD UP ON GRILLE FACE b) CLOSED DAMPER c) SLIPPING FAN BELT d) INADEQUATE RETURN DUCTWORK e) RESTRICTED AIR FLOW IN LIVING SPACE f) LEAKY RETURN DUCTWORK	a) CLEAN GRILLE FACE b) OPEN DAMPER c) FIX FAN BELT d) REPAIR RETURN DUCTWORK e) UNDERCUT DOORS, INSTALL MORE RETURN GRILLES, EDUCATE OCCUPANTS f) SEAL RETURN DUCTWORK
NOISY AIR AT TERMINALS	a) EXCESSIVE AIR VELOCITY b) CLOSED DAMPER BEHIND REGISTER OR GRILLE	a) INCREASE DUCT, BOOT, REGISTER OR GRILLE SIZE. DECREASE FAN SIZE. INCREASE DUCTWORK TEL b) OPEN DAMPER
NOISY DUCTWORK ("OIL CANNING")	a) EXCESSIVE SYSTEM PRESSURE	a) CHECK FAN SIZE, DUCT SIZE, AND DUCT MOUNTINGS

Ductwork Troubleshooting 3

PROBLEM	POSSIBLE CAUSES	POSSIBLE SOLUTIONS
AIR DISTRIBUTION PROBLEMS WITHIN CONDITIONED SPACE	a) WRONG SUPPLY OUTLETS b) SUPPLY OUTLETS WRONG SIZE c) OUTLETS IN WRONG LOCATION d) WRONG SUPPLY AIR TEMP. e) THROWS NOT ADEQUATE f) SPREAD NOT CORRECT g) EXCESSIVE DROP (COOLING) h) RESTRICTED RETURN(S)	a) REPLACE OUTLETS b) RESIZE OUTLETS c) RELOCATE SUPPLY OUTLETS d) CORRECT SUPPLY AIR TEMP. e) ADJUST VANES OR REPLACE f) ADJUST VANES OR REPLACE g) ADJUST TEMP. OR VANES h) CLEAR RETURN(S)
BUILDING UNDER NEGATIVE PRESSURE	a) EXCESSIVE SUPPLY LEAKAGE TO OUTDOORS b) RESTRICTED SUPPLY DUCTWORK	a) SEAL SUPPLY LEAKS b) REPAIR SUPPLY DUCTWORK
BUILDING UNDER POSITIVE PRESSURE	a) EXCESSIVE RETURN LEAKAGE TO OUTDOORS b) RESTRICTED RETURN DUCTWORK c) MAKE-UP AIR TO RETURN SYSTEM	a) SEAL RETURN LEAKS b) REPAIR RETURN DUCTWORK c) RESTRICT OR ELIMINATE MAKE-UP AIR
ROOM UNDER NEGATIVE PRESSURE	a) INADEQUATE SUPPLY AIR	a) SEAL SUPPLY LEAKS, FIX SUPPLY RESTRICTIONS
ROOM UNDER POSITIVE PRESSURE	a) INADEQUATE RETURN AIR	a) SEAL RETURN LEAKS, FIX RETURN RESTRICTIONS
COLD & DAMP COOLING (Note: Sensible Ratio = Sensible Cooling Capacity/Total Cooling Capacity)	a) TO MUCH SENSIBLE COOLING CAPACITY, NOT ENOUGH LATENT COOLING CAPACITY, i.e., SENSIBLE RATIO TOO HIGH	a) CONSULT MANUFACTURER, LOWER BLOWER SPEED MIGHT CURE PROBLEM.



PROBLEM	POSSIBLE CAUSES	POSSIBLE SOLUTIONS
TEMPERATURE RISE TOO HIGH (USUALLY SHOULD BE BETWEEN 40° AND 80°F.) (Note: The causes for high temp. rise are the same as for tripping fan limits)	a) USUALLY, NOT ENOUGH AIR FLOW THROUGH SYSTEM b) DIRTY OR RESTRICTED FILTER c) DIRTY OR RESTRICTED COOL COIL d) UNDERSIZED OR RESTRICTED RETURN AIR SYSTEM e) UNDERSIZED OR RESTRICTED SUPPLY AIR SYSTEM f) OVERFIRED FURNACE g) BLOWER PROBLEM (TOO SLOW SPEED, BAD BEARINGS, LOW VOLTAGE TO MOTOR, DIRTY BLOWER WHEEL, WRONG ROTATION, BAD BELT)	a) INCREASE AIR FLOW b) REPLACE OR CLEAN FILTER c) CLEAN COOLING COIL d) REPAIR RETURN SYSTEM e) REPAIR SUPPLY SYSTEM f) DOWNSIZE OR REPLACE FURNACE g) REPAIR BLOWER PROBLEM
TEMPERATURE RISE TOO LOW (USUALLY SHOULD BE BETWEEN 40° AND 80°F.)	a) USUALLY, TOO MUCH AIR FLOW THROUGH SYSTEM b) BLOWER SPEED TOO HIGH c) NO RETURN DUCT SYSTEM d) EXTREMELY LEAKY RETURN DUCT SYSTEM	a) DECREASE AIR FLOW THRU SYSTEM b) DECREASE BLOWER SPEED c) INSTALL RETURN DUCT SYSTEM d) SEAL RETURN DUCT SYSTEM