Overview of the ACCA Residential HVAC Design Process- MRC 2015, ACCA Man J, S and D 2 Tech/2 PR

Course Description

This course is an overview of the HVAC design process developed by ACCA (Air Conditioning Contractors of America) for residential dwellings. It will acquaint the attendee with 2015 MRC requirements for design calculations, definitions, and specific code citations. The class will cover ACCA Manuals J, S, D, T as well as other pertinent ACCA documents that have impact on the design and performance of HVAC systems. It will cover the ANSI process for standards and review past and current design standards so that participants can distinguish which standards are current and which are not. Participants will be given sources for additional information as well as check lists for design documents to help insure that the design documents are for that specific project. Course Length 4 hours less three 15-minute breaks. Course breakdown is for 2 technical hours and 2 plan review hours.

Intended Audience

The class is intended for HVAC and building inspectors, HVAC students, HVAC suppliers, HVAC field personnel not needing full design understanding, as well as homeowners wanting a better understanding of their HVAC system. This is an entry level course and assumes that the participant has some mechanical and building code understanding as well as building construction understanding.

Course Objective

The course objective is to give attendees an understanding of what the entire HVAC design process entails. It will give the attendee enough information to determine if an HVAC design is complete and if it is for the project being build. The course will provide sources for additional HVAC design information as well as checklists for each design function.

Class Facilitators

The facilitators for this class are John D. Sedine and Aaron J. Sedine. Their resumes are attached to this document.

Course Outline

Introduction (10 minutes)

1. Introduction of facilitators
2. Review of course content and objectives

Prerequisite Information (10 minutes)

1. Review 2015 MRC code requirements for HVAC design documents including Energy Star version 3 and similar programs.
2. Review ACCA ANSI standard references cited in the 2015 MRC and their importance.
3. Discussion on using standards that are cited versus older versions of standards that would not be in compliance with the 2015 MRC.
4. Discussion on the need to ensure that the HVAC design is in compliance of the 2015 MRC and the benefit to the occupants as well as the environment.
5. Overview of ACCA residential design process and manuals and standards involved.

ACCA Residential Design Process and Manuals

1. **Manual J Residential Load Calculation** (70 minutes)
    - Review of past editions
    - Review of current ANSI edition and separation of manual into a normative section and informative section.
    - Overview of heat gain / heat loss and how it relates to building systems
    - Discussion on block loads versus room by room loads
    - Do's and Don'ts of performing load calculations (Mandatory Provisions)
    - Review typical building construction and the different elements that have an impact on heat gain / heat loss calculations.
    - Review other impacts on calculations such as occupancy loads, ventilation loads, appliance, and lighting loads.
    - Discuss heat transfer and the different mathematical calculations for heating and cooling loads as well as those for exterior walls versus interior wall.
    - Review Manual J manual long form for block load or room by room load.
    - Discussion over a typical 3-bedroom 3-bathroom home with basement and resulting loads.
    - Review of load calculation form and required data that the document should contain.
    - Questions

2. **Manual S Equipment Selection** (30 minutes)
    - Review current ANSI edition.
    - Review normative section and informative section.
    - Discussion on furnace efficiency factor in regard to input and output.
    - Discussion on mixed air temperature and amount of outdoor air allowed through a gas furnace.
    - Discussion of sensible and latent capacities for cooling equipment.
    - Discussion of mixed air temperature and outdoor air on cooling equipment.
    - Overview of size limits for residential HVAC equipment.
    - Discussion on the verification path for HVAC equipment.
    - Questions

3. **Manual D Residential Duct Systems** (55 minutes)
    - Review current ANSI edition
    - Review what part is normative section and what part is informative
    - Discuss how ductwork calculations are done based upon "total effective length - TEL".
    - Acquaint participants with "equivalent lengths of fittings" and discuss "good fittings" and "bad fittings".
    - Review and discuss duct sizing and friction rate work sheets.
    - Discuss static pressure, available static pressure, and friction rate.
    - Perform sample duct sizing calculations
    - Discuss factors that alter available static pressures and resulting friction rates.
    - Review of duct friction rate slide rules.
    - Discussion on zoned systems, using building spaces for plenums, flexible duct, and other topics from the informative section as necessary.
    - Questions

4. **Manual T Air Distribution Basics** (10 minutes)
    - Brief discussion on ASHRAE "comfort zone" or breathing zone.
    - Discuss air stagnation, a bodies perception of "draft", and typical air velocities found during winter and summer.
    - Questions

5. **Manual B Test and Balance** (10 minutes)
    - Brief discussion on the important of air balancing.
    - Questions

6. **Other ACCA resources that may be of interest** (10 minutes)
    - **www.acca.org**
    - **Free standards and checklists**
    - **Bob's House**
    - **ACCA ANSI Standard 4 Maintenance of Residential Systems**
    - **ACCA ANSI Standard 5 Quality Installation Specification**
    - **ACCA ANSI Standard 6 Restoring the Cleanliness of HVAC Systems**

7. **Questions?** (5 minutes)

An Overview of ACCA's Residential HVAC System Design Process

(2 Technical – 2 Plan Review)

John D. Sedine
Technical Services Committee
Air Conditioning Contractors of America

Presentation Overview: ACCA Manual J, Manual S, Manual D

1. Provide a fundamental understanding on the basics of what it takes to do an accurate residential mechanical system design:

2. Provide verification points and caveats
   - *Code officials:* For the purpose of issuing a permit
   - *Quality control personnel:* Checking consistency/accuracy
3. Highlight relevant ACCA resources and opportunities

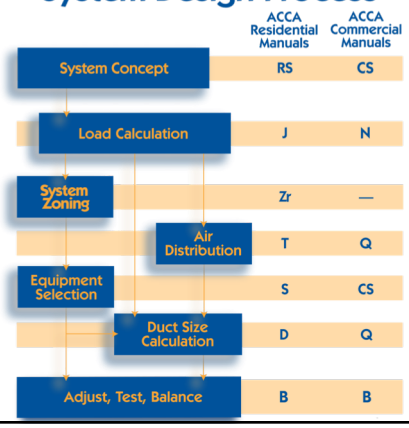
Disclaimer: This is NOT a design course

Designer's Objective

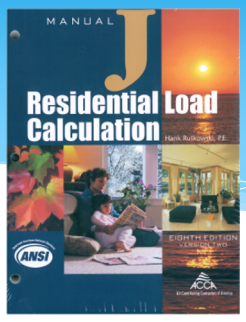
To design a mechanical system that can add (heating) or remove (cooling) heat energy at a rate (BTUs per hour) that will allow the home's indoor environment to achieve the design conditions.

This will keep occupants comfortable and safe and provide for energy-efficient operation.

System Design Process

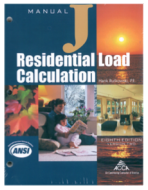


Part 1 – Load Calculation



ACCA/ANSI 2 Manual J - 2016

- **Standard required in:**
  - 2015 IRC §M1401.3, and
  - 2015 IECC §R403.7
- **Comprised of two sections**
  - Normative: 9 pages of text and 200 pages of tabular information that are the enforceable requirements
  - Informative: 390 pages of in depth discussion, documentation, and examples
- **Latest ANSI approval in Feb 2016**



Load Calcs: Heat Gain / Heat Loss

Summer

- Heat flows INTO the home
  - Sensible heat – dry heat (dry bulb; thermometer)
  - Latent heat – wet heat (wet bulb; humidity)

Heat Gain … so we need cooling

Winter

- Heat flows OUT of the home
  - Sensible heat only

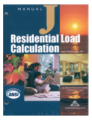
Heat Loss … so we need heating

Heat flow is a rate; the units are Btu/h. (Analogous to mph).

Manual J Load Design Conditions

Two design conditions … hence, two sets of peak loads.

	Outdoor Design Temp (Geographic-specific)	Indoor Design Temp
Heat Gain (summer)	1% db condition	75 F
Heat Loss (winter)	99% db condition	70 F



Loads That Must Be Accounted For

(as applicable to the specific home)

- **Fenestration** (windows, glass doors, skylights)
- **Opaque panels** (wood/metal doors, above & below grade walls, partition walls, ceilings, floors)
- **Infiltration**
- **Ventilation**
- **Internal** (number of people and appliances)
- **System** (ducts and blower)

Basic Load Equation

Load = U x A x ΔT

U = the heat transfer performance index
(how well a material transfers heat; it's the reciprocal of R-value)

A = the Area of the surface (window, wall, ceiling, etc.)

ΔT = the temperature difference across the surface

Load units are Btu/h

Designer Software Options

Simple load calculation – MJ8$_{AE}$ (Abridged Edition)

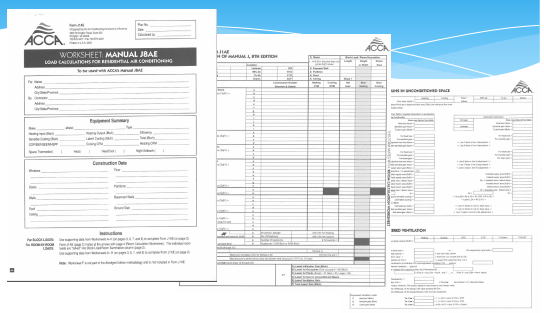
- Dwelling must be 100% compatible with AE Checklist
- Can be done by hand or using ACCA MJ8 speedsheet

Full load calculation – Full MJ8

- Can be done by hand, but extremely time consuming
- Usually use third party software[1]

[1] ACCA vets third party software for compliance with MJ8 procedures, those that pass received "Powered by Manual J" recognition (see: http://www.acca.org/standards/approved-software)

Manual J, Form J1$_{ae}$ (Block Load)



Load Calculation
Min. Verification Points

- **Location** (City, State)
- **Outdoor design temperatures and grains** (Why deviating from MJ8 Tables 1A or 1B?)
- **Indoor design temperatures** (75°F db cooling, 70°F db heating unless superseded by code/regulation)
- **Orientation** matches actual home or plan
- **Occupants** = number of bedrooms + 1
- Conditioned **floor area** = home or plan
- **Eave overhang** depth and **internal shading** = home or plan / default
- Number of **skylights** = home or plan
- **Sensible + latent heat gain = total heat gain**

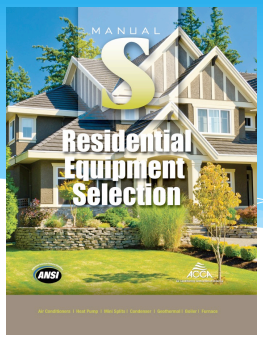
What to Watch Out For …

Some practitioners will try to fudge the numbers to get bigger loads:

- Change the design temperatures (outdoor and/or indoor)
- Design to the worst case scenario (e.g., very loose house)
- Add more occupants than 'number of bedrooms plus 1'
- Calculate duct loads even when ducts in conditioned space
- Not include window overhangs and shading
- Puff up internal loads
- Use a factor of safety

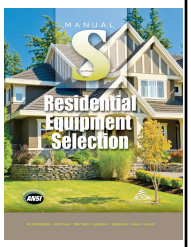
The above practices are not supported by ACCA. Manual J instructs practitioners to be thorough and reflect the ACTUAL conditions.

Part 2 - Equipment Selection



ANSI/ACCA 3 Manual S - 2014

- **Standard required in:**
  - 2015 IRC §M1401.3, and
  - 2015 IECC §R403.7
- **Comprised of two sections:**
  - Normative: 22 pages of enforceable requirements
  - Informative: 270 pages of in-depth discussion, documentation, and examples
- **Latest ANSI approval in May 2014**



Overview Equipment Selection Steps

1. **Start with sizing values**
   - MJ8 heating load: For furnaces and boilers
   - MJ8 cooling load: For cooling-only and heat pump units
2. **Manual S provides sizing rules**
   - Sets upper and lower limits for equipment total capacity
3. **Designer must use OEM performance data**
   - Capacity values must be for operating conditions

Size Limits For Each Equipment Type

Size Limits for Cooling-Only Equipment

Equipment Type	Single Speed	Two Speed	Variable Speed (See Note 8)
	Ducted or Ductless Total Cooling Capacity		
Air-Air	Max = 1.15 Min = 0.90	Max = 1.20 Min = 0.90 FS	Max = 1.30 Min = 0.90 RS
Water-Air pipe loop system	Max = 1.15 Min = 0.90	Max = 1.20 Min = 0.90 FS	Max = 1.30 Min = 0.90 RS
Water-Air open-piping system	Max = 1.25 Min = 0.90	Max = 1.30 Min = 0.90 FS	Max = 1.35 Min = 0.90 RS
Zone Damper Systems	To minimize excess air issues, zone damper systems shall have as little excess cooling capacity as possible when full-cooling capacity is compared to the *Manual J* block load for the space served.		

Size Limits for Fossil Fuel Furnaces

Output Capacity for Heating-Only	Single Stage	Multi Stage	Modulate Burner
	Sizing value to 1.4 x sizing value	Sizing value to 1.4 x sizing value at full capacity	Sizing value to 1.4 x sizing value at full capacity
Preferred [3] Output Capacity for Heating and Cooling	Sizing value to 1.4 x sizing value	Sizing value to 1.4 x sizing value at full capacity	Sizing value to 1.4 x sizing value at full capacity
Maximum [4] Output Capacity for Heating and Cooling	Sizing value to 2.0 x sizing value	Sizing value to 2.0 x sizing value at full capacity	Sizing value to 2.0 x sizing value at full capacity

Heat Pump Sizing Limits

Size Limits for Condition A Heat Pumps
JSHR < 0.95; or HDD / CDD < 2.0

Equipment Type	Single Speed	Two Speed	Variable Speed	
	Ducted or Ductless		Ducted	Ductless
Air-Air	Max = 1.15 Min = 0.90	Max = 1.20 Min = 0.90 FS	Max = 1.20 Min = 0.90 RS	Max = 1.30 Min = 0.90 RS
Water-Air pipe loop system	Max = 1.15 Min = 0.90	Max = 1.20 Min = 0.90 FS	Max = 1.20 Min = 0.90 RS	
Water-Air open pipe system	Max = 1.25 Min = 0.90	Max = 1.25 Min = 0.90 FS	Max = 1.25 Min = 0.90 RS	

Size Limits for Condition B Heat Pumps
JSHR = 0.95 or greater; and HDD / CDD = 2.0 or greater

Equipment Type	Single Speed	Two Speed	Variable Speed
Air-Air Ducted or Ductless	Max = +15,000 Min = 0.90	Max = +15,000 Min = 0.90 FS	Max = +15,000 Min = 0.90 RS
Water-Air pipe loop system	Max = +15,000 Min = 0.90	Max = +15,000 Min = 0.90 FS	Max = +15,000 Min = 0.90 RS
Water-Air open pipe system	Max = +15,000 Min = 0.90	Max = +15,000 Min = 0.90 FS	Max = +15,000 Min = 0.90 RS

Designer must heed the notes for the tables.

AHRI Ratings

A piece of equipment's AHRI rating is evaluated for air at:
80°F db / 67°F wb entering the indoor unit, and
95°F db entering the outdoor unit.

A standardized testing point for equipment capacity and efficiency, but inappropriate for use in equipment sizing and selection.

No one wants an 80°F indoor environment in the summer! And not every location will have a 95°F outdoor design temperature.

Equipment Sizing / Selection
Min. Verification Points

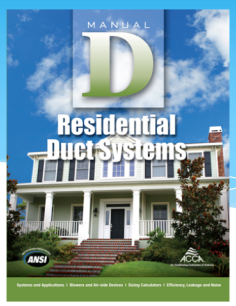
	Cooling Equipment	Heating Equipment
Equipment Information	• Type • Model	• Type • Model
Capacities satisfy design conditions	• Sensible Capacity • Latent Capacity • Total Capacity	• Total Output Capacity • Auxiliary Heating Cap.
Within load sizing limits	• To be verified	• To be verified
Blower Info (at design conditions)	• CFM • ESP	• CFM • ESP

What to Watch Out For …

Some designers will:

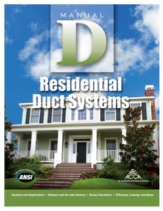
- Seek (incorrectly) to use AHRI rated capacities instead of OEM engineering performance data
- Not interpolating the OEM performance data for the capacity at design conditions
- Misread / misapply OEM performance data tables
  (can be very confusing, and will come in different configurations)
- Round up to next size
- Push for equipment outside of the sizing limits

Part 3 – Duct System Design

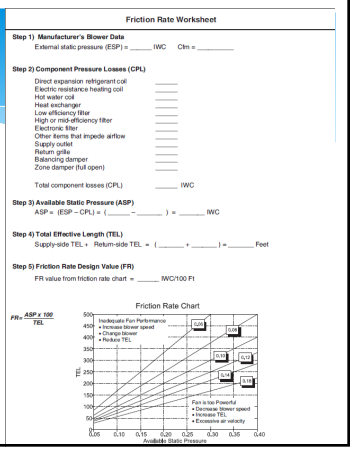


ANSI/ACCA 1 Manual D - 2016

- **Standard required in:**
  - 2015 IRC §M1601.1 and §M1602.2
  - 2015 IMC §603.2
- **Comprised of two sections**
  - Normative: 43 pages of enforceable requirements
  - Informative: 213 pages of in-depth discussion, documentation, and examples
- Latest ANSI Approval in Oct 2016



Friction Rate Worksheet



Step 1) Manufacturer's Blower Data

External static pressure (ESP) = 0.67 IWC Cfm = 1,000

Step 2) Component Pressure Losses (CPL)

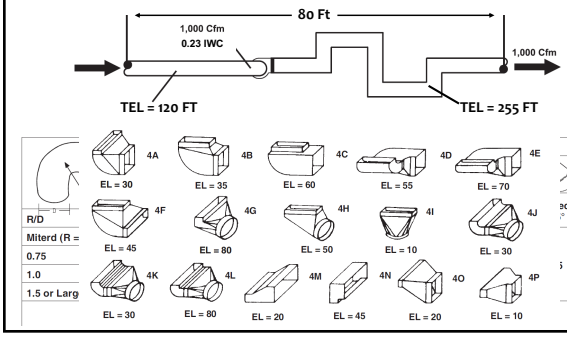
Direct expansion refrigerant coil	0.25
Electric resistance heating coil	
Hot water coil	
Heat exchanger	
Low efficiency filter	
High or mid-efficiency filter	
Electronic filter	0.10
Other items that impede airflow	
Supply outlet	0.03
Return grille	0.03
Balancing damper	0.03
Zone damper (full open)	
Total component losses (CPL)	0.44 IWC

Step 3) Available Static Pressure (ASP)

ASP = (ESP – CPL) = (0.67 – 0.44) = 0.23 IWC

Step 4) Total Effective Length (TEL)

Supply-Side TEL + Return-Side TEL = (255 + 120) = 375 Feet



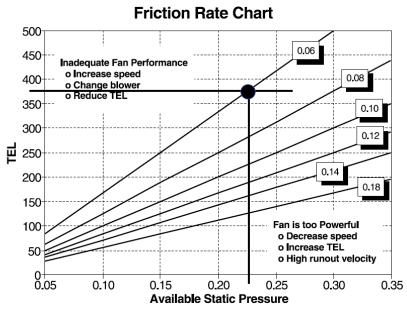
Step 5) Friction Rate Design Value (FR)

FR value from friction rate chart = 0.06 IWC/100 Ft

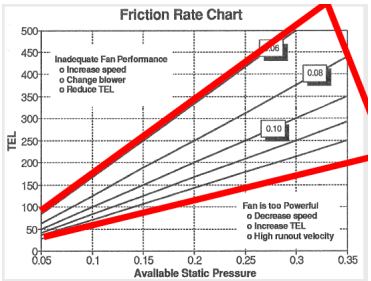
$FR = \frac{ASP \times 100}{TEL}$

$FR = \frac{.23 * 100}{375}$

$FR = 0.061$ IWC / 100 Ft



Friction Rate Chart



- Outside of the "wedge" may lead to velocity problems

Finding Each Room Cfm

$$Room\ CFM = Blower\ CFM * \frac{MJ\ Room\ Load}{MJ\ Total\ Load\ (htg\ or\ clg)}$$

- One value for cooling and one value for heating
- The designer must use the larger of the two cfm values for sizing the duct runs

Reminder: Loads are in Btu/hr

Example

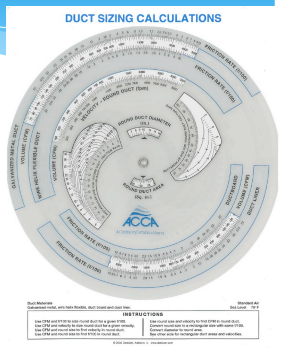
- Air handler delivers 1000 Cfm at 0.23 IWC (net)
- Total heating load: 60,000 Btu/h
- Total cooling load: 48,000 Btu/h

$$Room\ CFM = \frac{Blower\ CFM\ x\ MJ\ Room\ Load}{MJ\ Total\ Load\ (htg\ or\ clg)}$$

Blower Cfm = 1000					
Total heating load = 60,000 Btu/h					
Total cooling load = 48,000 Btu/h					
	C - Btu/h	H - Btu/h	C - Cfm	H - Cfm	Design Cfm
Room 1	4800	5800	100	97	100
Room 2	19200	25200	400	420	420
Room 3	24000	29000	500	483	500

FR & Cfm → Duct Size & Velocity

- Using a duct slide rule, the Cfm and calculated FR will:
  - Provide values for sizing the ducts
    - Round
    - Rectangular
  - Provide an associated velocity in feet per minute (fpm)



Velocity Limit

- Compare the velocity (feet per minute, fpm) at the design cfm with the limits for turbulence/noise control
- If the velocity exceeds the limits, then use the cfm for the limit velocity – resulting in bigger diameter ducts

Air Velocity for Noise Control Subject to Notes 1, 2 and 8								
Component	Supply Side (Fpm)				Return Side (Fpm)			
	Conservative		Maximum		Conservative		Maximum	
	Rigid	Flex	Rigid	Flex	Rigid	Flex	Rigid	Flex
Trunk Ducts	700	700	900	900	600	600	700	700
Branch Ducts	600	700	900	900	500	600	700	700
Supply Outlet Face Velocity	Size for Throw		700 Note 7		—		—	
Return Grille Face Velocity	—		—		—		500	
Filter Grille Face Velocity	—		—		—		300	

Manual D
Min. Verification Points

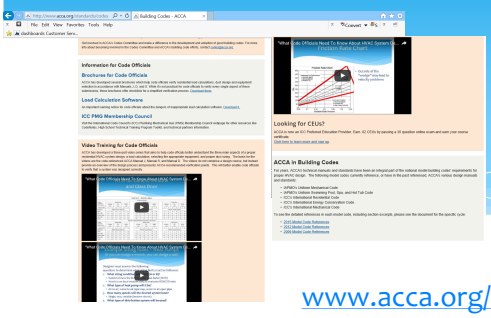
ACCA recommended minimum:

- ESP from blower table at Design Airflow (CFM)
- Total Component Pressure Losses (CPL)
- Available static pressure (ASP = ESP – CPL)
- Lengths: longest supply duct, longest return duct, TEL
- Determined Friction Rate
- Used Manual J room loads to determine Heating/Cooling CFMs
- Ensure maximum airflow velocity limits are not exceeded

What to Watch Out For …

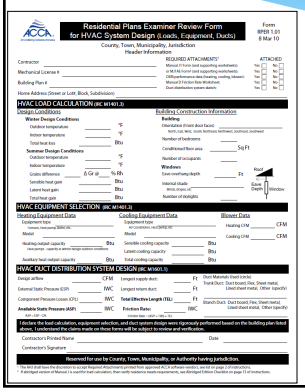
- **Designers that ALWAYS use a FR of 0.10**
  - It needs to be calculated every time for the specific duct system details
- **Check the math**
  - ASP = ESP – CPL
  - FR = (ASP x 100) / TEL
  - Spot check a few register CFMs
- **Not using balancing hand dampers in the runout branches**
- **Not altering the design for a house plan that is rotated to the opposite street side**

Part 4: ACCA-Available Resources



www.acca.org/codes

Free Form


Residential Plans Examiner Review Form
for HVAC System Design (Loads, Equipment, Ducts)

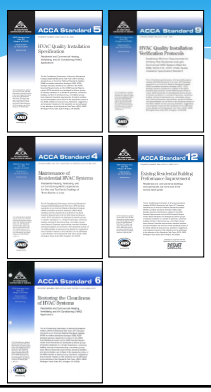
ACCA Design Review Form

Everything you need to check on one form.

- Load calculation
- Equipment selection
- Duct system design

Free to download at
www.acca.org/codes

Free Standards



Free PDF Downloads on HVAC

- Quality Installation (ACCA 5 QI)
- QI Verification (ACCA 9 QIvp)
- Quality Maintenance (ACCA 4 QM)
- Quality Restoration (ACCA 6 QR)
- Whole House Evaluation (ACCA 12 QH)
- and more

Free to download at
www.acca.org/quality

Free Training for Code Officials (and Others!)

Three-part video training on Manuals J / D / S

- Approximately 45 minutes for each segment
- A bit more detailed than this presentation
- Free! … www.ACCA.org/codes

CEUs available from ICC

- ACCA is an ICC Preferred Education Provider
- See: http://www.acca.org/certification/code-essentials
- 0.2 CEU; Cost for the J / D / S test = $60

CEUs have associated costs.

ACCA Technical Reference Note

"Computing Manual J Infiltration Load Based Upon a Target Envelop Leakage Requirement"

Shows how to convert a maximum code allowable leakage limit (say, 3 or 5 ACH 50 per the ICC IECC) to:

1. Manual J infiltration CFM value, and then to
2. infiltration load contributions (Btuh) of:
   - sensible heating,
   - sensible cooling, and
   - latent cooling.

Released: Oct 2016

Free ACCA Membership for ICC Code Offices

To obtain ACCA member benefits for free, contact:

Karla Price Higgs
Vice President, Member Services
International Code Council
KHiggs@iccsafe.org

Educational: QI Design …

[Load Calcs, Equipment Selection, Duct Design, etc.]

Residential HVAC Design FOR QUALITY INSTALLATION

Commercial HVAC Design FOR QUALITY INSTALLATION

Offered via:

- In-person training (3-day class)
- Online training (18 hours of videos, plus assessments)
- Offline DVDs

5-year certificates provided for successful passage of final exam

These each have associated costs.

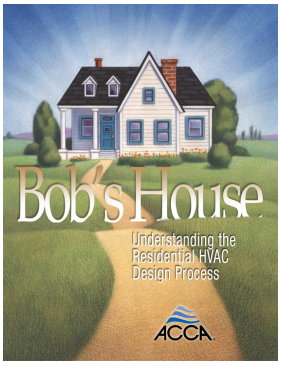
Educational: Technician Training & Certification

On-line learning

- *Technician Field Practices for Quality Installation*
- *Home Evaluation and Performance Improvement*
- *Friction Rate Primer and Duct Design Fundamentals*
- *Duct Diagnostics & Repair*

Convenient … affordable … on-demand training focused on quality HVACR installation, maintenance, home performance, and more.

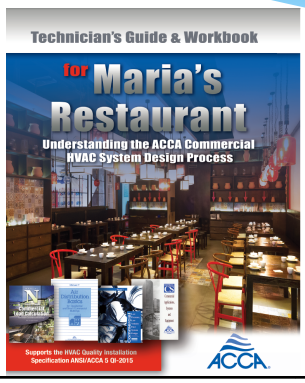
These each have associated costs.



Bob's House

A case study for understanding the residential HVAC design process as described in the ACCA residential design manuals.

May be purchased at www.acca.org/store/



Maria's Restaurant

A case study for understanding the commercial HVAC design process as described in the ACCA commercial design manuals.

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Questions ??

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