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An Overview on ACCA's Residential HVAC System Design Process

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

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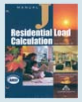
1. Provide a fundamental understanding on the basics of what it takes to do an accurate residential mechanical system design:



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

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Disclaimer: This is NOT a design course!

Designer's Objective

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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.

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Benefits of Proper Design

- **Comfort Related**
  - Better part-load humidity and temperature control
  - Smaller temperature swings between rooms
  - Improved humidity control
  - Less drafts and noise
  - Improved occupant comfort / satisfaction
- **Economic Related**
  - Lower project costs
  - Lower operating expenses
  - Reduced installed load on the public utility system
- **Equipment Related**
  - Proper ducts installed
  - Proper electrical circuit sizing
  - Part load operation
    - Reduced cycling (loading / unloading)
    - Longer equipment life
  - Less nuisance service calls
- **Health Related**
  - Reduced potential for mold growth
  - Less contribution to asthma and other respiratory conditions

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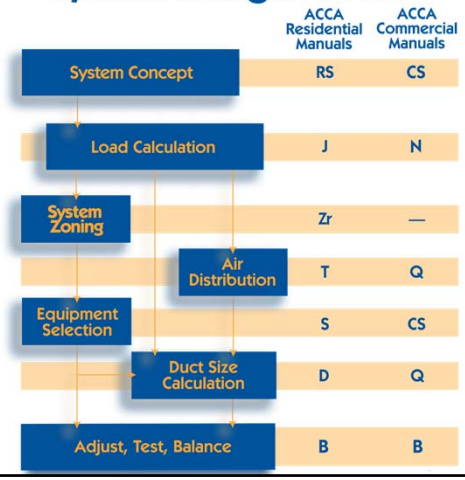
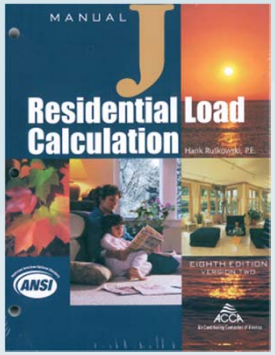
System Design Process



Part 1 – Load Calculation



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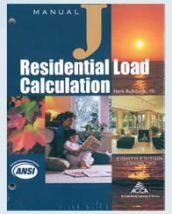
ACCA/ANSI 2 Manual J - 2016

- **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**



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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

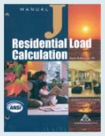
Heat Loss … so we need heating

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)

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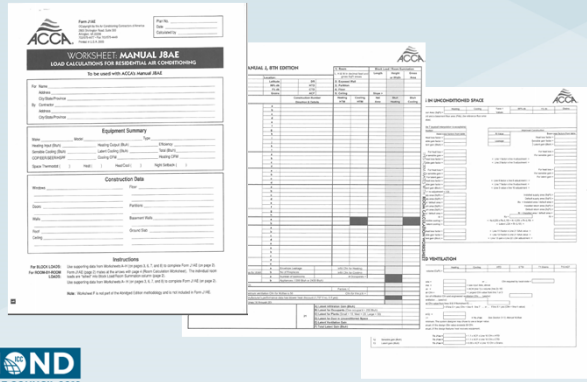
Manual J, Form $J1_{ae}$ (Block Load)



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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**

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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.

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Part 2 - Equipment Selection

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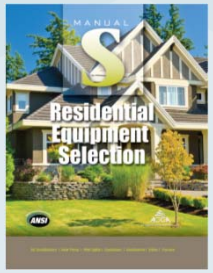
ANSI/ACCA 3 Manual S - 2014

- **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**



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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

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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
Zone Damper Systems	Zone damper systems should have as little excess capacity as possible when full capacity is compared to the ***Manual J*** block load for the space served.		

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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.

Heat Pump Size Limits Conditions

Condition A Size Limits apply when:
- JSHR < 0.95 or HDD/CDD < 2.0
- Moisture control is primary concern

Condition B Size Limits apply when:
- JSHR ≥ 0.95 and HDD/CDD ≥ 2.0
- Heating performance is primary concern

JSHR = sensible cooling load / total cooling load
HDD = heating degree day (base 65°F)
CDD = cooling degree day (base 50°F)
Source for HDD and CDD is MJ8, ASHRAE, or NOAA

Size Limits & Compressor Speed

- Single Compressor Speed
  - Use OEM performance data for only compressor speed
- Multi (2 or more) Compressor Speed
  - Use OEM performance data for high-speed
- Variable Compressor Speed
  - Use OEM performance data for the speed used for AHRI rating test

BUT cooling capacity must be based on OEM performance data for the design conditions and NOT on AHRI rating

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

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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

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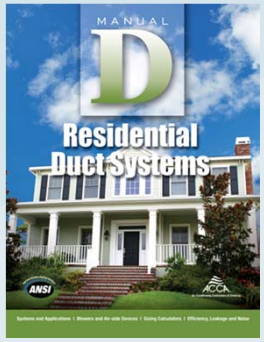
Part 3 – Duct System Design



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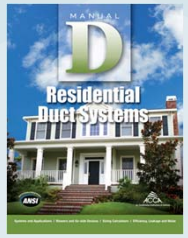
ANSI/ACCA 1 Manual D - 2016

- **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



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Friction Rate Worksheet

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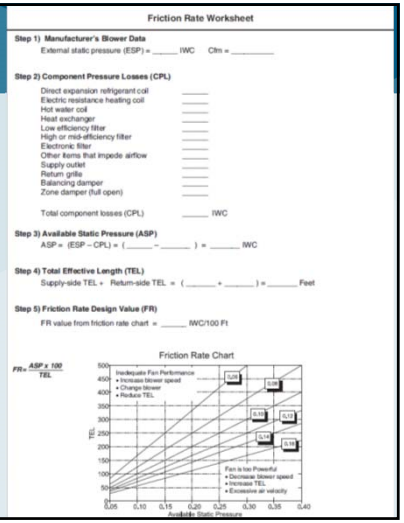

Friction Rate Worksheet

Step 1) Manufacturer's Blower Data
External static pressure (ESP) = _____ IWC Cfm = _____

Step 2) Component Pressure Losses (CPL)
Direct expansion refrigerant coil
Electric resistance heating coil
Hot water coil
Heat exchanger
Low efficiency filter
High or mid-efficiency filter
Electronic filter
Other items that impede airflow
Supply outlet
Return grille
Balancing damper
Zone damper (full open)
Total component losses (CPL) _____ IWC

Step 3) Available Static Pressure (ASP)
ASP = (ESP – CPL) = (_____ – _____) = _____ IWC

Step 4) Total Effective Length (TEL)
Supply-side TEL + Return-side TEL = (_____ + _____) = _____ Feet

Step 5) Friction Rate Design Value (FR)
FR value from friction rate chart = _____ IWC/100 Ft

Friction Rate Chart

Step 1) Manufacturer's Blower Data

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

Step 2) Component Pressure Losses (CPL)

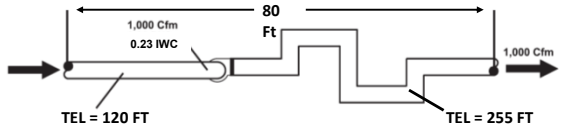
Direct expansion refrigerant coil	0.25
Electric resistance heating coil	
Hot water coil	
Heat exchanger	
Low efficiency filter	
High or mid-efficiency filter	
Electronic filter	0.10
Other items that impede airflow	
Supply outlet	0.03
Return grille	0.03
Balancing damper	0.03
Zone damper (full open)	
Total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

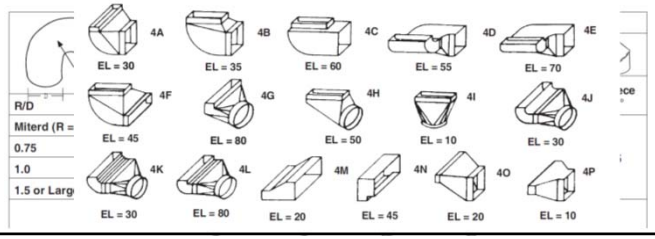
Step 3) Available Static Pressure (ASP)

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)

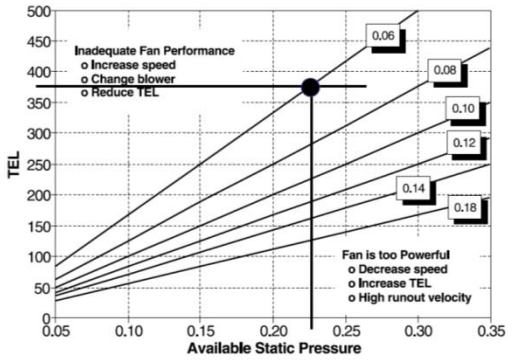
FR value from friction rate chart = 0.06 IWC/100 Ft

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

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

FR = 0.061 IWC / 100 Ft

Friction Rate Chart

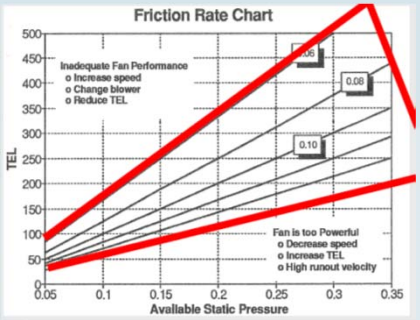


Friction Rate Equation

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

- FR is friction rate
  - Units of IWC/100
- Available Static Pressure (ASP):
  - Blower ESP minus component pressure losses
  - Component pressure losses e.g.: coil, registers, grille
- TEL is total effective length of longest path
  - Sum of straight sections and fittings

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

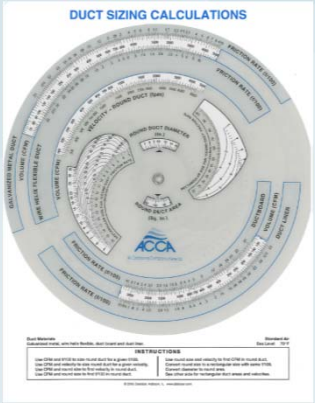
- Air handler delivers 1000 Cfm at 0.23 IWC (net)
- Total heating load: 60,000 Btu/h
- Total cooling load: 48,000 Btu/h

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

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)



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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

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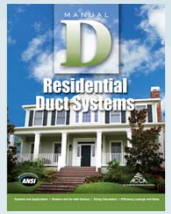
What to Watch Out For …

- **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**



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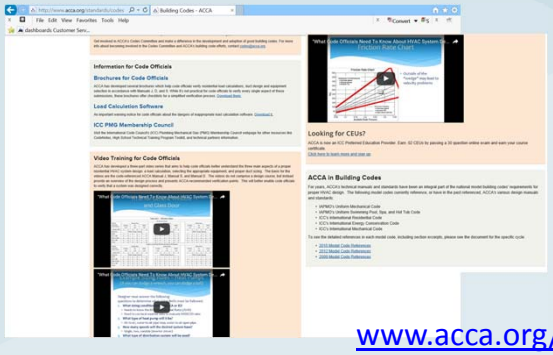
Part 4: ACCA-Available Resources



www.acca.org/codes

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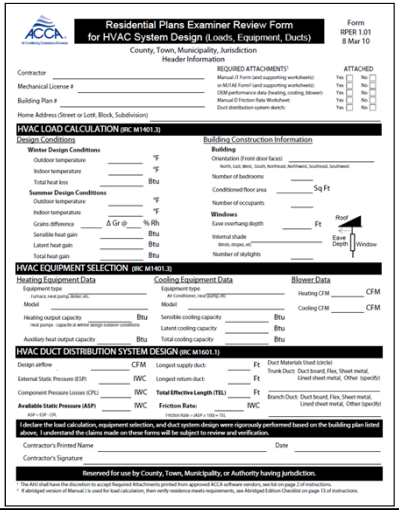

ACCA Design Review Form

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

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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.

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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.

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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

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Educational Offerings

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.

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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*
- *Etc.*

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

These each have associated costs.

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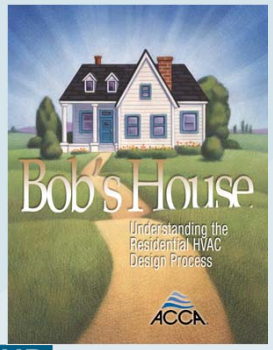
HVAC Primer, residential



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/

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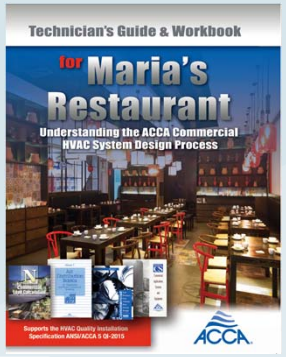
HVAC Primer, commercial



Maria's Restaurant

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

May be purchased at

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Questions ???

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