Right-Sized HVAC Design

The Missing Ingredient in Most Homes

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The "House is a System"

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- HVAC are subsystems;
- HV & AC "condition air" for human comfort, duh!
- HVAC move and circulate air;
- HVAC affects building pressure;
- HVAC sustains life in the home (i.e., makes the house come alive)

If HVAC is the backbone of a "House as a System," then:

- The load calculation is the backbone of the HVAC system
- Required by Code (IRC, IECC)
- Necessary to:
  - Select HVAC equipment size;
  - Determine supply CFM by room
  - Select supply outlets;
  - Select return inlets;
  - Design the duct system
  - Diagnose client comfort issues

Standards of the Industry

Load Calcs **System Size** **Duct Design**

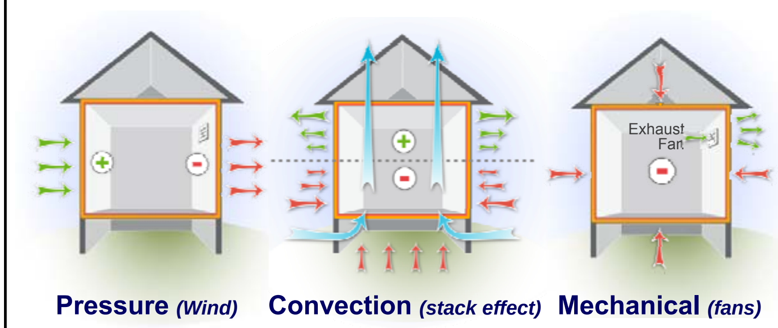
Why Manual J, S, D Training? What's Changed?

- For most in the Great Plains, 2009 IECC in force.
  - Blower door test (7ACH50) is optional to visual inspection,
  - Duct pressure testing (8 cfm/100 ft^2 of CFA), and
- For Illinois, 2012 IECC effective, January 1, 2013.
  - Mandatory Blower door test (5ACH50),
  - All *"hard-ducted"* w/ duct pressure testing (4 cfm/100 ft^2 of CFA), and
  - Mandatory whole-house ventilation (ASHRAE 62.2)
- For the average Illinois home: (2-story, 3-bdrm, 2,200 ft^2 w/bsmt)
  - A -33% reduction in envelope air-leakage (155/105 CFMn)
  - A deliberate mechanical ventilation strategy (60/240 CFMn)
  - A net reduction of 250 to 400 CFMn across the building envelope.

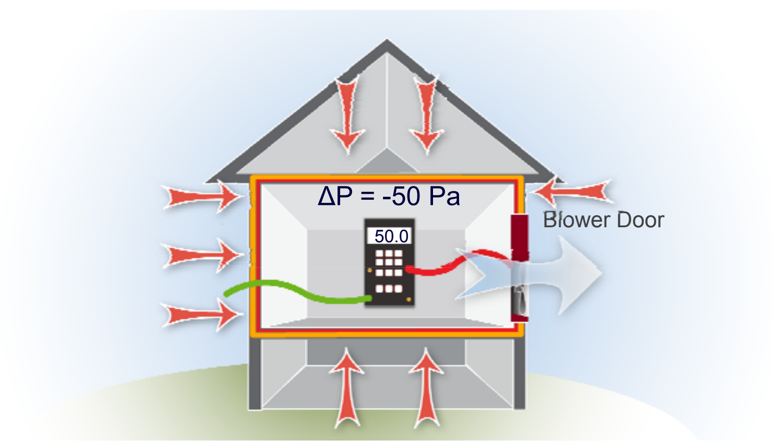
Why Manual J, S, D Training?

- Load estimating (MJ8), equipment sizing (MS), and duct-design (MD) concepts must be re-introduced to builders, contractors, and home owners.
- Why? They do not readily recognize that equipment size, and therefore installation and operating costs, dramatically decrease and long term comfort increases when load estimates are no longer based on rules-of-thumb and record-setting weather conditions.
- **NOTE:** *The amount of effort devoted to the design work is closely tied to the designer's ability to charge for this work.*

How Air Moves Through Buildings



Blower Door Testing

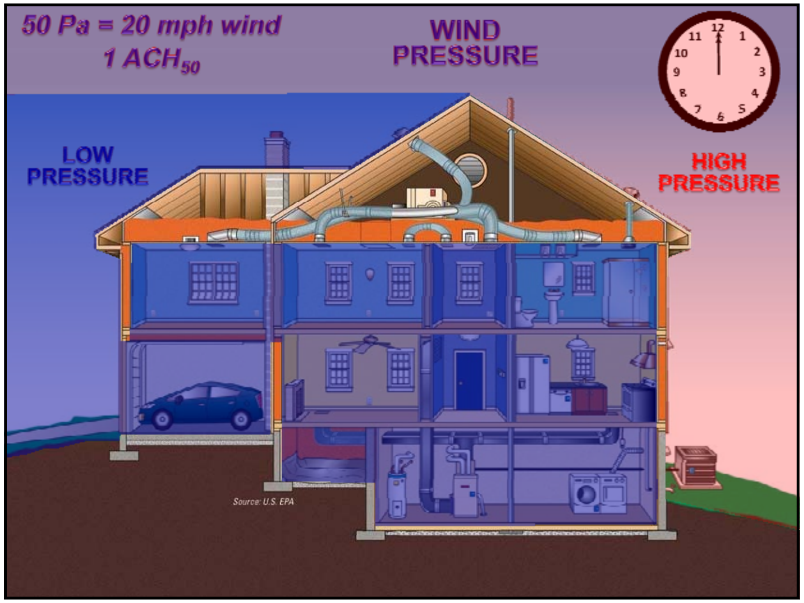


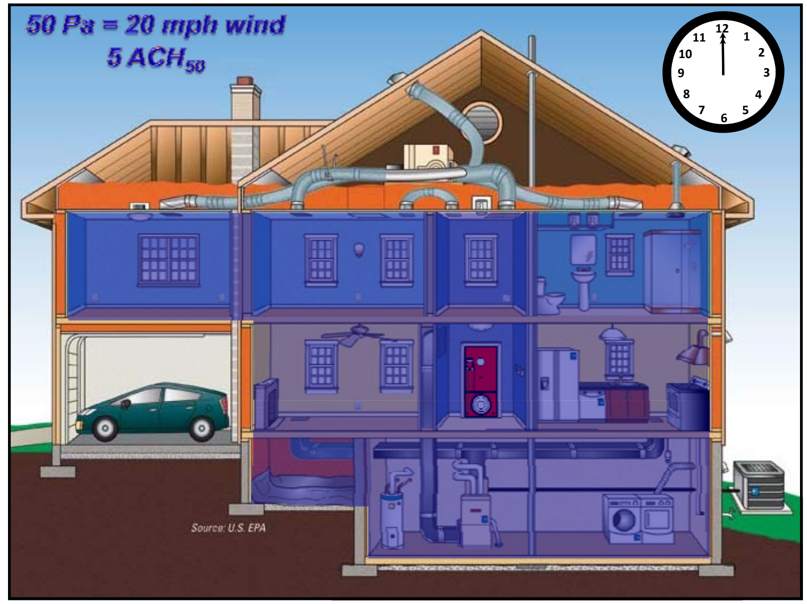
R402.4.1.1 – Blower Door Testing

(Air Leakage Rate of $3ACH_{50}$ or $5ACH_{50}$ Required)

Use of a calibrated fan to quantify/evaluate air leakage…

- **Installation**. Components of the envelope and air barrier are installed in accordance with the thermal- and air-barrier table.
- **Testing**. The building shall be tested/verified with a blower door to quantify rate of air leakage not exceeding 5 ACH50.
- Where required by the AHJ, Blower Door Testing shall be conducted by an ***approved*** third party.





Calculating ACH_{50}

ACH_{50}=(CFM_{50} X 60 min/hour) ÷ Vol.

- **Blower Door Flow Reading** = 2,550 cfm_{50}
- **House Volume** = 27,000 cu/ft
- **ACH_{50}** = (2,550 x 60) ÷ 27,000 = 5.7 ACH_{50}

(Multiply by 60 to convert from minutes to hours)

Approximate Leakage Area

16”

16”

Divide CFM_{50} by 10

Then take Sq. Root

For example:

2,550 CFM_{50} ÷ 10 = 255 sq”

√ 255 = 16” x 16” hole

It’s like having a window open 24 / 7 / 365

2009 IECC Air Leakage 7ACH$_{50}$

4 mph wind = 0.35 ACH$_{nat}$
(140 cfm or 8,400 cubic/ft of natural ventilation/hr)

20 mph wind = 7.0 ACH$_{50}$
(2,800 cfm or 168,000 cubic/ft of natural ventilation/hr)

(1,500 sq/ft home w/full basement)

2012 IECC Air Leakage 5ACH$_{50}$

4 mph wind = 0.25 ACH$_{nat}$
(100 cfm or 6,000 cubic/ft of natural ventilation/hr)

20 mph wind = 5.0 ACH$_{50}$
(2,000 cfm or 120,000 cubic/ft of natural ventilation/hr)

(1,500 sq/ft home w/full basement)

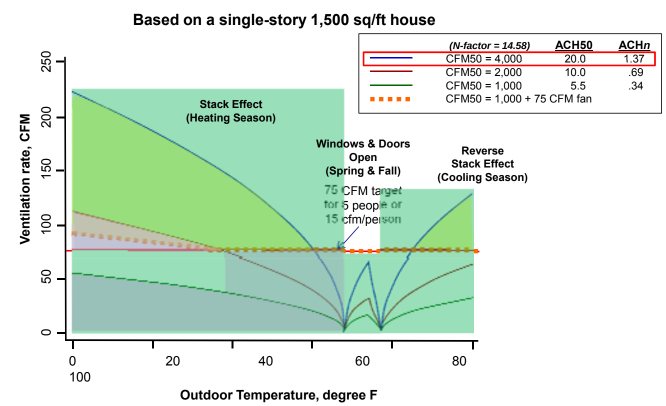
ENERGYSTAR Tighter than Code Air Leakage 2ACH$_{50}$

4 mph wind = 0.1 ACH$_{nat}$
(40 cfm or 2,400 cubic/ft of natural ventilation/hr)

20 mph wind = 2.0 ACH$_{50}$
(800 cfm or 48,000 cubic/ft of natural ventilation/hr)

(1,500 sq/ft home w/full basement)

Mechanical *vs* Natural Ventilation



Source: University of Illinois – Building Research Council

Duct Pressure Testing

2012 IECC "Total" Duct Leakage
(page R34 left side of page)

Total duct leakage is based on 3 cfm/100 ft^2 of CFA with no air handler, or 4 cfm/100 ft^2 with air handler installed.

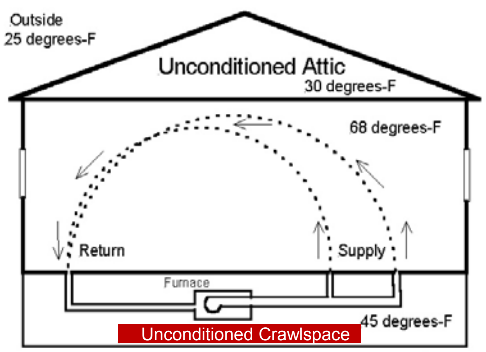
- Rough-in no air handler ……………… 3 cfm
- Rough-in with air handler ……………. 4 cfm
- Post construction with air handler ….. 4 cfm

Example:

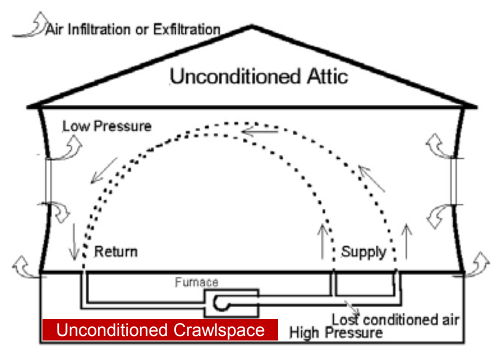
*(2,400 sq' ÷ 100) x 3 cfm = **72 cfm** of total duct leakage*

*(2,400 sq' ÷ 100) x 4 cfm = **96 cfm** of total duct leakage*

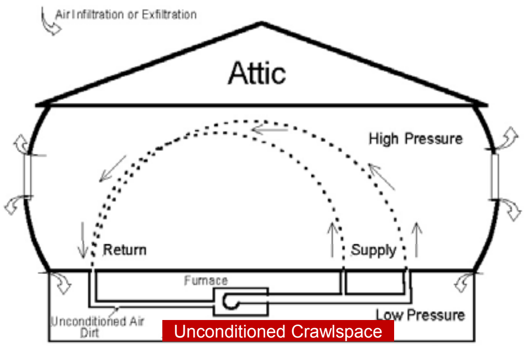
Balanced Duct System - No Leaks



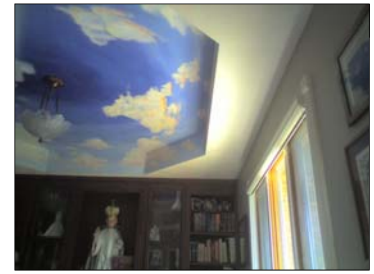
Supply Leaks in Unconditioned Space



Return Leaks in Unconditioned Space



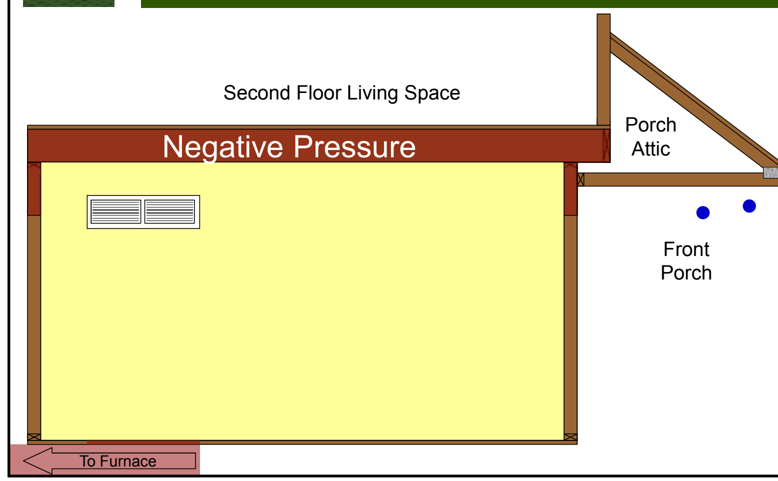
Tray Ceiling - Return Duct



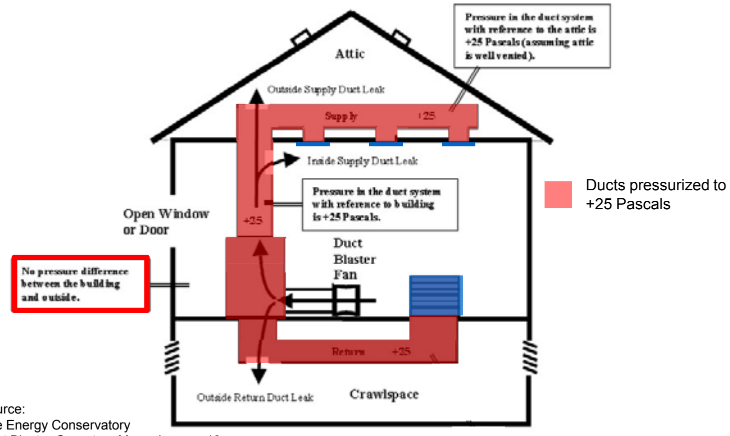
Infrared photos was taken without the blower door operating!!

Building Cavities are Not Ducts

Duct Leakage to the Outside

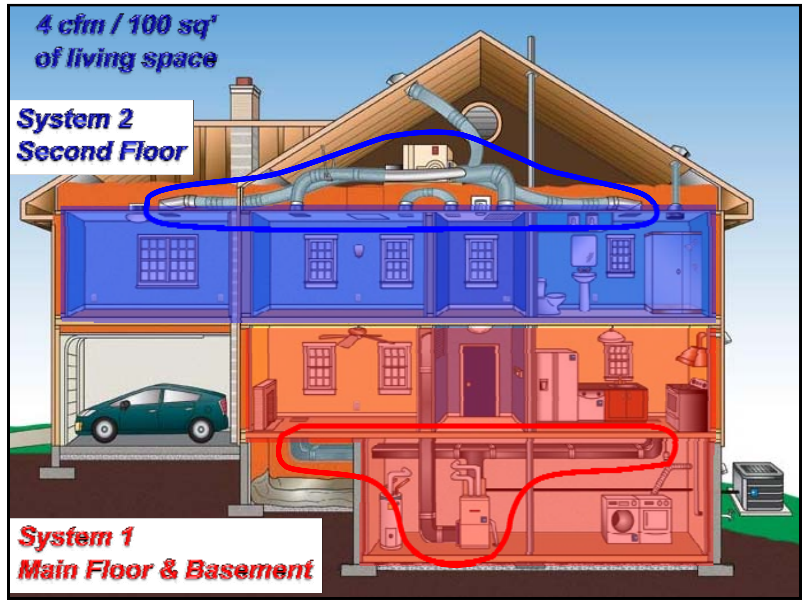


"Total" Duct Leakage Test
(no Blower Door)

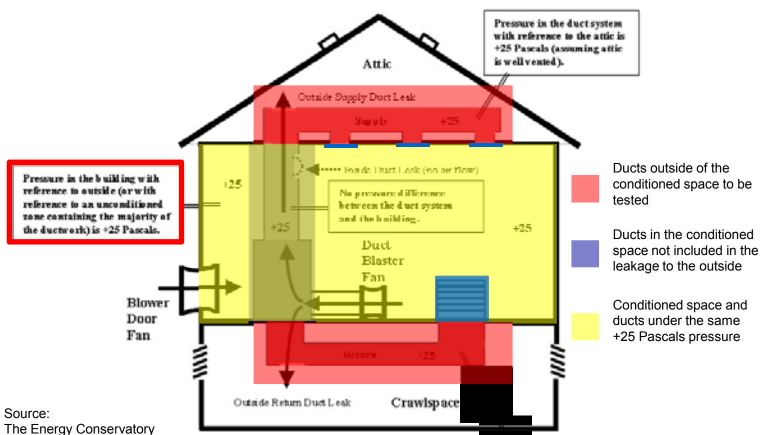


Ducts pressurized to +25 Pascals

Source:
The Energy Conservatory
Duct Blaster Operators Manual - page 18



Duct Leakage to the *"Outside Only"*
(2009 IECC)



Ducts outside of the conditioned space to be tested

Ducts in the conditioned space not included in the leakage to the outside

Conditioned space and ducts under the same +25 Pascals pressure

Source:
The Energy Conservatory
Duct Blaster Operators Manual - page 28

Wrong- vs. Right-sized Equipment

Oversized equipment will:

- Cause equipment to short-cycle; more frequent start-stops increase maintenance ($).
- Degrade summer humidity control.
- Increase potential for mold growth.
- Satisfy thermostat location but room hot/cold spots created.
- Require larger ducts, increased circuit sizing, larger refrigerant line sets ($).

Reasons for Oversized equipment:

- (1) A guess was made on the equipment's capacity at design conditions or
- (2) Mistakes were made in the equipment selection process.
- (3) Multi-zone systems add to installed cost.
- Great care is taken to measure and test equipment performance at operating conditions.
- Contractors using this data to select equipment will meet the comfort needs of their clients.

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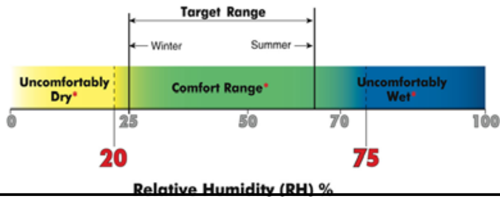
Undersized Equipment

- Does not maintain desired temperature and humidity. Equipment runs and runs but cannot satisfy the thermostat or the occupant.
- However, it is the lesser of the two evils:
  - Slightly undersized cooling equipment (5% or less) may actually provide more comfort at a lower cost.
  - You still get very good dehumidification on mild rainy days when you still want some cooling, and everyday you are running the A/C you are saving money.
- Small, modulating condensing gas furnaces should be available in 12-24 kBtuh capacities. Purely a manufacturing issue



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Oversizing Impacts

Comfort
- Marginal part load temperature control
- Large temperature differences between rooms
- Degraded humidity control
- Drafts and noise
- Occupant discomfort/dissatisfaction

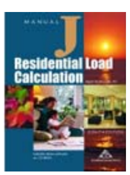
Equipment
- Larger ducts installed
- Increased electrical circuit sizing
- Excessive part-load operation
  - Frequent cycling (loading/unloading)
  - Shorter equipment life
- Nuisance service calls

Economic
- Higher installed costs
- Increased operating expense
- Increased installed load on the public utility system

Health
- Potential to contribute to mold growth
- Potential to contribute to asthma and other respiratory conditions

R403.6 – Equipment Sizing ACCA Manual 'J', Manual 'S'

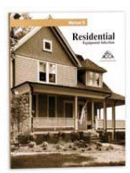
- *Manual J8th* is only used to calculate the heating and cooling loads.
- *Manual J8th* guides HVAC designers to use ACCA *Manual S* to select equipment that is the right size (see § 10-4 of *Manual S*).
- *Manual S* sets equipment sizing limits, as summarized in Table 1.



Manual S Equipment Selection Sizing Limitations		
Equipment	Sizing Limits	Reference
Furnaces	100% - 140% of total heating load	Section 2-2
Boilers	100% - 140% of total heating load	Section 2-2
Air conditioners	115% of total cooling load*	Section 3-4
Heat pumps	115%[1] or 125%[2] of total cooling load*	Section 4-4
Supplemental heat (heat pumps)		
• Electric	Based on equipment balance point	Section 4-8
• Dual fuel	100% - 140% of total heating load	Section 6-8
Emergency Heat (heat pumps)	Based on local codes	Section 4-9

Manual S Input for Design Air Flow (*Manual D*)		
Mode of Operation	Requirement	Reference
• Heating	Temperature rise requirement	Section 2-6
• Cooling	Air flow associated with the selected equipment's capacity	Section 3-11

[1] Heat pumps in a *cooling* dominant climate are allowed to be 115% of the cooling load.
[2] Heat pumps in a *heating* dominant climate are allowed to be 125% of the cooling load.
* The size of the cooling equipment must be based on the same temperature and humidity conditions that were used to calculate the *Manual J* loads.



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R403.6 – Equipment Sizing Applying Manual S to a Heating Example

- Select a furnace for a home with a **57,000 Btu/h** heating requirement.
- Furnace must deliver as least **57,000 Btu/h** to maintain 70F in the home when the outdoor temperature dips to design temp.
- *Manual S* sets a sizing limit for furnaces using Table 1.
- Based on home's load and sizing limitations, the furnace must produce **57,000 Btu/h ≤ heating requirement ≤ 79,800 Btu/h**.
- Furnace shall have a capacity no larger than 140% of heating load.
  - (140% x 57,000 = 79,800 Btu/h)

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R403.6 – Equipment Sizing
Applying Manual S to a Cooling Example

- Select an air conditioner for a home with the following *Manual J8th* cooling loads:

Sensible Cooling	22,000 Btu/h
Latent Cooling	8,000 Btu/h
Total Cooling	**30,000 Btu/h**

- *Manual S* sets a sizing limit for air conditioners using Table 1.
- Based on home's load and sizing limitations, air conditioner must produce **30,000 Btu/h ≤ cooling requirement ≤ 34,500 Btu/h**.
- Air conditioner shall have a capacity no larger than 115% of total cooling load.
  - (115% x 30,000 = 34,500)

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Geothermal System Install/Pathology

1,650 ft², Single-Family Ranch on Crawl,

Marissa, IL (Climate Zone 4)

- Ceiling, R-38 (cellulose)
- Walls (2x4), R-13
- Windows, U-0.57(insulated wd)
  - 19% Glazing Area
  - 17% of Conditioned Floor Area
- 2x Doors, U-0.39
- Floor over crawl, R-30

Geothermal System Install

1,650 ft², Single-Family Ranch on Crawl,

Marissa, IL (Climate Zone 4)

Product specifications

MODEL	CAPACITY	HEATING BTU/HR	COP	COOLING BTU/HR	EER
GXT024C	Full Load	19,700	4.7	27,500	21.9
	Part Load	16,400	5.0	21,200	29.8
GXT036C	Full Load	28,600	4.4	39,300	19.8
	Part Load	22,600	4.4	29,600	28.7
GXT048C	Full Load	39,500	4.2	49,900	18.5
	Part Load	31,200	4.8	38,800	26.6
GXT060B	Full Load	47,400	3.9	60,100	17.1
	Part Load	37,300	4.4	47,200	24.0
GXT072B	Full Load	57,000	3.7	65,400	15.0
	Part Load	47,100	4.2	54,500	20.7

Unit Notes
Rated in accordance with ISO Standard 13256-1, which includes pump penalties.
Heating capacities based on 68.0°F DB, 59.0°F WB entering air temperature.
Cooling capacities based on 80.6°F DB, 66.2°F WB entering air temperature.
Entering water temperatures Full Load: 32°F heating / 77°F cooling.
Entering water temperatures Part Load: 41°F heating / 68°F cooling.

GeoComfort Geothermal Systems

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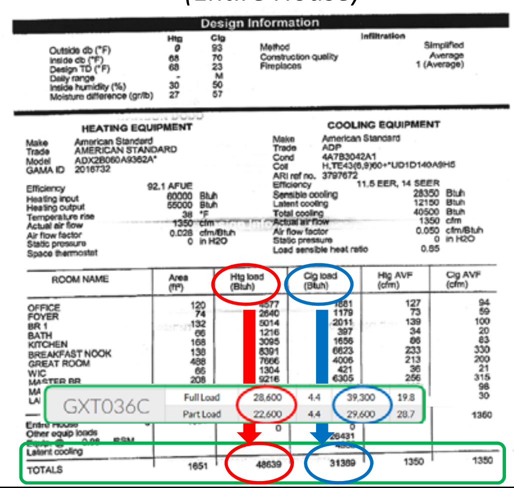
Right-J Analysis After Install

(Entire House)

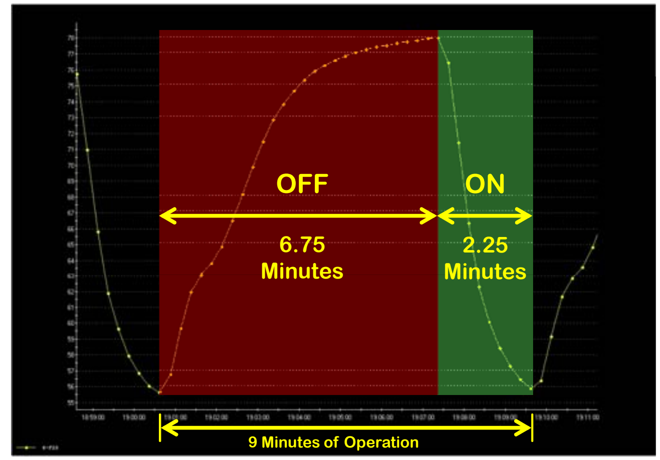


2 Story Office Building

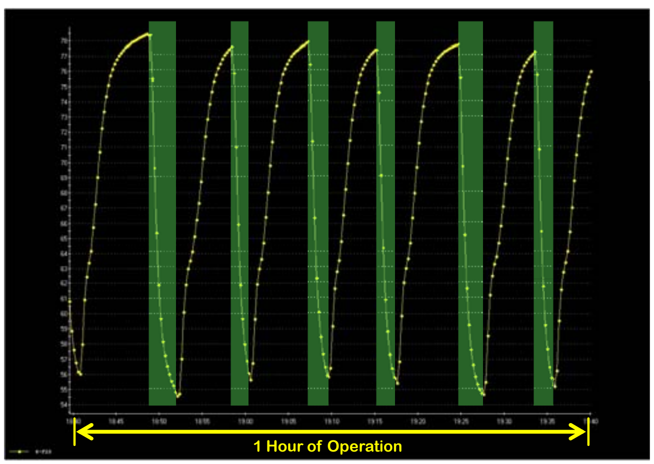
(with an efficient building shell)

13 condensers

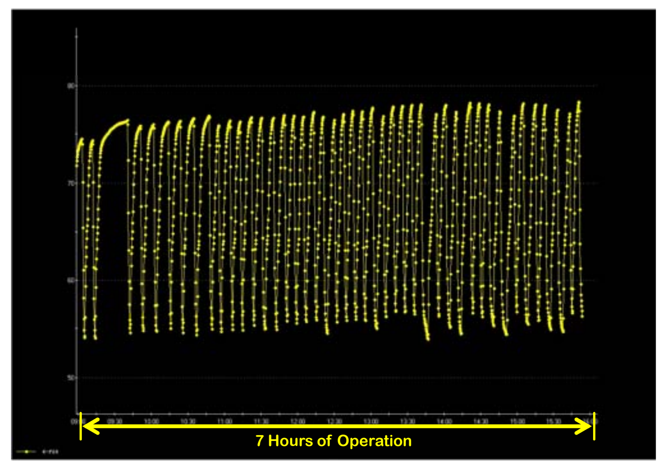
9 Minute Cycle Time (95° day)



1 Hour of Operation



7 Hours of Operation



Thank you!

Questions?

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