Field Application of Advanced Residential Air Conditioning Systems

Presented By Greg Spencer, Residential Cooling Service Coordinator with Lennox Industries

How Ratings Are Established

Size of Indoor Coil

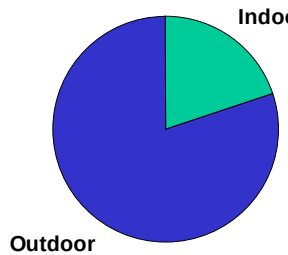
Type of expansion device

Size of Outdoor Coil

Efficiency & type of compressor

Efficiency of blower motor

Relative Energy Usage



How Ratings Are Established

- Includes indoor blower energy.“Default Furnace” measurement generous 365 watts per 1,000 CFM (W/Mcfm) ⇒ Most competitors will use default (A variable speed motor beats the default (Takes off roughly 100 W/Mcfm).

- There are many combinations, so a manufacturer must certify which coil combination will be the “Highest Sales Volume Tested Combination” (HSVTC)

- SEER is a system measurement carried by the condensing units & heat pumps

Energy Guide Labels

(www.eere.energy.gov)

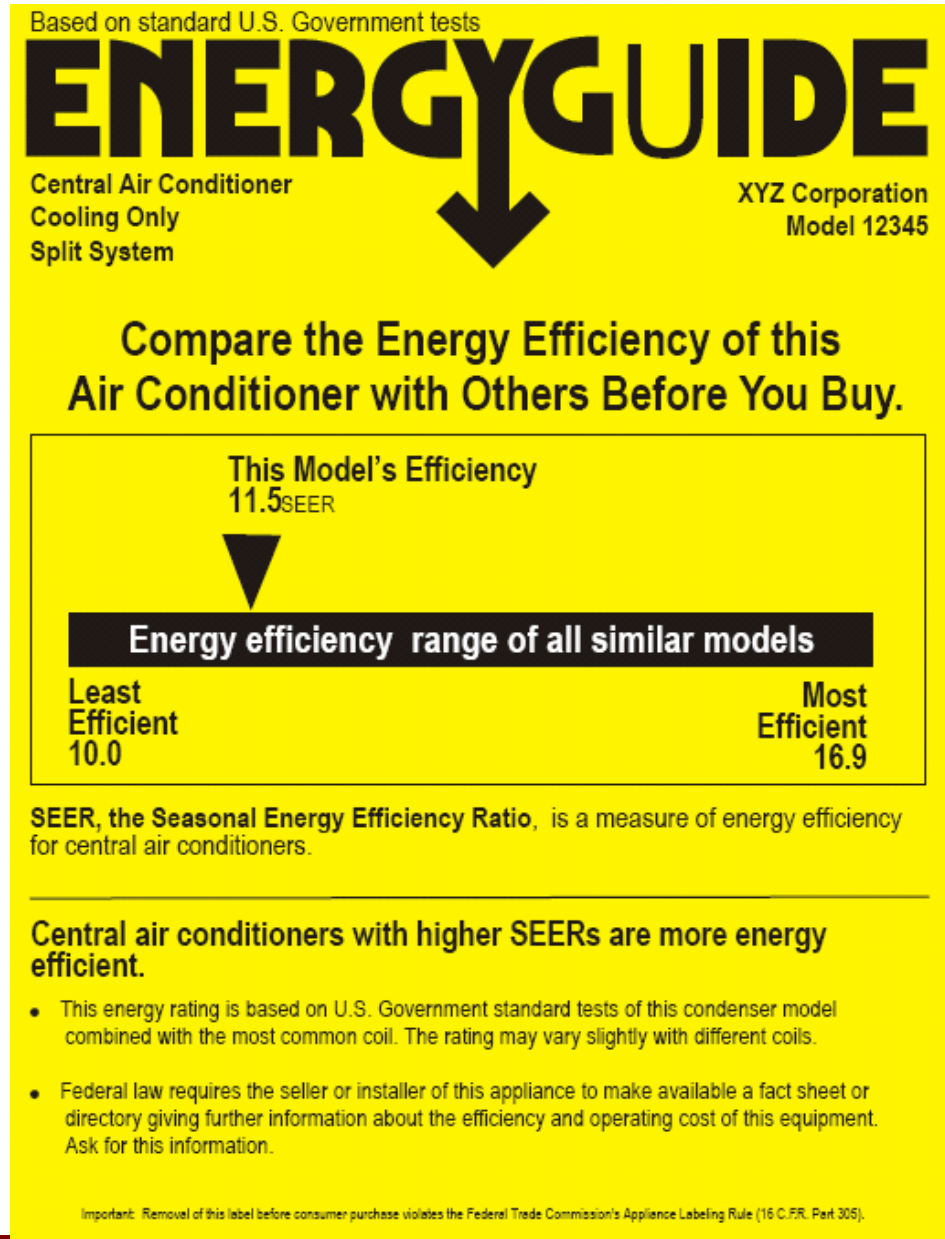
What is ENERGY GUIDE ?

- Federal law requires the Energy Guide labels be placed on central air conditioners and heat pumps.
- Energy Guide labels feature energy use and operating cost information to help shoppers compare appliance models.
- ENERGY STAR labels marks appliances with superior energy efficiency.
- ENERGY STAR label may appear on the Energy Guide label if a particular model qualifies.

Energy Guide Labels

Top

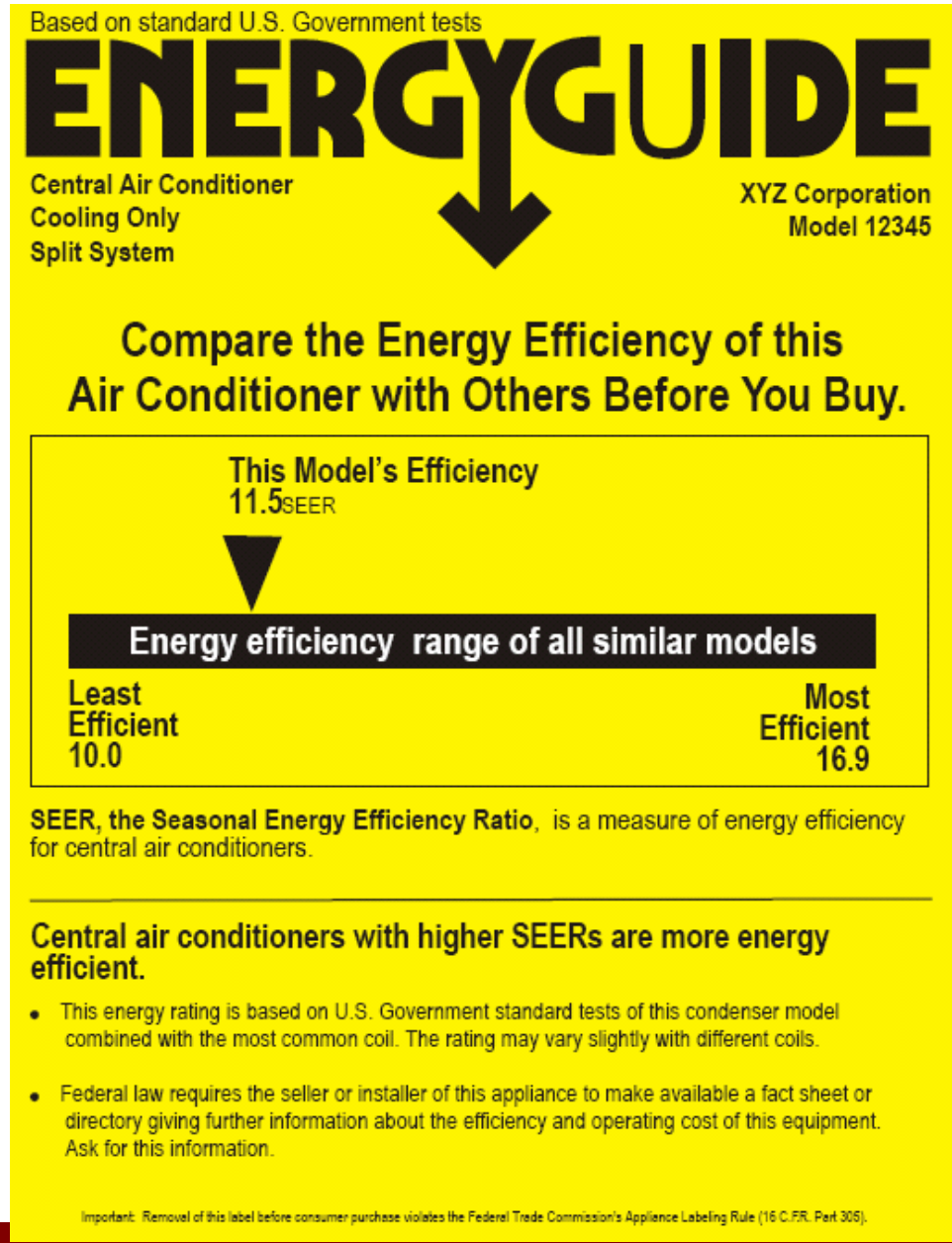
You'll find the manufacturer name, model number, type of appliance, and capacity.



Energy Guide Labels

Middle

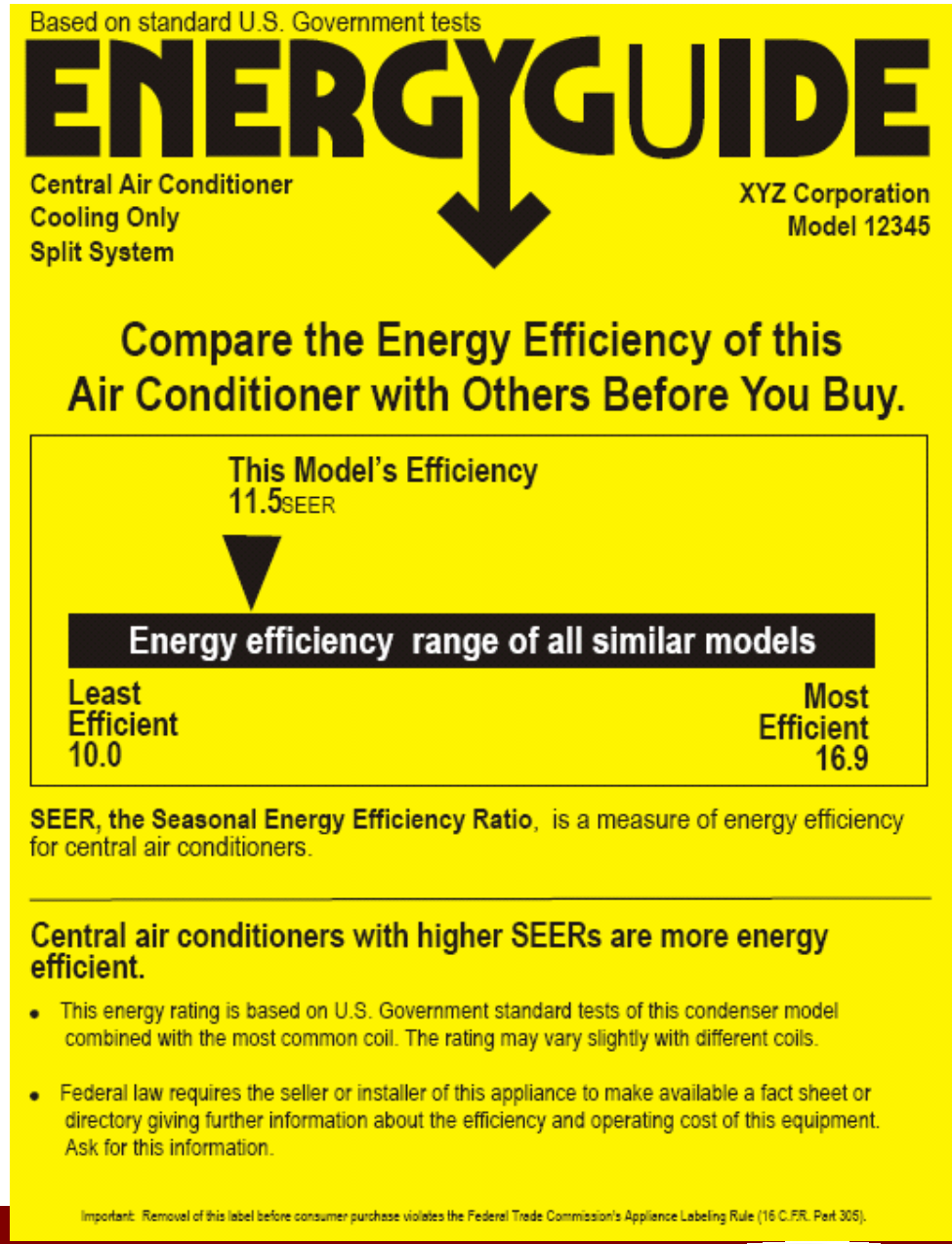
The label shows how a particular model compares in energy efficiency with other models on the market of comparable size and type. Using a line scale, the label indicates where the model falls within a range of most and least efficient units.



Energy Guide Labels

Middle

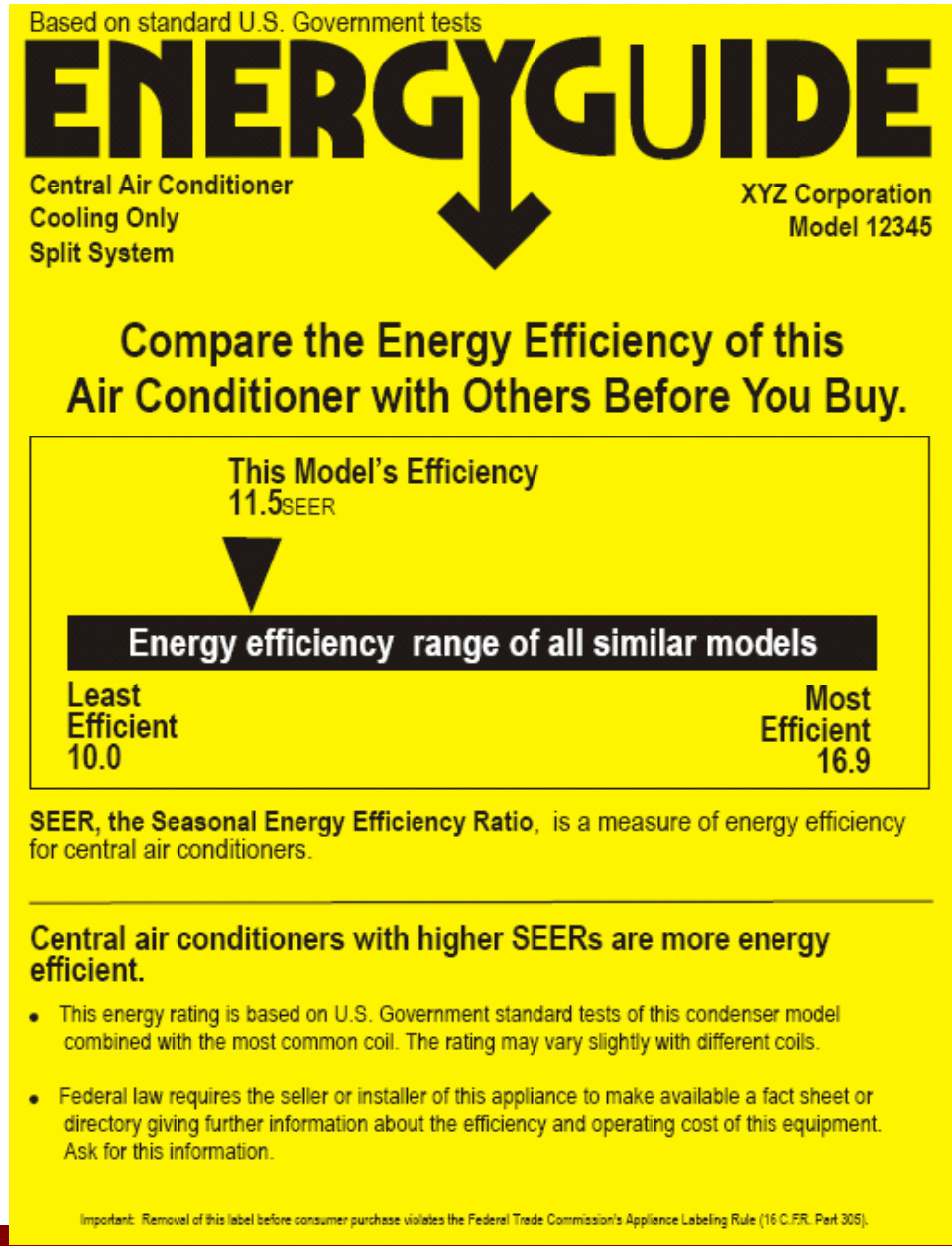
Central air conditioners and heat pumps list Seasonal Energy Efficiency Rating (SEER) or other similar efficiency measures.



Energy Guide Labels

Bottom

An estimate of annual operating costs will appear for appliances that are rated by annual energy consumption. This estimate is based on a recent national average of energy prices and assumes typical operating characteristics.



Energy Star Program

(www.energystar.gov)

What is Energy Star?

- Voluntary product labeling program from the U.S. Environmental Protection Agency and the Department of Energy.
- To earn the Energy Star, products must meet strictly established energy efficiency standards.
- Includes new homes, buildings and over 35 product categories, including HVAC.
- Label is recognized by over 40% of U.S. consumers.

Energy Star Program

Why?

Government-backed symbol

- Provides unique third-party credibility
- Enhances the trust factor with consumers.
- Major HVAC manufacturers currently participate as ENERGY STAR Partners.
- Wealth of consumer information.
- Specific resources for HVAC contractors.

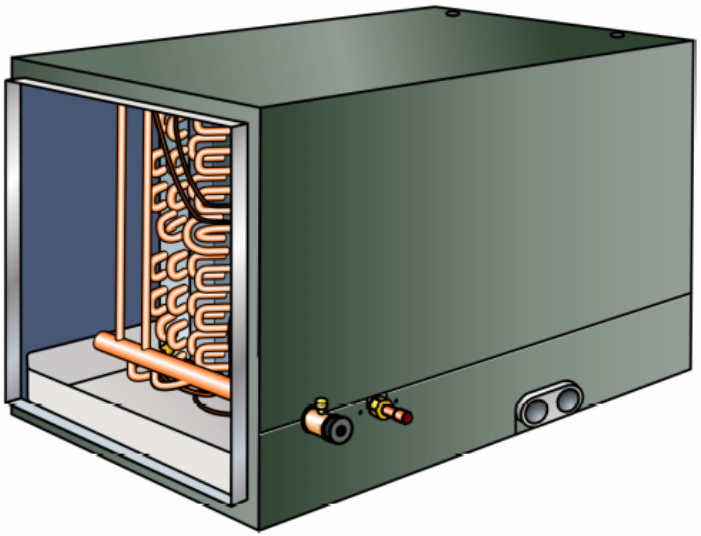
Three Cooling System Loading Conditions

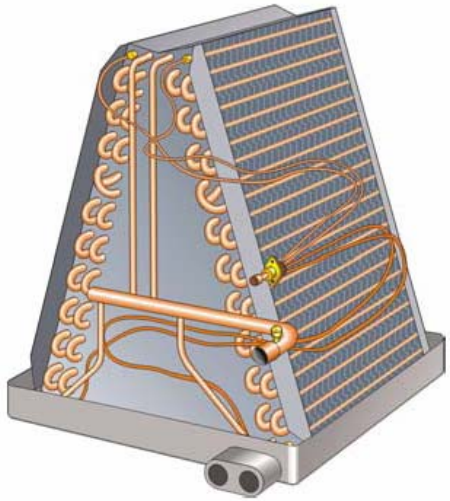
- Full System Load (System working at design conditions – Designed sensible load)
- Part System Load (Minimum to maximum cooling loading – Reduced latent reduction due to run times)
- No System Loading (No sensible cooling requirements – could be need for latent but no sensible loading)

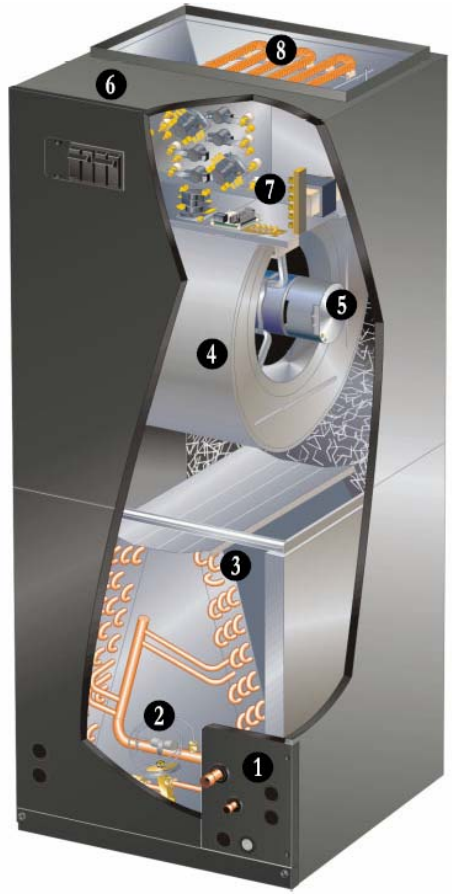
Full System Loading

- System Load Calculation (Manual J –Version 8)
- Equipment Selection & SEER (ARI or manufacturer product catalogs)
- Duct Sizing, Layout and system air balance (Manual D)
- Proper install equipment per installation instructions
- Proper equipment Set up per installation instructions

Equipment Installation





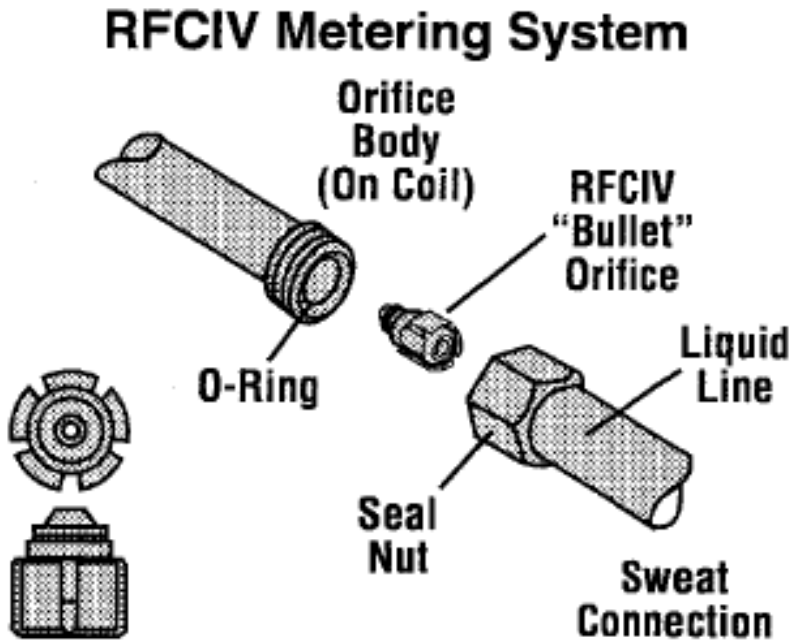


Different configurations

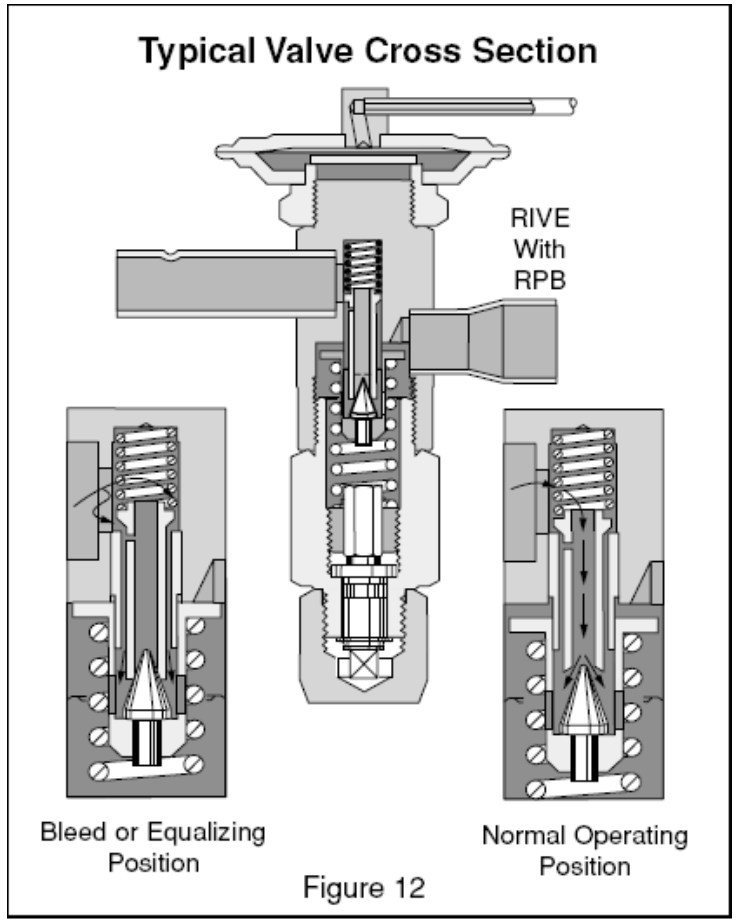
Proper installation and set up

Correct sized metering device,

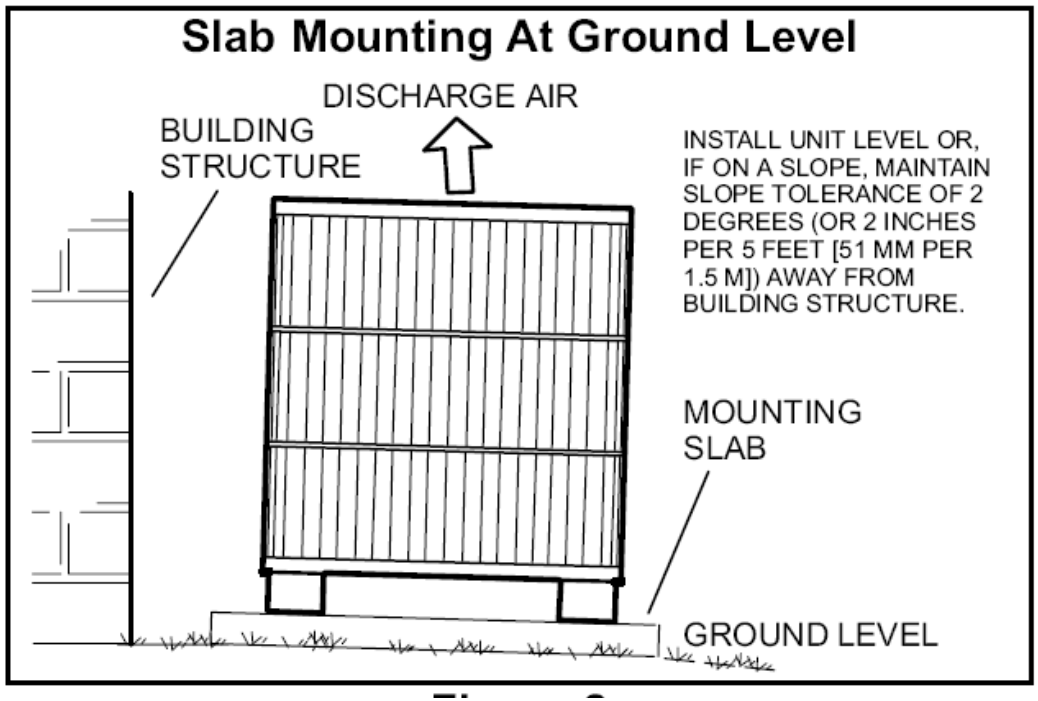
Equipment Installation



Fixed Orifice metering device

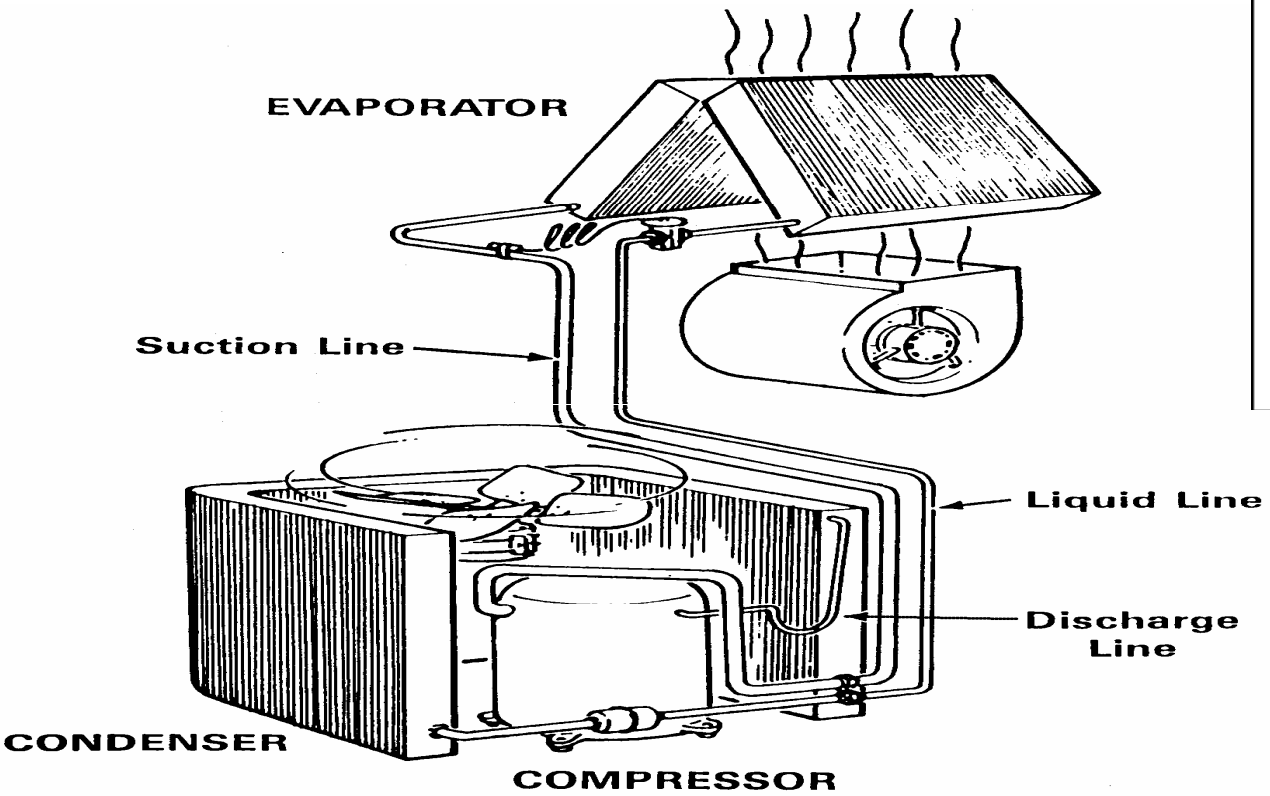


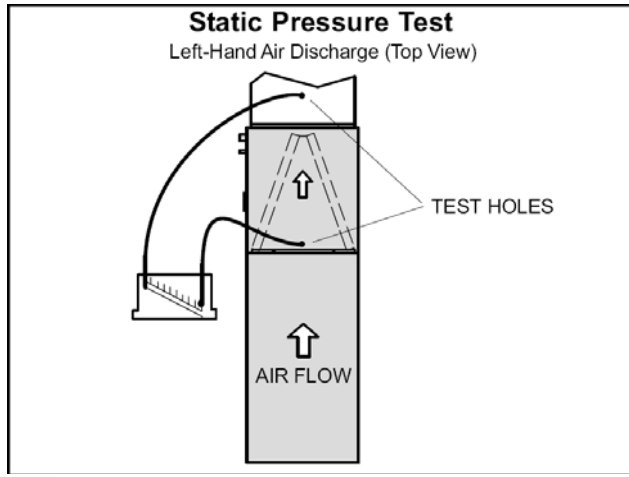
Equipment Installation



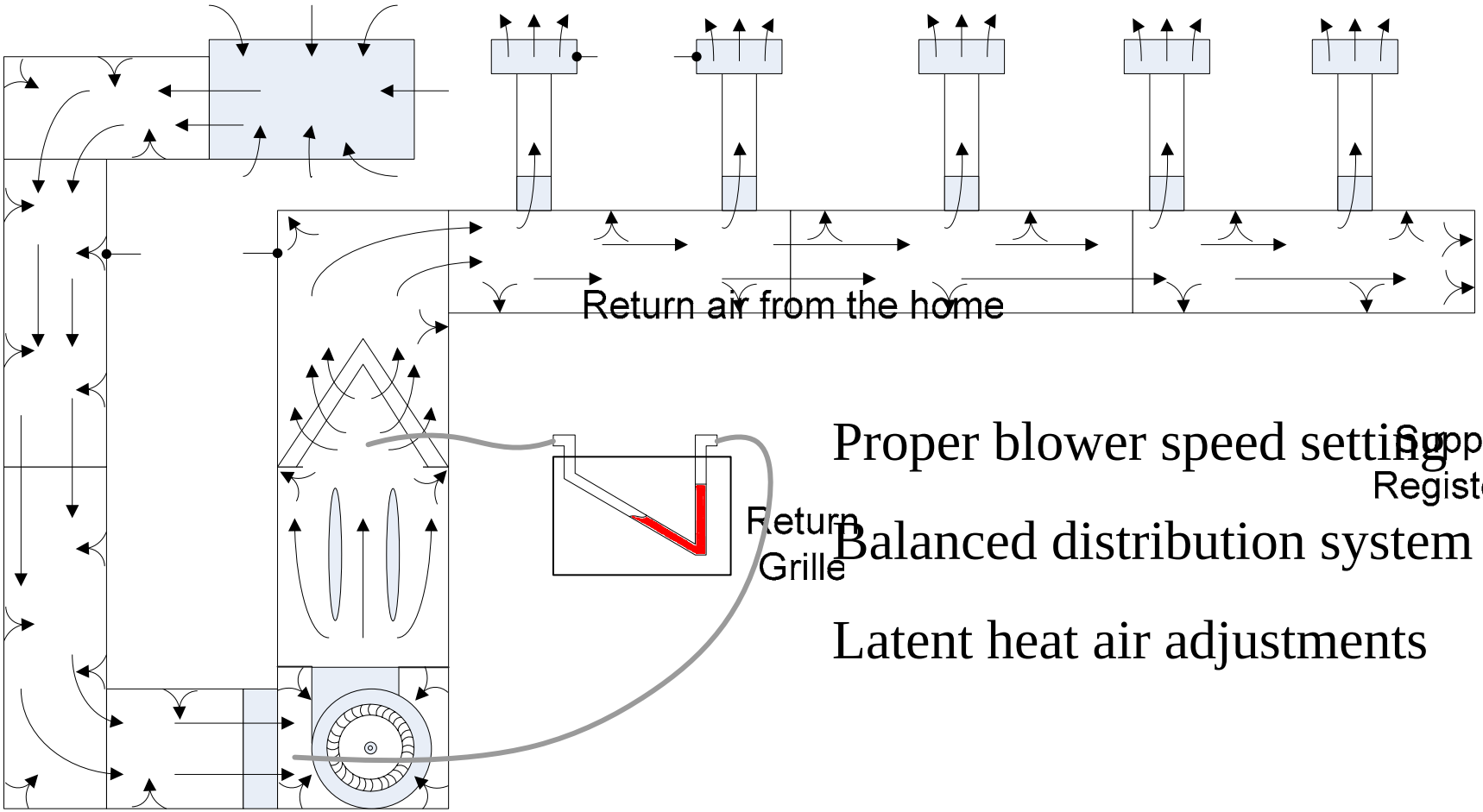
No metal to metal rubbing, proper refrigerant pipe routing, proper clearances around unit.

Equipment Set up (Indoor Blower)





Equipment Set up (Indoor Blower)



- Proper blower speed setting
- Balanced distribution system
- Latent heat air adjustments

Equipment Set up (Charging)

Several different ways of charging or checking charge in air conditioners and heat pumps in the installation instructions and service manuals.

Always use more than one method to charge or check charge in system.

- Weigh in
- Sub-cooling
- Superheat (Fixed Orifice, piston, flow-meter)
- Approach

Equipment Set up (Charging)

Fixed orifice charging by superheat

Under part load conditions, the fixed orifice will provide reduced latent capacity as compared to a TXV.

Superheat Values For Fixed Orifice Systems

*Dry bulb out-door	Wet bulb (air entering indoor coil)													
	50	52	54	56	58	60	62	64	66	68	70	72	74	76
40	15	18	20	23	26	29	32	34	38	41	43	46	48	51
45	13	16	18	21	24	27	30	33	36	39	41	44	46	49
50	11	14	16	19	22	25	28	31	34	37	39	42	44	47
55	9	12	14	17	20	23	27	30	33	36	38	40	42	44
60	7	10	12	15	18	21	24	27	30	33	35	38	40	43
65	-	6	10	13	16	19	21	24	27	30	33	36	38	41
70	-	-	7	10	13	16	19	21	24	27	30	33	36	39
75	-	-	-	6	9	12	15	18	21	24	28	31	34	37
80	-	-	-	-	5	8	12	15	18	21	25	28	31	35
85	-	-	-	-	-	-	8	11	15	19	22	26	30	33
90	-	-	-	-	-	-	5	9	13	16	20	24	27	31
95	-	-	-	-	-	-	-	6	10	14	18	22	25	29
100	-	-	-	-	-	-	-	-	8	12	16	21	24	28
105	-	-	-	-	-	-	-	-	5	9	13	17	22	26
110	-	-	-	-	-	-	-	-	-	6	11	15	20	25
115	-	-	-	-	-	-	-	-	-	-	8	14	18	24

* Dry-bulb temperature (ºF) of outdoor entering air.

NOTE - Do not attempt to charge system where a dash appears, system could be overcharged. Superheat is taken at vapor line service port. Vapor line superheat must never be less than 5ºF at the vapor line service port.

Equipment Set up (Charging)

Subcooling Values TXV Systems							
XC13 Model	-018	-024	-030	-036	-042	-048	-060
Temp. °F (°C)	3 (1.7)	6 (3.3)	11 (6)	7 (4)	7 (4)	10 (5.5)	10 (5.5)

Approach Values							
XC13 Model	-018	-024	-030	-036	-042	-048	-060
Temp. °F (°C)	12 (6.7)	12 (6.7)	7 (4)	10 (5.5)	7 (4)	7 (4)	9 (5)

____° Liquid Line Temperature °F (°C)

— ____° Outdoor Ambient Temperature °F (°C)

= ____° Approach Value °F (°C)

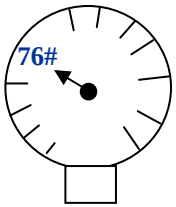
Sub-cooling & Superheat Calculation Explained

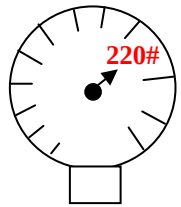
SL Temperature **60°**

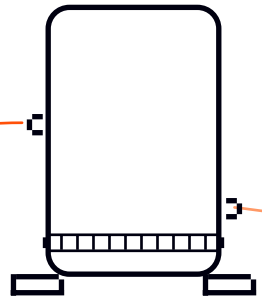
minus -

SL Pres. To Saturation **45°**

equals = **15°** Superheat







Indoor Coil

Outdoor Coil

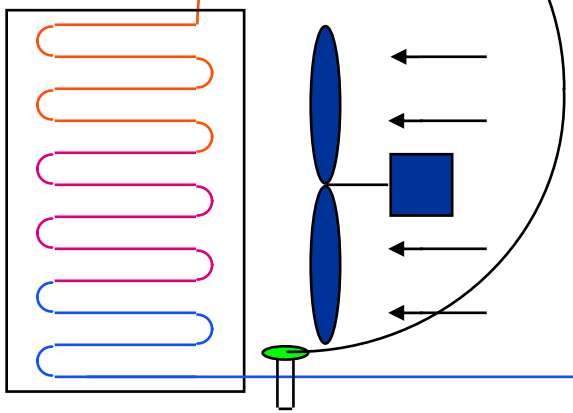
Superheated Vapor

Sensible

Saturated Vapor

Latent

Low Pres. Liquid



Sensible — High Pressure, High Temperature Vapor

Latent — Saturated Vapor

Sensible — High Pressure, Sub-cooled Liquid

LL Pres. to Saturation **108°**

minus -

LL Temperature **98°**

equals = **10°** Sub-cooling

Basic Refrigeration Circuit

Properly Charged Unit

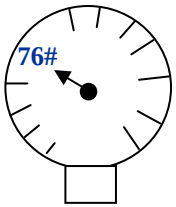
Sub-cooling & Superheat Calculation Explained

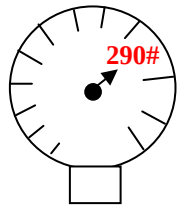
SL Temperature **60°**

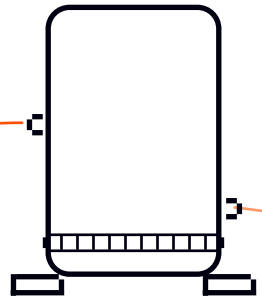
minus -

SL Pres. To Saturation **45°**

equals = **15°** Superheat







Indoor Coil

Outdoor Coil

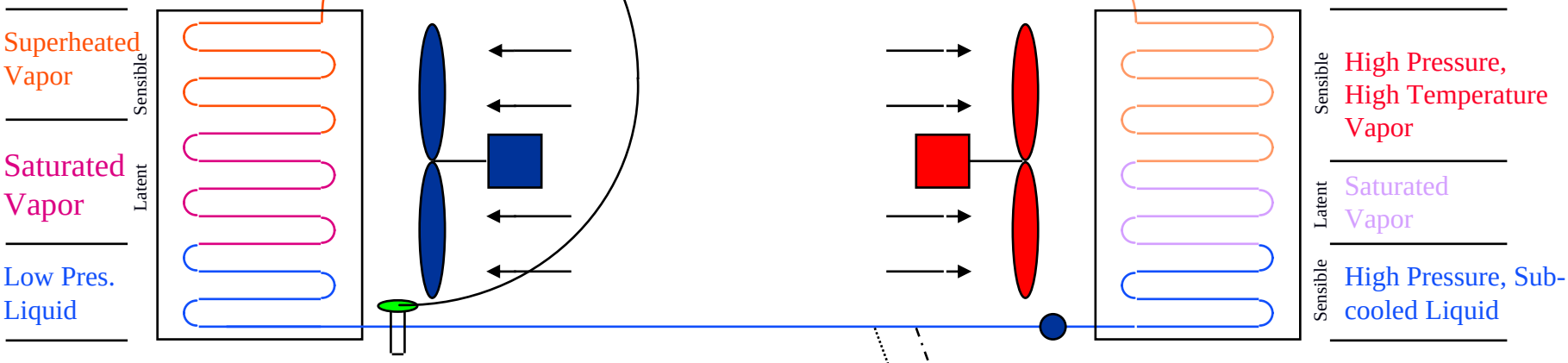
Superheated Vapor

Sensible

Saturated Vapor

Latent

Low Pres. Liquid



Sensible — High Pressure, High Temperature Vapor

Latent — Saturated Vapor

Sensible — High Pressure, Sub-cooled Liquid

LL Press. to Saturation **128°**

minus -

LL Temperature **108°**

equals = **20°** Sub-cooling

Basic Refrigeration Circuit

Over Charged Unit

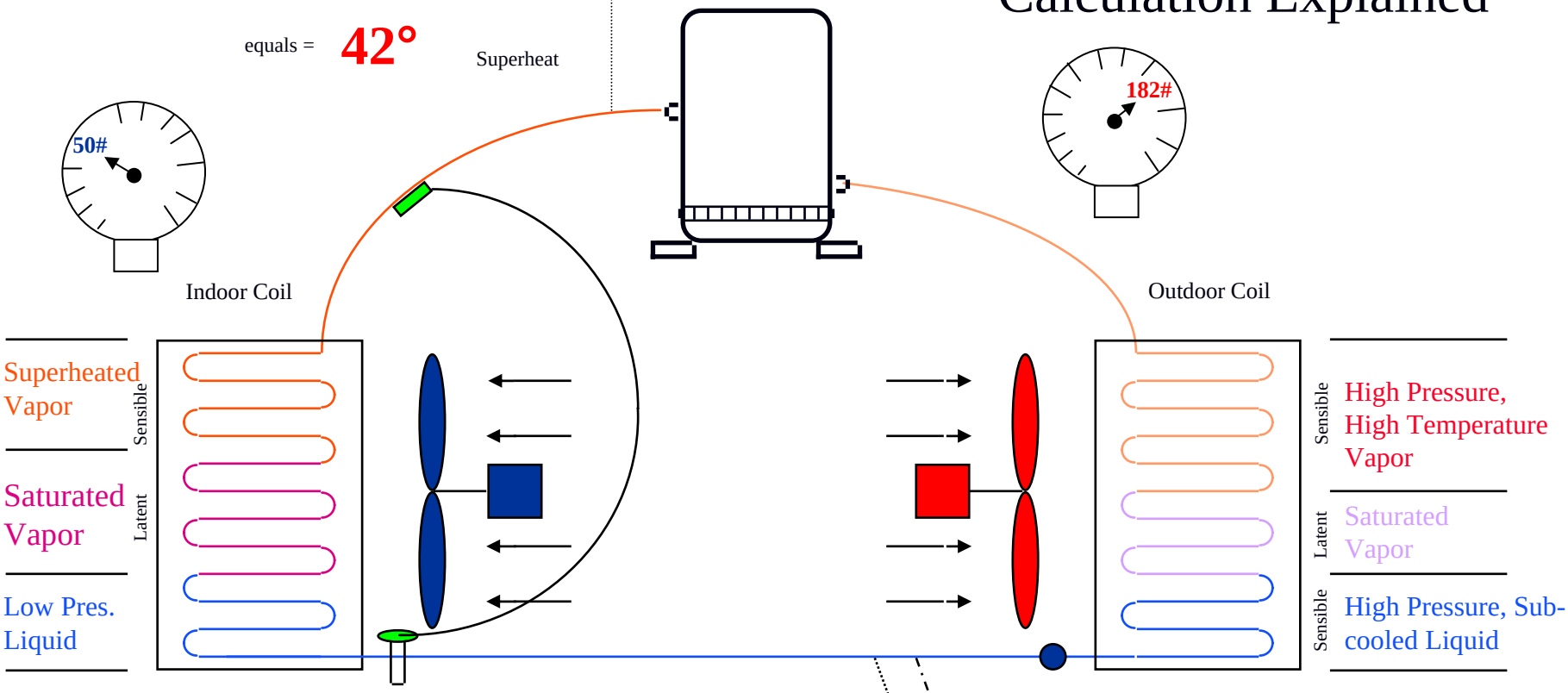
Sub-cooling & Superheat Calculation Explained

SL Temperature **68°**

minus -

SL Pres. To Saturation **26°**

equals = **42°** Superheat



LL Press. to Saturation **95°**

minus -

LL Temperature **95°**

equals = **0°** Sub-cooling

Basic Refrigeration Circuit

Under Charged Unit

Part and No System Loading

- Maximize amount of dehumidification done during cooling cycle.(Coldest coil)
- Prevent any re-evaporation of condensation back into the supply air system. (Cycle indoor supply fan, condensate management)
- Us of exhaust fans when high humidity is being added to home
- Proper venting of appliances (Ex:dryer)
- Elimination of moisture sources.

Reduction Measures

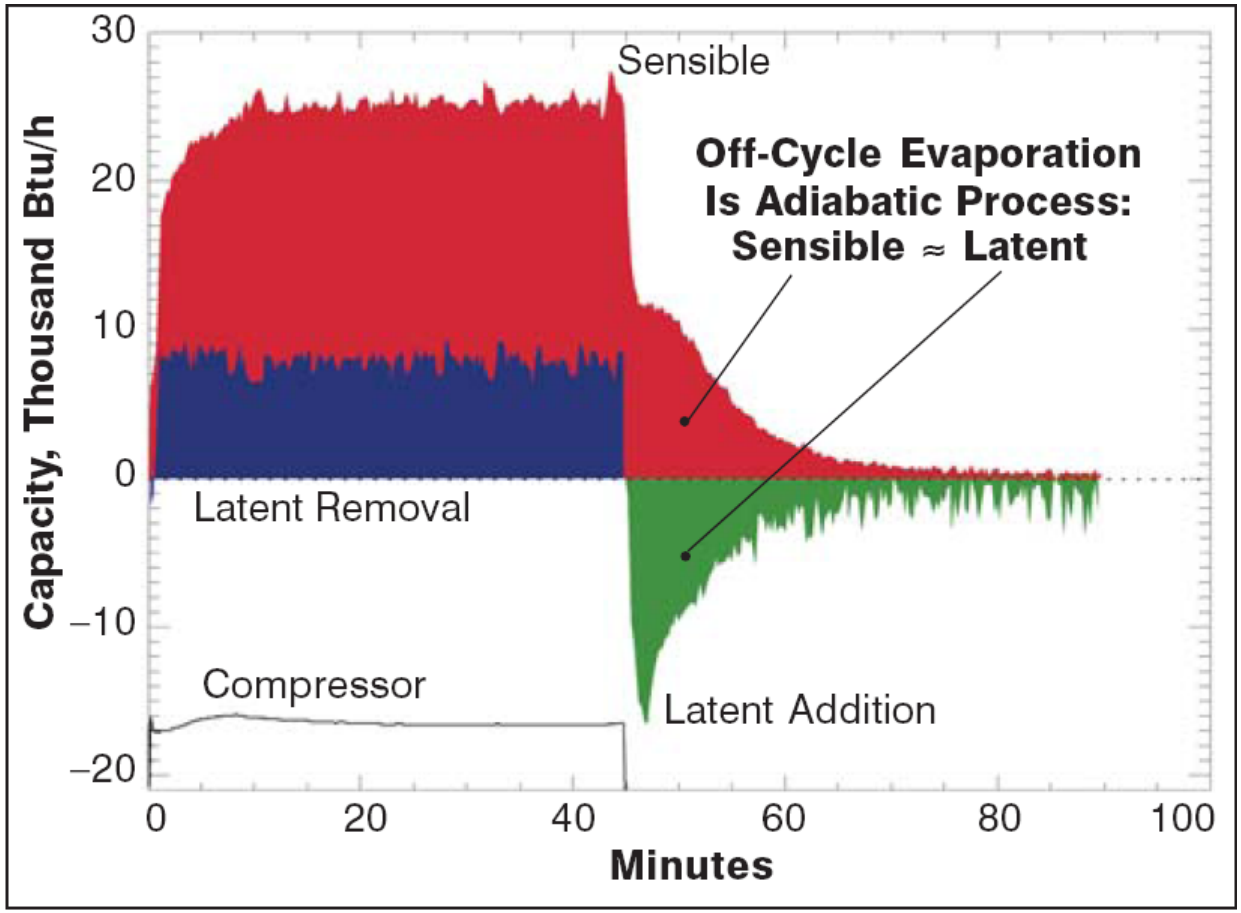


Figure 1: Transient sensible & latent capacity of cooling coil over an operating cycle (supply air fan operates continuously).

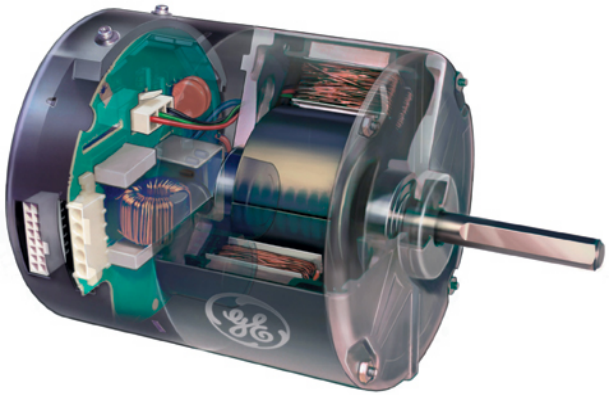
Dehumidification Control

- Room thermostat with dehumidification features.
- Indoor blower speed option setting
- Outdoor fan motor option setting
- Hot gas bypass
- Reheat
- Stand alone dehumidifiers

Room thermostat with dehumidification features

- Cooling call
- No cooling call
- Integrated with a reheat system

Equipment Set up (Indoor Blower)



GE ECM 2.3 or 2.5

Premium ECM

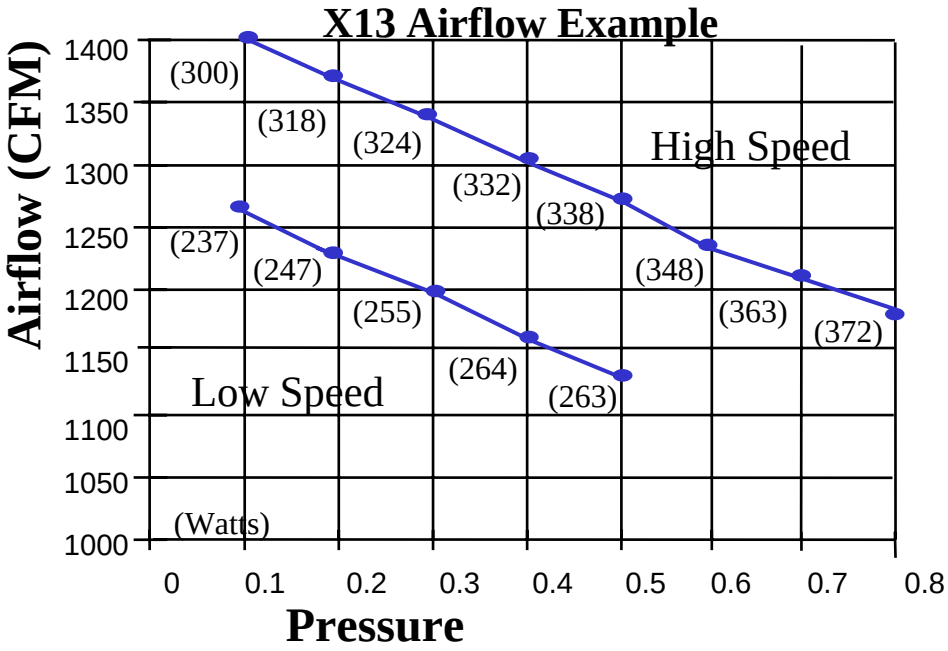
X13™

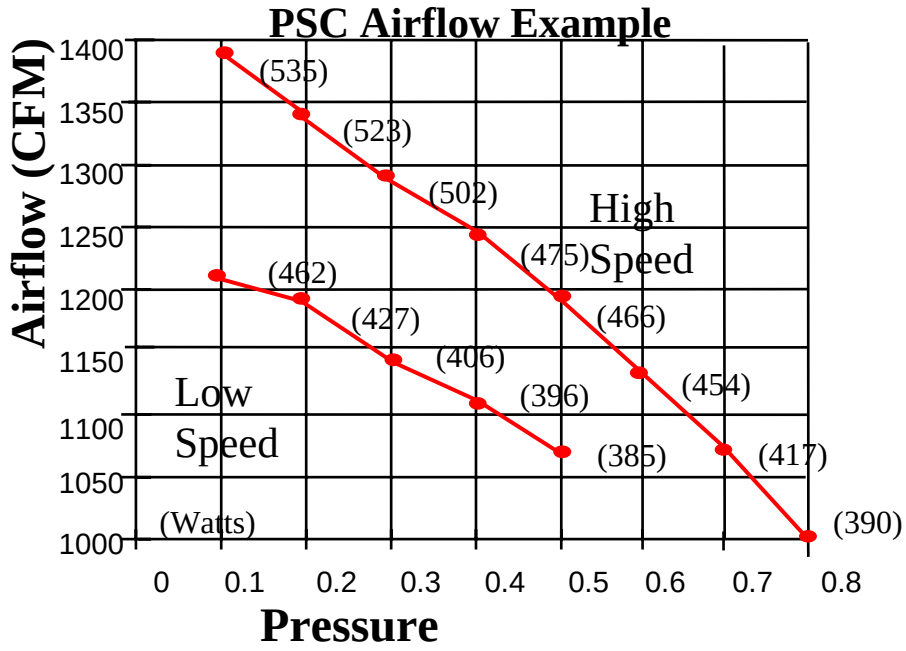
Standard ECM

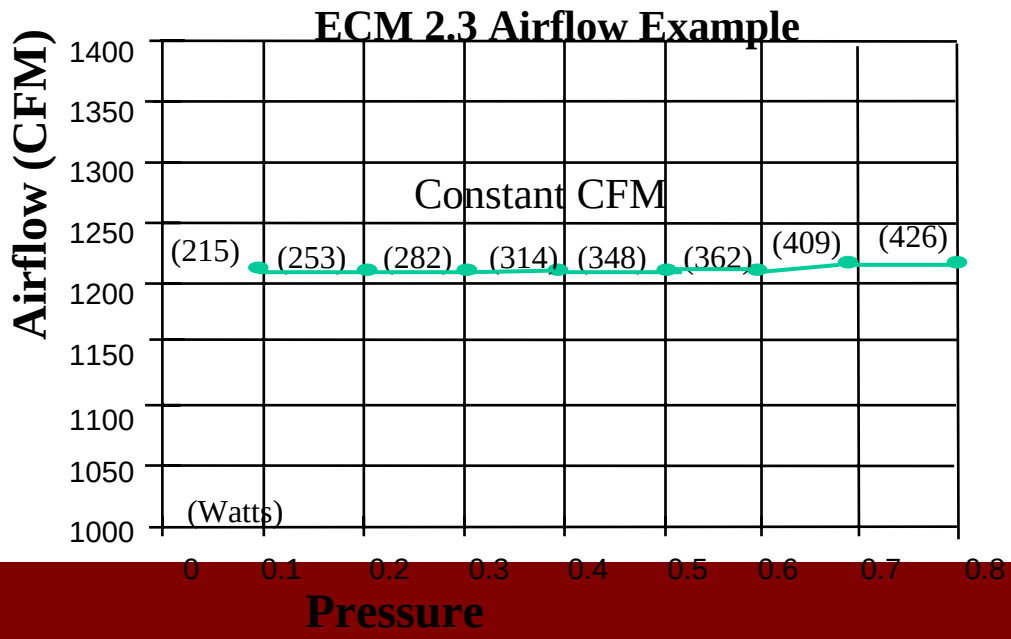
Motor can be programmed to have dedicated dehumidification speed taps.

Feature Benefit Comparison

Feature	PSC	X13	ECM 2.3/2.5
Input Voltages	120 or 240	120 or 240	120/240
Power Connection	Relay	Constant	Constant
Control Signals	High voltage	Low voltage	24VAC / PWM / DSI
Settings	2 to 5	2 to 5	Variable
Airflow Control	Speed	Torque	Constant
Speed Range	800- 1100	600-1100	200-1300
Off Delay - Slew	with external timer	off delay - slew	programmable
On Delay - Slews	with external timer	slew	programmable
Output channel	none	none	programmable
Bearings	SB or BB	BB	BB
Control Replacement	Motor	Motor	Modules


X13 Airflow Example
Airflow (CFM)
1400
1350
1300
1250
1200
1150
1100
1050
1000
(300)
(318)
(324)
(332)
(338)
(348)
(363)
(372)
High Speed
(237)
(247)
(255)
(264)
(263)
Low Speed
(Watts)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Pressure


PSC Airflow Example
Airflow (CFM)
1400
1350
1300
1250
1200
1150
1100
1050
1000
(535)
(523)
(502)
(475)
High Speed
(462)
(427)
(406)
(396)
(385)
(466)
(454)
(417)
(390)
Low Speed
(Watts)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Pressure

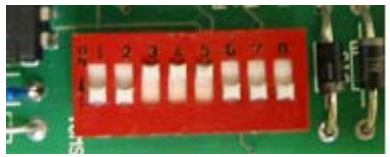

ECM 2.3 Airflow Example
Airflow (CFM)
1400
1350
1300
1250
1200
1150
1100
1050
1000
Constant CFM
(215)
(253)
(282)
(314)
(348)
(362)
(409)
(426)
(Watts)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Pressure

The interface board (tap board) functions may be on a separate circuit board or built into the OEM's main circuit board*.

Discrete field selection of airflow settings and comfort options.

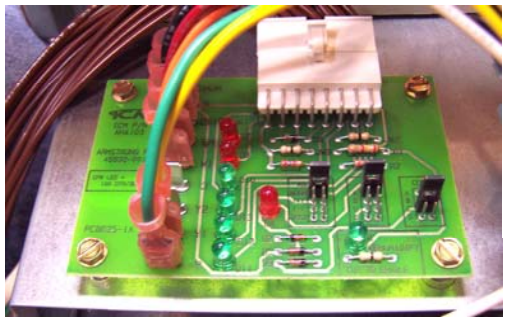
- Cooling Airflow
- Heating Airflow
- Trim/Adjust Multipliers
- Climate (delay) Profiles

OR



- Humidistat Option

Connect to



Connect to

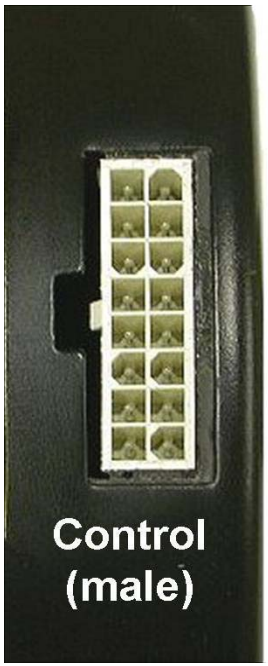
2.3 or 2.5

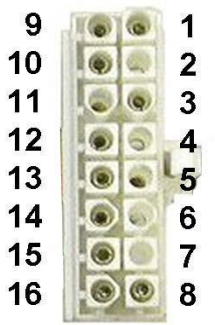
Thermostat Mode (model 2.3)

Most widely used method of control for residential systems

A 24vac thermostat can communicate directly to the motor or through an interface board (tap board).

ECM 2.3
Motor Control





Connector (female)

Pin number

1	Common C1
2	W/W1
3	Common C2
4	Delay tap select
5	Cool tap Select
6	Y1
7	Adjust tap select
8	Output -
9	Return valve (heat pump only)
10	Humidistat (BK)
11	Heat tap select
12	24 VAC (R)
13	2nd stage heat (EM/W2)
14	2nd stage cool (Y/Y2)
15	Fan (G)
16	Output +

PWM (Pulse Width Modulation) Mode (model 2.3)

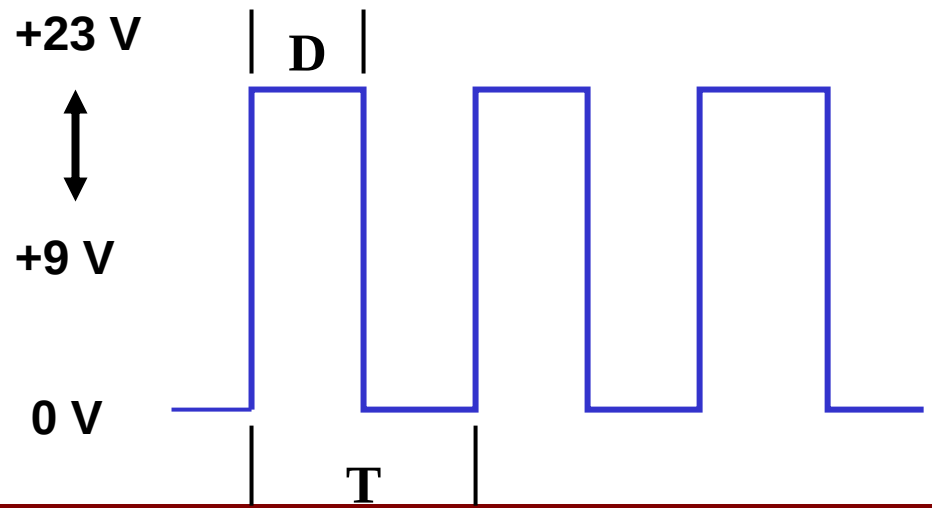
Best suited for commercial systems although some OEM's have, and are currently using it in residential applications

- **Controlled by an external PWM (pulse width modulated) signal**
- **Suitable for fully variable speed systems (EX: Zoning)**
- **PWM simply uses two signals, a start/stop signal and a PWM signal**

$$\% \text{ Demand} = \frac{D}{T} \times 100$$

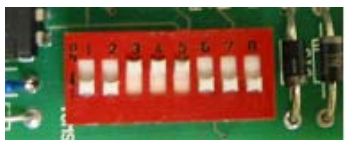
(in torque or airflow)

PWM (Duty Cycle)

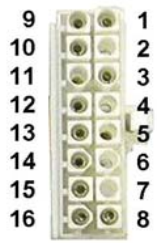


PWM (Pulse Width Modulation) Mode Cont.

OR



ECM 2.3
Motor Control



Connector
(female)

Pin number

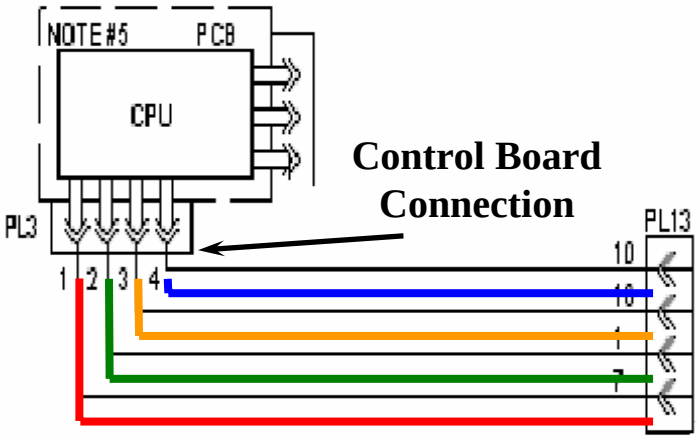
1	Connected to PWM common
2	NC*
3	Connected to PWM common
4	NC*
5	NC*
6	NC*
7	NC*
8	NC*
9	NC*
10	PWM signal
11	NC*
12	NC*
13	NC*
14	NC*
15	Start/Stop signal: 33VAC or 23VDC
16	NC*

* Not Connected

DSI (Digital Serial Interface) Mode (model 2.5)

Next generation serial communicating systems

- **Controlled by Digital Bus System Controller**
- **Digitally communicates with the motor: Speed, Airflow, Starts, Stops…**
  - 2 leads for power (12 VDC)
  - 2 leads for communication



Pin

1 12 VDC

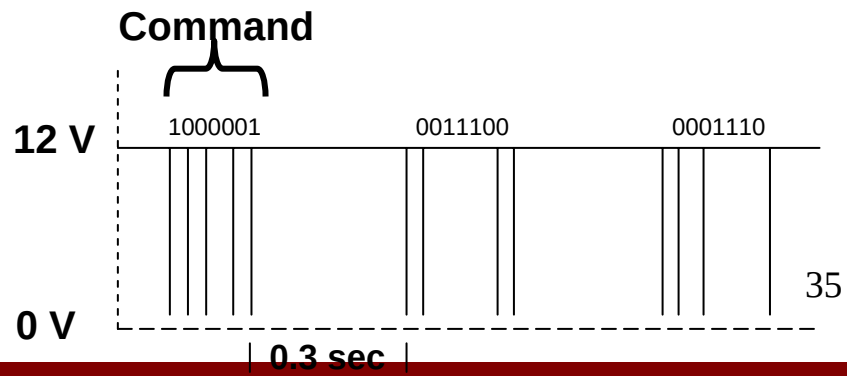
2 GND

3 Transmit/Receive

4 Transmit/Receive

16 pin connector on motor

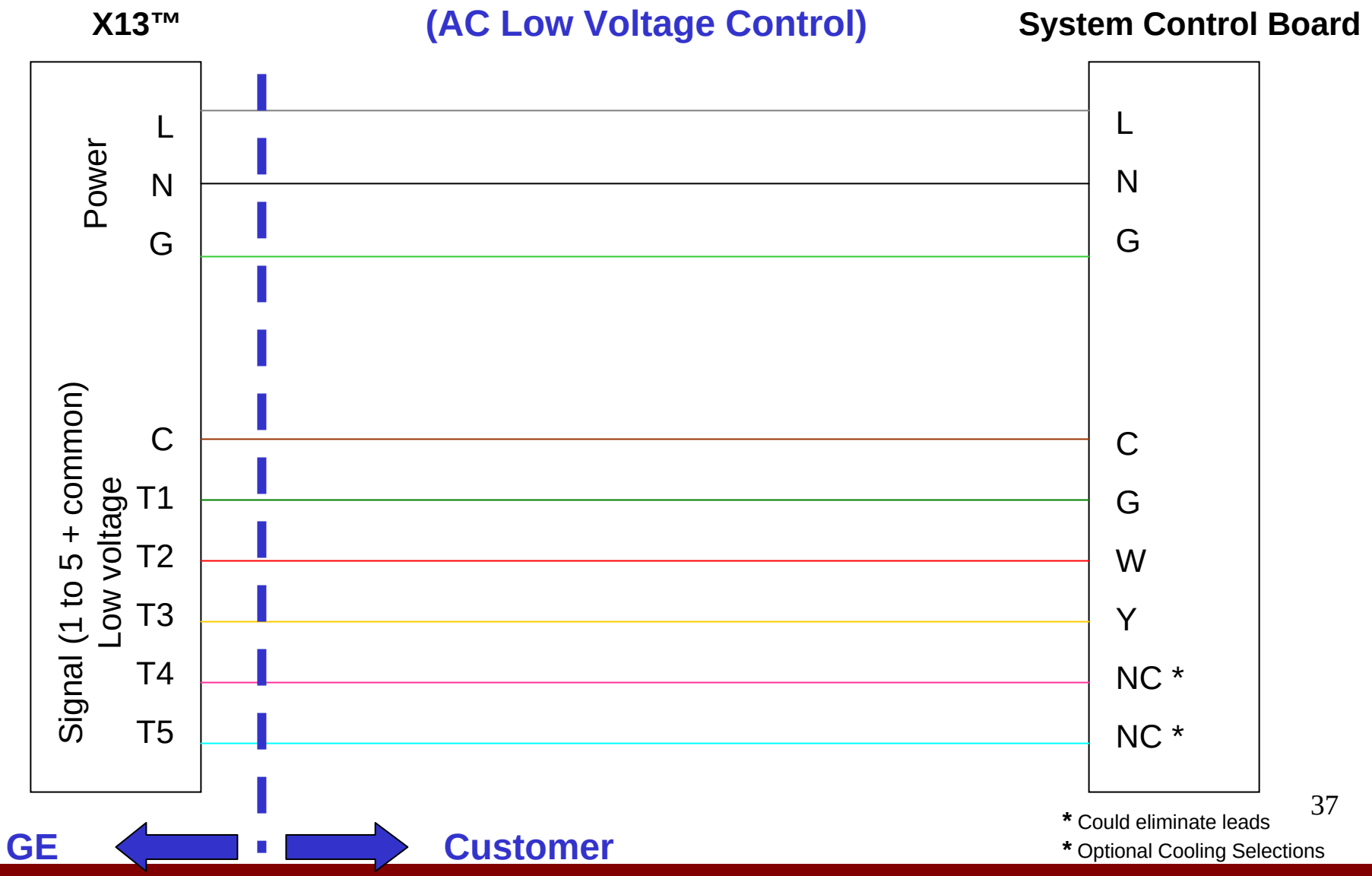
Communication Example



X13™ Feature Set

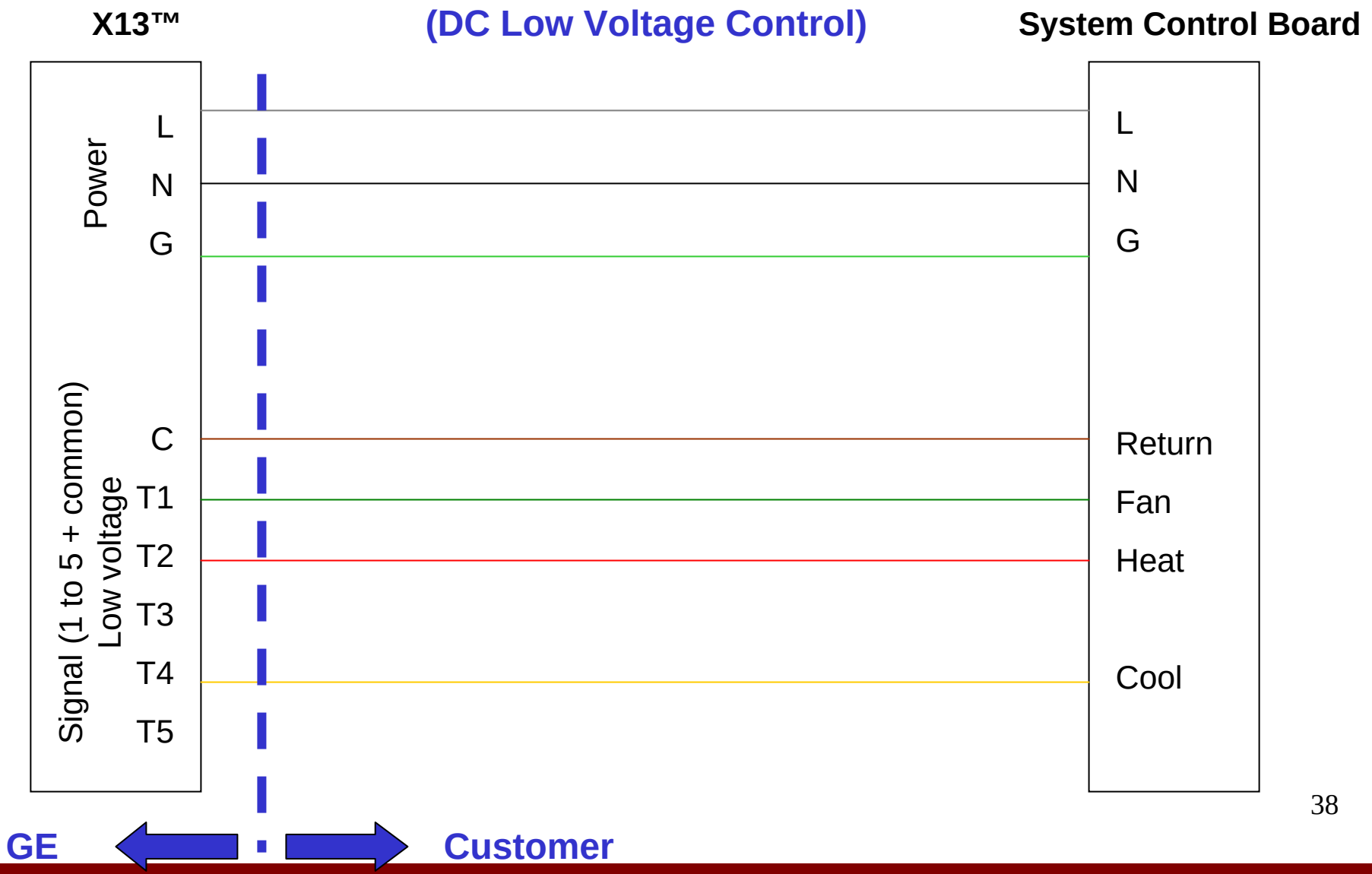
- ❑ Fully encapsulated electronics (all conductive surfaces potted)
- ❑ 3 Phase Brushless DC (single phase AC input)
- ❑ Ball Bearing construction
- ❑ Integral control module
- ❑ FCC B EMI filter
- ❑ Approx 1 inch shorter than current Premium ECM 2.3/2.5

Harness Schematic Options



* Could eliminate leads
* Optional Cooling Selections

Harness Schematic Options



Outdoor fan motor option setting

- Motor can be programmed to have dedicated dehumidification speed taps.
- Inputs can be sent to the motor to vary or change speeds depending on demands

Other Residential HVAC ECM Motor Applications

Outdoor Condenser (ECM 142)

Similar to the 2.3/2.5 construction

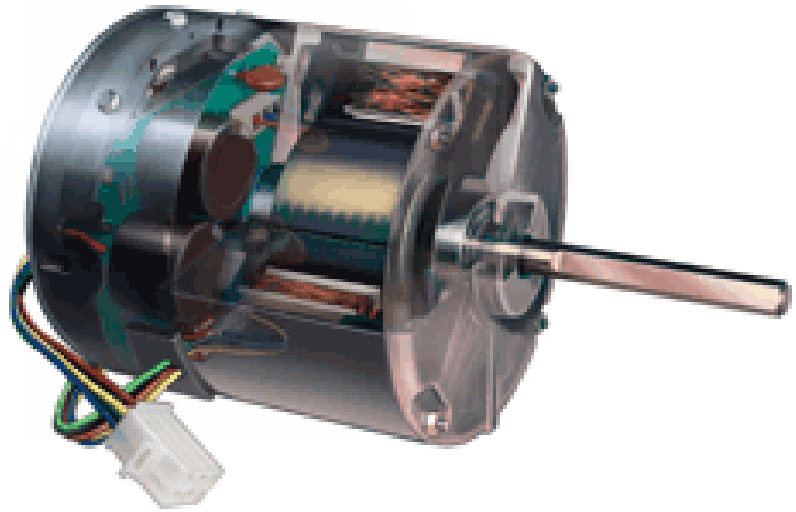
Constant speed instead of constant airflow

240vac power input

Optional Remote Mounting

24vac Control Inputs

1/3 Hp



Outdoor Condenser (ECM 142)

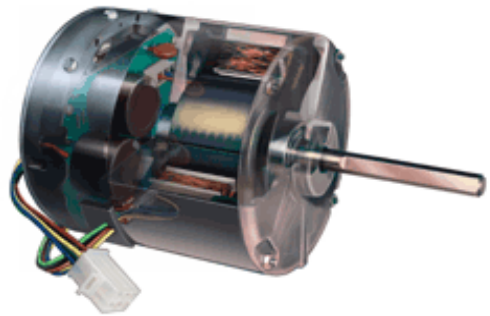
Two Power Inputs

- Line voltage and 24vac inputs

Repair

- One piece motor replacement
- Form drip loops and mount per OEM specifications (center on stator area)

SIX-WIRE CONNECTION DIAGRAM



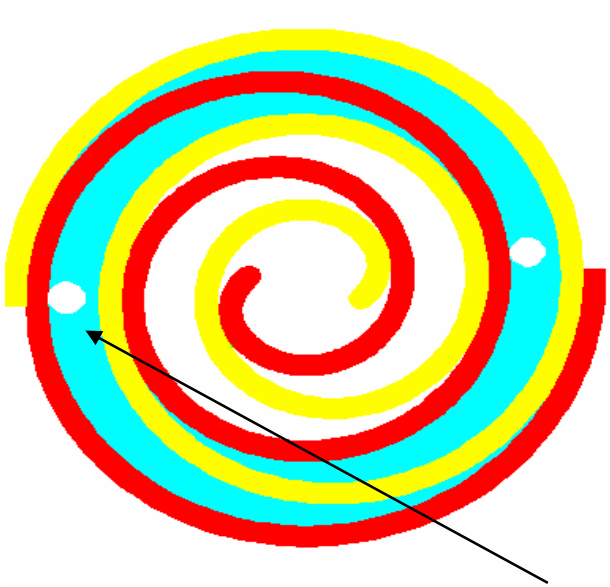
Compressor option (Two stage)

✓**Humidity Control (67% Part Load Capacity)**

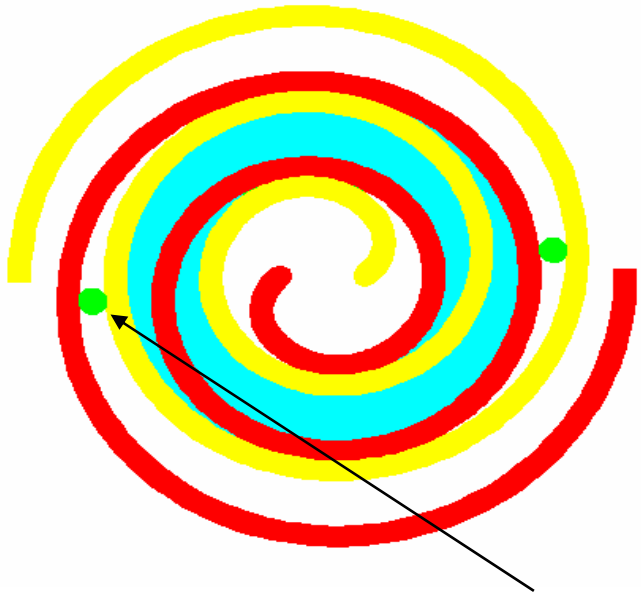
✓**Simpler Design**

- **Scroll Design**
- **No Shutdown To Change Capacity**
- **Less Applied Components**

Compressor option (Two stage)

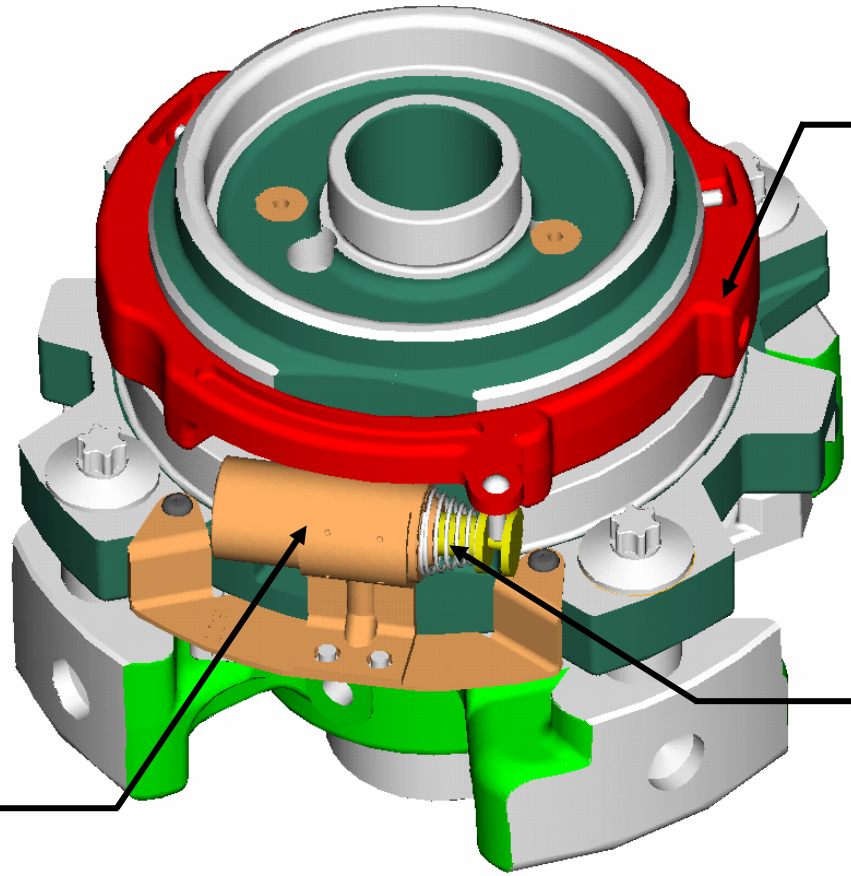


Bypass Ports Closed

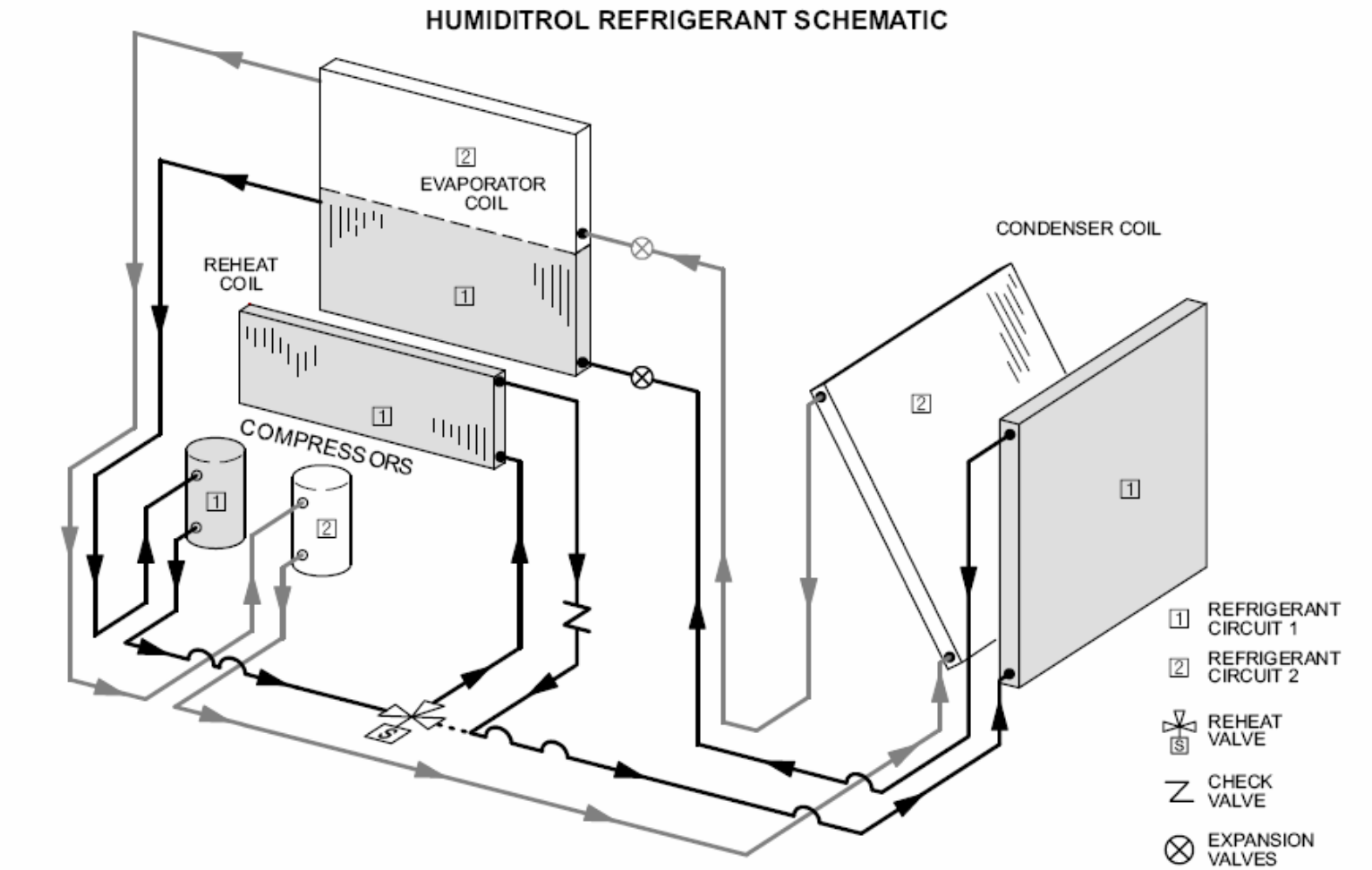


Bypass Ports Open

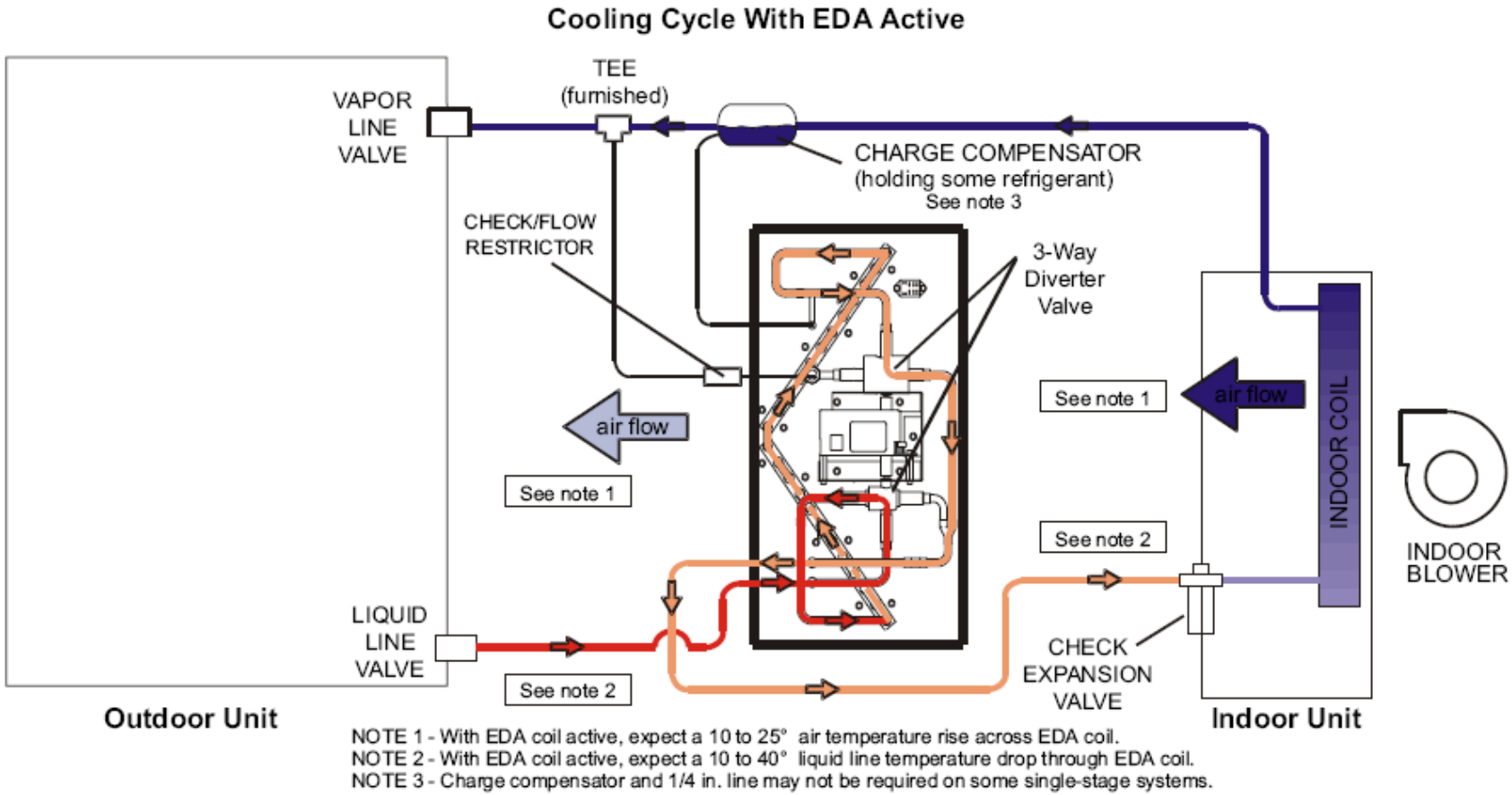
Compressor option (Two stage)

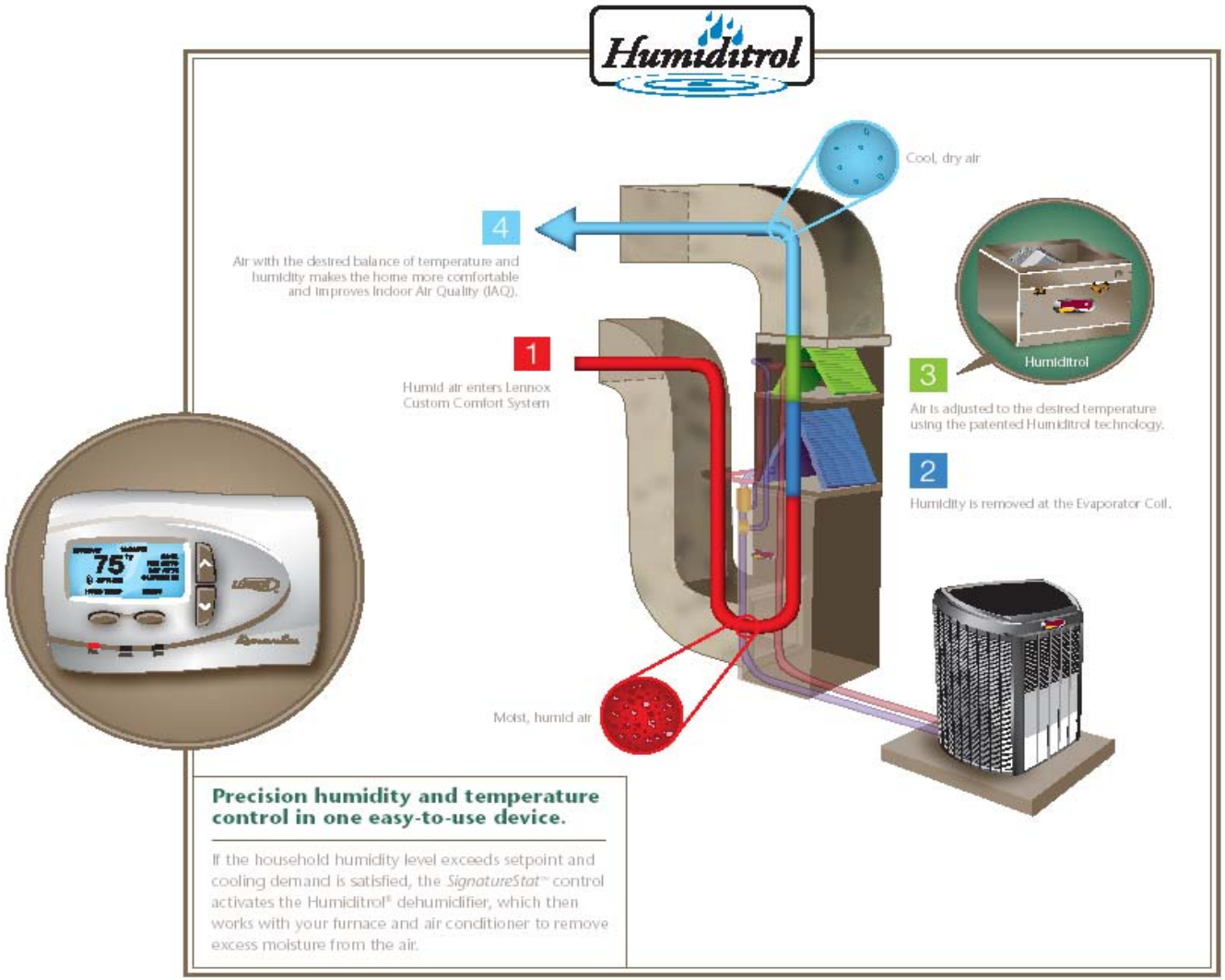


Hot gas bypass



Reheat


Cooling Cycle With EDA Active
VAPOR LINE VALVE
TEE (furnished)
CHARGE COMPENSATOR (holding some refrigerant)
See note 3
CHECK/FLOW RESTRICTOR
3-Way Diverter Valve
air flow
See note 1
See note 1
air flow
INDOOR COIL
INDOOR BLOWER
See note 2
See note 2
LIQUID LINE VALVE
CHECK EXPANSION VALVE
Outdoor Unit
Indoor Unit
NOTE 1 - With EDA coil active, expect a 10 to 25° air temperature rise across EDA coil.
NOTE 2 - With EDA coil active, expect a 10 to 40° liquid line temperature drop through EDA coil.
NOTE 3 - Charge compensator and 1/4 in. line may not be required on some single-stage systems.


Humiditrol
Cool, dry air
4
Air with the desired balance of temperature and humidity makes the home more comfortable and improves Indoor Air Quality (IAQ).
1
Humid air enters Lennox Custom Comfort System
Humiditrol
3
Air is adjusted to the desired temperature using the patented Humiditrol technology.
2
Humidity is removed at the Evaporator Coil.
75°
Moist, humid air
Precision humidity and temperature control in one easy-to-use device.
If the household humidity level exceeds setpoint and cooling demand is satisfied, the SignatureStat™ control activates the Humiditrol® dehumidifier, which then works with your furnace and air conditioner to remove excess moisture from the air.

Reports on Dehumidification

Report on Dehumidification

Available electronically at http://www.osti.gov/bridge

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Report on Dehumidification

System research took 20 homes in the Houston area to evaluate the humidity control performance and operating cost of six different integrated dehumidification and ventilation systems

Report on Dehumidification

Standard Reference Houses .....

Energy-efficient Reference Houses .....

Stand-alone Dehumidifier in Hall Closet System .....

Stand-alone Dehumidifier in Conditioned Attic System .....

Ultra-Aire System .....

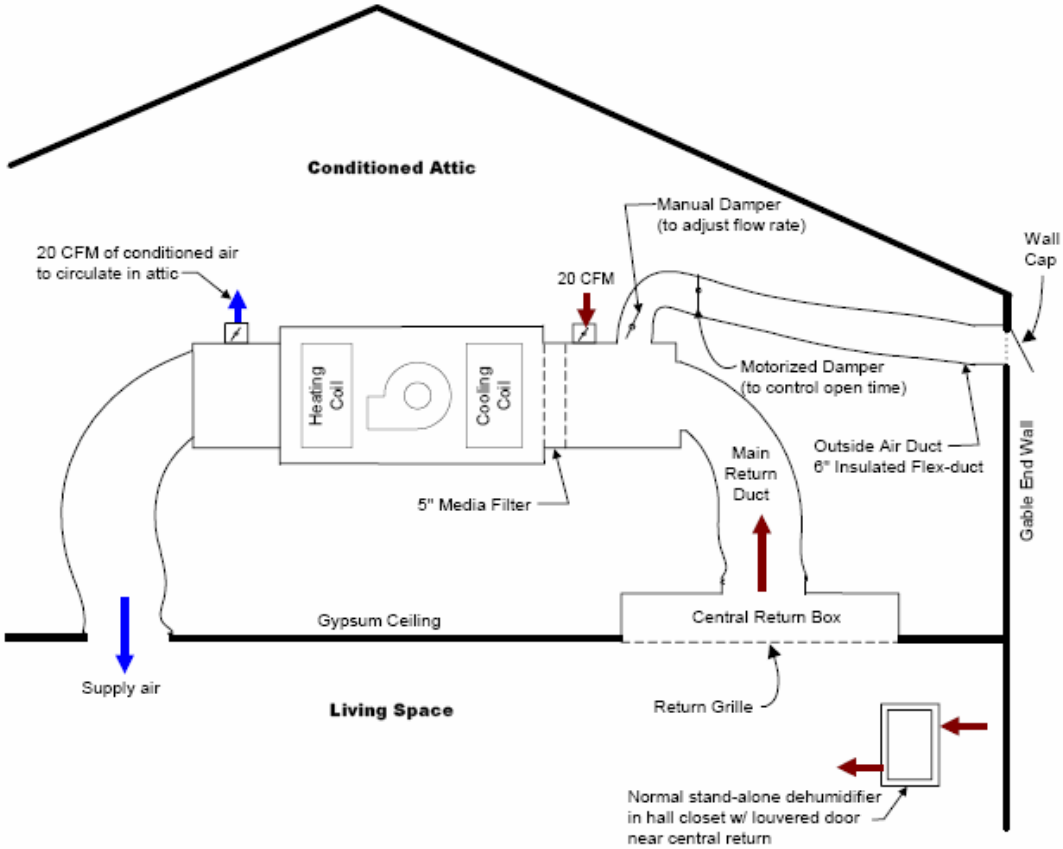
Filter-Vent with Dehumidifier in Ducted Cabinet System .....

Energy Recovery Ventilator System .....

Two-Stage Cooling and ECM Fan System .....

Stand Alone Dehumidifier

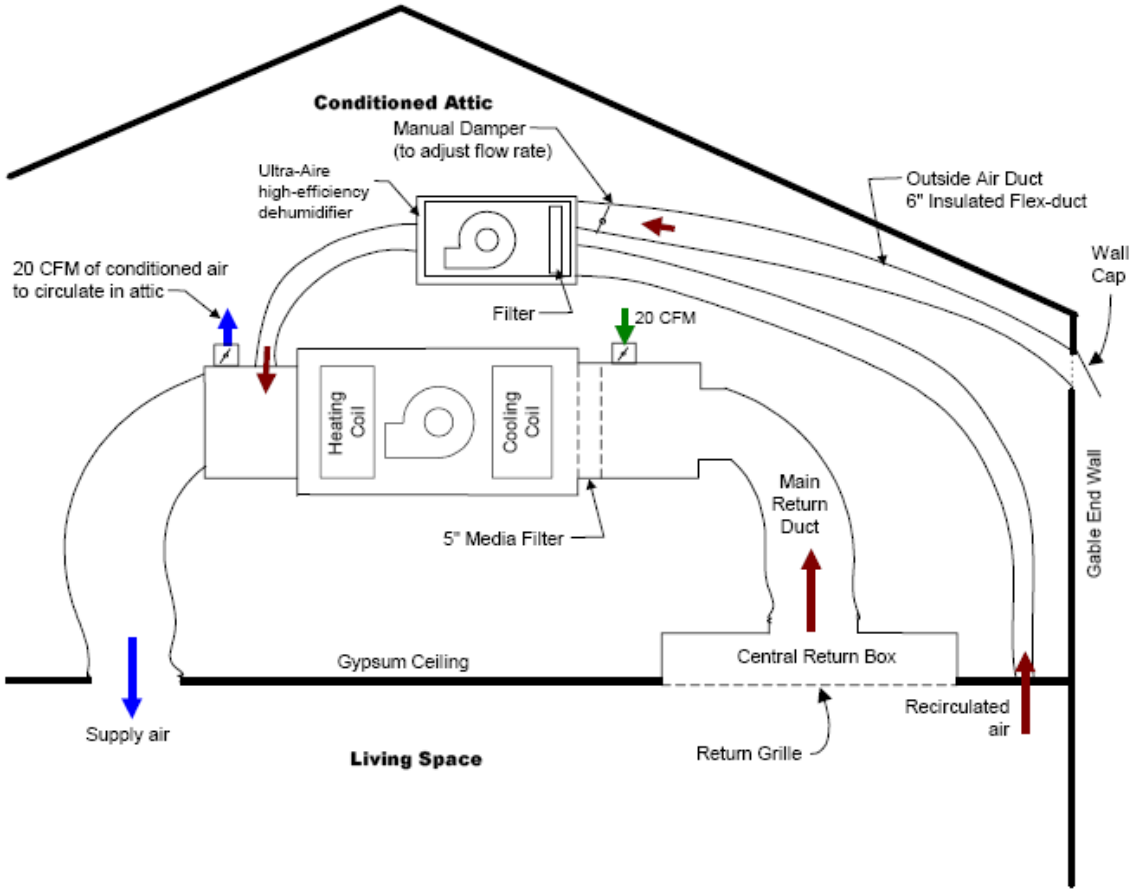
Stand Alone Dehumidifier



UltraAire System

Figure A-3a. Photograph of UltraAire system located in conditioned attic

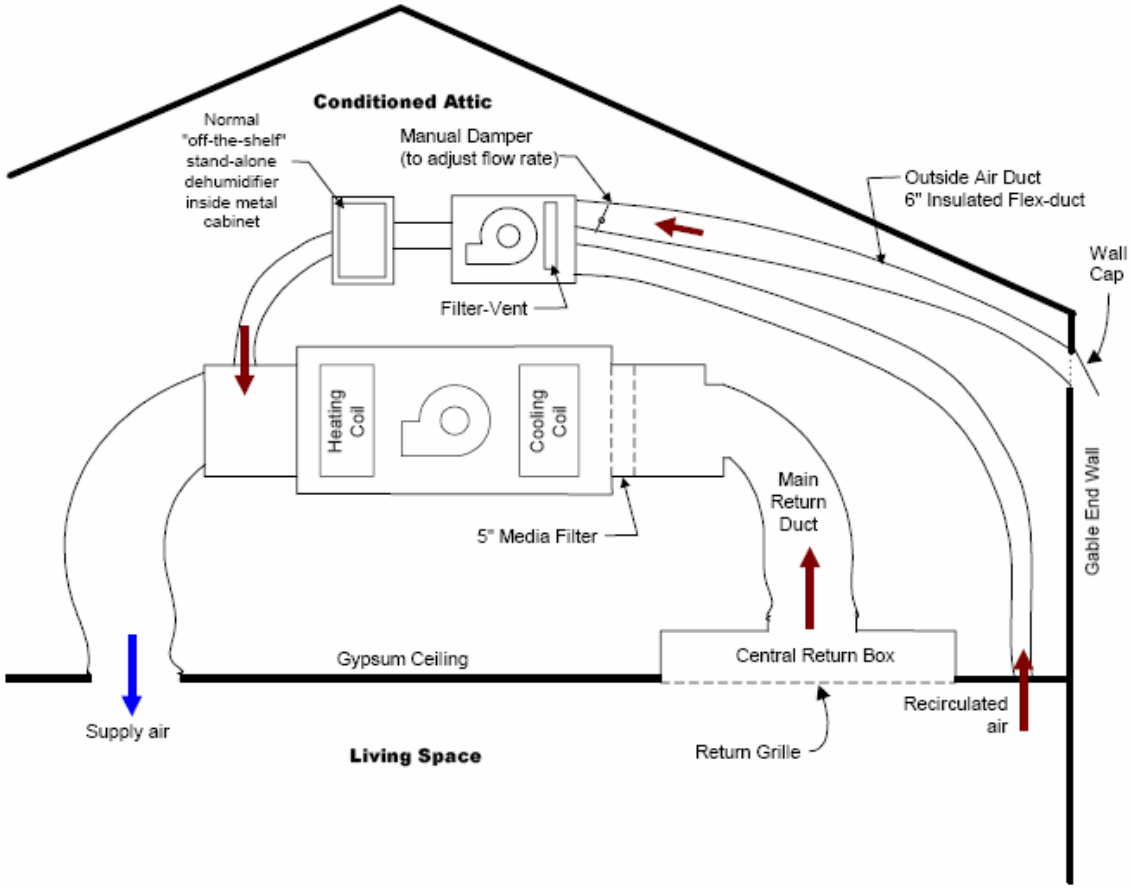
UltraAire System



Filter-Vent System

Figure A-4a. Photograph of Filter-Vent system with ducted dehumidifier in conditioned attic

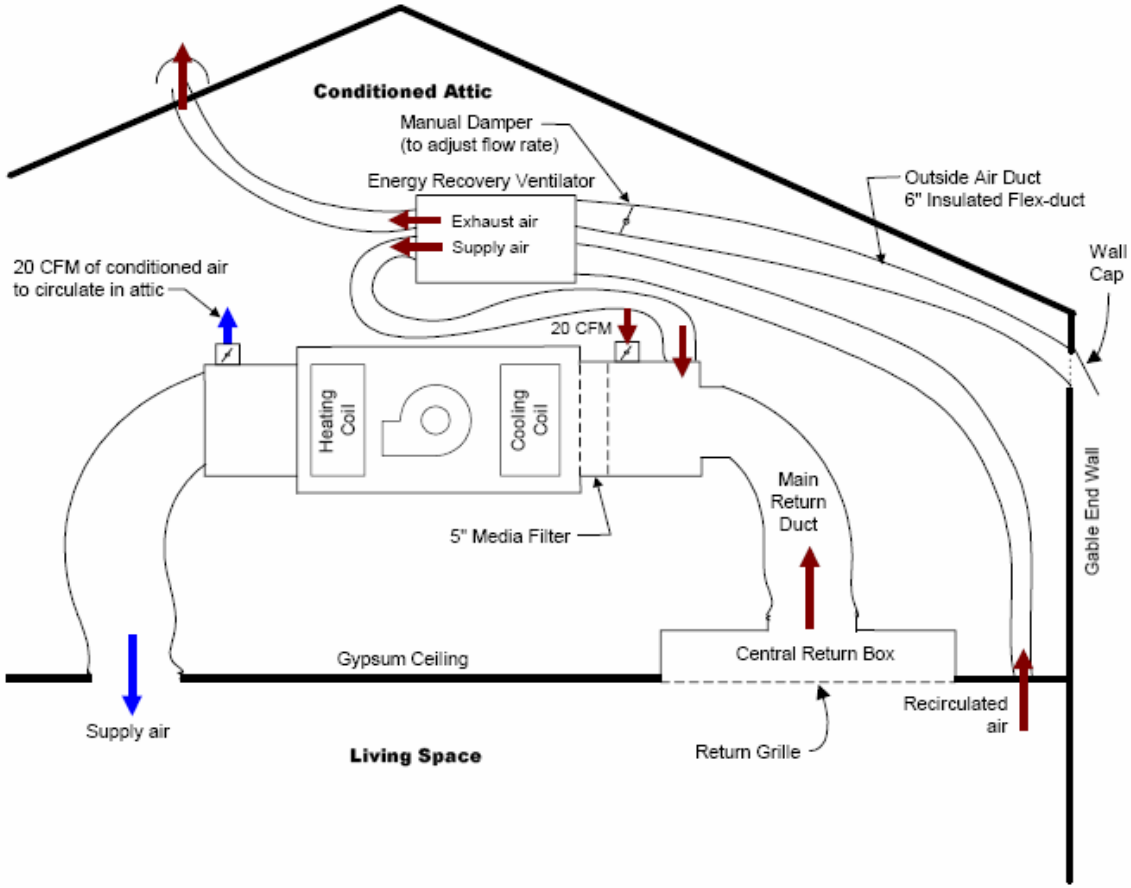
Filter-Vent System



ERV System

Figure A-5a. Photograph of ERV system located in conditioned attic

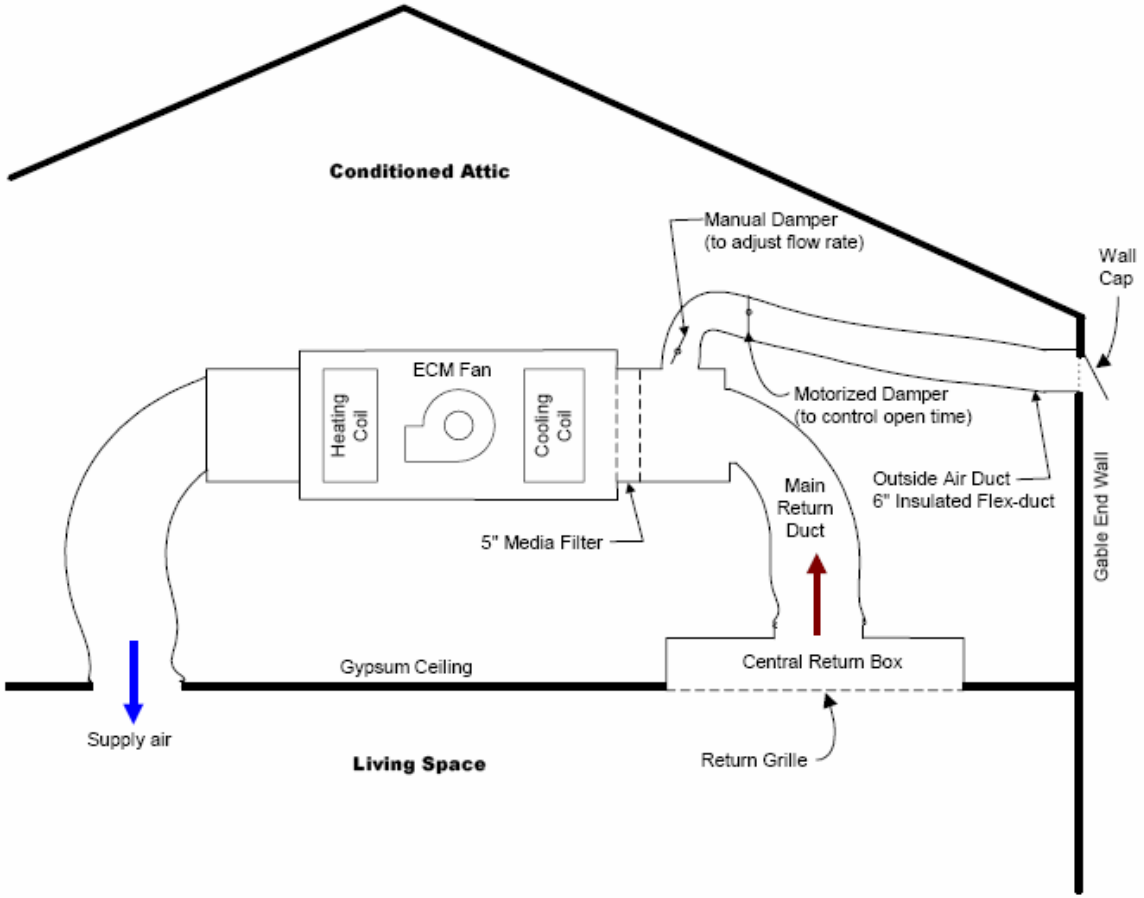
ERV System


Conditioned Attic
Manual Damper
(to adjust flow rate)
Energy Recovery Ventilator
Exhaust air
Supply air
Outside Air Duct
6" Insulated Flex-duct
Wall
Cap
20 CFM of conditioned air
to circulate in attic
20 CFM
Heating Coil
Cooling Coil
Main
Return
Duct
5" Media Filter
Gable End Wall
Gypsum Ceiling
Central Return Box
Recirculated
air
Supply air
Living Space
Return Grille

ECM fan & Thermidistat

Figure A-6a. Photograph of air handler unit of two-stage compressor with ECM fan and Thermidistat system

ECM fan & Thermidistat



Conclusions

All of the systems with dehumidification of re-circulated air, separate from the cooling system, exhibited much better humidity control than those with dehumidification of ventilation air only (ERV) and those with dehumidification only as part of the cooling system.

Training Information

- Lennox, Carrier and Trane all offer class-room or on line training.
- Air Conditioning Contractors Association www.acca.org (Manuals and CDs)
- Air Conditioning and Refrigeration Institute www.ari.org - “CoolNet” for “Certified Products and Ratings”