



Building Performance SOLUTIONS

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Building Performance Solutions HVAC Design Guide, 2007

HVAC sizing, system design, layout, and installation shall be sized according to (Air Conditioning Contractor of America), ACCA manual J8, 8th edition, and selecting equipment sizes based on manual S specifications and installing ductwork delivery systems using Manual D and air terminal devices according to Manual T.

ACCA manual J is a load calculation procedure for residential dwellings. It provides guidance for procedures to calculate room-by-room heating and cooling loads and is widely considered the industry standard method. Manual S provides steps for properly selecting equipment based off of the loads determined using Manual J. Also, the manual provides guidance in determining capacities of various types of equipment. The primary purpose of Manual D is to ensure that a given duct layout will be able to provide the determined air flows calculated by Manual J. Manual D ensures proper air flow to the space and return air to the equipment. Thus, guarantying proper duct size to a space and leading from a space. Finally, Manual T addresses room air distribution and room air motion to the space. This relates to the above through the performance of the air terminal devices and their performance.

Systems shall be sized designed using the following criteria:

- Design Conditions for Denver, Colorado shall be used as indicated in the 2005 American Society of Heating and Refrigeration Engineers (ASHRAE) Handbook of Fundamental local design conditions.
- Outdoor design conditions shall be based on the 99.6% and .4% design temperatures for the city that the home is being constructed.
- Denver's design conditions are between -1.7°F Winter, 93.2°F Summer drybulb (59°F wetbulb) with a maximum humidity not to exceed, 50% RH.
- Heating Degree Days are 6,415 and cooling degree days are 419.
- Indoor Design Temperatures are to be based on a thermostat maximum set-point 70°F for heating and 75°F for cooling.
- Infiltration rates will be assumed as “tight” construction unless instructed otherwise by Harvard Communities.
- Fireplaces and other accessories shall be assumed as “tight” unless instructed otherwise by _____(builder)

Airflow calculations and duct sizing shall be based on the average flows required to each room by completing and analysis of the 4 main cardinal orientations and averaging the required airflows to determine the needs in a production (non-site specific setting) plan determined by calculations from the ACCA Manual J software systems.(Note: For community scale projects such as Stapleton where the lots are not assigned at the product design phase this method should be used. If the house is being produced on site specific (predetermined) development or a custom lot, where the actual cardinal orientation is known then the actual orientation should be used.

The siting of the house should also be considered with regards to adjacent buildings when calculating the cooling loads on the homes. Shading of end units or corner lots should be evaluated separately from homes situated between 2 others.

Building Component and Testing Input Specifications for System Design

Component	Description	Input value
Below grade slabs		
Slab Edge/underslab		
Crawl space walls		
Below Grade walls		
Rim joist/box sill		
Above grade walls		
House to garage wall		
Attic insulation-flat		
Attic insulation-vaulted		
Floors over unconditioned		
Exterior doors-solid		
Windows-below grade		
Windows/glass doors		
Equipment location		
Duct Leakage/sealing		
Fireplaces		
Air Changes/hour		

Additional Sizing and Specification Guidelines:

- The heating and cooling equipment should be sized as accurately as possible **no larger than 110% of the calculated load, after altitude derating (not to exceed 4% 1,000 ft of elevation)** and indoor and outdoor equipment should match.
- Air conditioning equipment should be sized for the calculated sensible load and 50% of the unused latent capacity could be added to the sensible capacity.
- If the total cooling load exceeds the equipment capacity by > 10% then move to the next larger size unit.
- CFM will be matched to equipment selected
- The highest efficiency available should be selected

- Units should be ARI rated, with the certificate provided in the Manual J calculation sheet to at least 13 SEER with Non-CFC refrigerants (R-410A or Puron) and all indoor coils equipped with a Thermal Expansion Valve (TXV).

Airflow and duct sizing of the systems and to each individual room shall match designed airflow calculations from the ACCA Manual J to within +/- 10% of the average requirements for that room, based on the average of the 4 orientations of that specific home.

Supply and Return Ducts

All supply and cold air returns are to be hard ducted. No panned joists or stud bays, no exceptions. All supply and return ductwork shall be located inside the conditioned space of the building envelope. (No ducts on exterior walls, attic spaces, etc.). If any portion of supply and returns installed outside conditioned space (Builder)_____ must be notified prior to installation. Any ducts installed outside conditioned space shall be insulated to R-8 or greater and every attempt shall be made by contractor to maintain as much of the duct buried insulation..

Ducts are to be sized and installed in accordance with room-by-room loads calculations derived from proper Manual J calculation and the sizing and location of duct work using ACCA Manual D and the supplemental design specifications provided within this document.

(Builder) to supply and install hard plastic supply air vent covers to cover all supply air vents that meet OSHA requirements, have a debris filter, and allow air to pass through. Do not install sheet metal as cover.

Determine and Size Air Distribution System:

Harvard has defined and set up criteria for its Manual D designs. The following limitations and properties will assist the designer during selection and generation of an accurate duct system. An air-side system should provide the correct amount of conditioned air, supply it to each conditioned space, return the air properly, and maintain uniform occupant comfort.

System Layout:

- Use the Air Conditioning Contractor's of Americas (ACCA's) Residential Duct Systems Manual D methodology in combination with the velocity and static rules as stated below.
- A best attempt shall be made to keep duct work within conditioned space. It is discouraged to place duct work in exterior walls, or insulated between the house and garage. If plans do not permit certain duct runs inside conditioned space Harvard shall be notified at the design phase and prior to installation of systems. Harvard will ask assistance in the field with certain prescribed airsealing and insulating measures in these instances.
 - All air handlers shall be located within the conditioned space
 - Ductwork outside conditioned space shall all be insulated to a minimum of R-8
- Efficient furnace location that accommodates simplified duct distribution/return system layout.
- Duct work should be integrated into the framing of the house to minimize conflicts and maximize performance.
- The duct work should be sized for balanced airflow and quiet operation

- Zone Control should be used for comfort only. It will not reduce the envelope load
- Central or simplified return systems are to be incorporated, decreasing materials installation time and providing better temperature uniformity
 - Strategically placed central return grilles for each floor designed to return air from most effective location
 - Return air transfers properly sized from all enclosed rooms except bathrooms and laundry and rooms with no supply ducts.
- Don't install returns from areas where contaminated air may exist. For example, bathrooms, garages, laundries, etc.
- Second floor returns on single HVAC system homes should be designed to draw at least the calculated amount of the airflow supplied to the second floor and sleeping rooms with respect to the < 3.0 Pa, Interzonal Air Pressure requirement as indicated above.
- Homes with 2 systems should be designed to meet the same requirements.
- Contractor to calculate duct performance on every duct run, as the longest run methodology typically seen in the HVAC industry is not applicable.
- Readily available parts and standard duct sizes should be used as much as possible

Simplified return air duct system design criteria:

We recommend a simplified return system. It has been indicated that a highly distributed return system ends up being simply a major source of leakage, and reduced system performance. Returns only draw from a small immediate area; increasing their number will not significantly increase comfort.

Return design criteria are as follows:

- Second floor returns on single HVAC system homes should be designed to draw at least the calculated amount of the airflow supplied to the second floor and sleeping rooms with respect to the < 3.0 Pa, Interzonal Air Pressure requirement as indicated above.
- Homes with 2 systems should be designed to meet the same requirements.
- Master bedrooms and large areas should have dedicated return air and secondary sleeping rooms should be configured with properly sized transfer grilles or means of pressure relief.
 - Returns shall be designed to move the same amount of air as the room or areas for which they serve. (e.g. if a Master Suite has 200 CFM total supply the return equally designed/matched.)
- Return ducts should have at least one 90 degree bend (PREFERABLY TWO) between the air handler and the return grille inlet.
 - Certain simplified return systems and compact supply systems may require the installation of a smooth, cleanable acoustic duct lining in the return drop to the furnace to reduce furnace blower motor noise. Best practice is to line the 1st 5' of the supply trunk and the last 10' of the return trunk in these instances.
- The air velocity in the return duct (trunk) should be sized at a velocity less than < 550 feet per minute, with a preference of 300 ft/min
- Friction losses per 100 ft. of (inches of water column, IWC) of Return Ductwork shall be between 0.02 to 0.03 IWC.

Supply System Design Strategies

The supply run-outs should be sized specifically to match the room design flows; we have found that doing anything but fine balancing (typically cutting down flows) with damper adjustments is very difficult. Although, it is recommended that these dampers be installed in smaller rooms that have minimal supply (i.e. walk in closets, laundry and small bathrooms (rooms with target flows of 5-10 CFM))

- Supply trunk velocities should be at a minimum of 600 ft/min and a maximum of 750 ft/min, or less, based on average flow.
- Supply run-outs should be sized in one inch increments (i.e. 4, 5, 6, 7, 8) to meet the flow requirements instead of the typical two inch (4, 6, 8). Conventional even-diameter sizing does not provide the required level of precision.
- Friction losses, pressure drop per 100 ft. (inches of water column, IWC) of all Supply Trunks shall be a maximum of 0.05 to 0.06 IWC per 100 feet of duct.
- A single supply diffuser should not exceed 125 CFM
 - In some rooms multiple duct runs may be necessary where one large one might provide adequate flow. This is done to prevent “cold air dump” complaints when the fresh air ventilation system runs the air handler in the fan-only mode for ventilation during the winter.
 - No single supplies should exceed 125 CFM and/or air velocities greater than 500 FPM per register to avoid complaints of cold air blowing on occupants (e.g. Bedrooms)
- Supply branches should be sized to a velocity of 500 ft/min with a maximum velocity of 700 ft/min in instances of confined spaces with approval of (Builder) _____.
- Friction losses, pressure drop per 100 ft. (inches of water column, IWC) of all Supply Branches shall be a maximum of 0.07 to 0.08 IWC per 100 feet of duct.
- Takeoffs should be taken from the sides or top of the trunk. They should not be taken from the ends; those will have excess flow due to a combination of static and velocity pressure. Cut outs in the bottom of supply trunks for basement supplies are not allowed.

Crawl Spaces

Unventilated and mechanically conditioned crawl space assembly to have a supply run off the main supply trunk into the crawl space, this shall be provided on the plans and installed by the HVAC contractor.

The following must be completed:

- Install and size a dedicated supply duct(s) to evenly circulate air throughout the crawl space, equal to but not exceeding 50 cfm/1,000 square feet of conditioned crawl space.
- A transfer grille shall be placed on the crawl space wall for pressure relief back the the furnace mechanical area.

Interzonal Air Pressure

Inter-zonal air pressure difference between bedrooms and house and basement and house, when doors are closed and the air handler(s) operational, will be limited to +/-3 Pa. Smaller bedrooms should have means of pressure relief by the installation of transfer grilles in lieu of ducted returns. Large sleeping rooms, such as; master bedrooms shall have a separate, ducted return designed to keep pressures at +/- 3.0 Pa with the door closed.

Transfer grille sizing details and information can be furnished by (Builder) upon request. See figure 1 for appropriate transfer grille sizing and figure 2 for typical transfer grille free area and flow calculations.

Transfer Grille Sizing Specifications

Transfer grilles sized to maintain room pressures ≤ 3.0 Pascals (Pa) for all enclosed rooms with doors, except kitchens, laundry and bathrooms.

Master Bedrooms shall have a separate hard ducted returned designed to match the flow rate of all supplies into the Master Suite area (including bath area and closets)

Assumptions:

- Door Width: 32 inch
- Door undercut-average 0.5 inch
- Airflow under door-average cfm 30 cfm

Fig. 1

Component Selection with Calculated Room Supply Airflow

Room Total Supply Airflow (cfm)	Net Free Area required (with door)	Airflow under Door with .5" undercut	Required Transfer Grille Net Free Area (less door gap)	Transfer Grille required Airflow	Jump Duct equivalent Diameter (if installed)
50 cfm	32 in2	30 cfm	16 in2	20	4"
75 cfm	46 in2	30 cfm	30 in2	45	6"
100 cfm	62 in2	30 cfm	46 in2	70	7"
125 cfm	77 in2	30 cfm	61 in2	95	8"
150 cfm	93 in2	30 cfm	77 in2	120	9"
175 cfm	109 in2	30 cfm	93 in2	145	10"
200 cfm	124 in2	30 cfm	108 in2	170	11"

Fig. 2

Transfer Grille Airflow and Sizing Specifications

Actual grille size (W x H)	Nominal/listed grille size W x H)	Total Net Free Area(in2)	Airflow(cfm) at 2.5 pascals (Pa)
11.75" x 5.75"	10" x 4"	24 in2	32 cfm
13.75" x 5.75"	12" x 4"	30 in2	48 cfm
11.75" x 7.75"	10" x 6"	38 in2	61 cfm
9.75" x 9.75"	8" x 8"	40 in2	65 cfm
13.75" x 7.75"	12" x 6"	46 in2	69 cfm
15.75" x 7.75"	14" x 6"	55 in2	94 cfm
15.75 x 9.75	14" x 8"	75 in2	109 cfm
13.75" x 13.75	12" x 12"	97 in2	127 cfm

If installing Tamarack Return Air Pathways (R.A.P.) the sizing and flow measurements are the same as referenced above.

Transfer sizing example

A bed room has 100 CFM supply flow, what size must the transfer grille above the door be to keep the room pressure below at 2.5 Pa total pressure?

- 1. Fig. 1 indicates a room flow of 100 cfm requires a 62 in2 opening to maintain a room pressure < 2.5 Pa.*
- 2. Fig. 1 indicates the door with a .5" undercut of 16 in2 will flow 30 cfm and 46 in2 of transfer grille "free area" will be required to exhaust the remaining 70 cfm.*
- 3. Fig. 2 indicated an "Actual" 13.75 x 7.75" (nominal 12" x 6") return grille has a net free area of 46 in2 and can flow 69 cfm at 2.5 Pa room pressure.*

Supply Ventilation System

Controlled mechanical supply ventilation system design using the Honeywell W8150A-1001 system as follows; A minimum of 6" or 7" diameter hard duct (fresh air inlet) connected to the return plenum of the air handling unit (AHU) with the following components: see fig. 4 for details

1. manual balancing damper to regulate the volume of outside air (located upstream of the mechanical fresh air damper)
2. Honeywell W8150A ventilation timer control unit and transformer on furnace (connected in series with the fan on the AHU), and
3. Honeywell, EARD-6 or 7 mechanical fresh air damper to prevent outside air from influencing the temperature of the furnace heat exchanger when ventilation system is not operating. This also serves to disconnect outside air from the house when the fan is not operating, and to limit ventilation air flow if the fan is operating for long continuous periods.
4. The fresh inlet air duct shall be connected on the main return "drop" on the furnace, (Not closer to) of 5' from top of the opening in the return plenum duct to the furnace blower compartment. (where the return air duct connects to the air handling unit) Additionally, make certain there is a minimum 5' between fresh air duct tap in location and any return grille.

Fresh air duct shall have insect screen on exterior vent hood and shall be insulated to its full length at minimum of R-4 to prevent condensation

Outside fresh air hood shall not be located be within 10' feet horizontal any exhaust source. If within 10' feet horizontal, then the intake hood shall be offset vertically be at least 3" feet.

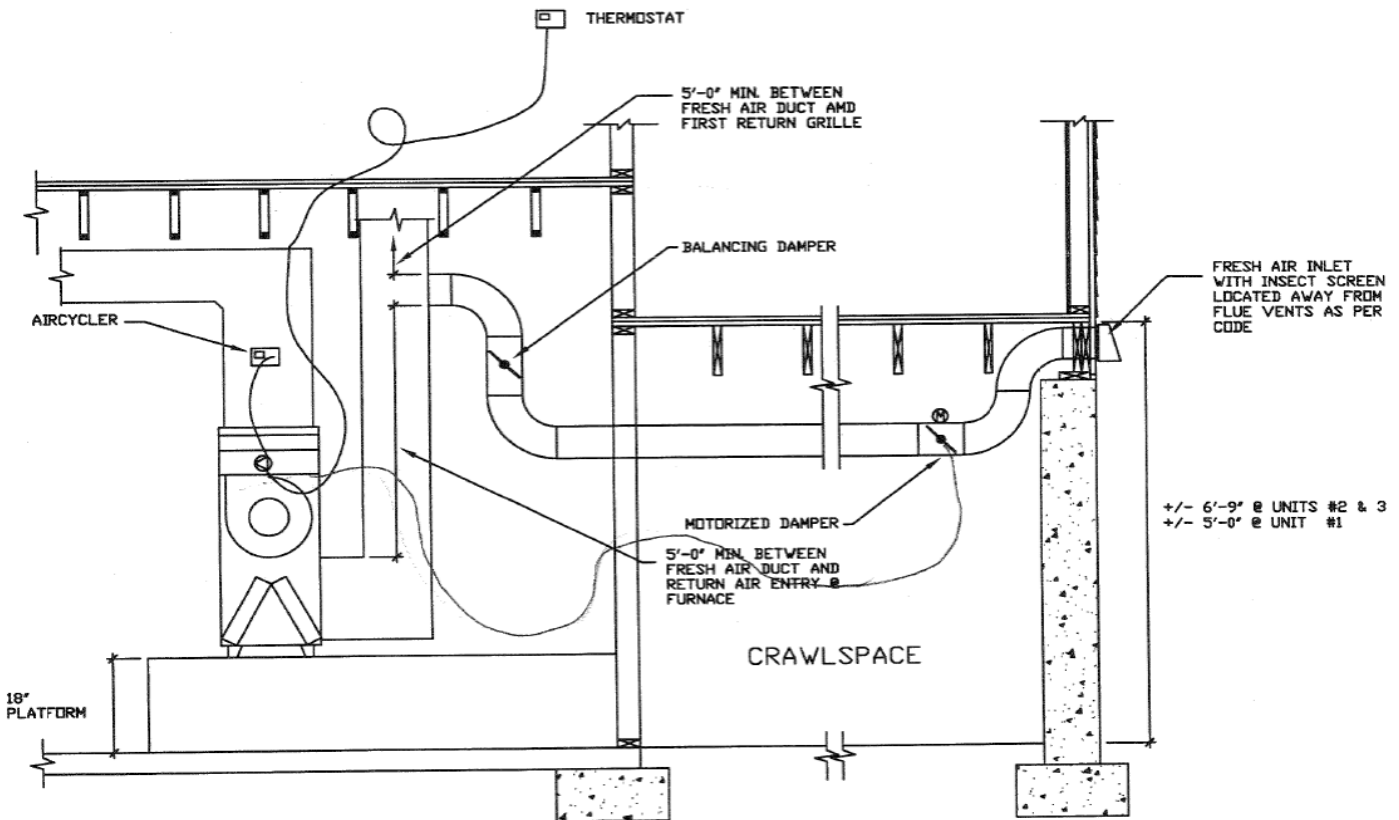
Set-up procedures and airflow adjustment:

1. Set manual balancing damper for a flow rate based on the total number of bedrooms and the conditioned floor area, according the ASHRAE 62.2 Excel calculator provided by Harvard Communities that is to be provided with all Manual J calculation worksheets with the mechanical drawings. See fig.3 for example
2. Set Honeywell W8150A controller to
 - a. Airflow (CFM) rate according to ventilation rate from Excel calculation worksheet
 - b. Total above grade conditioned floor are of house, if basement finished add the conditioned floor area to the total conditioned floor area, excluding crawl spaces.
 - c. Enter the number of above grade bedrooms. If basement finished add the basement bedroom to the total number of bedrooms.
 - d. Set pair of "dip" switches to the following settings: ASHRAE 62.2 and 60% under "Ventilation Standard" on W8150A controller.

Fig. 3

ASHRAE 62.2-2003 flow requirement if continuous				
CFA (ft ²)	2 bedrm Vent. rate (cfm)	3 bedrm Vent. rate (cfm)	4 bedrm Vent. rate (cfm)	5 bedrm Vent. rate (cfm)
1500	38	45		
2000	43	50	58	
2500	48	55	63	70
3000	53	60	68	75
3500	58	65	73	80
4000	63	70	78	85
4500	68	75	83	90
5000	73	80	88	95
5500	78	85	93	100

Fig. 4



(A) DIAGRAMATIC SECTION OF VENTILATION SYSTEM
NTS

Criteria for Proper Air Terminal Selection

For proper performance the HVAC designer should analyze performance data, make sure noise levels are acceptable, ensure proper throw, and check pressure drop.

- Avoid blowing air directly on occupants or on planned bed locations
- Supply terminals should be selected for a terminal velocity of 50 fpm
- Return Grilles should be sized with a maximum velocity at the face of the grille at less than 450 FPM. (This helps reduce noise).
- Supply air should not “short circuit” with return terminal(s)

Duct Sealing

All duct joints including the round pipe is to be sealed with UL-181 approved low-toxic mastic. NO TAPE ALLOWED.

Building designs that allow for compact/simplified duct systems with few joints will enhance the cost effective achievement of this performance standard. All joints on ductwork must be sealed with duct mastic and no tapes of any type may be substituted. Flex duct to duct boot connections shall be sealed at the connection (joint) with UL approved, mastic backed tape and 2 large plastic zip ties shall be added to the connection area over the tape. *See leakage and testing protocol with regards to duct sealants, joint connections and testing protocol.*

Duct distribution performance-leakage requirements

Total air distribution system leakage for systems, including air handler cabinet and tested in its operational configuration as left for the homeowners. (E.g. no opening shall be sealed temporarily for testing purposes) The only opening that can be sealed is the mechanical ventilation duct hood at the exterior.

Duct leakage testing protocol are defined by (Builder) as the following:

1. Ducts located within conditioned space
 - a. Required to maintain a leakage of 7% of the conditioned floor space area in cubic feet per minute or less at 25 Pa, EFL equivalent)
2. Ducts located outside conditioned space (i.e. attic ductwork)
 - a. Required to maintain a leakage of 3%, of the conditioned floor space area in cubic feet per minute or less at 25 Pa, EFL equivalent)
 - b. Any portion of a system (Ducts or air handlers) not fully buried/encapsulated (i.e. completely covered with insulation) or inside the thermal envelope shall be required to meet the 3% requirement as indicated above.
3. If homes have 2 HVAC systems the above criteria can apply simultaneously to the same house. The percentages for leakage will be based on the conditioned area that each unit serves and the above definitions.

Contractors verification/confirmation of Rough Stage testing benchmark leakage numbers and equipment operational capacity within manufacturer performance ranges.

Test shall be confirmed by the contractor’s test and Approved form (attached) to be filled out for (Builders) Project Managers. Test to be verified by third party testing on homes of Harvard’s determination. (Currently 100%)

- Total duct leakage test demonstrating compliance with above standards

- External Static Pressure be Measured at Rough
 - Furnace fan must be placed on cooling speed
 - Furnace filter with a MERV rating ≥ 5 should be placed in the filter rack
 - Coil should be installed and measures taken to protect the coil from being contaminated with construction contaminants.
 - Static pressure in the return should be measured in the center fan compartment, between the filter and blower.
 - Static pressure in the supply should be measured in the plenum, directly above the air handler and below the air conditioner coil.
 - Total external static pressure should be **less than .5"WC, (125 pascals)**
 - If the test fails, check all returns for proper installation. If pressure is over .5"WC, rework duct system until it passes.
- Verify that any requirements of the HVAC system that relate to the Energy Star thermal By-pass checklist are adhered to.

Systems review on-site

All new (Builder) plans shall have a site-walk prior to or during the installation of the HVAC system to review the mechanical system design and identify any potential conflicts or installation issues with the proposed design as indicated on the mechanical plans. This walk to is to be attended by the (Builder) on-site Project Management staff and all affected parties. Changes or alterations to the plans will be made for future production of the plans, reflected on the mechanical designs. Any changes impacting the bid proposal for services shall be conveyed to (Builder) within a specified period of time.

Rough Stage Testing

(Builder)_____ will conduct third party quality control inspections/testing at the rough mechanical stage. The third party contractor will submit verification in document form to verify that all of the above criteria have been met. If third party documentation does not show compliance with all of the above mentioned items, the HVAC contractor will be responsible to repair or replace any part of the system that does not meet the requirements and re-test the system with the same testing company to show complete compliance at HVAC contractors cost. This process shall not delay the production time line of specific

- Total duct leakage test
- Total system static pressures compared to manufacturer specifications
- General systems installation inspection
- Ventilation systems installation and performance (if installed at test)
- Thermal by-pass inspection(s).
- Insulation installation quality inspection(s).

Contractor final inspection

- A final HVAC startup and commissioning must be completed. This will ensure proper zone control, velocities, staging, ventilation air, and refrigerant charging including the following with a short commissioning report supplied by the contractor;

- Heat Rise (furnace only) after five minutes. Heat rise should be in the mid-range of the manufacturer's specifications
- Air Conditioner Approach Temperature after 10 minutes runtime to manufacturer's procedures and within manufacturer specifications
- Ventilation systems installation, house specific fractional run time set up and test

Final Stage Inspections (performed by third party)

Comprehensive HVAC system testing and commissioning will be performed by an independent third party inspector to demonstrate compliance with the system design performance standards described in this document. Testing will be completed randomly on **15%** or all new models not previously built. This testing is to be completed at the same time as the final site specific Environments for Living, Built Green and Energy Star ratings.

- Total system static pressure compared measured and compared to manufacturer specifications and ACCA Manual D friction losses designs/calculations for ductwork.
- Furnace heat rise, heat rise should be in midrange of the manufacturer's spec.
- AC Commissioning Sub-cooling and superheat tests performed on the AC system (as applicable).
- Total system flow with room by room breakdown compared to within + - 10% of the manual J and D design specifications.
- Ventilation system performance compared to the prescribed ASHRAE 62.2-2003 ventilation standards.
- Local exhaust fan flow measurements verified to within AHSRAE 62.2 prescribed exhaust flows.
- Room pressures measured and verified to not exceed 3 Pa when compared to the main body of the house with the air handler(s) operational.

(Builder)High Performance Initiative

Minimum HERS energy rating score of **less, < than 75 HERS Expanded Index points** using the Rating processes and following the testing protocol outlined in the 2006 Mortgage Industry National Home Energy rating Standards (RESNET Guidelines) for determining duct leakage (both total and to the outside), and insulation installation, Thermal By-pass as defined by the EPA Energy Star Program and additional combustion safety, ventilation performance, house pressurization and drainage planes/durability measures as required by the Environments for Living (EFL) Program.

Additional performance standards indicated by Energy Star, programs, Built Green Colorado® shall be adhered to. see also: www.eflbuilder.com and www.builtgreen.org and www.energystar.gov

Performance standards reflected in sales, construction, and customer service dialogue.

(Builder) Communities completes performance testing on 100% of its homes in any given community on an annual basis. (Builder) in continually collecting and monitoring this performance data in an effort to continually improve its building processes, energy efficiency, durability and comfort control systems.

