4. DAVID WEEKLEY HOMES EAGLE SPRINGS AND WATERHAVEN COMMUNITIES, HOUSTON, TEXAS

4.1 Executive Summary

Gate 3 - Community: Eagle Springs / Waterhaven, David Weekley Homes, Houston, TX

Overview

In this project, BSC is working with David Weekley Homes in Houston to construct two energy-efficient communities. BSC has performed technical review and both technical and non-technical training to David Weekley personnel in order to execute this project.

Key Results

There are several key results of this project. First, there will be a total of 29 homes that meet the 40% savings target at Waterhaven and Eagle Springs. Second and more importantly, David Weekley has been expanding their BA construction practices to the entire division, resulting in hundreds of new homes that are Builder's Challenge certified. Finally, BSC has educated DWH employees to the benefit of energy efficiency, and in turn DWH has raised the level of awareness and demand for energy efficient homes in the Houston market.

Gate Status

This project is gate 3 and meets all of the gate requirements.

Table 4.1: Stage Gate Status Summary

"Must Meet" Gate Criteria	Status	Summary
Source Energy Savings	Pass	40-44% savings relative to Building America Benchmark
Quality Control Requirements	Pass	QC requirements integrated through Masco EFL program and other DWH procedures.
Market Coverage	Pass	A total of 29 houses have already been built. The market is single-family, market-rate homes in a hot-humid climate.
Neutral Cost Target	Pass	These homes have a positive net cash flow when additional first-costs are financed as part of a traditional 30 year mortgage.

"Should Meet" Gate Criteria	Status	Summary
Marketability	Pass	These homes are part of a marketing campaign that has resulted in David Weekley outperforming other builders despite the weak housing market conditions.
Market Coverage	Pass	The builder is expanding the energy efficiency techniques used in these houses to all houses built in Houston and is considering expanding to other markets in Texas.
Builder Commitment	Pass	The builder is expanding the energy efficiency techniques used in these houses to all houses built in Houston and is considering expanding to other markets in Texas.
Gaps Analysis	Pass	Gaps overcome included the relatively high training requirements. Gaps still to address include the relatively high cost of bringing ducts inside conditioned space.

Quality Assurance	Pass	The QA/QC criteria and checklist were incorporated into DWH's standard work process.

Conclusions

These technologies have proven successful and DWH will be implementing them on a wider scale. DWH has performed demonstrations of the advanced framing technique for the Dallas, San Antonio, and Austin divisions, and these divisions are evaluating the adoption of these techniques. Under the BA program, BSC will provide support and training to the new divisions of DWH as they adopt the BA technologies. Key activities include training in advanced framing techniques, implementation of water management details with insulating sheathing, air sealing techniques, and mechanical and plumbing system selection.

4.2 Introduction

4.2.1. Project Overview

David Weekley Homes (DWH) is currently the nation's largest privately-owned homebuilder. DWH builds single-family homes in seventeen cities in Texas, Colorado, Florida, Georgia, and North and South Carolina. For this project, DWH agreed to build two communities in the Houston area to a higher level of energy savings in order to evaluate the costs and benefits of meeting the Building America program requirements.

In 2008, DWH unveiled its David Weekley Green Homes program. This program is intended to promote certain features designed to make homes more economically sustainable over the long term and reduce energy usage and the resulting environmental impact.

As part of the David Weekley Green program, DWH agreed to build two communities to a higher level of energy efficiency in order to evaluate the costs and benefits of meeting the Building America program requirements. The two communities are Eagle Springs—Princeton Park and Waterhaven. The two communities are both located in suburban northeast Houston. When complete, Eagle Springs—Princeton Park will contain 36 houses and Waterhaven will contain 112 houses. All of the houses are single-family, slab-on-grade, with a combination of brick veneer and fiber cement siding. These two developments are located in Humble, Texas and consist of one- or two-story single-family houses between 1500 and 3500 square feet and three to six bedrooms. Houston is in DOE climate zone 2A, which is considered a hot humid climate.

DWH has many developments in the Houston area; however the Eagle Springs and Waterhaven developments are intended to be a test of the technologies and construction techniques required for high performance houses. If these two communities are successful, DWH will adopt this technology package across many more developments across Texas. In many of DWH's developments in Houston, DWH works with the Environments for Living (EFL) program by Masco Corporation to provide energy and comfort guarantees to the homebuyers. In these two communities, DWH is building houses to the EFL's highest level of efficiency, the Platinum level. In addition, DWH is adding insulating sheathing to the walls for additional insulating value.

Figure 4.2.1: Front elevation of model home at Eagle Springs

4.2.2. Project Information Summary Sheet

PROJECT SUMMARY	
Company	David Weekley Homes
Company Profile	Largest privately-held homebuilder in the U.S., building primarily single-family houses in 17 cities in 5 states
Contact Information	Mike Funk 14444 NW Freeway Houston, TX 77040 (713) 570-5000
Division Name	Houston
Company Type	Homebuilder
Community Name	Eagle Springs—Princeton Park and Waterhaven
City, State	Houston, TX
Climate Region	Hot-Humid (DOE climate zone 2A)

SPECIFICATIONS	
Number of Houses	36 (Eagle Springs) and 112 (Waterhaven)
Municipal Address(es)	NA
House Style(s)	single family
Number of Stories	1 to 2
Number of Bedrooms	3 to 6
Plan Number(s)	16 different plans, many with multiple options
Floor Area	Approximately 1500 to 3500 ft^2
Basement Area	No basements
Estimated Energy Reduction	44-51% over BA Benchmark

Estimated Energy Savings	$1250 to $2900
Estimated Cost	Sales prices $205,000 and up
Construction Start	March 2008
Expected Buildout	2010

4.2.3. Targets and Goals

The Building America goals for this project are Hot Humid 40% whole house energy savings over the BA Benchmark. All of the houses achieve this goal. Additionally, these houses are being built with insulating sheathing and advanced framing, in order to test the cost-effectiveness and constructability of production-scale advanced framing in the Hot Humid climate zone and market.

4.3 Whole-House Performance and Systems Engineering

4.3.1. Energy Analysis Summary

Table 4.2: Estimated Whole House Energy Use for [insert name of project, city, state]

ESTIMATED WHOLE HOUSE ENERGY USE BY PLAN NUMBER					
Plan No.	Source (MMBtu/year)	Site (MMBtu/year)	Area + Bsmt (sq ft)	No. of Bedrooms	% Electric
3863	155	68	2288 + 0	4	52
1379	193	88	3319 + 0	4	49

With the enclosure and mechanical characteristics presented in Table 4.3.1, this plan achieves a performance level of 40 to 41% reduction relative to the Building America Benchmark.

4.3.1.1. Parametric Energy Simulations

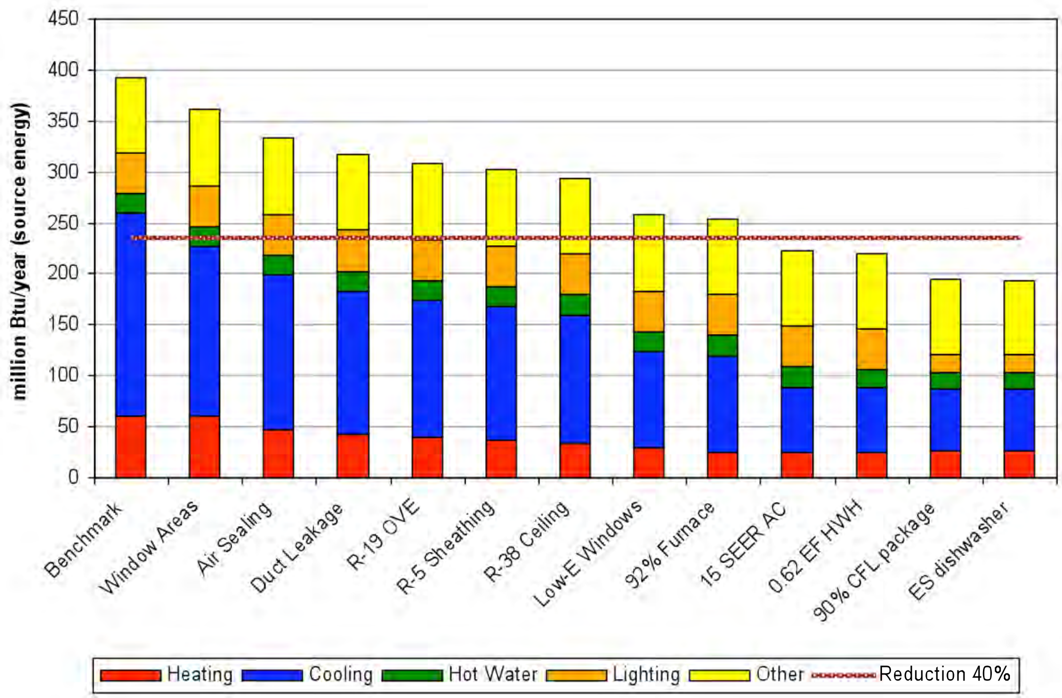

Figure 4.3.1: Parametric energy simulations for Eagle Springs plan number 1379

4.3.1.2. End-Use Site and Source Energy Summaries

Table 4.3: Summary of End-Use Site-Energy for Waterhaven plan number 3863

	Annual Site Energy			
	BA Benchmark		Prototype	
End-Use	kWh	therms	kWh	therms
Space Heating	246	353	217	175
Space Cooling	8797	0	3025	0
DHW	0	181	0	147
Lighting*	2391		1401	
Appliances + Plug	5850	0	5167	0
OA Ventilation**	66		591	
Total Usage	17350	534	10401	322
Site Generation	0	0	0	0
Net Energy Use	17350	534	10401	322

Table 4.4: Summary of End-Use Source-Energy and Savings for Waterhaven plan number 3863

	Estimated Annual Source Energy		Source Energy Savings	
			Percent of End-Use	Percent of Total
	BA Benchmark	Prototype 1	Prototype 1 savings	Prototype 1 savings
End-Use	106 BTU/yr	106 BTU/yr		
Space Heating	41	22	**48%**	**8%**
Space Cooling	101	35	**66%**	**26%**
DHW	20	16	**19%**	**1%**
Lighting*	27	16	**41%**	**4%**
Appliances + Plug	67	59	**12%**	**3%**
OA Ventilation**	1	7	**-795%**	**-2%**
Total Usage	258	155	**40%**	**40%**
Site Generation	0	0		**0%**
Net Energy Use	258	155	**40%**	**40%**

4.3.2. Discussion

4.3.2.1. Enclosure Design

Table 4.5 (below) summarizes the building enclosure assemblies used for this project.

Table 4.5: Enclosure Specifications

ENCLOSURE	SPECIFICATIONS
Ceiling	
Description -	Rafter-framed vented attic with radiant barrier

Insulation -	R-38 cellulose at ceiling plane
Walls	
Description -	2x6 advanced framing exterior, 2x4 advanced framing interior
Insulation -	1" XPS insulating sheathing (R-5) with R-19 cellulose cavity insulation
Foundation	
Description -	Slab on grade, post-tensioned
Insulation -	None
Windows	
Description -	Double Pane Vinyl Spectrally Selective LoE²
Manufacturer -	Champion Window
U-value -	0.34
SHGC -	0.34
Infiltration	
Specification -	2.5 in^2 leakage area per 100 ft^2 envelope
Performance test -	All houses tested and passed

These houses feature advanced framing, which includes 2x6 exterior walls and 2x4 interior (partition) walls, both spaced at 24" on center instead of the standard 16" on center. All joists and rafters are stack-framed, meaning that single top-plates can be used, and headers above doors and windows are eliminated where the wall is not load-bearing. All of this results in less thermal bridging and an enclosure that reduces the amount of heat flowing through the wall. Please refer to the appendix for details on the framing techniques.

4.3.2.2. Mechanical System Design

Table 4.6 (below) summarizes the mechanical systems used by this project.

Table 4.6: Mechanical system specifications

MECHANICAL SYSTEMS	SPECIFICATIONS
Heating	
Description -	95% AFUE natural gas furnace
Manufacturer & Model -	Lennox
Cooling (outdoor unit)	
Description -	15 SEER air conditioner
Manufacturer & Model -	Lennox Elite series
Cooling (indoor unit)	
Description -	Evaporator coil
Manufacturer & Model -	Advanced Distributor Products LM series
Domestic Hot Water	
Description -	0.62 EF gas tank water heater
Manufacturer & Model -	A.O. Smith ProMax Plus High Efficiency
Distribution	
Description -	R-8 flex duct in vented attic

MECHANICAL SYSTEMS	SPECIFICATIONS
Leakage -	5% or lower leakage to exterior
Ventilation	
Description -	Supply-only system integrated with AHU
Manufacturer & Model -	Lennox LVCS
Return Pathways	
Description -	Transfer grilles/jump ducts/active returns at bedrooms, central returns in hallways
Dehumidification	
Description -	Variable-speed AHU
Manufacturer & Model -	Lennox
PV System	
Description -	None
Manufacturer & Model -	
Solar Hot Water	
Description -	None
Manufacturer & Model -	

4.3.2.3. Lighting and Miscellaneous Electrical Loads

Except for decorative fixtures, all builder-installed bulbs are compact fluorescent.

4.3.2.4. Site-generated Renewable Energy

No site-generated renewable energy systems are included. Future solar systems could be integrated on the large roof areas of these plans.

4.4 Construction Support

4.4.1. Construction Overview

Construction of these two developments began in the first half of 2008 and continued into 2009. Implementation of advanced framing techniques was relatively easy once the framing inspector was educated on the concept of advanced framing. Significant oversight from the site supervisor and framing inspector is needed to effort was needed to prevent framing subcontractors from lapsing into standard framing techniques. Energy inspections on every house before installation of insulation and after drywall installation are necessary to achieve this level of air tightness.

4.4.2. Educational Events and Training

BSC performed education and training for several different groups of DWH's employees. BSC has trained DWH's sales agents in the sales advantages of energy efficiency; and DWH's quality coaches, site supervisors, and certain subcontractors in the areas of advanced framing, enclosure air sealing, duct sealing, and HVAC system sizing.

4.4.3. Systems Testing

Several site visits were conducted by BSC to help educate DWH and subcontractors on advanced framing and air sealing techniques. Every house is tested for enclosure and duct air tightness by the EFL program representative. BSC has also performed enclosure and duct air tightness tests on a subset of the houses to verify EFL results. Site visit reports are contained in an appendix to this report.

4.4.4. Monitoring

No whole-house energy monitoring is planned for these developments.

4.5 Project Evaluation

The following sections evaluate the performance of the final production building designs using energy simulations and targeted field tests, if needed. References are made to the results from site visits, which are included as an appendix to this report.

4.5.1. Source Energy Savings

Requirement:	*Final production home designs must provide targeted whole house source energy efficiency savings based on BA performance analysis procedures and prior stage energy performance measurements.*
Conclusion:	***Pass***

The houses in these developments meet the source energy savings "must meet" criteria. These houses provide targeted whole house source energy savings higher than 40% based on BA performance analysis procedures and energy performance measurements

4.5.2. Market Coverage

Requirement:	*Must have a minimum of 10 homes per project (including projects from all teams). At least five homes must be completed by March/April to be used as a case study in the annual Joule* report.*
Conclusion:	***Pass***

The Eagle Springs community currently has 18 houses completed and the Waterhaven development currently has 11 houses completed and is completely closed out. In addition, David Weekley Homes Houston has over 400 homes in the Houston area that are Builder's Challenge certified.

4.5.3. Neutral Cost Target

Requirement:	*The incremental annual cost† of energy improvements, when financed as part of a 30 year mortgage, must be less than or equal to the annual reduction in utility bill costs relative to the BA benchmark house.*
Conclusion:	***Pass***

The houses in these developments meet the "must meet" neutral cost target. These houses are being sold in the competitive market with no outside incentives. The incremental annual cost of energy improvements, when financed as part of a 30 year mortgage, is estimated to average $400 per house. The annual reduction in utility bills is estimated to average $2500 per house. Both of these are relative to the BA Benchmark house.

4.5.4. Marketability

Requirement:	*Based on initial response from model homes, should be marketable relative to the value-added benefit seen by consumers at increased or neutral cost.*
Conclusion:	***Pass***

The houses in these developments meet the "should meet" requirement for marketability. Given the slow housing market, the houses are selling well, and other builders in the area are now attempting to adopt the energy practices DWH has been implementing in these houses.

4.5.5. Market Coverage

Requirement:	*Project case studies should cover a representative range of weather conditions and construction practices in major metropolitan areas in the targeted climate region.*
Conclusion:	***Pass***

These houses cover the single-family market in a Hot-Humid climate. Success in this location has prompted the expansion of advanced framing techniques to all DWH building in Houston and other DWH divisions in Texas have begun studying the adoption of the technologies in these two communities. This will result in the DWH divisions in Dallas, Austin, and San Antonio adopting similar building practices.

4.5.6. Builder Commitment

Requirement:	*Should demonstrate strong builder commitment to continued construction at current or future BA performance targets.*
Conclusion:	***Pass***

DWH has demonstrated commitment to continued construction at this performance level. As mentioned previously, the technologies in these developments have been rolled out to the rest of the developments in Houston and other divisions of DWH are evaluating the option of adopting similar energy measures.

4.5.7. Gaps Analysis

Requirement:	*Should include a summary of builder technical support requirements, gaps analysis, lessons learned, optimal builder business practices, what not to do, documentation of failures, recommendations for policy improvements, and remaining technical and market barriers to achieving current and future performance levels.*
Conclusion:	***Pass***

The builder required support from BSC in a number of areas. First, BSC provided crucial advice on advanced framing and insulating sheathing in several formats: drawings, meetings, and site visits. It became apparent that the best way to achieve the correct results was to make the subcontractors redo any work they did that was not per the advanced framing principle, even if it was performed adequately under standard framing techniques. Also, the David Weekley Green Homes marketing program has been important to promote the added value of these energy-efficient houses. The remaining technical barriers include decorative lighting such as chandeliers that currently only use incandescent bulbs, the expense of bringing ducts into the conditioned space through the use of conditioned attics or dropped soffits, and the lack of appropriate reduction methods to address miscellaneous electric and gas loads.

4.5.8. Quality Assurance

Requirement:	Should provide documentation of builder's energy related QA and QC processes.
Conclusion:	***Pass***

The houses in these developments meet the QA/QC "must meet" criteria. DWH, EFL, and BSC have defined and executed critical design details, construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors. Also, the QA/QC "should meet" requirement for quality control integration were met. Health, safety, durability, comfort, and energy related QA, QC, training, and commissioning requirements were integrated within the BSC team scope of work.

4.6 Conclusions/Remarks

Construction of Eagle Springs will continue into 2010. These technologies have proven successful and DWH will be implementing them on a wider scale. DWH has performed demonstrations of the advanced framing technique for the Dallas, San Antonio, and Austin divisions, and these divisions are evaluating the adoption of these techniques. Under the BA program, BSC will provide support and training to the new divisions of DWH as they adopt the BA technologies. Key activities include training in advanced framing techniques, implementation of water management details with insulating sheathing, air sealing techniques, and mechanical and plumbing system selection. All homes will meet both the Builder's Challenge and Building America requirements.

4.7 Appendices

4.7.1. BSC Case Study: Eagle Springs and Waterhaven Communities

4.7.2. 2009-08-07 David Weekley Header Design

4.7.3. 2009-06-18 Advanced Framing Details SK-1

4.7.4. 2009-03-13 Quality Control Process Discussion with Mike Funk

4.7.5. 090227 Site Visit Report

4.7.6. 2009-03-12_13 Site Visit Report

4.7.7. 2009-02-04 Builder’s Challenge Certificate

Appendix E.4.7.1
BSC Case Study: Eagle Springs and Waterhaven Communities

1/2009

Case Study

Eagle Springs and Waterhaven Communities

Houston, Texas

Overview

This project includes two David Weekley Homes developments near Houston, Texas: Eagle Springs and Waterhaven. These two developments are located in Humble and Atascocita, Texas and consist of one- or two-story single-family houses between 1800 and 3500 square feet and three to six bedrooms. The project is located in DOE climate zone 2A, which is a hot-humid climate. When built-out, Eagle Springs will contain 36 houses, and Waterhaven will contain 112 houses.

David Weekley Homes (DWH) has many developments in the Houston area; however the Eagle Springs and Waterhaven developments are intended to be a test of the technologies and construction techniques required for high performance houses. In many of DWH's developments in Houston, DWH works with the Environments for Living (EFL) program by Masco Corporation to provide energy and comfort guarantees to the homebuyers. In these two communities, DWH is building houses to the EFL's highest level of efficiency, the Diamond level. In addition, DWH is adding insulating sheathing to the walls for additional insulating value.

These houses feature advanced framing, which includes 2x6 exterior walls and 2x4 interior (partition) walls, both spaced at 24" on center instead of the standard

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Project Profile

Project Team: David Weekley Homes, Building Science Corporation

Address:
Humble, Texas and Atascocita, Texas

Description:
One- and two-story single family homes; 1,800 ft^2 to 3,500 ft^2; 3 to 6 bedrooms, 2 to 4 bathrooms

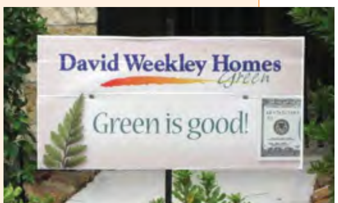
Completion Date:
Under construction; approximately 25 houses complete as of January 2009; complete build-out will be 169 houses

Estimated Annual Energy Savings:
$1,300 to $2,500 per year; 40-to-45% projected source energy savings relative to the Building America Benchmark

Building Science Corporation
30 Forest Street
Somerville, MA 02143
www.buildingscience.com

Builder Profile

David Weekley Homes (DWH) is the third-largest privately-held homebuilders in the United States. DWH currently builds houses in sixteen cities in Texas, Arizona, Colorado, Florida, Georgia, and North and South Carolina.



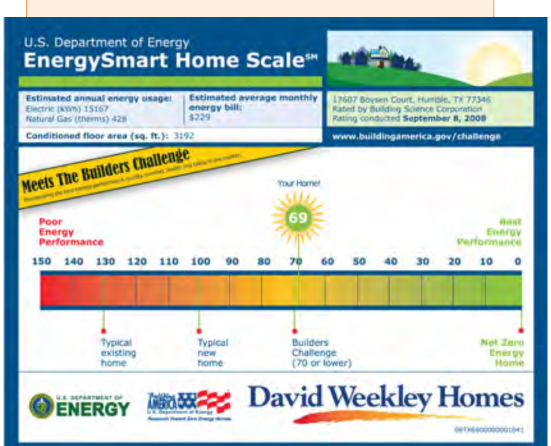
In 2008, DWH unveiled its David Weekley Green Homes program. This program is intended to promote certain features designed to make homes more economically sustainable over the long term and reduce energy usage and the resulting environmental impact.

Participating Programs & Certifications

U.S. Department of Energy's Building America Program

Masco Environments for Living®

U.S. Environmental Protection Agency ENERGY STAR® Program



16" on center. All joists and rafters are stack-framed, meaning that single top-plates can be used, and headers above doors and windows are eliminated where the wall is not load-bearing. All of this results in less thermal bridging and an enclosure that reduces the amount of heat flowing through the wall.

BSC has been on site for several frame walks during construction to examine how the integration of the building systems was working in a production setting. David Weekley has been very successful in integrating advanced framing and insulating sheathing into the design and construction of homes in these communities.

DWH personnel are pleased with both the advanced framing and insulating sheathing technologies. DWH has documented a 5-10% reduction in both board-feet and cost of framing each house due to advanced framing. Additionally Mike Funk, the Houston-area quality coach for DWH, has remarked that the combination of insulating sheathing, cellulose insulation, high-quality windows, and air sealing techniques makes the homes significantly quieter than their competitors' homes in the area, which is important because of a nearby airport.

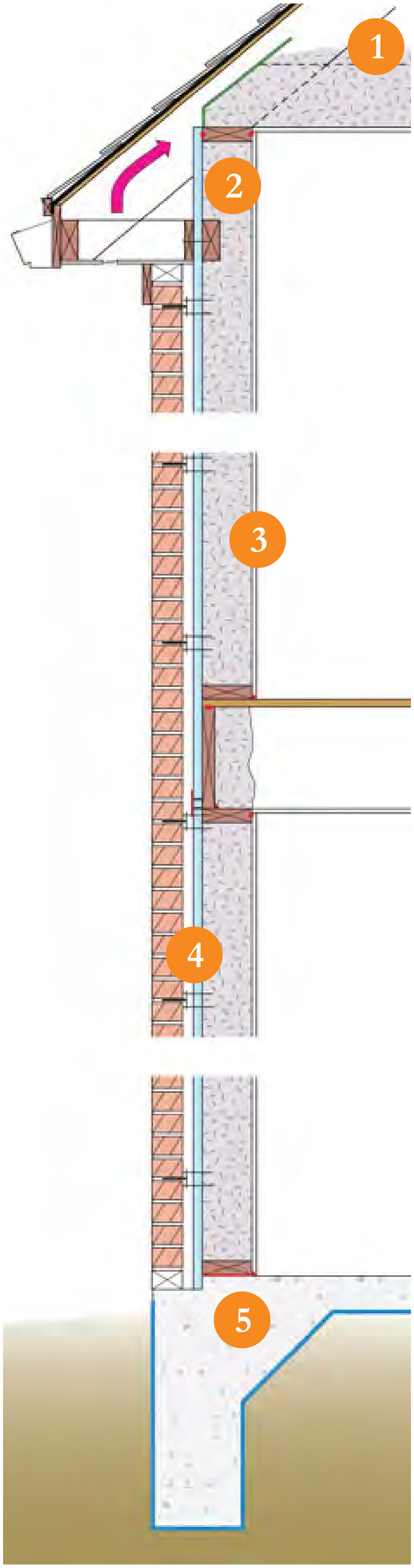
Marketability

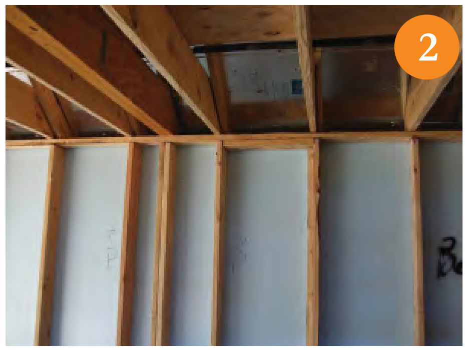
Given the current housing slow-down, these houses are selling well. The energy efficiency features, backed up by the energy guarantee program, are an aspect that helps close the deal for many customers who are considering houses built by DWH and other builders in the area.

The advanced framing technology in particular is working out very well for DWH. The slow-down in the housing market means that subcontractors are willing to take some time to learn new techniques, where they previously would have gone to other standard framing jobs. Once the subcontractors have learned the new techniques, advanced framing saves 5-10% of board-footage of framing, 5-10% of the cost of framing materials, and about 30% in number of framing pieces. The reduction in number of framing pieces should result in a reduction in the labor needed to frame the house, but the magnitude of this savings has not yet been quantified. DWH is so pleased with the results of advanced framing that it is planning to expand the practice to other developments in Houston, and to try it in select developments in Dallas, Austin, and San Antonio as well.

Quality Assurance & Quality Control

- Design follows BSC Building America Performance Criteria (QA)
- ACCA Manual J analysis ensures right-sized mechanical systems (QA)
- A durability checklist (QC) was created to address areas where quality of work has an effect on the energy performance, indoor air quality and durability of the house. Team members then verified these items in the field to ensure they were installed or constructed as required. Here are some examples from the checklist that apply:
  - Air Barrier System - Interior air barrier composed of gypsum board connected via sealant to framing at perimeter and penetrations; also sealed at rim joists and ceiling-to-wall interface. Additional air barrier resistance provided by taped joints on exterior insulating sheathing layer.
  - Solar-Driven Vapor – Movement of vapor from brick to interior is controlled via a 1" cavity between brick and sheathing, with vents at top and bottom of the wall. Inward vapor diffusion is also controlled by the semi-permeable insulating sheathing.





Building Enclosure

④ **Roof:** Vented hip roofs with asphalt shingles

② **Framing:** OVE 2x6 wood frame walls

Air Sealing: Expanding foam was used to seal between the sill plate and the slab; draftstopping in building chases and behind bathtubs and showers; enclosure penetrations sealed with expanding foam; drywall caulked at all openings, wall corners, and top and bottom plates

① **Roof Insulation:** R-38 blown cellulose at the ceiling plane

③ **Wall Insulation:** R-25; R-20 damp-sprayed cellulose in the 2x6 wall cavity plus 1" R-5 XPS

④ **Drainage Plane:** XPS insulating sheathing; all horizontal and vertical joints taped with sheathing tape; windows are pan-flashed to the exterior of XPS sheathing; all roof-to-wall transitions have flashing and kick-out flashings.

⑤ **Foundation:** 4"-thick post-tensioned monolithic slab with turned-down edges poured over 6-mil polyethylene as a capillary break; slab edge insulation was not used due to termite risk.

Window Specifications: Double-pane Low-E; U=0.34, SHGC=0.34

Infiltration: 0.25 in^2 leakage area per 100 ft^2 envelope

Features: Mature trees were left in the development where possible

Climate Specific: In a hot-humid climate, a high level of comfort at a low cost requires, (in this order of priority):

- glazing with low solar heat gain;
- air sealing;
- opaque areas with moderately high thermal insulation; and
- glazing with thermal resistance at least high enough to avoid wintertime condensation.

In a hot-humid climate, a high level of durability requires:

- a continuous water drainage layer behind the cladding, integrated with window, door, roof, and other penetration flashings, to protect water sensitive materials located deeper in the assembly;
- a capillary suction break between foundation materials in soil contact and walls above;
- water vapor diffusion resistance between water absorptive claddings and wall sheathing to retard moisture movement driven by solar heat; and
- interior finish materials that do not retard water vapor movement to allow drying to the inside air.

Mechanical Design

HERS Index Score: 63 to 70 depending on model

❶ **Heating:** 94% AFUE natural gas furnace

Cooling: 15 SEER air conditioner in vented attic

Ventilation: Lennox VCS central-fan-integrated supply (CFIS) with fan cycling and motorized damper to prevent over-ventilation

Return Pathways: Jump ducts at all bedrooms

Ducts: R-6 flex ducts in vented attic

DHW: 0.62 EF natural gas hot water heater in vented attic

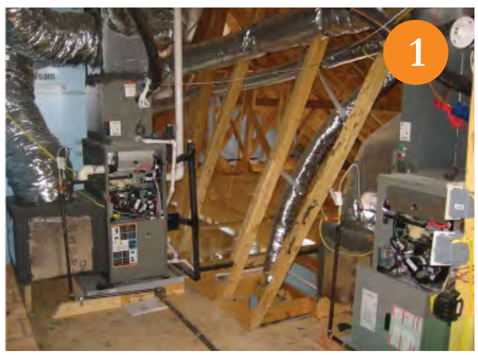
Appliances: Energy Star dishwasher, refrigerator and range

Water Management

❷ **Landscape Plan:** Positive drainage away from foundation provided via sloping of grade around entire perimeter of foundation (front, back and sides)

Systems Testing

Enclosure air tightness and duct air tightness are tested on every house as part of the Masco EFL program. BSC also performs QA tests on a subset of the homes periodically, to ensure consistency.



Lessons Learned & Future Projects

BSC has learned that the best way to change a subcontractor's habit is to make the subcontractor go back and fix anything they did incorrectly, even if it is not necessary. This came up repeatedly with the advanced framing. DWH or BSC personnel would point out unnecessary framing pieces to the subcontractor, only to have the same unnecessary framing pieces be installed in the next house. It was only when DWH started making the subcontractor go back and take out the unnecessary pieces that the subcontractor began implementing advanced framing correctly.

These houses have very complex geometries on both walls and ceilings. In certain places better details would have prevented excess work and waste on the part of the subcontractor, such as on the front elevation of certain houses where a double-wall is built for architectural effect; or in closets that have 8' ceiling heights surrounded by rooms with 9' or 10' ceiling heights.

Technology Gaps & Barriers

Currently the cost of XPS insulating sheathing is too high to expand to more production builders.

In this hot-humid climate, a low-cost dehumidifying ventilation system would be beneficial, but is not available on the market.

The majority of the energy consumption in these houses is due to occupant-controlled miscellaneous electric loads, which we currently have few tools to address.

This case study has been prepared by Building Science Corporation for the Department of Energy's Building America Program, a private/public partnership that develops energy solutions for new and existing homes. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

For more information about Building America go to www.buildingamerica.gov

Building Science Corporation
30 Forest Street
Somerville, MA 02143
www.buildingscience.com

For more information about this or other case studies by Building Science Corporation and the Building America Program go to: www.buildingscienceconsulting.com/buildingamerica

Appendix E.4.7.2
2009-08-07 David Weekley Header Design

2009.08.07

Mike Funk
David Weekley Homes
1111 North Post Oak
Houston, TX 77055
Ph. 832.687.0364
Email. mfunk@dwhomes.com

Re: Typical Header Design for Advanced framing

Mr. Funk:

The following are some recommendations for header design for homes in Houston, TX, designed using advanced framing techniques. The following is intended to be used to simplify the design and sizing of headers over windows for common window opening sizes.

The following is based on a maximum building width of 36 feet and a ground snow load of less than 20 psf. The load values listed below can be used by a registered structural engineer to design specific header sizes. The values are from ***Table 2.10 Loadbearing Wall Loads from 20 psf Roof Live Load (For Wall Studs, Headers and Girders), Wood Framed Construction Manual 1995 SBC***.

Supporting a roof and ceiling only	800 plf
Supporting a roof, ceiling, and 1 center bearing floor	1102 plf

Alternately, the following prescriptive sizes would be recommended:

Supporting a roof and ceiling only		Supporting a roof, ceiling, and 1 center bearing floor	
Opening width	Header Design	Opening Width	Header Design
< 3'-8"	1 – 2x8	< 3'-8"	1 – 2x10
3'-8" < 6'-6"	2 – 2x10	3'-8" < 6'-5"	2 – 2x12

For other building configurations please refer to the attached Table: ***Spans for Minimum No. 2 Grade Single Header for Exterior Bearing Walls***, or ***Table R502.5(1) Girder Spans and Header Spans for Exterior Bearing Walls*** of the 2006 IRC.

Sincerely,

Peter Baker, P.Eng.
Building Science Corporation

CC: Joseph W. Lstiburek, Ph.D., P.Eng. Building Science Corporation

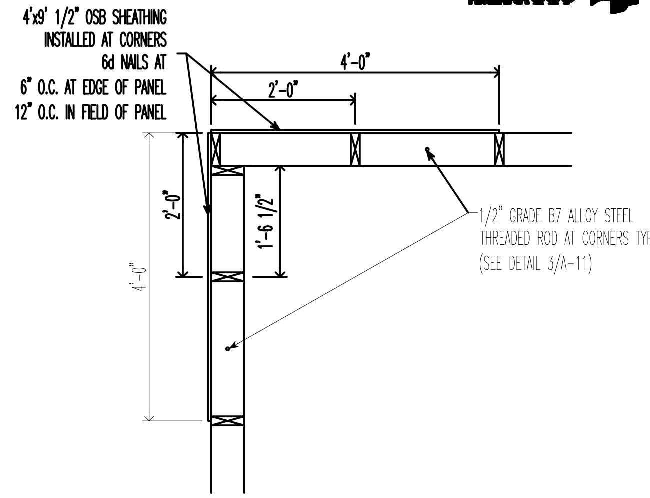
Attach: Table: Spans for Minimum No. 2 Grade Single Header for Exterior Bearing Walls

SPANS FOR MINIMUM No.2 GRADE SINGLE HEADER FOR EXTERIOR BEARING WALLS[a,b,c]

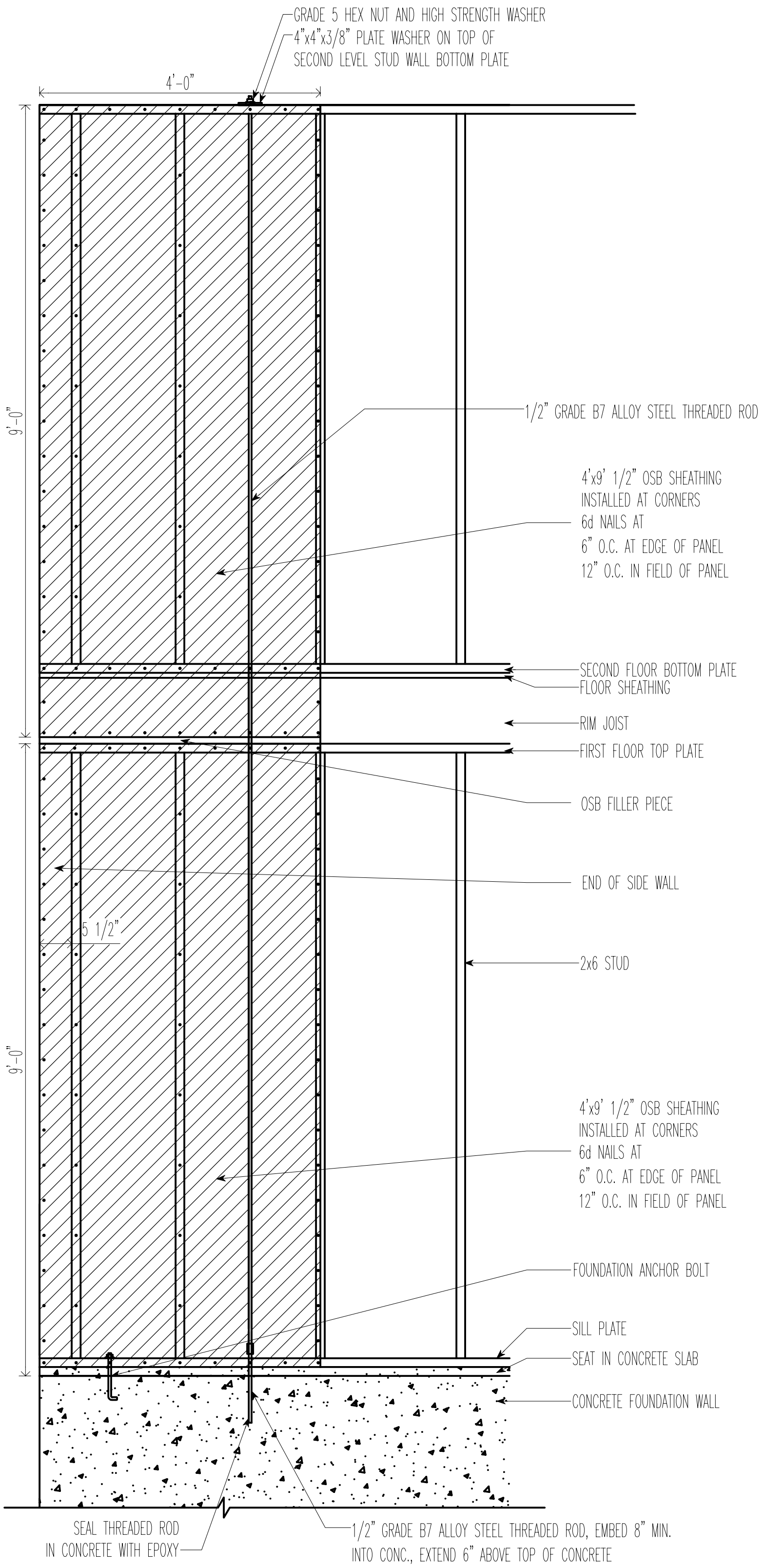
SINGLE HEADERS SUPPORTING	SIZE	Wood Species	GROUND SNOW LOAD (psf)								
			≤ 20[d]			30			50		
			Building Width (feet)[e]								
			20	28	36	20	28	36	20	28	36
Roof and Ceiling	2x8	Spruce-Pine-Fir	4-10	4-2	3-8	4-3	3-8	3-3	3-7	3-0	2-8
		Hem-Fir	5-1	4-4	3-10	4-6	3-10	3-5	3-9	3-2	2-10
		Douglas-Fir or Southern Pine	5-3	4-6	4-0	4-7	3-11	3-6	3-10	3-3	2-11
	2x10	Spruce-Pine-Fir	6-2	5-3	4-8	5-5	4-8	4-2	4-6	3-11	3-1
		Hem-Fir	6-6	5-6	4-11	5-8	4-11	4-4	4-9	4-1	3-7
		Douglas-Fir or Southern Pine	6-8	5-8	5-1	5-10	5-0	4-6	4-11	4-2	3-9
	2x12	Spruce-Pine-Fir	7-6	6-5	5-9	6-7	5-8	4-5	5-4	3-11	3-1
		Hem-Fir	7-10	6-9	6-0	6-11	5-11	5-3	5-9	4-8	3-8
		Douglas-Fir or Southern Pine	8-1	6-11	6-2	7-2	6-1	5-5	5-11	5-1	4-6
Roof, ceiling and one center-bearing floor	2x8	Spruce-Pine-Fir	3-10	3-3	2-11	3-9	3-3	2-11	3-5	2-11	2-7
		Hem-Fir	4-0	3-5	3-1	3-11	3-5	3-0	3-7	3-0	2-8
		Douglas-Fir or Southern Pine	4-1	3-7	3-2	4-1	3-6	3-1	3-8	3-2	2-9
	2x10	Spruce-Pine-Fir	4-11	4-2	3-8	4-10	4-1	3-6	4-4	3-7	2-10
		Hem-Fir	5-1	4-5	3-11	5-0	4-4	3-10	4-6	3-11	3-4
		Douglas-Fir or Southern Pine	5-3	4-6	4-1	5-2	4-5	4-0	4-8	4-0	3-7
	2x12	Spruce-Pine-Fir	5-8	4-2	3-4	5-5	4-0	3-6	4-9	3-6	2-10
		Hem-Fir	5-11	4-11	3-11	5-10	4-9	4-2	5-5	4-2	3-4
		Douglas-Fir or Southern Pine	6-1	5-3	4-8	6-0	5-2	4-10	5-7	4-10	4-3
Roof, ceiling and one clear span floor	2x8	Spruce-Pine-Fir	3-5	2-11	2-7	3-4	2-11	2-7	3-3	2-10	2-6
		Hem-Fir	3-7	3-1	2-9	3-6	3-0	2-8	3-5	2-11	2-7
		Douglas-Fir or Southern Pine	3-8	3-2	2-10	3-7	3-1	2-9	3-6	3-0	2-9
	2x10	Spruce-Pine-Fir	4-4	3-7	2-10	4-3	3-6	2-9	4-2	3-4	2-7
		Hem-Fir	4-7	3-11	3-5	4-6	3-10	3-3	4-4	3-9	3-1
		Douglas-Fir or Southern Pine	4-8	4-0	3-7	4-7	4-0	3-6	4-6	3-10	3-5
	2x12	Spruce-Pine-Fir	4-11	3-7	2-10	4-9	3-6	2-9	4-6	3-4	2-7
		Hem-Fir	5-6	4-3	3-5	5-6	4-2	3-3	5-4	3-11	3-1
		Douglas-Fir or Southern Pine	5-8	4-11	4-4	5-7	4-10	4-3	5-6	4-8	4-2

For SI: 1 inch=25.4 mm, 1 pound per square foot = 0.0479 kPa.
a. Spans are given in feet and inches.
b. Table is based on a maximum roof-ceiling dead load of 15 psf.
c. The header is permitted to be supported by an approved framing anchor attached to the full-height wall stud and to the header in lieu of the required jack stud.
d. The 20 psf ground snow load condition shall apply only when the roof pitch is 9:12 or greater. In conditions where the ground snow load is 30 psf or less and the roof pitch is less than 9:12, use the 30 psf ground snow load condition.
e. Building width is measured perpendicular to the ridge. For widths between those shown, spans are permitted to be interpolated.

Appendix E.4.7.3
2009-06-18 Advanced Framing Details SK-1



2 | TYPICAL CORNER FRAMING PLAN
NTS



1 | TYPICAL CORNER FRAMING ELEVATION
NTS

ADVANCED FRAMING 2003/2006 IRC REFERENCES

SINGLE TOP PLATE

- IRC 2000, 2003, and 2006, in Section R602.3.2 Top Plate: Exception: A single top plate may be installed in stud walls, provided that the plate is adequately tied at joints, corners, and intersecting walls by a minimum 3-inch-by-6-inch by 0.036 inch-thick (76 mm by 152 mm by 0.914 mm) galvanized steel plate that is nailed to each wall or segment of wall by six 8d nails on each side, provided that the rafters or joists are centered over the studs with a tolerance of no more than 1 inch (25.4 mm). The top plate may be omitted over lintels that are adequately tied to adjacent wall sections with steel plates or equivalent as previously described.
- IRC 2000, 2003, and 2006, in Figure 602.3(2): The figure label states "single or double top plate."
- IRC 2000, 2003, and 2006, in Section R602.5: Interior, nonbearing walls shall be permitted to be constructed with 2-inch-by-3-inch (51 mm by 76 mm) studs spaced 24 inches (610 mm) on center or, when not part of a braced wall line, 2-inch-by-4-inch (51 mm by 102 mm) flat studs spaced at 16 inches (406 mm) on center. Interior, nonbearing walls shall be capped with at least a single top plate. Interior, nonbearing walls shall be fireblocked in accordance with Section R602.8.
- IRC 2003 and 2006, Table R602.3(1): For top or sole plate to stud (end nail), two 16d fasteners are required.

NO HEADERS IN NON-LOAD-BEARING WALLS

- IRC 2000, 2003, and 2006, Section R602.7.2: Nonbearing walls. Load-bearing headers are not required in interior or exterior nonbearing walls. A single, flat 2-inch-by-4-inch (51 mm by 102 mm) member may be used as a header in interior or exterior nonbearing walls for openings up to 8 feet (2438 mm) in width if the vertical distance to the parallel nailing surface above is not more than 24 inches (610 mm). For such nonbearing headers, no cripples or blocking is required above the header.
- IRC 2000, 2003, and 2006 Table R702.3.5 Minimum Thickness and Application of Gypsum Board: Allows the use of 24-inch-on-center framing for fastening gypsum board with either fasteners or adhesive 1/2 inch thickness or greater.
- IRC 2000, 2003, and 2006 Section R703 Exterior Covering: Structural sheathing and siding requirements are based on Table R703.4. Note that footnote "a" specifies that the table is based on 16 inches on center and that studs-spaced-24-inches-on-center siding shall be applied to sheathing approved for that spacing.
- IRC 2003 and 2006 Section R602.10.2 Seismic Design Category D2: In Seismic Design Category D2, cripple walls shall be braced in accordance with Table R602.10.1.

DRYWALL CLIPS

- IRC 2000, 2003, and 2006, Section R602.3 Design and Construction: Exterior walls of wood-frame construction shall be designed and constructed in accordance with the provisions of this chapter and Figures R602.3(1) and R602.3(2) or in accordance with AF and PA's NDS. Components of exterior walls shall be fastened in accordance with Table R602.3(1) through R602.3(4). [Excerpt]
- IRC 2000, 2003, and 2006, Figure R602.3(2): Note: A third stud and/or partition intersection backing studs shall be permitted to be omitted through the use of wood back-up cleats, metal drywall clips, or other approved devices that will serve as adequate backing for the facing materials.

FILE: 07219 H-Wee.DWG

SK-1

Advanced Framing Details

SCALE AS NOTED

PROJECT:
DAVID WEEKLEY HOMES
EAGLE SPRINGS
Houston, TX

ARCHITECT:
BUILDING SCIENCE CORPORATION
30 FOREST STREET SOMERVILLE, MASSACHUSETTS 02143 PH: 978-589-5100

E-233

Appendix E.4.7.4
2009-03-13 Quality Control Process Discussion with Mike Funk

Quality Control Process Discussion with Mike Funk, David Weekley Homes, Houston

On March 13, 2009, Aaron Townsend and Ken Neuhauser of BSC met with Mike Funk of David Weekley Homes to communicate the quality criteria and documentation requirements for the Builders Challenge program and to ascertain whether existing processes would satisfy these requirements.

General DWH Quality Process Overview

Construction work at DWH sites is conducted by subcontractors. DWH Builders perform as site supervisors. Procedures for subcontractors are set out in a manual, Building The Weekley Way (BTWW). Aaron received a 2007 version of the manual at the meeting. Mike Funk indicated that the 2009 version will be available soon and that he can make that available to us.

Specifications are revised ~ 1/yr although minor changes may take place throughout the year. Periodic changes to specifications and methods are communicated by Mike Funk to the contractors through planned meetings. Contractors re-bid approximately quarterly based on current specific specifications.

No substitutions of products or materials are permitted. Mike Funk indicated that there had been problems with substitutions in the past.

DWH-Houston builds all of its homes to EFL standards. DWH-Houston is switching over to EFL Platinum from EFL Diamond level. The Diamond level addresses heating and air conditioning, Platinum is a whole house assessment based on the HERS scale. EFL programs dictate some specifications as well as quality assurance implementation testing and inspections.

DWH contracts an inspections firm, Burgess Construction Consultants, Inc., to conduct inspections on every home. DWH contracts with Energy Sense Systems to conduct the testing and inspections required in the EFL program. Burgess personnel attend training sessions conducted by DWH. Burgess has an inspection form that they use. BTWW also has a checklist. Completion of the inspections according to this checklist is required for payment, although the checklists are not retained by DWH. Builders (DWH site supervisors) also have checklist that they may use. However, given the volume of homes inspected, a separate paperwork file is not maintained for each home. Mike Funk contends that maintaining a separate checklist file for each home, by Burgess, DWH supers, etc. would not be practical.

Water Management Design Documentation

Typical wall details cover water management strategies. Each home plan has a drawing set. In addition, there is a set of typical details. Mike Funk conveyed that most of the details were provided by- or based on guidance from BSC.

Enclosure Energy Performance Design Documentation

Window performance specifications derive from EFL program by reference. Contractors are direct to achieve EFL performance standard. EFL performance standard implies the functional window performance specifications.

It was not clear how much of the energy performance specifications – required insulation, infiltration and duct leakage targets, equipment efficiencies – are set out in the DWH-provided specifications.

HVAC Performance Design Documentation

Mike Funk indicated that HVAC specifications are those that have been developed with Armin and that Armin has the most recent version. These specifications also provide guidance on the application of Manual J. The HVAC contractors that DWH-Houston uses generally retain an engineer for the Manual J sizing. Mike Funk indicated that the Manual J summary reports would be available to Aaron from the engineers. The plans for each home include AC layout (not clear whether this is part of the house plans or something prepared by the HVAC contractor or engineer).

HVAC layouts include bath fans and vents as well as vents for kitchen and dryer exhaust.

Mike Funk referred Aaron to Brian Davis, one of the HVAC contractors for information on duct design and system sizing.

HVAC Implementation Quality Assurance

Mike Funk acknowledged that they still have some minor balancing issues despite the efforts at duct layout. Still, they have not had comfort problems which Mike Funk takes as indication of adequate performance.

Quality Assurance on Energy Sense Testing

Mike Funk is supportive of having Aaron follow on heels of Energy Sense to facilitate better replication of rough-in testing conducted by Energy Sense. Mike Funk suggests that Luis (from Energy Sense) would accompany Aaron to verify that testing procedures are comparable. Aaron is concerned that the logistics of this would interfere with the goal of "blind" quality assurance testing. Aaron to follow up with Mike Funk.

Follow Up Items:

Follow-up with Mike Funk

- [ ] Request set of typical details
- [ ] Request copy of EFL performance standards used by DWH
- [ ] Coordinate on visit to Houston and duct testing by Energy Sense

Request from HVAC contractors

- [ ] Request MJ reports
- [ ] Request sample set of HVAC plans showing duct layout as well as HVAC specific specifications

Appendix E.4.7.5
090227 Site Visit Report

Site Visit Report

David Weekley Homes

Houston, Texas

Eagle Springs and Waterhaven Developments

February 26-27, 2009

Aaron Townsend and Jonathan Smegal

Building Science Corporation
70 Main Street Westford, MA 01886

P: 978.589.5100 F: 978. 589.5103
www.buildingscience.com

Summary

Aaron Townsend and Jonathan Smegal of BSC visited David Weekley developments in and around Houston on February 26 and 27, 2009. The purpose of the trip was to compare the results of the duct testing EnergySense does at rough with the results of the duct testing BSC does at final. The results of observing the EnergySense testing suggest that BSC should perform at least an initial quality assurance check on a few of EnergySense's tests, with further testing to be determined based on the results of the initial QA check. The results of the testing performed by BSC at Eagle Springs do not contradict the EnergySense results for one of the two systems, but the second system is not included in EnergySense's results and it is undetermined at this time if EnergySense tested the second system.

Background

Every house that David Weekley builds in Houston is now part of the EFL program by Masco. As part of the EFL program, EnergySense performs inspections and tests on each house. The EnergySense duct leakage tests are performed after the rough installation of the AHU, ducts, and register boots ("at rough"), while the BSC duct leakage tests are performed after the house is complete ("at final"). Because the "at rough" tests are performed before drywall is installed, the duct mask is applied directly to the sheet metal boots, and the test measures leakage in the boots, ducts, and AHU, and in the joints between the boots, ducts, and AHU. The "at final" tests measure all of these in addition to the leakage between the boots and the drywall and between the drywall and the register grill.

Observation of EnergySense Testing

The morning of February 26, Aaron and Jonathan met with Luis Rodriguez and Mark Gonzales of EnergySense and observed while one of EnergySense's testers (Jason) performed a duct leakage test of two houses in David Weekley's Bridgeland community (18322 West Williams Bend Drive and 18226 West Williams Bend Drive, Cypress TX). Both houses failed the duct leakage tests by margins large enough that further attempts at sealing by the tester could not meet the targets.

The first house (18322 West Williams Bend Drive) had a target of around 75 cfm25 and an actual leakage of around 95 cfm25. Using the smoke machine, leakage was observed to be coming from the AHU cabinet, joints between the supply and return plenums and the flex duct, and out of the zone valve boxes attached to the supply plenum. The joints between the supply and return plenum and the flex duct did have mastic but there was substantial leakage at several of the joints.

The second house (18226 West Williams Bend Drive) had a target of around 95 cfm25 and an actual leakage of around 125 cfm25. The tester again used the smoke machine and identified leakage in the same areas as the first house, but with substantially more leakage from the AHU cabinet.

In both cases the leaking areas were marked with spray paint and EnergySense failed the house on its inspection and will reinspect after the HVAC contractor provides performs further air sealing.

The photos below illustrate the testing process and the major leakage areas found.






Discussion of Testing and Quality Control with Luis Rodriguez

Luis Rodriguez is the head of EnergySense's field operations. Mark Gonzalez is the lead tester for the EnergySense's north Houston office. During the break between testing the two houses Luis discussed the compensation of the testers. The testers are paid a base hourly wage plus bonuses for each house that passes. This is designed to incentivize the testers to work with the HVAC contractor to perform air sealing measures before EnergySense performs the duct leakage tests, to minimize the number of times EnergySense has to test a house and therefore the cost of testing for both EnergySense and the builder. Unfortunately this also incentivizes the tester to pass every house he can reasonably pass.

Luis also described EnergySense's quality control measures. EnergySense performs quality control by randomly retesting 1% of the houses. Retesting is done by Luis, Mark, or one other top field representative.

Given the high incentive for the testers to pass houses and the relatively low percentage of houses that are retested in the quality control program, BSC should perform random retesting to protect our interests and also those of David Weekley.

Testing of Duct Systems at Eagle Springs

During the afternoon of February 26 and on February 27, Aaron and Jonathan tested two duct systems in one house at Eagle Springs to determine how well the EnergySense results (measured at rough) matched BSC's results (measured at final).

The house tested was 17635 Bridger Bend. It is a plan 4103 with media room bonus option and contains 3192 square feet of conditioned floor area. Most of the house is on the first floor, with only the bonus media room and a small half-bath on the second floor. The house contains two independent space conditioning systems. The first system conditions the entire first floor and the second system conditions the second floor media room and half bathroom. Other details of the two systems are included at the end of this report.

First, a manual multi-point blower door test was performed. The wind was gusty both February 26 and 27. The test results are shown in the table below. The leakage at 50 Pa was 2084 cfm50 (C=173.7, n=0.635, correlation coefficient=0.997), within BSC's target of 2155 cfm50 but about 10% higher than EnergySense's reported value of 1890 cfm50. EnergySense's target was 1915 cfm50, giving only a 25 cfm50 passing margin.

House pressure wrt outside (Pa)	Flow (cfm)
-50.9	2059
-41.4	1832
-30.5	1430
-20.5	1125

Next, a duct leakage test was performed on the downstairs duct system per BSC's standard procedure. Duct mask was used to tape over the supply and return grills and the duct blaster was used to pull air out of the return. Results were 159 cfm25 total leakage and 50 cfm25 to outside. The large difference was unexpected since all the ducts are located in the attic. The registers were inspected for caulking, which was present in most but it was impossible to determine if the caulking was located in the proper location between the drywall and the sheet metal boot to provide the intended air barrier continuity.

In order to attempt to replicate EnergySense's tests at rough, the ends of the supply ducts were sealed using plugs made from fiberglass batts and plastic trash bags. A better method would have been to remove the register grills and duct mask to the sheet metal supply boots, however there was not sufficient duct mask available to do this and therefore the alternative method was used. Photos showing the construction sequence for these plugs are included at the end of this report. The plugs appeared to do a good job of sealing the ducts from the interior space. During depressurization testing of the ducts no air movement could be felt by hand nor measured by the Alnor Balometer after installation of the plugs.

When using the duct plugs, the duct pressure tap was moved to a supply register, to be consistent with the method EnergySense uses. After testing was complete the pressure tap was moved back to the return grill and the pressures were compared. The difference was 0.1 Pa, which is the resolution of the manometer.

Using the plugs, the duct leakage was measured as 57 cfm25 total and 30 cfm25 to outside. This suggests that 30 cfm25 is leaking from the air handler cabinet and the joints between the ducts, that 57-30=27 cfm25 is leaking around the return grill and the plugs, that 50-30=20 cfm25 is leaking from the supply boots to outside, and 159-50 = 109 cfm25 is leaking from the interior to the duct system either around the duct mask or around the register grill and sheet metal boot.

The second floor system was tested with both methods as well and showed similar trends although the absolute values of the leakage were all smaller, as it was a smaller duct system. The table below shows the results of both tests.

System	EnergySense		BSC					
	Target duct leakage, cfm25 (3% of floor area)	Measured duct leakage, cfm25 (at rough)	Target duct leakage, cfm25 (5% of air handler flow)		Measured duct leakage, cfm25 (at final, with duct mask)		Measured duct leakage, cfm25 (at final, with fiberglass plugs)	
			Total	To outside	Total	To outside	Total	To outside
1st floor	75	74	No target	?	159	50	57	30
2nd floor	No test data	No test data	No target	?	66	34	32	20

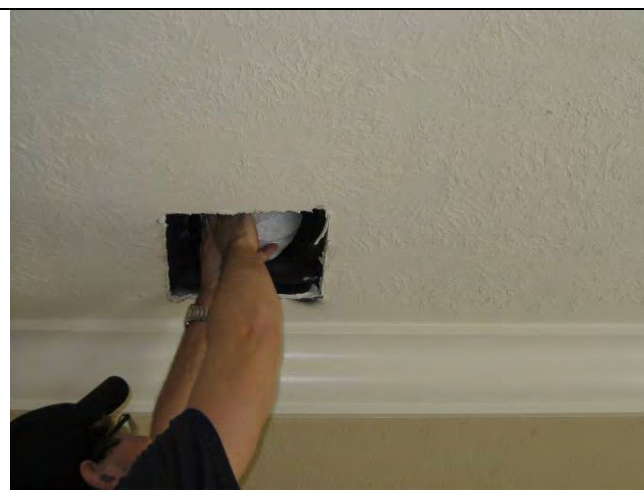
Future tests should determine the amount of leakage around the registers by sealing to the drywall instead of the register. This should be done with paper and painters tape instead of duct mask to prevent damage to the painted drywall. Also, the return grill should be sealed as well as possible using duct mask and the duct mask sealed to the drywall using painters tape as well.

Relevant details about the two forced-air systems in this house:

Downstairs system:
19 registers: 8 four-inch ducts, 3 six-inch ducts, 8 eight-inch ducts
Single return in front hallway.
Large (12”) jump duct from master bedroom and normal size jump ducts from other bedrooms.
? ton AC unit
? cfm nominal airflow

Upstairs system:
7 registers: 1 four-inch duct, 6 eight-inch ducts
Single return in the only large room on 2nd floor (media room)
No jump ducts as the only other room on the 2nd floor is a half-bath.
? ton AC unit
? cfm nominal airflow

Steps for constructing and using fiberglass plugs

 Cut R-13 fiberglass batt to appropriate length (4' for 8" ducts, 3' for 6" ducts, 2' for 4" ducts).	 Cut fiberglass in half lengthwise.
 Peel off kraft facing and roll into cylinder.	 Place roll inside plastic trash bag.
 Remove supply register.	 Compress fiberglass cylinder and place in supply

	duct.
 Expansion of fiberglass cylinder should completely fill supply duct. No airflow was felt around fiberglass plug during the depressurization testing.	

Appendix E.4.7.6
2009-03-12_13 Site Visit Report

Site Visit Report

David Weekley Homes

Houston, Texas

Sunset Ridge, Bridgeland, Northpointe, and Eagle Springs Developments

March 12-13, 2009

Aaron Townsend and Ken Neuhauser

Building Science Corporation
70 Main Street Westford, MA 01886

P: 978.589.5100 F: 978. 589.5103
www.buildingscience.com

Summary

Aaron Townsend and Ken Neuhauser of BSC visited David Weekley Homes developments in and around Houston on March 12 and 13, 2009. The primary purpose of the trip was to conduct quality assurance testing on duct leakage testing previously conducted by Energy Sense. BSC elected to pursue this testing work after observing the Energy Sense testing and also comparing the results of the duct testing Energy Sense does at rough with the results of the duct testing BSC does at final. The plan was for BSC to replicate duct leakage testing at rough in homes where Energy Sense had conducted this testing within the week prior to BSC's visit. Construction progress since the Energy Sense testing precluded replicating the earlier testing conditions in all but one of the homes identified as having received Energy Sense duct testing at rough in the prior week. Consequently the QA testing was non-conclusive as it was not possible to determine to what extent significant variances in testing numbers resulted from differences in testing conditions.

Also during this visit to the Houston area, BSC met with Mike Funk of DWH to review documentation requirements for the Builders Challenge program. Aaron Townsend and Mike Funk also discussed a process for continuing the QA testing of the Energy Sense work that would assure replication of testing conditions. Visits to various DWH developments also afforded the opportunity to conduct a frame walk of a non-Building America home.

Background

Every house that David Weekley builds in Houston is now part of the EFL program administered by Masco. As required by the EFL program, a Masco company, Energy Sense, performs inspections and tests on each house. The Energy Sense duct leakage tests are performed after the rough installation of the AHU, ducts, and register boots ("at rough"), while the BSC duct leakage tests are performed after the house is complete ("at final"). Because the "at rough" tests are performed before drywall is installed, the duct mask is applied directly to the sheet metal boots, and the test measures leakage in the boots, ducts, and AHU, and in the joints between the boots, ducts, and AHU. The "at final" tests measure all of these in addition to the leakage between the boots and the drywall and between the drywall and the register grill.

Previous testing efforts by BSC sought to understand the variance between Energy Sense "at rough" testing data and BSC final testing data. During observing the Energy Sense testing, BSC personnel learned of a compensation structure for the Energy Sense testers that appears to pose a conflict of interest. Given the high incentive for the testers to pass houses and the relatively low percentage of houses that are retested in Energy Sense's quality assurance program, BSC decided to perform random follow-on testing "at rough" to protect our interests and also those of David Weekley.

BSC Duct Leakage Testing

Planned Testing Operation

BSC obtained from Energy Sense a list of the DWH homes in which it had conducted the "at rough" duct testing during the week leading up to BSC's visit. BSC then planned to retest a number of these homes without notifying Energy Sense in advance. Given the relatively slow housing market, it was expected that a portion of the houses tested in the previous week would not yet have drywall installed; however all but one of the eleven houses tested in the week prior to BSC's arrival had drywall installed, including two that had been tested only two or three days prior to BSC's arrival in Houston. BSC conducted duct leakage testing using Duct Blaster®

equipment and procedures on three of the homes which Energy Sense had tested. One of those homes was still in the "at rough" stage. The two others had been recently drywalled. The presence of drywall contractors, or recent application of drywall compound that had not yet dried, rendered testing infeasible at many homes. At other homes, it was determined that the presence of installed drywall would substantially impair the ability to obtain conclusive data.

The Table 1 below presents results of the duct leakage test performed by BSC on this visit as well as the duct leakage test result reported by Energy Sense for the same homes.

Table 1 - Results for Tested Duct Systems

Address	SubDiv	Energy Sense Testing Date	Energy Sense Target	Energy Sense Results	BSC Results
				System 1	System 1
11335 Sandstone Canyon	Sunset Ridge	03/10/09	63	57	77
18322 W. Williams Bend Dr	Bridgeland	03/04/09	75	73	72
17423 Morgans Lake Dr	Bridgeland	03/04/09	75	74	130

Table 2 below summarizes the conditions on March 12th of the homes in which Energy Sense had conducted duct systems testing during the previous week. For those homes tested by BSC a summary of the testing operation is provided. For those homes not tested, the notes indicate reasons for not testing of the other homes.

Table 2 - Summary of Testing Feasibility on March 12th, 2009

Address	SubDiv	Tested by BSC (yes/no)	Notes (BSC)
11335 Sandstone Canyon	Sunset Ridge	Yes	drywall not installed; duct mask still present from Energy Sense testing
18322 W. Williams Bend Dr	Bridgeland	Yes	drywall installed and texture applied; applied duct mask to inside of sheet metal boot flanges; mastic had been applied over leakage areas observed during previous testing 2/27/09

17423 Morgans Lake Dr	Bridgeland	Yes	drywall installed; applied duct mask to inside of sheet metal boot flanges; used smoke machine to look for leaks; only saw small leakage around AHU, nowhere else; suspect leakage is into wall cavities at drywall-boot interfaces.
18226 E. Willow Oak Bend Dr	Bridgeland	No	drywall installed - did not test
19138 Northfork Bend Ln	Northpointe	No	drywall installed - did not test
12527 Baldwin Springs	Northpointe	No	drywall installed - did not test
12927 Northpointe Bend	Northpointe	No	drywall installed - did not test
27511 Guthrie Ridge Ln	Cinco	No	per builder: drywall done or being installed
2323 Monarch Terrace Dr	Firethorne	No	per builder: drywall done or being installed
17222 PINE HOLLOW LANDING	Pine Forest Landing	No	per builder: drywall done or being installed
15831 Sonoma Park Dr	Sonoma Ranch	No	per builder: drywall done or being installed

Leakage Testing Results and Observations

Sunset Ridge – BSC found one home in a condition comparable to the Energy Sense testing condition. Neither cavity insulation nor drywall had not been installed in this home and duct mask was still adhered to the supply boots. BSC personnel verified adhesion of this duct mask and installed duct mask at return for installation of the duct blaster equipment. The duct leakage test result obtained by BSC for this home was 35% higher than the reported result from Energy Sense.

Figure 1 - supply boot with duct mask

Note that the duct mask from Energy Sense testing two days prior is still in place. Adhesion and seal of the in-place duct mask was verified before testing.

Rather than perform additional diagnostics to study the leakage and search for possible explanations for the difference in results, BSC opted to move on to other sites in hopes of obtaining a larger sample.

Bridgeland – After many calls to builders and after checking on home sites at multiple developments in person, BSC was compelled to test duct work in homes where "at rough" conditions could not be replicated. In the Bridgeland development, BSC conducted a duct leakage test at two homes where drywall had already been installed. In one case, spray-applied texture had already been applied to the drywall surfaces. In order to replicate conditions of the Energy Sense testing as nearly as possible, duct mask was applied to the inside of the sheet metal boot flanges as depicted in Figure 2 below.

Figure 2 - Supply boot with duct mask adhered to inside of flange

In one of the homes, the BSC duct leakage test results were essentially the same as those reported by Energy Sense for the home's duct system. This home had been visited previously by both Energy Sense and BSC while BSC was observing Energy Sense "at rough" testing (see Site Visit Report for February 26 and 27). At that time, Energy Sense had determined that the system failed to meet the duct leakage target and used an artificial fog generator to identify leakage locations. Energy Sense then marked these leakage locations with spray paint. Energy Sense retested the system on March 4th. Observations on March 12th confirmed that locations marked by Energy Sense had been further sealed by the HVAC contractor using mastic since the initial testing.

Figure 3 - Remedial duct sealing at area noted by Energy Sense

In another home in this subdivision, BSC duct leakage test results were approximately 75% higher than those reported by Energy Sense. BSC had not observed the initial testing by Energy Sense for this home. In order to identify a possible reason for the disparity in duct leakage results, BSC used the fog generator to locate leakage sites. We considered the possibility that we may have missed masking a boot and/or that the ductwork had been damaged since the Energy Sense testing. We had surmised that significant leakage caused by damage to the duct work would be revealed by pressurizing the system with fogged air. We found no sign of un-masked boots. The only fog observed leaking from the duct system was at the AHU cabinet however taping the cabinet did not significantly reduce the 60 cfm25 difference between Energy Sense's reported results and BSC's measurement. Given that there were no visually evident leakage areas, one possibility is that a good deal of the leakage is into wall cavities at the return grills.

Lessons Learned

What we learn from this visit is that it is very difficult to replicate Energy Sense "at rough" testing conditions if the drywall contractors have installed the drywall, which often happens no more than a day or two after the Energy Sense testing.

While in the Houston area, Ken Neuhauser and Aaron Townsend met with Mike Funk. During these discussions, Mike Funk indicated that he would coordinate with Aaron Townsend to find out specific dates that Energy Sense would be testing duct systems so that Aaron could arrange to be in the homes on the same day or the next. Mike Funk also suggested that Luis Rodriguez from Energy Sense should accompany Aaron to help determine the cause of any discrepancies. It was noted that the arrangement with Energy Sense would need to be carefully orchestrated to preserve the goal of follow-on testing without influencing the Energy Sense testing.

The one observation where BSC duct leakage testing results agreed with those reported by Energy Sense occurred for a home where an initial test was observed by BSC. Under BSC's observation, Energy Sense determined that the duct system did not meet the performance target and, therefore, required remedial duct sealing. BSC observations confirmed that this remedial duct sealing was implemented at the areas prescribed by Energy Sense. Energy Sense then retested the duct system after the remedial duct sealing and it was results from this testing that agree with BSC duct leakage testing results.

While there certainly is not sufficient data to draw conclusions, the situation described above does raise questions as to whether incentives have influenced reported results. Whether there may or may not have been an incentive to report the results more favorably, it stands to reason that the presence of third party observers would have negated any such perverse incentives that may or may not have existed. BSC learned on previous visit that the Energy Sense personnel performing the duct leakage testing are paid a base hourly wage plus bonuses for each house that passes. Luis Rodriguez of Energy Sense had explained that this is designed to incentivize the testers to work with the HVAC contractor to perform air sealing measures before EnergySense performs the duct leakage tests, to minimize the number of times EnergySense has to test a house and therefore the cost of testing for both EnergySense and the builder. Unfortunately this also incentivizes the tester to pass every house he can reasonably pass.

BSC is certainly not in a position to suggest that there is in fact a problem of bogus testing results. Howver, there is an appearance of a conflict of interest. It would be worthwhile for Energy Sense to explore, with its client, a compensation structure that relieves this appearance of a conflict of interest. The incentive for the Energy Sense rater in the field to work with HVAC contractors to achieve duct leakage targets may be useful. Ultimately, the HVAC contractor needs to be motivated to have duct systems meet the performance target on the first attempt. For example, the HVAC contractor would have an incentive to achieve tight duct systems if the contractor bore the cost of retesting a system. However the incentives are structured, the integrity of the performance recognition system (EFL, Builders Challenge) and the interests of the builder pursuing quality assurance would be better served by the elimination of any apparent conflicts of interest.

Appendix E.4.7.7
2009-02-04 Builder's Challenge Certificate

U.S. Department of Energy

EnergySmart Home Scale℠

Estimated annual energy usage:
Electric (kWh) 15167
Natural Gas (therms) 428

Estimated average monthly energy bill:
$229

Conditioned floor area (sq. ft.): 3192

17607 Boysen Court, Humble, TX 77346
Rated by Building Science Corporation
Rating conducted **September 8, 2008**

www.buildingamerica.gov/challenge

Meets The Builders Challenge
Recognizing the best energy performance, quality, comfort, health and safety in the market.

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David Weekley Homes

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