1. FOULDS RESIDENCE, CONCORD, MA

1.1 Executive Summary

Gate 2 – Prototype: Foulds Residence, Concord, MA

Overview

The Foulds Residence is a custom house being built by Synergy Companies Construction, LLC in Concord, MA. The house is a Cape Cod style design with 5 bedrooms and 4 full bathrooms. Building Science Corporation is the design architect, architect of record, and design engineer. Synergy Companies Construction, LLC builds new construction houses and renovates existing housing to meet high performance specifications. The Foulds Residence is currently under construction and is scheduled to be completed in March of 2010.

Key Results

The Foulds Residence is being built to meet high performance specifications for both the enclosure and mechanical systems and includes a 5.75 kW PV array on its south facing roof. The house is advanced framed with 4" of rigid insulation on the exterior and will have a high efficiency mechanical system in the basement with ductwork delivering conditioned air and ventilation throughout the house. After the house is completed, Building Science Corporation will do performance testing to ensure the house performs as designed.

Gate Status

Below is a table indicating that the Foulds Residence Gate 2 Prototype passes the "Must Meet" Gate Criteria at this point during construction.

Table 1.1: Stage Gate Status Summary

"Must Meet" Gate Criteria	Status	Summary
Source Energy Savings	Pass	The Foulds Residence design achieves an 81.8% source energy savings over the 2009 Building America Benchmark with a 5.75 kW PV system.
Prescriptive-Based Code Approval	Pass	The Foulds Residence meets the 7th Edition Massachusetts One-and Two-Family Dwelling Code (based on 2003 ICC International Residential Code) and exceeds the IECC 2006 Section 404 Compliance (adopted by Massachusetts effective October 6, 2008) by over 50%.
Quality Control Requirements	Pass	A project specific durability checklist was created during design and used on-site during construction to ensure critical details and practices are executed. Site visit reports are created after each site visit and distributed to both the builder and homeowner. The Foulds Residence will also have third-party verification as part of USGBC's LEED for Homes program.

"Should Meet" Gate Criteria	Status	Summary
Neutral Cost Target	Pass	The Foulds Residence exceeds the neutral cost target when the cost of improvements is financed as part of a 30 year mortgage. This annual amortized cost is less than the energy savings of the homes compared to the 2009 Building America Benchmark.

Quality Control Integration	Pass	The durability checklist is used on-site in combination with details from the drawing set including enclosure details, air sealing and advanced framing details as well as detailed framing and mechanical plans.
Gaps Analysis	Pass	Through the design phase and first phase of construction, the team has identified issues that were not covered in the drawing set or specifications and needed to be resolved in the field or worked out for future projects.

Conclusions

When completed in March of 2010, the Foulds Residence will be an example of an energy-efficient, durable, comfortable and healthy high performance home in a cold climate. The home is designed to achieve a 81.8% savings in source energy when the high performance enclosure and high efficiency mechanical system is combined with a 5.75 kW PV array on the south facing roof of the house. This percentage is equal to approximately $5,000 in utility bill savings taking into account the local utility costs.

Though the project team worked closely with the builder toward the end of the design phase and through the first phase of construction, issues came up in the field that had not been identified in the drawing set or specifications and needed to be resolved. Among these issues is the design and construction of headers over side-by-side windows, how to increase the durability of a home's foundation when it is in an area with a high water table, and how to meet code requirements for venting of combustion appliances. The resolution of these issues can be translated into drawings and notes and included in future projects.

The project team will continue to monitor construction until completion and will then test the home's performance to see how it compares to what was predicted.

1.2 Introduction

1.2.1. Project Overview

The design of the Foulds Residence began in August of 2008. Architects and engineers at BSC developed the drawing set and specifications for the high performance custom home to be built in Concord, MA. The house is a Cape Cod style design with 5 bedrooms and 4 full bathrooms. It is sited in an existing neighborhood outside of Boston in DOE Climate Zone 5A (BSC's "cold" climate). BSC worked closely with the homeowner to design a house that combined the desired design aesthetic, both interior and exterior, with high performance.

Early in the design process, the project team worked to integrate the architectural, structural, and mechanical components into the plans and specifications. Various enclosure assemblies and mechanical systems were modeled. The models were then used as a tool in deciding which parameters were most cost effective and should be included in the project. See the Enclosure Specifications and Mechanical System Specifications below for a detailed description of each component.

Fortunately, the site is oriented North – South and is ideal for the design and implementation of a photovoltaic array. A large low-slope south facing roof allows light into the Master Bedroom and provides a large enough area for a 5.75 kW PV array, accounting for 93% of the home's predicted electricity need. See the site plan below.

Figure 1.2.1: Foulds Residence site plan and elevation

As of the end of October 2009, the main structure of the home is almost completely framed and the builder will soon start installing 4" of rigid insulation on the outside face of the studs. Once the rigid insulation is installed on the main structure of the house, the builder will then frame the garage and the living room roof. See the overall progress photos below.

Figure 1.2.2: Main house foundation and applied dampproofing

Figure 1.2.3: First floor framing

Figure 1.2.4: First floor wall framing

Figure 1.2.5: Second floor framing

Figure 1.2.6: Second floor wall framing

Figure 1.2.7: Roof framing and sheathing

The Foulds Residence is not only part of the Building America Program, but is also registered in Builders Challenge and in the USGBC's LEED for Homes program, designed to achieve Platinum certification.

1.2.2. Project Information Summary Sheet

PROJECT SUMMARY	
Company	Synergy Companies Construction, LLC
Company Profile	Synergy Companies Construction, LLC specializes in building, remodeling, customized efficient insulating, weatherproofing and solar energy systems for both residential and commercial projects.
Contact Information	Gary Bergeron Synergy Companies Construction, LLC 87 Brockelman Road Lancaster, MA 01523 (978) 424-3028 http://www.synergy-companies.com
Division Name	n/a
Company Type	Custom home builder and remodeler
Community Name	n/a
City, State	Concord, MA
Climate Region	5A

SPECIFICATIONS	
Number of Houses	1
Municipal Address(es)	33 Riverdale Road Concord, MA 01742
House Style(s)	Custom single family Cape Cod design
Number of Stories	2
Number of Bedrooms	5
Plan Number(s)	BSC plan – “Concord Cape”
Floor Area	2,794 ft^2 – first and second floor
Basement Area	1,528 ft^2– finished basement
Estimated Energy Reduction	81.8%
Estimated Energy Savings	$5,072
Estimated Cost	$600,000
Construction Start	July 2009
Expected Buildout	March 2010

1.2.3. Targets and Goals

The Foulds Residence was designed to achieve an 81.8% reduction in source energy relative to the 2009 Building America Benchmark. Without the 5.75 kW PV array, the home was predicted to achieve a 55.2% savings. The design surpasses the goal of achieving a 40% energy use reduction in cold climates.

The project team designed the house to not only meet the energy use reduction goal, but also to meet the needs of the homeowner. The homeowner wanted a design that fit into the aesthetic of the existing neighborhood, provided comfortable living spaces, would remain durable and have low maintenance costs as well as have low operating costs. By integrating the architecture, mechanical systems, structural layout and landscaping all together, the Foulds Residence design will translate into a built home that serves as an example of a high performance custom home in a cold climate.

The Foulds Residence is seeking third party verification under the following programs:

- Builders Challenge
- USGBC LEED for Homes – goal of Platinum certification

1.3 Whole-House Performance and Systems Engineering

1.3.1. Energy Analysis Summary

Table 1.2: Estimated Whole House Energy Use for Foulds Residence, Concord, MA

ESTIMATED WHOLE HOUSE ENERGY USE		
Source (MMBtu/year)	Site (MMBtu/year)	Area + Bsmt (sq ft)
154	84	2794 + 1528
	% Electric	No. of Bedrooms
	33%	5

Table 1.3: Estimated Net Energy Use with 5.75 kW PV array for Foulds Residence, Concord, MA

ESTIMATED WHOLE HOUSE ENERGY USE		
Source (MMBtu/year)	Site (MMBtu/year)	Area + Bsmt (sq ft)
63	57	2794 + 1528
	% Electric	No. of Bedrooms
	1%	5

With the enclosure and mechanical characteristics presented in Table 1.6 and Table 1.8, (below), this plan achieves a performance level of 81.8% reduction relative to the Building America Benchmark with a 5.75 kW PV array.

1.3.1.1. Parametric Energy Simulations

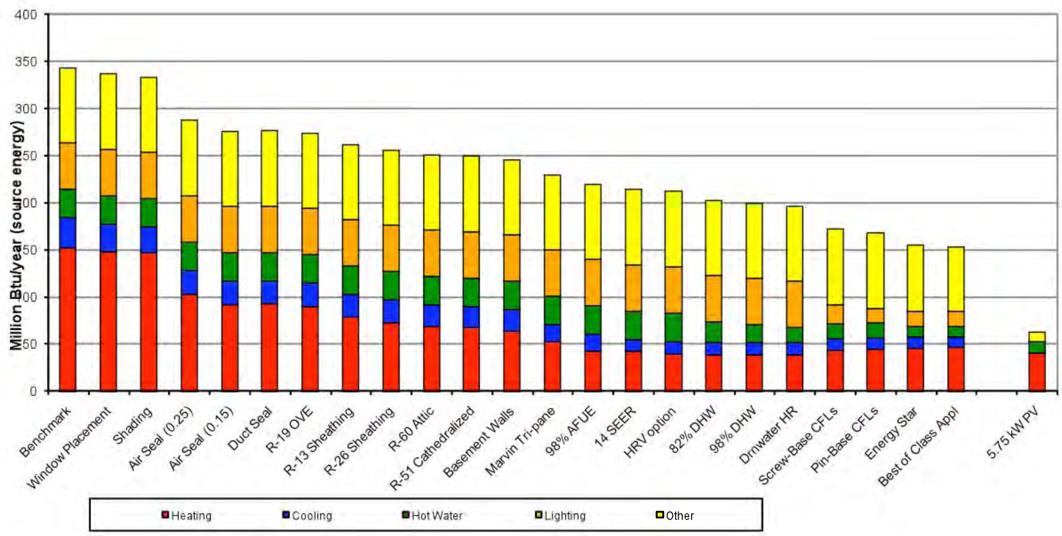

Figure 1.3.1: Parametric energy simulations for the Foulds Residence, Concord, MA

1.3.1.2. End-Use Site and Source Energy Summaries

Table 1.4: Summary of End-Use Site-Energy

	Annual Site Energy			
	BA Benchmark		Prototype	
End-Use	kWh	therms	kWh	therms
Space Heating	1003	1290	475	380
Space Cooling	2814		975	
DHW	0	275	0	106
Lighting*	4281		1376	
Appliances + Plug	5853	116	5207	80
OA Ventilation**	0		0	
Total Usage	13951	1681	8033	566
Site Generation	0	0	7902	0
Net Energy Use	13951	1681	131	566

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation. It is included in Space Heating and Cooling

Table 1.5: Summary of End-Use Source-Energy and Savings

	Estimated Annual Source Energy		Source Energy Savings	
			Percent of End-Use	Percent of Total
End-Use	BA Benchmark 10^6 BTU/yr	Prototype 10^6 BTU/yr	Prototype savings	Prototype savings
Space Heating	152	47	**69%**	**31%**
Space Cooling	32	11	**67%**	**6%**
DHW	30	12	**61%**	**5%**
Lighting*	49	16	**68%**	**10%**
Appliances + Plug	80	69	**14%**	**3%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	344	153	**55%**	**55%**
Site Generation	0	-91		**26%**
Net Energy Use	344	63	**82%**	**82%**

Notes:
The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.
The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

The Foulds Residence achieves an 81.8% source energy use reduction relative to the 2009 Building America Benchmark.

1.3.2. Discussion

1.3.2.1. Enclosure Design

Table 1.6 (below) summarizes the building enclosure assemblies used for this project.

Table 1.6: Enclosure Specifications

ENCLOSURE		SPECIFICATIONS
Ceiling		
	Description -	Vented attic framed with engineered roof rafters at 24" o.c. over main house, cathedralized ceiling on north side of house, flat ceiling on south side of house, unvented attic framed with dimensional roof rafters at 24" o.c. over breakfast area
	Insulation -	R-60 at ceiling level on north side of house (2" foil-faced polyisocyanurate rigid insulation and 7 ½" high density closed cell spray foam), R-63 cellulose at ceiling level on south side of house, R-63 high density closed cell spray foam under roof sheathing over breakfast area
Walls		
	Description -	2x6 advanced framing
	Insulation -	R-26 2 layers 2" foil-faced polyisocyanurate rigid insulation on exterior face of studs with R-19 cellulose in stud bays, R-13 2" high density closed cell spray foam at second floor rim joist area
Foundation		
	Description -	Conditioned basement with concrete foundation walls and concrete slab

ENCLOSURE	SPECIFICATIONS
Insulation -	R-10 2" XPS rigid insulation fastened to inside face of foundation wall with R-15 unfaced batt insulation in stud bays of 2x4 framed wall inboard of XPS, R-10 2" XPS rigid insulation under slab, R-13 2" high density closed cell spray foam at first floor rim joist area
Windows	
Description -	Triple-Pane Aluminum Clad Spectrally Selective LoE^2
Manufacturer -	Marvin
U-value -	0.25
SHGC -	0.38
Infiltration	
Specification -	1.5 in^2 leakage area per 100 ft^2 envelope
Performance test -	Goal of 1209 CFM 50 (1.8 ACH 50) (house not yet tested)

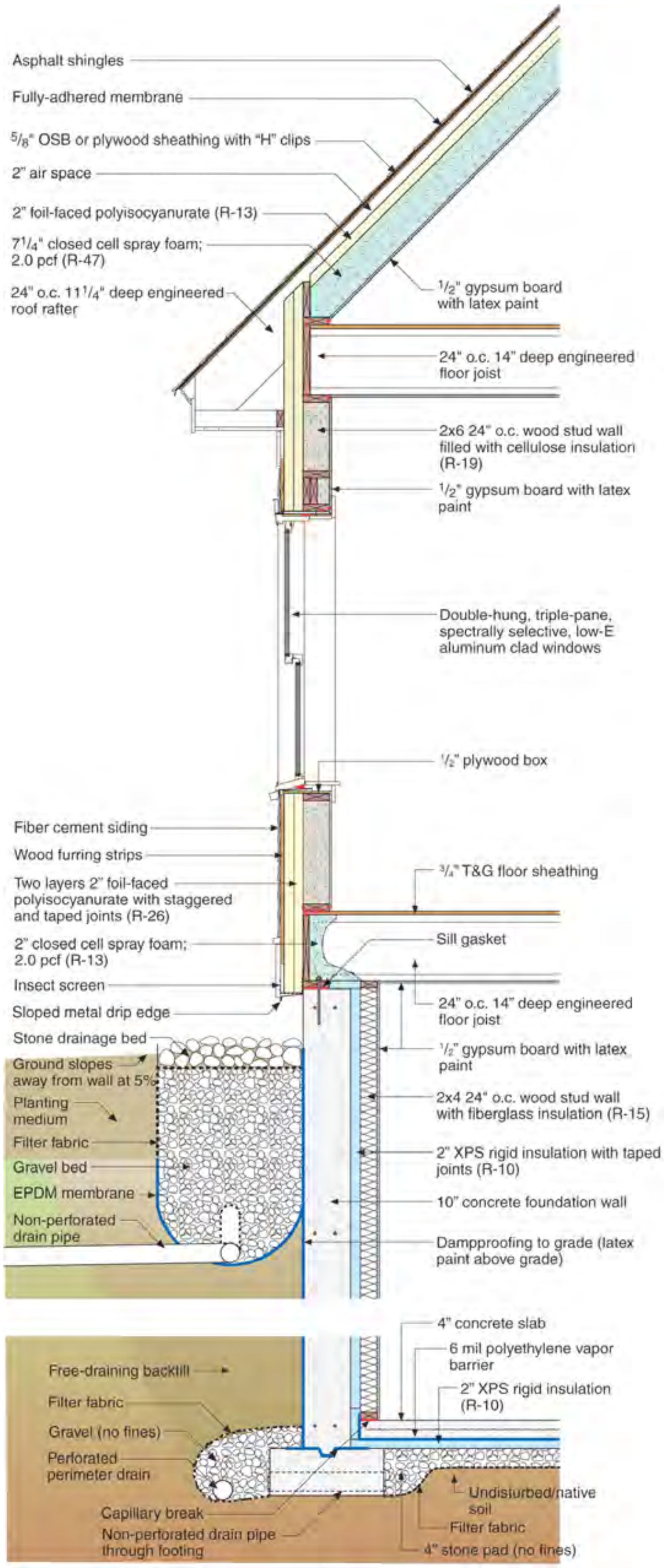

Figure 1.3.2: Foulds Residence North Façade Wall Section

The enclosure upgrades are discussed in greater detail below:

- **Ceiling –** There are both vented and unvented attics in the Foulds Residence. The unvented attic is over the breakfast area on the south side of the house and is insulated to R-63 with high density closed cell spray foam insulation. The attic over the living room bump out and the main structure of the house is insulated at the attic floor level with cellulose insulation to R-63. The roof on the north side of the house utilizes a combination of insulation types – 2” rigid insulation is held 2” down from the underside of the roof sheathing to allow for ventilation. High density closed cell spray foam is then installed in the remaining depth of the roof rafter. The rigid insulation combined with the spray foam insulates the north side of the roof to R-60.

- **Walls –** The walls of the main structure of the house and the living room bump out are insulated to R-45. This level of insulation is achieved using 4” of foil-faced polyisocyanurate insulation on the exterior of the studs and cellulose insulation within the 2x6 stud bays.

- **Foundation –** Originally, the design of the Foulds Residence’s foundation was 4” of rigid insulation to the interior of the concrete foundation wall. Once it was decided that the basement would be finished, the project team decided to use only 2” of rigid insulation attached to the inside face of the concrete wall with a 2x4 stud wall built out and insulated with R-15 unfaced batt insulation. The insulation for the underside of the slab remained the same, 2” of XPS below the slab and turned up where the slab meets the foundation wall.

- **Windows –** For performance reasons, the project team encouraged the homeowner to buy triple-glazed windows for his home. In order to help decide which windows were the best value, the project team compiled project specific quotes and window specifications into a table allowing the homeowner to compare the windows price, performance and payback. See Table 1.7 below. In the end, the homeowner chose the Marvin triple-glazed units, combining the specified performance with the desired aesthetics.

- **Infiltration –** The project team’s typical airtightness goal is a "leakage ratio" of 2.5 square inches/100 square feet surface area, which in this case is equal to 2016 CFM 50 (2.9 ACH 50). However, given the overall energy targets of the Foulds Residence, and the presence of skilled tradesmen, a tighter target of 1.5 square inches/100 square feet was chosen, equal to 1209 CFM 50 (1.8 ACH 50). This level of airtightness is designed to be achieved through the diligent use of the Airtight Drywall Approach and the Critical Seal at rim joist areas.

Table 1.7: Window Comparison Table

Description of Windows	U-value	SHGC	Window Cost	Added Cost	Annual Energy Cost	Cost Change	Simple Payback
Baseline: Andersen 400 Series	**0.34**	**0.29**	**$24,293**	**$0**	**$2,207**	**$0**	
Andersen 200 Series	0.34	0.30	$14,761	($9,532)	$2,198	($9)	NA
Marvin Integrity Wood Ultrex Series	0.34	0.32	$24,000	($293)	$2,179	($28)	NA
Marvin Clad Ultimate Series	0.34	0.30	$33,191	$8,898	$2,198	($9)	989
Marvin Clad Ultimate Tri-pane Series	0.25	0.38	$48,911	$24,618	$1,999	($208)	118
Harvey Tribute Series	0.33	0.32	$9,268	($15,025)	$2,169	($38)	NA
Harvey Triple Glazed Tribute Series	0.20	0.19	$11,106	($13,187)	$2,046	($161)	NA
Pella ProLine Series	0.33	0.30	$14,500	($9,793)	$2,193	($14)	NA
Pella Designer Series (DG+int. storm)	0.28	0.28	$30,500	$6,207	$2,111	($96)	65
Pella Architect Series	0.34	0.32	$31,500	$7,207	$2,179	($28)	257
ThermaProof 725 Series Low SHGC	0.20	0.22	$32,440	$8,147	$2,027	($180)	45
ThermaProof 725 Series High SHGC	0.20	0.44	$32,440	$8,147	$1,884	($323)	25

1.3.2.2. Mechanical System Design

Table 1.8 (below) summarizes the mechanical systems used by this project.

Table 1.8: Mechanical system specifications

MECHANICAL SYSTEMS	SPECIFICATIONS
Heating	
Description -	98% AFUE modulating gas furnace with ECM motor
Manufacturer & Model -	York YP9C060B12MP11 or Coleman CP9C060B12MP11
Cooling (outdoor unit)	
Description -	14 SEER heat pump split system w/ hybrid heat
Manufacturer & Model -	Carrier 24ABA430A31 14 SEER 2.5 ton
Cooling (indoor unit)	
Description -	2.5 ton matched coil to outdoor unit
Manufacturer & Model -	None specified
Domestic Hot Water	
Description -	Navien instantaneous gas water heater, 199 kBtu/hr, 0.98 EF
Manufacturer & Model -	Navien 98% CR240-A
Distribution	
Description -	2 zone sheet metal trunk and runouts in conditioned space
Leakage -	None to outside (5% or less)
Ventilation	
Description -	Heat recovery ventilator (HRV) balanced ventilation system
Manufacturer & Model -	Fantech VHR1404
Return Pathways	
Description -	Transfer grilles at bedrooms, returns on first and second floor and in master bedroom
Dehumidification	
Description -	None installed
Manufacturer & Model -	
PV System	

MECHANICAL SYSTEMS	SPECIFICATIONS
Description -	5.75 kW array
Manufacturer & Model -	None specified
Solar Hot Water	
Description -	None installed
Manufacturer & Model -	

For an in-depth discussion of the mechanical options and an explanation for specifying and designing a two zone mechanical system for the Foulds Residence, please see the following two files in the Appendix of this report:

- 2009-01-09 Foulds Residence Parametric Analysis
- 2009-01-23 Foulds Residence Two Zone

1.3.2.3. Lighting and Miscellaneous Electrical Loads

All compact fluorescent lighting and ENERGY STAR appliances were specified for the Foulds Residence. If installed as specified, these will contribute greatly to the increased energy performance of the house at 7.2% and 3.8% respectively.

1.3.2.4. Site-generated Renewable Energy

The Foulds Residence will have a 5.75 kW PV array installed on the south facing roof. This array is predicted to provide 93% of the home's annual electricity need. The builder is currently negotiating the cost of the system; it will be reported on in the 2010 annual report for this home.

1.4 Construction Support

1.4.1. Construction Overview

With BSC's office in close proximity to the Foulds Residence site, the project team frequently visits the site to monitor construction, review the durability checklist and construction schedule and answer any questions the builder may have. See the images below for an array of construction milestones and implemented high performance details.

More photos can be found on the project's photo blog at the following web address:

www.concordcape.posterous.com.

Figure 1.4.1: Applying capillary break on top of footings

Figure 1.4.2: Foundation wall dampproofing

Figure 1.4.3: Capillary break on top of foundation wall and under sill plate

Figure 1.4.4: 2" XPS turned up foundation wall between wall and concrete slab

Figure 1.4.5: Two stud corner

Figure 1.4.6: Rigid insulation between 2x6 window headers

1.4.2. Educational Events and Training

The project team plans to have open houses with the homeowner and builder to educate the community on high performance houses.

1.4.3. Systems Testing

When complete, the project team will perform the standard battery of performance testing, including overall air infiltration (blower door), duct leakage (total and to exterior), HVAC system static pressure and overall flow, HVAC register flows, room pressurization, and ventilation system flows.

1.4.4. Monitoring

The project team is planning on collecting monthly gas and electricity bills for the Foulds Residence for roughly a year, at a minimum. We will then compare these results to predictions from the energy models, and if possible, disaggregate heating loads for a further comparison with the model. We may also administer the previously-developed homeowner survey, for a complete battery of data. The local location and close relationship with the homeowner also lend themselves to other short-term energy testing experiments.

1.5 Project Evaluation

The following sections evaluate the research project results based on the ability to integrate advanced systems with production building practices in prototype homes. References are made to the results from field tests and energy simulations, which are included as an appendix to this report.

1.5.1. 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***

With the enclosure and mechanical characteristics presented in Table 1.6 and Table 1.8, this plan achieves a performance level of 81.8% reduction relative to the Building America Benchmark.

1.5.2. Prescriptive-based Code Approval

Requirement:	*Must meet prescriptive or performance safety, health and building code requirements for new homes.*
Conclusion:	***Pass***

The Foulds Residence was designed and constructed to meet the Seventh Edition of the Massachusetts One-and Two-Family Dwelling Code, which is based on the 2003 ICC International Residential Code. The home also meets all requirements set forth by the Town of Concord's Zoning Bylaws.

In addition, this design exceeds the IECC 2006 Section 404 Compliance (adopted by Massachusetts effective October 6, 2008) by over 50%.

1.5.3. Quality Control Requirements

Requirement:	*Must define critical design details, construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors.*
Conclusion:	***Pass***

A Durability Checklist was developed during design and implemented during the construction process, in order to ensure that critical design details would be implemented, that design intent would be carried out through construction as well as that the finished home would be one that is healthy, durable and energy efficient. Items on the Durability Checklist such as managing both interior and exterior water sources, identifying and creating an interior air barrier as well as preventing pests from entering the home were verified by team members while on site visits and will also be checked by a third party verifier as part of the USGBC's LEED for Homes certification process.

Site visit reports were completed after each site visit and distributed to the project team to ensure team members were aware of the current phase of construction and could prepare for future construction events.

In addition to creating the Durability Checklist and preparing Site Visit Reports, a Homeowner's Manual will be developed to ensure the home will operate as intended. The manual will describe key operational and maintenance measures, describe the lighting and appliances in the home, as well as include the makes and models of all the appliances. The Durability Checklist and Site Visit Reports are included in the Appendix of this report.

1.5.4. Neutral Cost Target

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

The Foulds Residence achieves a positive cost target with respect to annual mortgage payments. This means that the annual energy savings is higher than the additional annual amortized mortgage cost.

See The Neutral Cost Analysis Worksheet below. The house is expected to save $371 a year compared to the additional amortized mortgage payments. The mortgage is assumed to be a 30 year plan at a rate of 7%.

Table 1.9: Foulds Residence Neutral Cost Analysis

	Annual Electric Energy (Site)			Annual Gas Energy (Site)			
	Benchmark	Builder Standard Practice (Optional)	Prototype House	Benchmark	Builder Standard Practice (Optional)	Prototype House	Annual Utility Bill Reduction vs Benchmark
End Use	**(kWh/yr)**	**(kWh/yr)**	**(kWh/yr)**	**(therms/yr)**	**(therms/yr)**	**(therms/yr)**	**($/yr)**
Space Heating	1003		475	1290		380	$1,651
Space Cooling	2814		975	975		0	$1,998
DHW	0		0	275		106	$289
Lighting	4281		1376	0		0	$523
Appliances and MELs	5853		5207	116		80	$178
Ventilation	0		0	0		0	$0
Total Usage	**13951**	**0**	**8033**	**2656**	**0**	**566**	**$4,639**
Site Generation	0	0	7902	0		0	$1,422
Net Energy Use	**13951**	**0**	**131**	**2656**	**0**	**566**	**$6,062**
Added Annual Mortgage Cost w/o Site Gen.							**$2,863**
Net Cash Flow to Consumer w/o Site Gen.							**$1,776**
Added Annual Mortgage Cost with Site Gen.							**$5,691**
Net Cash Flow to Consumer with Site Gen.							**$371**

1.5.5. Quality Control Integration

Requirement:	*Health, Safety, Durability, Comfort, and Energy related QA, QC, training, and commissioning requirements should be integrated within construction documents, contracts and BA team scopes of work.*
Conclusion:	***Pass***

The Foulds Residence contract documents have critical construction details included that ensure the home's health, safety, durability, comfort and energy-efficiency. Below are examples of details included in the drawing set:

- Framing plans integrated with the mechanical layout to identify critical locations where different building trades need to coordinate
- Framing plans integrated with the plumbing layout to identify critical locations where different building trades need to coordinate
- Wall framing elevations identifying stud spacing, headers and number of jack and king studs at windows and doors
- Advanced framing and air sealing details identifying responsibilities of different trades
- Threaded rod hold-down details for corners of house
- Window and door details and installation sequences describing how to install windows and doors with 4" of rigid insulation on the outside of the house
- Wall sections calling out code backfill requirements for the perimeter of the house; this is critical since the house is being built in an area with a high water table
- Window and door schedules and specifications
- Duct sealing details
- Electrical box air sealing details

1.5.6. Gaps Analysis

Requirement:	*Should include prototype house gaps analysis, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level.*
Conclusion:	***Pass***

Though the Foulds Residence is still under construction, a few issues have been identified that have either been resolved in the field or will need further research and design to resolve for future projects.

- **Headers Over Multiple Windows:** Due to the frequency of leaks occurring in factory mulled windows, the project team decided to separate a series of windows (i.e. 2 or 3 in a row) with (2) 2x4s running from the bottom plate to the top plate. This allowed the use of individual plywood boxes for the installation of the windows in 4” of foam. However, the builder did not install a 2x6 on the flat that was designed to use for trim attachment. Rather, they added a 2x6 in the same plane as the headers, leaving only a 1” gap between headers and trim board to install rigid insulation. See Figure 1.5.1 and Figure 1.5.2 below. This issue will need to be researched further in the building code to find an appropriate solution that balances the aesthetics of multiple windows with both the structural requirements for window supports and the desired insulation levels.

Figure 1.5.1: Double header and trim board limit insulation over window

Figure 1.5.2: 2x4s extend from floor to ceiling, 2x6 sill provides continuous sill for all 3 windows

- **High Water Table:** During the design process, the homeowner discovered that the site had a high water table and requested the house be elevated 3‘+ in order to keep the bottom of the foundation out of the water table. This high water table prompted the project team to look more thoroughly into the issue and found there are structural implications for building in an area with a high water table. The drawings were modified to indicate the 3’+ and an appropriate free draining backfill as characterized by the Uniform Soil Classifications.

- **Triple-Glazed Windows:** Though the project team encouraged the homeowner to use high performance triple-glazed windows in the home, we had a difficult time acquiring lower cost high performance window samples in order to show the homeowner. In the end, the homeowner chose an expensive window that met his aesthetic requirements and our specifications. We have since received the requested window samples and would encourage the use of these windows in future projects.

1.6 Conclusions/Remarks

The Foulds Residence, when completed, will be an example of a high performance custom home in a cold climate. The design and specifications combined the aesthetic desires of the homeowner with the performance specifications set by the design team.

Throughout the rest of the construction process, the design team will visit the site to ensure critical details are implemented and later test the house to ensure the house performs as designed and the homeowner can move into a comfortable, durable and energy-efficient home.

1.7 Appendices

1.7.1. 2009-01-09 Foulds Residence Parametric Analysis

1.7.2. 2009-01-23 Foulds Residence Two Zone

1.7.3. 2009-01-26 Foulds Residence Window Comparison

1.7.4. 2009-03-10 Foulds Residence SK-01

1.7.5. 2009-03-10 Foulds Residence SK-02

1.7.6. 2009-05-22 Foulds Residence Durability Checklist

1.7.7. 2009-06-03 Foulds Residence Details

1.7.8. 2009-07-17 Foulds Residence 3D Images

1.7.9. 2009-09-02 Foulds Residence SK-03

1.7.10. 2009-10-21 Foulds Residence Site Visit Reports

Appendix D.1.7.1
2009-01-09 Foulds Residence Parametric Analysis

From:	Kohta Ueno, Building Science Corporation	Date:	January 9, 2009
To:	Brian Foulds Betsy Pettit, Katie Gunsch, Ken Neuhauser, Daniel Bergey, Building Science Corporation	Re:	Foulds Residence Parametric Energy Studies

The following memo covers the parametric analysis that BSC has done on some "tuning" of the energy features on the Foulds Residence, including some analysis on the relative cost effectiveness of these various measures, in terms of energy savings per dollar spent. Note that this is not a "full" parametric (i.e., from Benchmark to Prototype); it is a study of the specific items of interest that are at a decision point.

The final section of this report is a "decision list"—items that we should discuss and come to a decision on relatively soon, in order to allow further progress and development.

I believe that we will discuss these items in a conference call to be scheduled sometime for early next week.

Any questions can be directed to me or to Daniel Bergey, who was principally involved in running the energy simulations.

Thank you,

Kohta Ueno

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Assumptions and Approach

The analysis approach we took here was to start with a “baseline” building, which includes most of the improvements that we have already agreed upon. However, it does not include **all** of the planned upgrades, by any means; the characteristics are shown in Table 1 below.

Table 1: Characteristics of "baseline" residence

Building envelope	
Ceiling	R-60 loose fill vented attic insulation at ceiling level
Walls	R-19 2x6 OVE frame w. R-26 4" polyiso (x2 2" layers)
Foundation	Basement R-26 walls
	2" (R-10) XPS under basement slab floor
Windows	U=0.34, SHGC=0.29 (Andersen 400 Series)
Infiltration	2.5 sq in leakage area per 100 sf envelope
	2037 CFM 50 (2.8 ACH 50)
Mechanical systems	
Heat	96% AFUE gas furnace with ECM motor
Cooling	14 SEER air conditioner split system
DHW	0.54 EF conventional gas tank water heater
Ducts	Sheet metal trunk and runouts in conditioned space
Leakage	none to outside (5% or less)
Appliances	Conventional/standard efficiency
Ventilation	Central fan integrated ventilation system with motorized damper and FR-V controls (or equal)
	33% Duty Cycle: 10 minutes on; 20 minutes off

Then, we added and upgraded items in the building enclosure and mechanical system one by one, and examined their impacts. However, this was not done as a “straight through” linear procedure—some of them were “side branches” that were not continued in the main path. An overview of the items is shown in a flowchart in Figure 1 below.

The “side branches” are the windows (triple glazed units), and solar domestic hot water systems. Also note that the triple glazed windows are examined twice: once at Steps 13/14, and then later, at Step 21, before the addition of photovoltaics. Since many previous discussions had dismissed the use of triple glazed windows, we wanted to allow some comparisons and analysis of additional steps, without these windows.

The table listing the improvements will be presented several times; this is done to reduce the volume of information shown at a given time, reducing “clutter” in the tables.

- Economic-dominated analysis
- Energy-dominated analysis

The complete table is shown at the end of the report (Table 5).

In all of these tables, where the flowchart has branches, there is an added blank line, to indicate this break in flow.

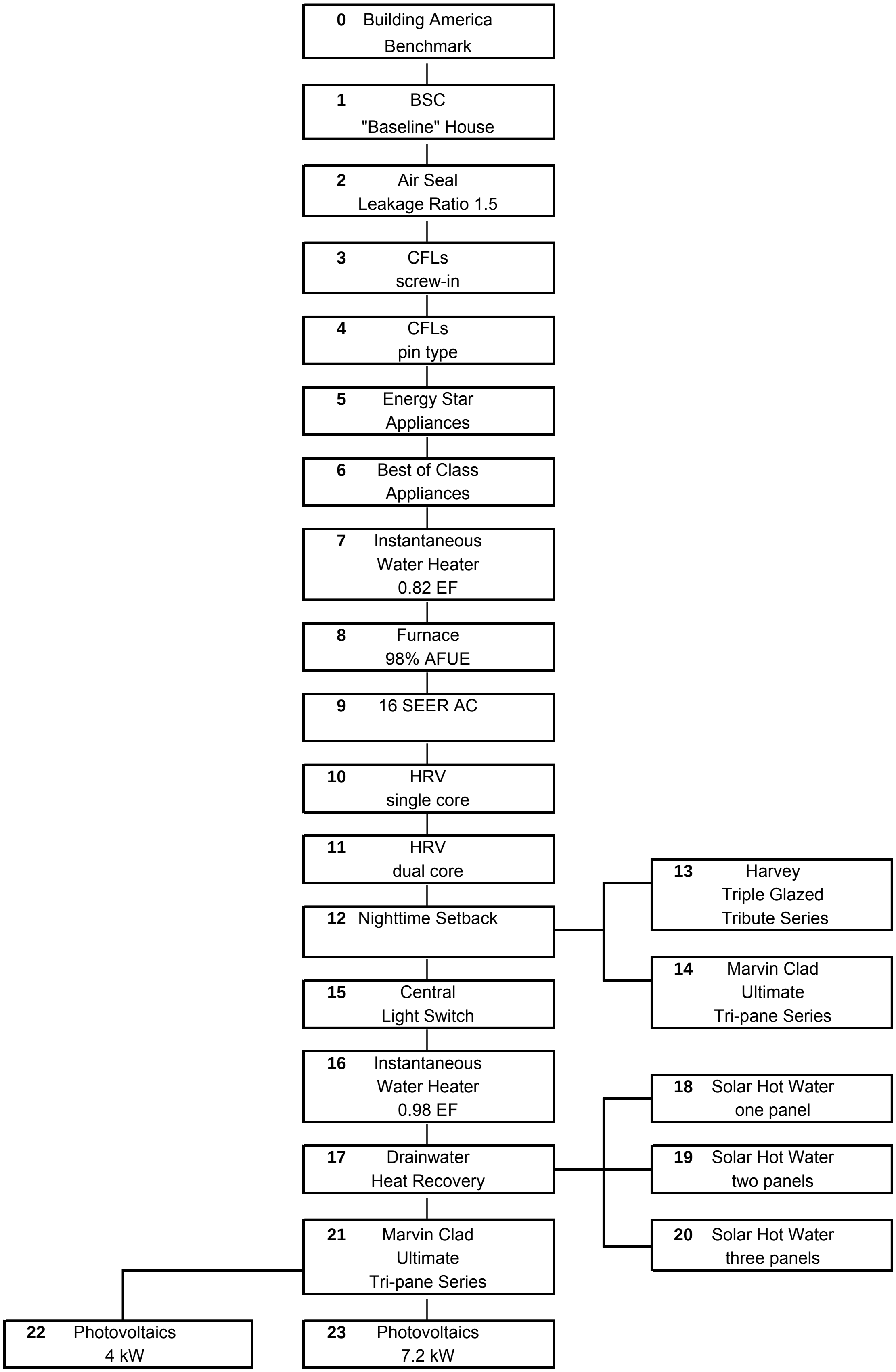


Figure 1: Flowchart for parametric improvements

Economic Evaluation

Basic Analysis

The economic analysis presented here has several additional parameters beyond what is given in our typical analysis. Note that this is not intended to be a complete life-cycle analysis, or include the escalation of fuel rates. However, it does go into more detail than previous simple payback calculations.

Column headings shown on previous analysis included:

- Estimated individual cost: an estimate of the upgrade cost associated with this measure (dollars)
- Item savings: the annual energy saving resulting from this upgrade (dollars/year)
- Increment payback: simple payback; the number of years required (at fixed energy costs, and not accounting for inflation or loan costs) to pay back the cost of the energy improvement measure (years)

But this analysis includes these additional items:

- Savings: the source energy savings resulting from this upgrade (million Btu/year)
- $\$/10^6$ Btu: dollars per million Btu saved per year. This column basically gives the "cost" a unit of energy savings—the lower the number, the more cost effective the measure is. Note that this is stated in terms of source energy (i.e., electricity at 3x energy cost metered at site) (dollars/million Btu/year)

Table 2: Parametric simulations: basic economic analysis

Parametric Run ID	Description of change	Estimated Individual Cost	Annual energy cost	Item Savings	Increment payback (yr)	Savings [10^6 Btu / yr]	\$ per 10^6 Btu Saved (1 yr)
0	Benchmark		$5,017				
1	Baseline	$13,000	$3,201	$1,816	7	92.3	$141
2	1 + Air Seal (1.5 Leakage Ratio)	$2,500	$2,952	$249	10	12.6	$199
3	2 + CFLs (screw-in)	$275	$2,820	$132	2	17.7	$16
4	3 + CFLs (pin type)	$0	$2,799	$20	0	2.9	$0
5	4 + EnergyStar Appliances	$700	$2,647	$152	5	9.7	$73
6	5 + Best in Class Appliances	$600	$2,629	$19	32	1.9	$321
7	6 + 0.82 EF Instantan. Water Heater	$700	$2,466	$163	4	8.1	$87
8	7 + 98% AFUE Furnace	$800	$2,444	$22	36	1.1	$725
9	8 + 16 SEER AC	$250	$2,438	$6	40	0.6	$403
10	9 + HRV (single core)	$1,000	$2,364	$74	13	11.5	$87
11	10 + HRV (dual core)	$500	$2,334	$29	17	1.3	$390
12	11 + Nighttime Setback	$100	$2,234	$100	1	5.2	$19
13	12 + Harvey Triple Glazed Tribute	($13,187)	$2,084	$150	-88	8.3	-$1,593
14	12 + Marvin Clad Ultimate Tri-pane	$24,618	$2,001	$234	**105**	11.4	**$2,159**
15	12 + Master Light Switch	$750	$2,232	$2	**426**	0.2	**$4,253**
16	15 + 0.98 EF Instantan. Water Heater	$1,000	$2,180	$53	19	2.6	$382
17	16 + Drainwater Heat Recovery	$650	$2,138	$42	16	2.1	$313

Parametric Run ID	Description of change	Estimated Individual Cost	Annual energy cost	Item Savings	Increment payback (yr)	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 yr)
18	17 + Solar Hot Water (one panel)	$6,325	$2,021	$117	**54**	5.8	**$1,083**
19	17 + Solar Hot Water (two panels)	$7,450	$1,982	$156	48	7.8	$961
20	17 + Solar Hot Water (three panels)	$8,530	$1,962	$176	48	8.7	$976
21	17 + Marvin Clad Ultimate Tri-pane	$24,618	$1,906	$232	**106**	11.3	**$2,187**
22	21 + Photovoltaics (4 kW)	$28,000	$1,323	$582	48	58.3	$480
23	21 + Photovoltaics (7.2 kW)	$40,500	$852	$1,053	38	105.5	$384

The main column we will be looking at here is the "dollars per million Btu saved per year"—as we stated above, it covers the cost of the "buying" a given unit of energy savings. Although it presents information similar to the simple payback, it eliminates energy costs as an additional variable. Energy costs, of course, can vary between locations and over time.

Note that some of the numbers in the latter columns are shown in orange. **These cells are highlighted to show that their financial advantage (simple payback or $/million Btu/year) is worse than the 4 kW of photovoltaic system (if the price is reduced by government subsidies).**

Measure-by-Measure Description

The upgrades can be described as follows:

1. Baseline House: this is a combination of all the previous measures shown in Table 1, including the basic air sealing, 4" of polyisocyanurate foam on the exterior of the house, and good mechanical systems. It also gives us a baseline feel of what the previous measures represent, in terms of this "cost effectiveness" metric ($/million Btu/year)

2. Air Seal (1.5 Leakage Ratio): increasing airtightness beyond BSC's typical standard of 2.5 square inches/100 square feet surface area to 1.5 results in a substantial improvement in energy performance, given the heating-dominated loads in this climate. However, airtightness of this level will require particular care in construction and detailing: we have achieved this in previous projects, but it is by no means a "given" unless special measures are taken.

3. CFLs (screw-in): this measure replaces all incandescent lighting with screw-base compact fluorescent light bulbs. It is one of the more cost-effective measures in the table above.

4. CFLs (pin type): pin-base compact fluorescent lights have a higher efficacy (light produced per unit energy, or lumens/watt) than screw-base CFLs. This is due to the higher quality of the ballast (transformer) in these lamps: it is a part of the lighting fixture, not the bulb, so it is not disposed at the end of the lamp (i.e,. glass bulb component) lifetime. Based on our research, it appears that this is simply a shopping exercise (for lights that use a pin-base bulb); the costs of these fixtures do not appear to be consistently higher than screw-base fixtures. Instead, it appears that aesthetic design has a much larger influence on price. Also note that tube-based lighting fixtures (including circle-line) have similar levels of efficacy.

   Another quick item to note: although GU24-base fixtures are nominally pin-based, they are a workaround to avoid California regulations (requiring pin-base CFLs); they are the same basic technology as screw-base lamps, and have similar efficacy levels. Therefore, when choosing fixtures, GU24 are to be avoided, if pin-base efficiency levels are needed.

5. Energy Star Appliances: this measure switches from conventional appliances to basic appliances that meet Energy Star requirements. Note that this results in reductions of both electricity consumption, and use of hot water (i.e., dishwasher and washing machine).
6. Best in Class Appliances: this measure goes further, to find "best in class" appliances, which will be sold at a price premium, but with better performance.
7. 0.82 EF Instantaneous Water Heater: this appliance has been discussed previously; it is a substantial efficiency upgrade from the conventional gas-fired tank water heater. Note that one of our current recommendations with instantaneous units is to add an electronic water conditioner (roughly $150-200 materials cost), which will reduce scale buildup in this unit and increase its lifespan. BSC's research has shown that this water conditioner can actually reduce existing scale that has accumulated in the piping.
8. 98% AFUE Furnace: this upgrade is a slight increase in efficiency (from 96% AFUE); it is also a furnace with an ECM motor, but adds modulation to the burner firing rate (from 35% to 100%, typical). This should result in an increase in comfort, as the airflow rate matches the firing rate, resulting in a near-constant air delivery temperature. The furnace will also operate at a lower rate for longer periods, resulting in less short-cycling of the system, and temperature variations from setpoint. In other words, in warmer weather, it "acts" like a smaller furnace, instead of an oversized unit for the worst day. In addition, bringing the airflow rate down to its minimum reduces blower fan electricity use (disproportionately to the speed reduction—a 1/3 reduction in fan speed results in a **2/3** reduction in fan power). Unfortunately, this reduction in fan energy use is not reflected in our models.
9. 16 SEER AC: this upgrade improves the efficiency of the cooling system from 14 SEER to 16 SEER. Note that in both cases (14/16), we are assuming a system that uses R-410a refrigerant (as opposed to R-22, the more ozone-depleting refrigerant that is currently being phased out by the EPA); this minimizes the price difference between 14 and 16 SEER. The cost difference between an R-22 and R-410a is at least $100.
10. HRV (single core): this measure upgrades the ventilation system from the central fan integrated system to a heat recovery ventilator (i.e., ventilation system with a heat exchanger), with an efficiency of roughly 70% heat recovery (typical range for commonly available products).
11. HRV (dual core): this upgrade changes to a higher-efficiency (~90%) heat recovery HRV; it is achieved by using two heat exchanger cores. Although greater heat is recovered, increased fan power is needed; however, the net result is an improvement.
12. Nighttime Setback: the use of a setback thermostat is an extremely effective (overall energy savings) and cost effective (payback, etc.) measure, assuming that the thermostat is used. The models used here show a wintertime setpoint of 71° F (daytime) and 66° F (nighttime for 8 hours/day). Of course, greater setbacks will result in greater savings (but up to a limit; recovery from deep setbacks may prove to be an annoyance to occupants).
13. Harvey Triple Glazed Tribute Series: this measure is the replacement of the Andersen 400 double-glazed, low-E, argon-filled windows with vinyl frame triple-glazed, low-E, argon-filled windows (U=0.20, SHGC=0.19). **This is shown as a "negative cost:" these windows are less expensive than the Andersen 400 Series windows**. This results in some odd results in our calculations: it is a measure that saves first cost, and saves energy, resulting in a "negative payback," and negative $/million Btu/year. Overall, these numbers are not terribly useful to compare to other figures.

14. Marvin Clad Ultimate Tri-pane Series: this is a triple glazed window (U=0.25, SHGC=0.38) that is considered more aesthetically acceptable; it also has a higher solar heat gain coefficient, which is better for "harvesting" wintertime solar heat through the windows. However, this must be approached with caution, as covered in "Window Solar Gain and Comfort" below. Furthermore, note that this upgrade cost is not purely attributed to the energy side; much of the Marvin cost is due to quality, instead.
15. Master Light Switch: this measure was discussed in our previous meeting; it would involve the addition of a subpanel for all lighting loads in the house (except outdoor lighting) that is controlled by a switch located near the most often-used entrance (e.g., garage door). The savings associated with this item are entirely a function of how much lighting is left on typically when leaving the house; however, based on our quick analysis, it is difficult to imagine that it is substantially higher than 2% of overall lighting use. This results in a very low energy savings; when combined with its high implementation cost (~$750) results in poor economic performance.
16. 0.98 EF Instantaneous Water Heater: this upgrades the instantaneous (tankless) water heater to a unit that has a higher rated efficiency. However, there are secondary reasons to justify this unit, as well. A version of this unit is available with a built-in "buffer tank"—this (a) prevents the "cold slug" problem discussed at our meetings, and (b) is completely compatible with a demand-based recirculation system. Furthermore, (c) our analysis shows that this unit is compatible with drainwater heat recovery (item 17), while the previous 0.82 EF unit will not provide acceptable results.
17. Drainwater Heat Recovery: this was another item discussed in our meetings ("GFX" or "Powerpipe" systems); incoming hot water is preheated by recovering the shower drainwater heat. Note that it only is effective during concurrent draws and drains, such as showers; it does not recover substantial heat for "batch" drainage (e.g., bathtubs, dishwashers, washing machines). Note that this system is compatible with the more expensive instantaneous hot water heater above (0.98 EF), but not the less expensive models (0.82 EF), due to the "turndown ratio" (minimum firing rate).
18. Solar Hot Water (one panel system): this represents a single-panel solar hot water system, including the Federal tax credits of $2000 (30% of cost of system up to $2000).
19. Solar Hot Water (two panel system): a two panel system; note that each **added** panel has a diminishing return on overall energy reduction: going from $117/year for the first panel, to $39/year for the next added panel
20. Solar Hot Water (three panel system): three panel system; similarly has diminishing returns ($20/year).
21. Photovoltaics (4 kW): this assumes a system cost of $7 per installed peak watt; it is meant to represent $10/installed watt with a 30% rebate.
22. Photovoltaics (3.2 kW additional): this adds 3.2 kW in addition to the previous 4 kW system, for a total of 7.2 kW (the estimated system size for the total roof area). A larger system will have a slightly lower per watt installed cost; we estimated this at $5.60 per installed peak watt ($8 with 30% rebate).

Basic Analysis Conclusions

One way to look at Table 2 is to "cull the herd" by finding the worse performing measures. The worst four performers in terms of $/million Btu/year are (shown in bold in the table above):

- Master Light Switch
- Marvin Tri-Pane windows (twice)

- Solar hot water (one panel system)

It is noted that this is identical to the worst performers in terms of the simple payback (although this is a metric we are trying to stop using). This list provides some items that appear to be the worst performers; however, those items change in the section below.

Extended Analysis (Lifetime)

One way to increase the realism of this exercise is to extend this economic analysis to include the rough lifetime of these measures, to give their dollars per unit energy savings over their lifetimes. Table 3 below adds the following columns to the previous analysis:

- Estimated lifetime: rough lifetime of the measure, at least until replacement or a repair that is a substantial fraction of the installation cost (years)
- $ per 10^6 Btu Saved (lifetime): this figure divides the "cost effectiveness" metric ($/million Btu/year) by lifetime (years), in order to obtain **$/million Btu saved over the lifetime of the item**. It is also equivalent to [the cost of the upgrade ($)] ÷ [annual energy savings (million Btu/year) × the lifespan of the measure (years)].

We believe this analysis, by taking into account the lifetime of the measure, is a much more realistic economic assessment than the previous measures—especially when taken from the point of view of a long-term homeowner/homebuyer (as opposed to a builder, maximizing "bang for buck" for labeled energy performance/HERS Index). Also, from a global perspective, this metric is far more relevant to optimizing energy use.

Table 3 below shows two of the previous columns (in grey), with the new columns of lifetime (years), and $ per 10^6 Btu Saved.

Table 3: Parametric simulations: extended economic analysis (grey columns repeated from previous)

Parametric Run ID	Description of change	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	$ per 10^6 Btu Saved (Lifetime)
0	Benchmark				
1	Baseline	92.3	$141		
2	1 + Air Seal (1.5 Leakage Ratio)	12.6	$199	75	$2.65
3	2 + CFLs (screw-in)	17.7	$16	5	$3.10
4	3 + CFLs (pin type)	2.9	$0	15	$0.00
5	4 + EnergyStar Appliances	9.7	$73	15	$4.84
6	5 + Best in Class Appliances	1.9	$321	15	$21.37
7	6 + 0.82 EF Instantan. Water Heater	8.1	$87	20	$4.33
8	7 + 98% AFUE Furnace	1.1	$725	20	$36.25
9	8 + 16 SEER AC	0.6	$403	20	$20.16
10	9 + HRV (single core)	11.5	$87	15	$5.78
11	10 + HRV (dual core)	1.3	$390	15	$26.00
12	11 + Nighttime Setback	5.2	$19	20	$0.96
13	12 + Harvey Triple Glazed Tribute	8.3	-$1,593	50	-$31.85
14	12 + Marvin Clad Ultimate Tri-pane	11.4	$2,159	50	**$43.18**
15	12 + Master Light Switch	0.2	$4,253	75	**$56.70**
16	15 + 0.98 EF Instantan. Water Heater	2.6	$382	20	$19.08
17	16 + Drainwater Heat Recovery	2.1	$313	75	$4.18

Parametric Run ID	Description of change	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	$ per 10^6 Btu Saved (Lifetime)
18	17 + Solar Hot Water (one panel)	5.8	$1,083	20	**$54.14**
19	17 + Solar Hot Water (two panels)	7.8	$961	20	**$48.04**
20	17 + Solar Hot Water (three panels)	8.7	$976	20	**$48.82**
21	17 + Marvin Clad Ultimate Tri-pane	11.3	$2,187	50	**$43.75**
22	21 + Photovoltaics (4 kW)	58.3	$480	30	$16.00
23	21 + Photovoltaics (7.2 kW)	105.5	$384	30	$12.79

Although the lifetimes can be argued and fine-tuned, they are a reasonable starting point for this discussion. When examined for the worst performers ("culling the herd"), the lowest items (shown in bold in the table above) are:

- Master light switch
- Solar hot water (one, two, and three panel systems)
- Marvin Tri-Pane windows (twice)

Note that the triple-glazed Marvin windows are much more advantageous in this analysis (assuming a lifespan of 50 years). In fact, they pencil in as a lightly better option than the solar hot water system. Of course, this analysis is very sensitive to lifespan—for instance, if the lifespan of the Marvin windows were only 40 years, instead of 50 years, they would be at $54.69 per 10^6 Btu saved (lifetime)—comparable to the solar hot water system.

Overall Energy Performance

This section shows the same list of measures, but with an emphasis on the overall energy numbers instead. Table 4 shows % improvement vs. Building America Benchmark, incremental/item improvement over Benchmark, annual dollar savings, $/million Btu/year, and HERS Index.

Table 4: Parametric simulations: energy performance

Parametric Run ID	Description of change	Incremental Over Bmrk	Item Savings	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	HERS Score
0	Benchmark					
1	Baseline	29.6%	$1,816	92.3	$141	
2	1 + Air Seal (1.5 Leakage Ratio)	**4.0%**	$249	12.6	$199	64
3	2 + CFLs (screw-in)	**5.7%**	$132	17.7	$16	61
4	3 + CFLs (pin type)	0.9%	$20	2.9	$0	61
5	4 + EnergyStar Appliances	3.1%	$152	9.7	$73	60
6	5 + Best in Class Appliances	0.6%	$19	1.9	$321	60
7	6 + 0.82 EF Instantan. Water Heater	2.6%	$163	8.1	$87	51
8	7 + 98% AFUE Furnace	0.4%	$22	1.1	$725	50
9	8 + 16 SEER AC	0.2%	$6	0.6	$403	50
10	9 + HRV (single core)	**3.7%**	$74	11.5	$87	50
11	10 + HRV (dual core)	0.4%	$29	1.3	$390	50
12	11 + Nighttime Setback	1.7%	$100	5.2	$19	50
13	12 + Harvey Triple Glazed Tribute	2.7%	$150	8.3	-$1,593	47
14	12 + Marvin Clad Ultimate Tri-pane	**3.7%**	$234	11.4	$2,159	45

Parametric Run ID	Description of change	Incremental Over Bmrk	Item Savings	Savings [10^6 Btu / yr]	\$ per 10^6 Btu Saved (1 year)	HERS Score
15	12 + Master Light Switch	0.1%	\$2	0.2	\$4,253	50
16	15 + 0.98 EF Instantan. Water Heater	0.8%	\$53	2.6	\$382	47
17	16 + Drainwater Heat Recovery	0.7%	\$42	2.1	\$313	47
18	17 + Solar Hot Water (one panel)	1.9%	\$117	5.8	\$1,083	46
19	17 + Solar Hot Water (two panels)	2.5%	\$156	7.8	\$961	46
20	17 + Solar Hot Water (three panels)	2.8%	\$176	8.7	\$976	45
21	17 + Marvin Clad Ultimate Tri-pane	**3.6%**	\$232	11.3	\$2,187	43
22	21 + Photovoltaics (4 kW)	**18.7%**	\$582	58.3	\$480	26
23	21 + Photovoltaics (7.2 kW)	**33.9%**	\$1,053	105.5	\$384	14

The highest performers (both in terms of item % source energy savings and HERS Index points) are shown in **red bold** in the table. In rough order, they are:

- 7.2 kW photovoltaic system (33.9%)
- 4 kW photovoltaic system (18.7%)
- Compact fluorescent lights (screw base 5.7%; pin base is additive on top, so would be a total of 6.6%)
- Heat recovery ventilator (single core) (3.7%)
- Marvin triple glazed windows (3.7%)
- Air leakage reduction (to 1.5 square inches per 100 sf) (4.0%)

Note that the solar hot water systems are not included in this list. Part of this is due to the fact that we have substantially reduced domestic hot water energy use by other means already, including a 0.98 EF water heater, Energy Star appliances, and drainwater heat recovery. By reducing the overall “size of the pie,” the “slice of the pie” associated with the solar hot water system is reduced.

Overall, the only item really being debated here are the triple glazed windows. We have said this before, but it is a huge bump in overall energy performance, but the costs are what cause our hesitation. But in terms of overall energy impact, the effect of improving the glazing is difficult to ignore.

We have contacted another manufacturer of triple glazed or better windows (ThermaProof); it is unclear whether or not they are capable of manufacturing product compatible with our construction schedule, and/or what their price point is. But it seems quite possible that they might have windows with equal or better performance, perhaps at a comparable or even lower price. However, availability and price will dominate this decision. Their products have pultruded fiberglass frames (same material as Marvin Integrity frames); wood interior finishes are available as an option.

Note, of course, that the HERS Index provides the number of LEED-H points, as shown in Figure 2 below. We are in Climate Zone 5 (upper curve).

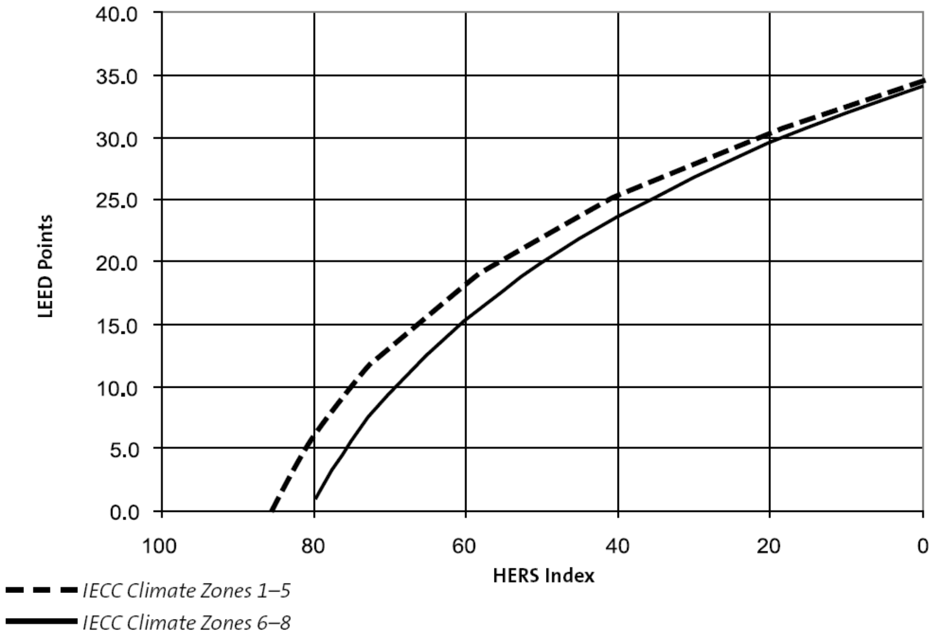


Figure 2: HERS Index Values and LEED Points

Lighting, Plug, and “Phantom” Load Management

We discussed non-appliance electrical loads in our previous meetings, including lighting, plug/miscellaneous end use loads, and “phantom” or “vampire” loads (continuous loads from electrical appliances in “off” or “standby” mode).

Lighting

Based on previous analysis, it does not appear that the “master light switch” is a reasonable solution, unless there is a non-energy or non-financial reason to specify this measure.

We also looked into the number of light fixtures shown in the current lighting plan, with a grid of many recessed “can” fixtures. The energy consumption of this lighting is entirely a function of occupant operation. However, it seems quite possible that having many lights ganged together will increase the overall lighting levels beyond what is truly appropriate. Multiple switches and dimmable fixtures would reduce the extent of “overlighting,” if operated reasonably. However, reducing the overall number of fixtures is another avenue to consider. BSC is looking into relevant lighting levels, and will provide recommendations of fixture density based on those figures.

“Phantom” Loads

As for “phantom” or “vampire” loads, we looked into some hard-wired measures as options. For instance, a switched outlet could be specified where an entertainment center or a computer workstation is likely to be installed; we would estimate the costs at on the order of $100.

However, we discovered was that hard wiring is both more costly and less flexible than some other measures, such as “smart” power strips, shown below in Figure 3 and Figure 4. The SmartStrip (Figure 3) controls multiple outlets based on whether a “master” outlet is drawing power. So, for instance, a television can be connected to the “master,” and the ancillary devices (VCR, cable box) can be connected to the controlled outlets. The power strip has “always on” outlets as well (e.g., for a TiVO/PVR).

Figure 3: Smart Strip LCG4 Energy Saving Power Strip w. Autoswitching Technology (~$35)

Figure 4: Belkin BG108000-04 Conserve 8-Outlet Surge Protector with Remote Switch (~$40)

The Belkin product (Figure 4) is a basic power strip, except that there is a remote switch (powered by a watch battery), which increases the likelihood that "phantom" load items will be switched off. This product also has "always on" outlets.

Further information on these products can be found on their respective Amazon pages.

http://www.amazon.com/Belkin-BG108000-04-Conserve-8-Outlet-Protector/dp/B001GQ2W6W/ref=sr_1_1?ie=UTF8&s=hi&qid=1231456622&sr=1-1

http://www.amazon.com/gp/product/B0006Q3B2W/ref=s9subs_c2_60_at2-rfc_p_si4?pf_rd_m=ATVPDKIKX0DER&pf_rd_s=center-2&pf_rd_r=06Q6HFFDJD46VH3FNZMH&pf_rd_t=101&pf_rd_p=463383371&pf_rd_i=507846

In addition, we have both of these products here at the office, to experiment with.

Window Solar Gain and Comfort

One item that we are currently analyzing is the comfort impacts of the large south-facing glazing. Correctly-shaded south-facing glazing is a core principle of solar or sun-tempered design; given our heating dominated climate, all of our models show great benefits in terms of heating use by increasing wintertime solar gain.

However, with an extremely well insulated and airtight building, we start to run the risk of solar overheating on cold but sunny days (at certain times of day). There are many variables that will interact here, including:

- Operation of interior shades
- Thermal mass inside that space
- Ability to redistribute the heat (with passive systems, such as fan cycling, or active systems, such as a differential thermostat)
- Occupant comfort limits

Note that our design includes overhang shading on the south-facing windows, to reduce the impact of summertime solar gain (i.e., cooling load).

We are currently examining this problem, to estimate the overall impact, and will determine appropriate solutions to the predicted temperature differences.

Radiant Floor Discussion

We discussed the idea of having a radiant floor in the bathroom, in order to reduce discomfort in bare feet during the wintertime. A water-based radiant (i.e., tubing or pipes) floor system is not easily integrated with either of the instantaneous water heater systems discussed earlier. Therefore, a calculation was done to estimate the consumption of using electric resistance heat under the tiles to provide a warm floor. This was done with the following assumptions:

- Surface area as per current master bathroom plan (81 sf)
- Ambient temperature of 71° F
- Floor temperature of 86° F
- Operation for 2 hours/day, for ½ of the year (colder seasons)

Based on these assumptions, the annual electricity consumption would be on order of 180 kWh (2.1 million Btu/year source energy). However, this heat is "recovered" as space heat at the interior—thus offsetting some need for space heat from the furnace. This electric resistance heat, of course, is intrinsically 1/3 the efficiency of fossil fuel combustion (i.e., heat from the furnace). So the net "extra" source energy use associated with this system is 120 kWh/year or 1.4 million Btu/year source energy.

This is equivalent to adding ~1/3 of an Energy Star refrigerator (at ~400 kWh/year). Expressed in another way, this is an increase the source energy consumption for heating (alone) by 2.5%. Of course, this assumes that the floor is **only** operated for this limited amount of time (2 hours/day, ½ of the year).

Changing over to a radiant floor system based on fossil fuel consumption would reduce the source energy use by roughly a factor of three (source-to-site conversion), to roughly 0.7 million Btu/year source energy. Note that no matter how this heated floor is done, it requires energy to heat a surface to 86° F in a 71° F space. As we mentioned above, it is not simple to integrate this with an instantaneous DHW system.

It would be possible to integrate a water-based radiant floor with a high efficiency **tank** water heater (i.e., not instantaneous). However, these systems (e.g., American Water Heater Polaris) have an energy factor (EF) in the 0.81 to 0.83 range—equivalent to the lower-end instantaneous hot water heaters. This drop in efficiency (from ~0.98 to ~0.82) is equivalent to 2.6 million Btu/year source energy.

Therefore, switching to a tank system would result in an energy penalty larger than the consumption from conservative operation of an electric radiant floor.

Overall, although the energy impact might be relative small, we would recommend against using electric resistance heat in this purpose; a philosophical argument can be found in letter to Fine Homebuilding cited below:

> *The Kitchens & Baths issue (FHB #191) included a feature on warming a granite kitchen countertop, as well as a separate article on choosing energy-efficient appliances. As long as our culture is worried about cold elbows on countertops, we cannot reduce energy consumption to any appreciable degree, despite Energy Star-labeled appliances.*
>
> *Ours is a gadget culture. Who can fault the architect who had the heated countertop installed? He was just pleasing his clients. I have installed a sink-top*

mini electric instant water heater for a customer. The blasted thing cycles continuously day and night, and is seldom used.

We don't have to return to hunting and gathering. Our appliances enable us to store, cook, and clean up after meals safely and conveniently. However, if we want to curb energy usage, we need to have some limits on how persnickety we are.

Jonathan Harris, via email
Fine Homebuilding Magazine, April/May 2008

Decision Points and Recommendations

Overall, BSC's recommendations for going forward are as follows, based on our previous parametric analysis:

- Space heat provided by 98% AFUE furnace: although there is not an exceptionally strong financial argument, the modulating fan would provide added comfort, and reduced electrical fan use (not measured in the model).
- 16 SEER is possible option; although financial reasons are not strong, higher end units often have better overall product quality. For instance, depending on manufacturer, this jump might upgrade the corrosion protection of the outdoor unit.
- 0.98 EF instantaneous hot water system, with drainwater heat recovery. This system is compatible with a demand recirculation system, does not have "cold slug" water problems, and is compatible with drainwater heat recovery.
- Pin-based CFL fixtures for maximizing lighting efficiency (strong financial argument)
- Air sealing to stringent levels (strong financial argument)
- Programmable thermostat with setbacks (strong financial argument)
- At least single core HRV (heat recovery ventilator, ~70%), if not dual core (~90%). The dual core unit is much less cost-effective for energy savings than the single core. Also, a greater product selection is available in single core HRVs; dual core are much rarer.
- Triple glazed windows: although this is a substantial cost line-item, if you examine the lifetime savings analysis, it becomes far more reasonable. For instance, with our assumptions, it comes in better than the solar hot water system. One might argue that the $25,000 cost of upgrading these windows, when bundled into the house cost, is somewhat easier to swallow. It is also important to note that much of the Marvin upgrade cost is due to quality, not energy. This item, alone, causes an improvement of 4 or 5 HERS Index points.

  Also, we are holding out hope that the ThermaProof windows might be a more cost-competitive performer, assuming availability and aesthetic acceptability.
- Photovoltaics would be a very reasonable measure; their economics do pencil in at better than the triple glazed windows, with our assumptions, including the effect of government incentives/subsidies. However, keep in mind though the commonly held belief that the price of photovoltaic systems will decline in the near future, as acceptance, production, and competition all increase.
- Solar hot water is a possibility, but a lower priority, given the economic case, and especially if roof space receiving solar gain is at a premium (given shading from trees).

- Energy Star appliances have a strong financial argument; best-in-class less so, but they are also likely to be top of the line appliances in terms of quality, fit, and finish.
- Master light switch is not recommended, unless the cost can be brought down significantly, and/or it is specified for non-energy reasons
- Control of miscellaneous end use loads and “phantom loads” are best handled by various “smart” power strips, assuming (of course) that they will be used.

Overall, it would be good to determine or articulate a specific strategy—if any—on determining the cost-based decisions on these upgrades. For instance, the high cost/high durability shingle/slates are being considered: there is a longevity benefit, but in terms of an economic argument, they have less of a payback (zero, meaning infinite payback period) than the worst of the energy measures. Furthermore, LEED-H, in itself, does not have “cost effectiveness” as a goal or requirement—it is a measurement system to reduce environmental impact. Therefore, if a high level of performance such as LEED Platinum is the goal, this often results in choices that are not based on simple rational returns on investment.

Table 5: Complete table of parametric simulation upgrades

Parametric Run ID	Description of change	Estimated Individual Cost	Incremental Over Bmrk	Annual energy cost	Item Savings	Increment payback (yr)	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	$ per 10^6 Btu Saved (Lifetime)	HERS Score
0	Benchmark			$5,017							
1	Baseline	$13,000	29.6%	$3,201	$1,816	7	92.3	$141			
2	1 + Air Seal (1.5 Leakage Ratio)	$2,500	4.0%	$2,952	$249	10	12.6	$199	75	$2.65	64
3	2 + CFLs (screw-in)	$275	5.7%	$2,820	$132	2	17.7	$16	5	$3.10	61
4	3 + CFLs (pin type)	$0	0.9%	$2,799	$20	0	2.9	$0	15	$0.00	61
5	4 + EnergyStar Appliances	$700	3.1%	$2,647	$152	5	9.7	$73	15	$4.84	60
6	5 + Best in Class Appliances	$600	0.6%	$2,629	$19	32	1.9	$321	15	$21.37	60
7	6 + 0.82 EF Instantan. Water Heater	$700	2.6%	$2,466	$163	4	8.1	$87	20	$4.33	51
8	7 + 98% AFUE Furnace	$800	0.4%	$2,444	$22	36	1.1	$725	20	$36.25	50
9	8 + 16 SEER AC	$250	0.2%	$2,438	$6	40	0.6	$403	20	$20.16	50
10	9 + HRV (single core)	$1,000	3.7%	$2,364	$74	13	11.5	$87	15	$5.78	50
11	10 + HRV (dual core)	$500	0.4%	$2,334	$29	17	1.3	$390	15	$26.00	50
12	11 + Nighttime Setback	$100	1.7%	$2,234	$100	1	5.2	$19	20	$0.96	50
13	12 + Harvey Triple Glazed Tribute	($13,187)	2.7%	$2,084	$150	-88	8.3	-$1,593	50	-$31.85	47
14	12 + Marvin Clad Ultimate Tri-pane	$24,618	3.7%	$2,001	$234	105	11.4	$2,159	50	$43.18	45
15	12 + Master Light Switch	$750	0.1%	$2,232	$2	426	0.2	$4,253	75	$56.70	50
16	15 + 0.98 EF Instantan. Water Heater	$1,000	0.8%	$2,180	$53	19	2.6	$382	20	$19.08	47
17	16 + Drainwater Heat Recovery	$650	0.7%	$2,138	$42	16	2.1	$313	75	$4.18	47
18	17 + Solar Hot Water (one panel)	$6,325	1.9%	$2,021	$117	54	5.8	$1,083	20	$54.14	46
19	17 + Solar Hot Water (two panels)	$7,450	2.5%	$1,982	$156	48	7.8	$961	20	$48.04	46
20	17 + Solar Hot Water (three panels)	$8,530	2.8%	$1,962	$176	48	8.7	$976	20	$48.82	45

Parametric Run ID	Description of change	Estimated Individual Cost	Incremental Over Bmrk	Annual energy cost	Item Savings	Increment payback (yr)	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	$ per 10^6 Btu Saved (Lifetime)	HERS Score
21	17 + Marvin Clad Ultimate Tri-pane	$24,618	3.6%	$1,906	$232	106	11.3	$2,187	50	$43.75	43
22	21 + Photovoltaics (4 kW)	$28,000	18.7%	$1,323	$582	48	58.3	$480	30	$16.00	26
23	21 + Photovoltaics (7.2 kW)	$40,500	33.9%	$852	$1,053	38	105.5	$384	30	$12.79	14

Appendix D.1.7.2
2009-01-23 Foulds Residence Two Zone

2009-01-23 Foulds Two HVAC Zoned System

From:	Kohta Ueno, Building Science Corporation	Date:	January 23, 2009
To:	Brian Foulds Betsy Pettit, Katie Gunsch, Ken Neuhauser, Daniel Bergey, Building Science Corporation	Re:	Foulds Residence Two HVAC Zoned System

The following memo is a discussion of our logic behind specifying a two-zone HVAC system for the Foulds Residence.

Thank you,

Kohta Ueno

Parallel Thermostat Discussion

The concept that was discussed earlier was to have two thermostats (one on the first floor, one on the second floor), to act in **parallel** on a single-zone HVAC system. I believe that this was intended to be like a "cheaper version of a zoned system." The idea is that the two thermostats would act (in logic terms) as an OR switch:

- OR = on when **either** inputs is on
- AND = on only when **both** inputs are on

The section below walks through how the system would behave. One overarching point to remember is that this "parallel thermostat systems" has limitations on what it can do: it can only turn the **entire** HVAC system on and off (i.e., it is not truly zoned), and of course, it can't cool one space and heat another.

Operation Walk-Through

One reason why this idea has been proposed is that the homeowners often use their house in a one-story-at-a-time mode. During the day, they are mostly on the first floor; in the evenings, they are in the second floor bedrooms. Therefore, there might be some energy savings and comfort enhancements by having two points of control.

For instance, walking through wintertime operation:

- In the evening, the downstairs thermostat would be setback (e.g., 65° F), they would all head upstairs, and run the upstairs thermostat at a more comfortable setpoint (e.g., 68° F).
- During the night, the upstairs will be kept at setpoint (e.g., 68° F).
- The downstairs thermostat would call for heat less often (at 65° F). Assuming that it is "incidentally conditioned" by calls for heating from upstairs, it is possible that the downstairs will not call for heating at all.
- At the start of the day, the downstairs thermostat would turn on to recover from the setback. However, this means that the second floor would quickly become overheated, if it had been maintaining setpoint all night.
- During the day, we might assume that the unoccupied upstairs is setback (e.g., 65° F), and the downstairs is run at a more comfortable temperature. However, due to stack effect, the second floor often naturally ends up warmer than the first floor. If this were the case, again, the second floor would become overheated, by running the system in order to satisfy the first floor thermostat.

A similar exercise could be done for cooling. It seems quite likely that given stack effect, if the second floor thermostat is being satisfied, the lower floors might become overcooled.

In summary, this strategy will only save energy when the zone being "set back" is "losing space conditioning" (heating or cooling) at a faster rate than the "occupied zone." Otherwise, it will result in greater energy consumption, but with the benefit of greater comfort in the "occupied zone."

Zoned System

Overall, I believe that the best solution would be to switch to a two zone system; I would recommend one zone per floor. The first floor and basement would be on one zone, and the second floor on the second zone. In that case, we would actually achieve savings based on setting back zones for occupancy/non occupancy, as discussed above. However, this requires the addition of a second trunk duct in the basement to feed the second floor, the controller, and two motorized dampers.

As an argument for this system, though, I have often found that controlling from two points independently (i.e., two zone system) has resulted in the zones being closer to setpoint/evenness in temperature, especially when fighting vertical stratification (stack effect differences). This is of particular importance given the large open stairwell connecting the two floors, as well as the solar "harvesting" on the south side of the house. Subdividing the house into two zones will at least reduce overheating of upper spaces to due stack effect. This first/second zoning works well with the homeowner's behavior patterns.

One might argue for three or four zones, due to the north/south orientation. This would likely keep all of those zones closer to temperature setpoint; however, I would argue that this is somewhat excessive.

Costs and Payback

A 1999 *Journal of Light Construction* article noted that a typical three- or four-zone system will run between $1,200 and $2,000, installed. We are only specifying two zones (first and second floor) for this system, so costs should be on the lower end.

Note that this measure is not really being specified for straight energy payback, but for increased comfort control.

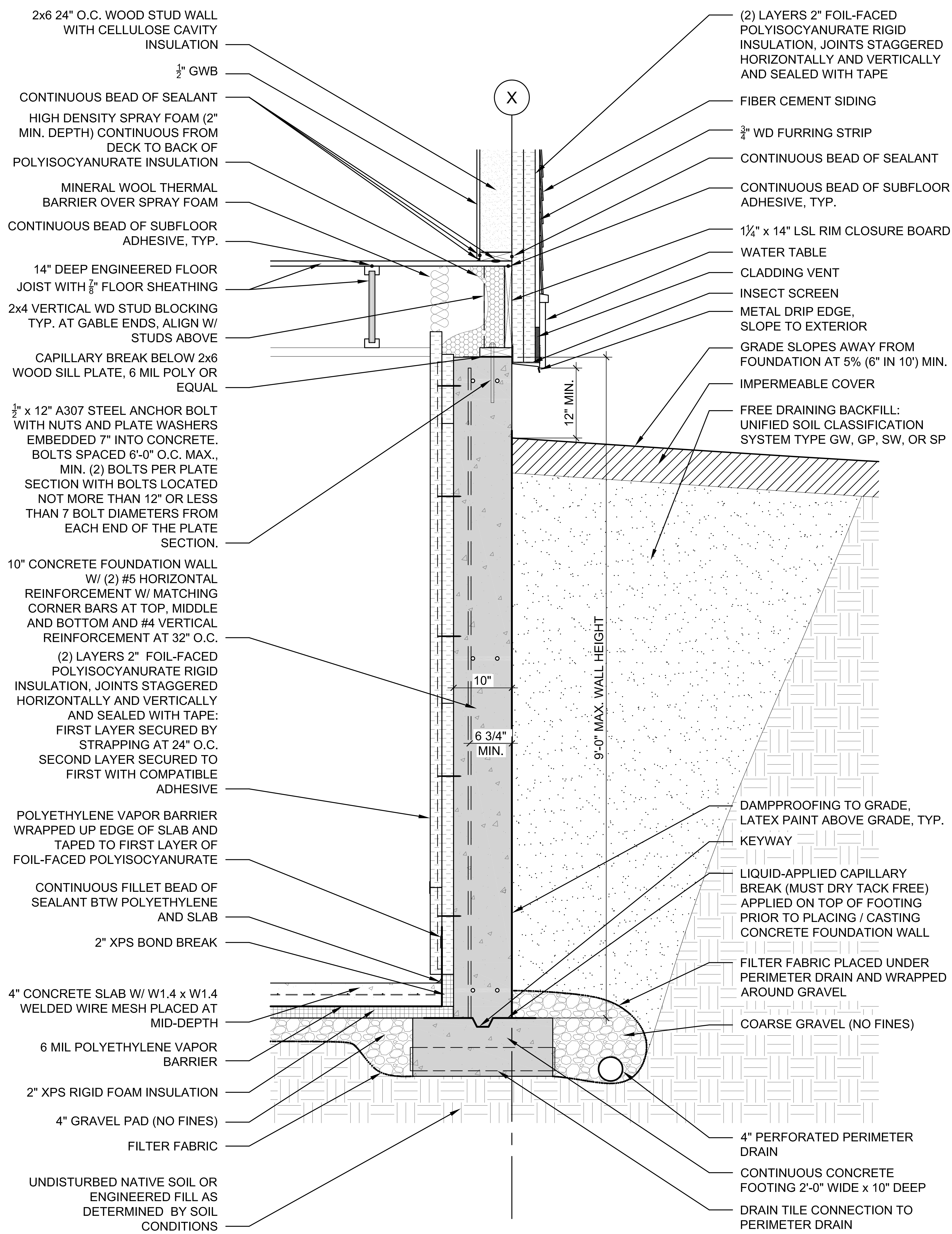
For reference, heating is on the order of $800-1050/year (at $1.60 and $2.20 per therm, respectively, and 11 cents/kWh). The nighttime setback for the **whole** house (wintertime setpoint of 71° F daytime and 66° F nighttime for 8 hours/day) results in $100/year savings (at $2.20 per therm). Setting back a zone would be some fraction of this amount (e.g., $50), which would result in a 20 year payback—not completely unreasonable, but not "low hanging fruit" either. Also, it is arguable that service lifetime for the components of this zoned system would not exceed 20 years.

Appendix D.1.7.3
2009-01-26 Foulds Residence Window Comparison

Foulds Residence
Window Comparison Table
2009-01-26

Description of Windows	U-value	SHGC	Window Cost	Added Cost	Annual Energy Cost	Cost Change	Simple Payback	Cost Target (30 year payback)	Cost Target (60 year payback)
Baseline: Andersen 400 Series	**0.34**	**0.29**	**$24,293**	**$0**	**$2,207**	**$0**			
Andersen 200 Series	0.34	0.30	$14,761	($9,532)	$2,198	($9)	NA	NA	NA
Marvin Integrity Wood Ultrex Series	0.34	0.32	$24,000	($293)	$2,179	($28)	NA	NA	NA
Marvin Clad Ultimate Series	0.34	0.30	$33,191	$8,898	$2,198	($9)	989	$24,563	$24,833
Marvin Clad Ultimate Tri-pane Series	0.25	0.38	$48,911	$24,618	$1,999	($208)	118	$30,533	$36,773
Harvey Tribute Series	0.33	0.32	$9,268	($15,025)	$2,169	($38)	NA	NA	NA
Harvey Triple Glazed Tribute Series	0.20	0.19	$11,106	($13,187)	$2,046	($161)	NA	NA	NA
Pella ProLine Series	0.33	0.30	$14,500	($9,793)	$2,193	($14)	NA	NA	NA
Pella Designer Series (DG+int. storm)	0.28	0.28	$30,500	$6,207	$2,111	($96)	65	$27,173	$30,053
Pella Architect Series	0.34	0.32	$31,500	$7,207	$2,179	($28)	257	$25,133	$25,973
ThermaProof 725 Series Low SHGC	0.20	0.22	$34,000	$9,707	$2,027	($180)	54	$29,693	$35,093
ThermaProof 725 Series High SHGC	0.20	0.44	$34,000	$9,707	$1,884	($323)	30	$33,983	$43,673

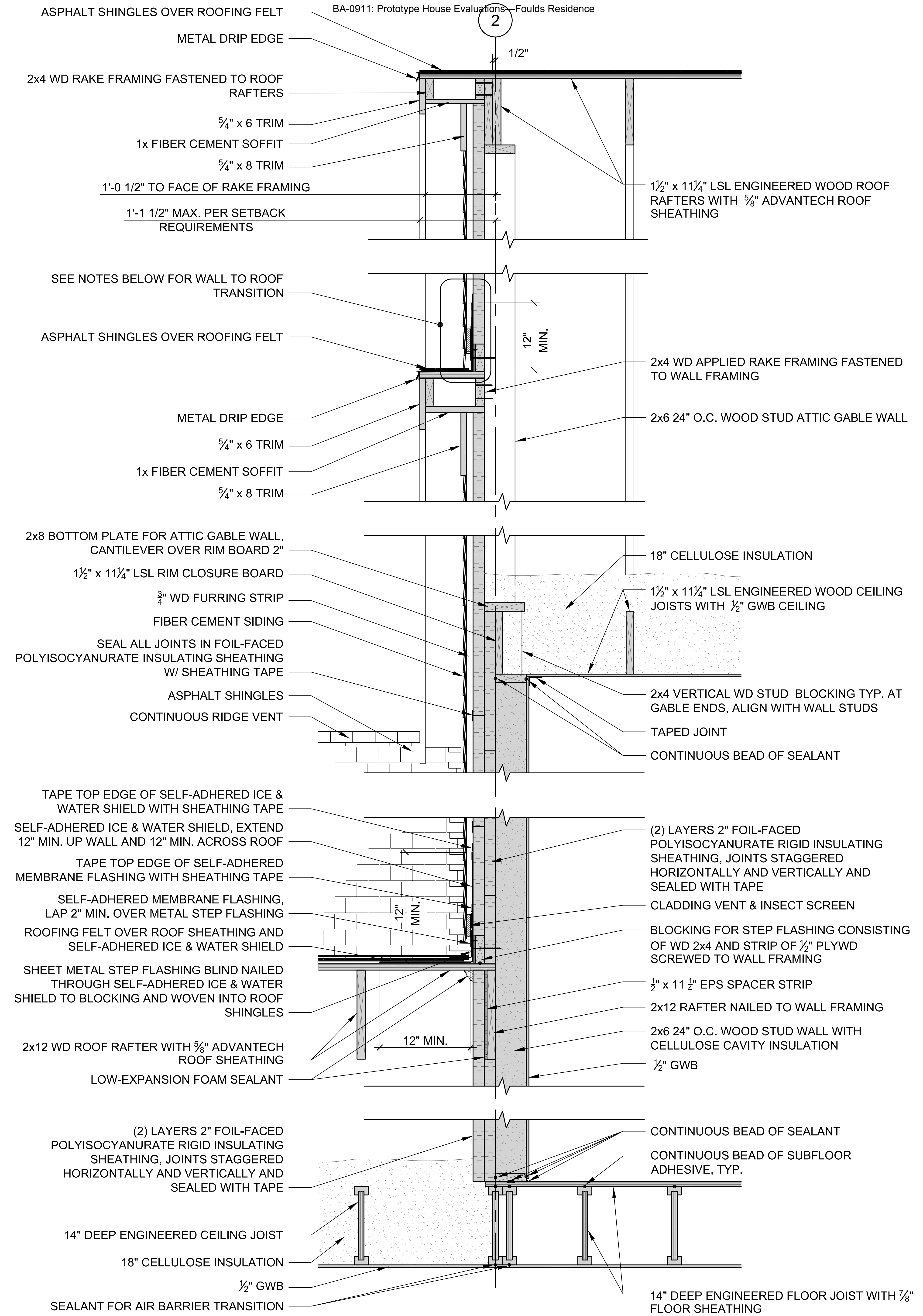
Appendix D.1.7.4
2009-03-10 Foulds Residence SK-01



bsc

Project:	Foulds Residence	Sheet Title:
Date:	2009-03-10	SK-01
Drawing Title:	TYPICAL FOUNDATION WALL AT FULL BASEMENT	
Drawing File:	WALL SECT_Foulds_SK_01.dwg	
Drawing Scale:	3/4" = 1'-0"	

Appendix D.1.7.5
2009-03-10 Foulds Residence SK-02



Project:	Foulds Residence
Date:	2009-03-10
Drawing Title:	GABLE WALL AT GRID LINE 2
Drawing File:	WALL SECT_Foulds_SK_02.dwg
Drawing Scale:	3/4" = 1'-0"

Sheet Title:

SK-02

Appendix D.1.7.6
2009-05-22 Foulds Residence Durability Checklist

Builder Name:	Synergy Companies Construction LLC
Project:	Foulds Residence
Lot Number:	33 Riverdale Road, Concord, MA

BSC Building America Quality Control Checklist

Part 1 - Pre-drywall Inspection

Foundations	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
A drainage plane must be provided with sub-grade drainage for below grade spaces	Plans & Sections, BSC Information Sheet 101	☐	☐
Exterior or interior perimeter footing drainage system is installed		☐	☐
Drainage membrane or draining insulation is installed around below grade walls		☐	☐
Free-draining backfill is installed over perimeter drainage		☐	☐
Sub-slab gravel bed is connected to perimeter drainage		☐	☐
Perimeter drainage is connected to storm water drain or sloped to daylight		☐	☐
A capillary break separating the entire foundation from the soil must be provided	Sections, BSC Information Sheet 101	☐	☐
A below-slab capillary break has been installed		☐	☐
A capillary break has been installed on the foundation wall and footings (horizontal and vertical surfaces)		☐	☐
Use soil gas resistant construction techniques	Plans, BSC Information Sheet 110	☐	☐
Floor openings, concrete joints, and foundation checks have been sealed against gas entry		☐	☐
Floor drains and sumps have been sealed against gas entry		☐	☐
Passive vent stack with "T" in sub-slab gravel bed has been installed		☐	☐

Pre-Cladding	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
Protect construction materials from moisture before installation	n/a	☐	☐
Keep all building materials dry during storage on-site		☐	☐
Separate wood from concrete or masonry with appropriate capillary break	Sections & Details, n/a	☐	☐
Sill plates separated from foundation wall with capillary break		☐	☐
A drainage plane must be provided that is integrated with flashings	Sections, BSC Information Sheets 300, 302	☐	☐
Drainage plane has been installed in a continuous manner		☐	☐
Sheet material has been properly lapped to drain water		☐	☐
All flashing elements specified have been correctly installed		☐	☐
Drainage plane overlaps flashing or connected by a transition membrane		☐	☐
A drainage plane must be accompanied by a drainage space	Sections, BSC Information Sheet 300	☐	☐
Materials to create drainage gap have been installed as specified		☐	☐
Intentional drainage spaces are clear of construction debris		☐	☐
Subsill flashing: windows and doors must be "pan-flashed"	Details, BSC Information Sheet 301	☐	☐
All windows and door openings are "pan-flashed"		☐	☐
Pan-flashing installed with end dams and positive slope towards the exterior		☐	☐
Flashing materials are correctly lapped		☐	☐
Reservoir claddings must be "uncoupled" from wall assemblies	Sections, BSC Information Sheet 304	☐	☐
Reservoir claddings (such as brick, stucco and fiber cement) are back-ventilated with min. 1/4" ventilation space (1" for brick) or are installed over a moisture-tolerant and vapor impermeable material		☐	☐
A continuous air barrier must be provided	Sections, BSC Information Sheets 403, 404, 405, 406	☐	☐
Air sealing provided between bottom plates and floor deck		☐	☐
Rim joists areas are caulked or sealed with sprayed foam		☐	☐
Carrying beams running to outside walls and beam pockets are sealed		☐	☐
Perimeter of windows and doors are sealed on the interior side with low-expansion foam or sealant		☐	☐
Bathtubs on exterior walls have draftstopping materials installed behind tub		☐	☐
Walls and ceilings separating attached garages from living space are properly sealed by: installing gas-proof membrane, taping gypsum board, and sealing all penetrations		☐	☐
Chimney chases and interior soffits running to exterior walls have been draftstopped and air sealed		☐	☐
Electrical wiring or outlets on exterior walls and other penetrations have been sealed		☐	☐
Only airtight-rated recessed lights installed in insulated ceilings		☐	☐
Vapor control of wall, roof and foundation assemblies must be provided as specified	Sections, BSC Information Sheet 311	☐	☐
Materials with vapor permeability characteristics matching the products specified for each assembly in the construction documents have been installed		☐	☐
Vented above-grade wall drainage cavity protected by insect screen	Sections	☐	☐

Pre-insulation	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
Wet rooms should have floor drainage	Plans, BSC Information Sheet 305	☐	☐
Floor drainage installed in laundry rooms		☐	☐
Paper faced gypsum board should not be used in any part of the building constructed before the roof is applied	n/a	☐	☐
Plumbing should not be located in exterior walls	n/a	☐	☐
Make plumbing easy to inspect and repair and insulate plumbing pipes to keep them warm (above dewpoint temperatures)	Plans, BSC Information Sheet 305	☐	☐
Access panels for plumbing inspection have been installed.		☐	☐
Pipe insulation has been installed on exposed hot and cold runs not located in walls.		☐	☐

Pre-drywall	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
Install insulation to meet HERS Insulation Installation Grade 1	BSC Information Sheet 501	☐	☐
Few installation defects, only very small gaps around wiring, electric outlets, etc. and incomplete fill amounts to 2% or less. Gaps running clear through the insulation amount to no more than 2% of the total surface area covered by the insulation. Wall cavity insulation is enclosed on all six sides and in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity.		☐	☐
ENERGY STAR Thermal Bypass Inspection Checklist has been completed		☐	☐

Part 2 - Finish Inspection

Mechanical System Inspection	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
Sealed Combustion Equipment	Plans, BSC Information Sheet 601	☐	☐
Sealed combustion equipment provided as specified		☐	☐
Sealed combustion equipment installed as specified		☐	☐
Ventilation system design must have the capacity to meet the requirements of ASHRAE 62.2 and must be commissioned at 60% of ASHRAE 62.2	Plans, BSC Information Sheet 610	☐	☐
Ventilation system provided and installed as specified		☐	☐
Ductwork to inside and outside are properly installed and connected		☐	☐
Ventilation system control has been installed and commissioned as specified		☐	☐
Air filter housings must be airtight to prevent bypass or leakage		☐	☐
Interior spaces must be air pressure balanced (less than 3 Pascals between all spaces). Transfer grilles or jump ducts to be provided for any closed room without a return grille (except bathrooms, closets, pantries and laundry rooms)	Notes & Plans, BSC Information Sheets 604	☐	☐
Transfer grilles have been installed where indicated on the plans		☐	☐

Builder Name:	Synergy Companies Construction LLC
Project:	Foulds Residence
Lot Number:	33 Riverdale Road, Concord, MA

BSC Building America Quality Control Checklist

Duct systems properly sized and placed	Plans	☐	☐
Duct runs are placed where indicated on the drawings or layout has been revised with mechanical designer		☐	☐
Conditioning system design loads must be determined according to ACCA Manual J and equipment must be sized using ACCA Manual S	Plans	☐	☐
Air conditioning system supplied and installed as specified		☐	☐
Ducts should be located inside the enclosure air barrier.	Notes & Plans, BSC Information Sheet 602	☐	☐
Building cavities not used as part of the forced air supply or return system		☐	☐
Supply and return ductwork sealed to be airtight	Notes & Plans, BSC Information Sheet 603	☐	☐
Ductwork has been air sealed at joint locations and equipment connections		☐	☐
Ductwork is sealed to supply and return boots		☐	☐
Protect ductwork during construction	n/a	☐	☐
Ductwork rough-in protected from construction debris		☐	☐
Supply and return duct boots have been covered during interior finishing		☐	☐
Exhaust vents and intake ducts correctly placed	Notes & Plans, BSC Information Sheet 606	☐	☐
Exhaust and intake ducts installed where indicated on plans		☐	☐
Clothes dryers vented outdoors		☐	☐

Landscaping	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
Provide strips around buildings free of planting and organic mulch	Landscape Plans	☐	☐
A 24" wide strip free of organic mulch and planting has been provided around buildings		☐	☐
Bushes and trees are at least 36" away from building		☐	☐
Site surface water is controlled by appropriate grading and landscape measures	Plans, Sections & Landscape Plans, BSC Information Sheet 101	☐	☐
Grade on all sides of building slopes away from building			
Patios and decks are installed lower than the finished floor and slope away from the building		☐	☐
Garage floor is lower than the finished floor and slopes away from the building		☐	☐
Driveway is lower than garage floor and slopes away from the building		☐	☐
Finished grade is lower than main floor and slopes away from the building		☐	☐
Stoops, porches and walkways are lower than the main finished floor and slope away from the building		☐	☐

Exterior Finish	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
Separate wood from concrete or masonry with appropriate capillary break	Sections	☐	☐
Deck and stair posts held off concrete with metal brackets or other non-organic spacer		☐	☐
Detail deck to house connection (including ledger to wall connection) to shed water away from house and to allow natural drying of assembly		☐	☐
Install exterior flashing and drainage	Plans & Sections, BSC Information Sheet 302	☐	☐
Step flashing at all roof/wall intersections and terminated with "kickout" flashing or overhang		☐	☐
Gutters and downspouts or other roof drainage system has been installed			
Select building materials that are insect resistant (steel framing, concrete framing, treated wood framing and sheathing, plastic or plastic composite cladding, cement or fiber cement cladding, brick or stucco cladding)	Plans	☐	☐
Insect resistant materials are installed where specified on the plans		☐	☐

Pre-occupancy	Location in Drawing Set, BSC Information Sheet Number*	Builder Verification & Initials	Third-Party Verification & Initials
Paper faced gypsum board should not be used in "wet areas"	BSC Information Sheet 407	☐	☐
Paper-faced gypsum board not used in bathrooms, showers, laundry rooms and mudrooms		☐	☐
Raise gypsum board minimum of 1/2" above concrete slab		☐	☐
An environmental separation between attached garages and living space must be provided, no air handling equipment located in garage	Plans, BSC Information Sheet 305	☐	☐
Walls and ceilings separating attached garages from living space are properly sealed by: installing gas-proof membrane, taping gypsum board, and sealing all penetrations		☐	☐
Washers should be equipped with single throw shut off valves	BSC Information Sheet 305	☐	☐
Washing Machine connections are equipped with a single throw shut off valve		☐	☐
No carpet in areas prone to get wet: bathrooms, laundry rooms, kitchens, and entryways	Plans, BSC Information Sheet 305	☐	☐
No carpet has been installed in bathrooms, laundry rooms, kitchens, and entryways		☐	☐
Vapor open design of construction assemblies maintained	BSC Information Sheet 311	☐	☐
Vapor-permeable finish materials that do not interfere with vapor open design have been installed		☐	☐

*** See www.buildingscience.com/doctypes/information-sheets.com.**

Builder Declaration for ID prerequisite 2.1 & 2.2

I hereby declare and affirm to USGBC that I have evaluated this project's durability risks, completed the Durability Risk Evaluation Form, and incorporated appropriate durability measures into the design to adequately address the moderate and high risks. The construction drawings and specifications have been updated accordingly, and the the measures were verified to be completed appropriately.

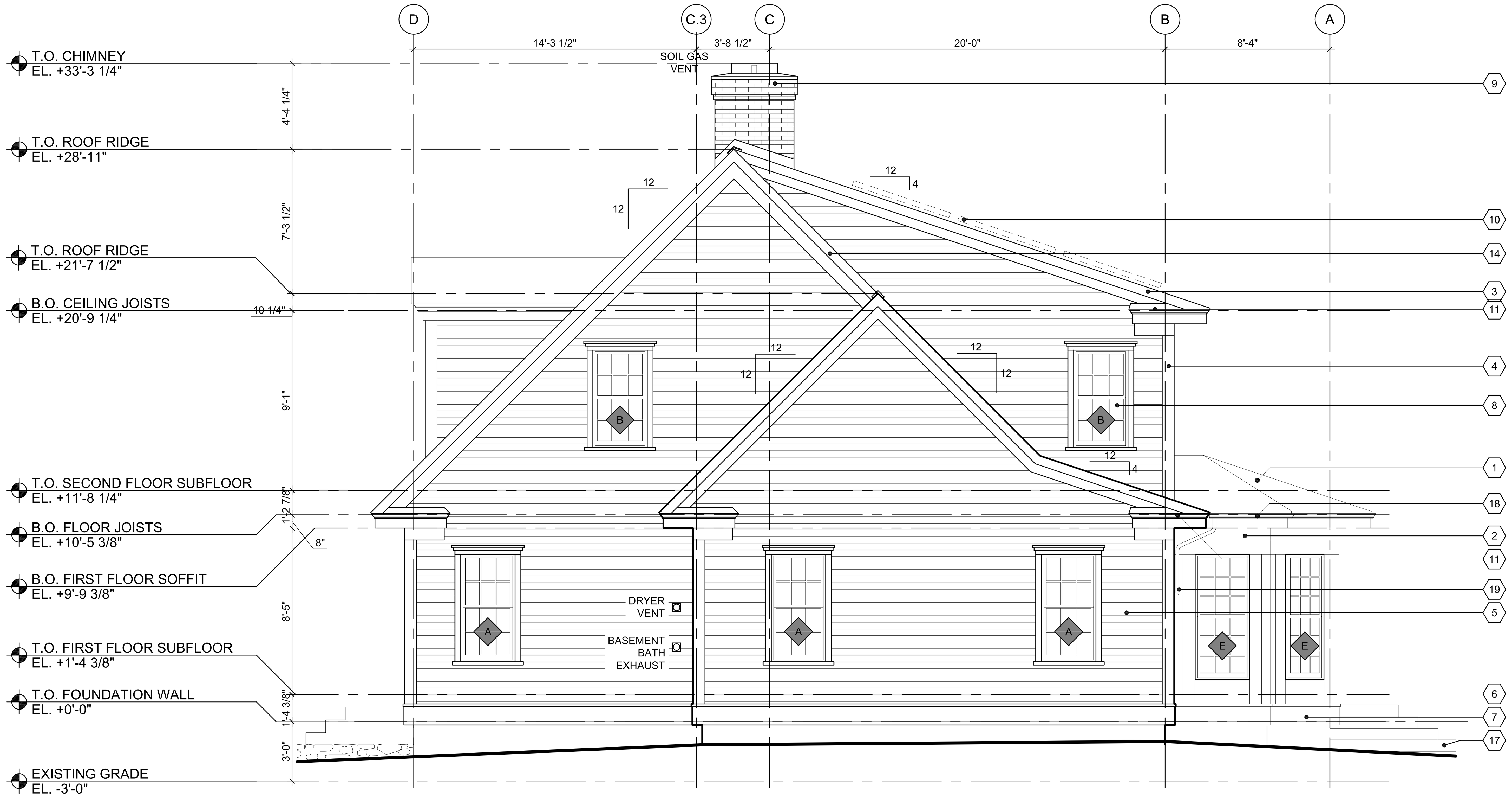
Name: ____________________

Title: ____________________

Signature: ____________________

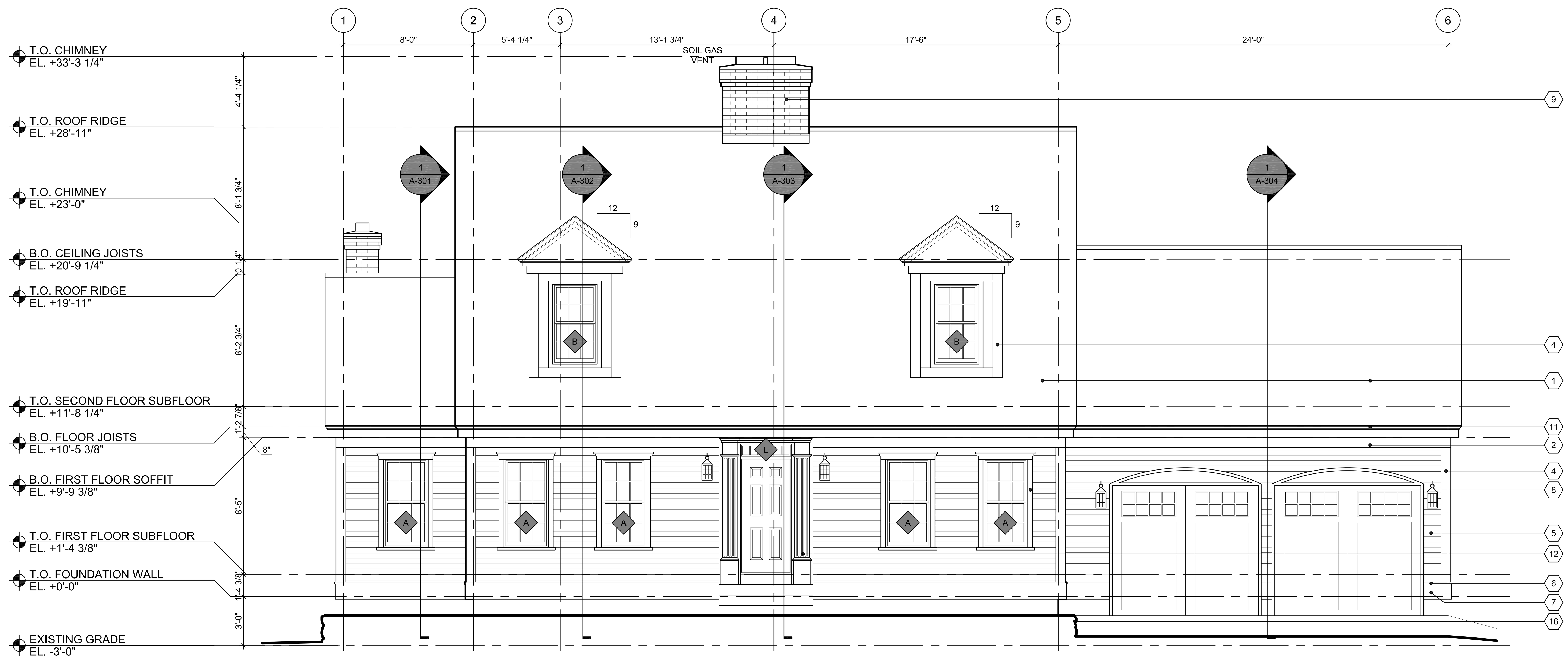
Date:

Appendix D.1.7.7
2009-06-03 Foulds Residence Details



2 RIGHT SIDE (WEST) ELEVATION

SCALE: 1/4" = 1'-0"



1 FRONT (NORTH) ELEVATION

SCALE: 1/4" = 1'-0"

GENERAL SHEET NOTES

1. FIRST FLOOR SOFFIT TO ALIGN AROUND PERIMETER OF HOUSE.
2. SEE LANDSCAPE PLAN FOR LANDSCAPE FEATURES AFFECTING HEIGHT OF GRADE.

SHEET KEYNOTES

1. ASPHALT SHINGLES
2. 5/4 x 8 FRIEZE BOARD TRIM
3. RAKE EDGE TRIM
4. 5/4 x 8 TRIM
5. FIBER CEMENT SIDING - EXPOSURE TO HAVE "GRADIENT" - 4" EXPOSURE AT TOP OF WALL AND INCREMENTALLY SMALLER AS SIDING REACHES BOTTOM OF WALL.
6. 2 x 2 TRIM
7. 5/4 x 12 TRIM
8. WINDOW TRIM
9. WOOD FRAMED MANUFACTURED BRICK VENEER CHIMNEY WITH CHIMNEY CAP
10. 5.75 kW PV ARRAY
11. 5/4 x 8 TRIM WITH 3" CROWN MOULDING
12. BUILT-UP DOOR TRIM
13. EGRESS WINDOW WELL AND LADDER
14. APPLIED RAKE EXTENSION AND TRIM
15. BULKHEAD ENCLOSURE - DOOR AND EXTENSIONS
16. TERRACE AND STONE RETAINING WALL, REF. LANDSCAPE PLANS.
17. WOOD DECK, REF. LANDSCAPE PLANS.
18. ALUMINUM GUTTER
19. RAIN LEADER CONNECTS TO ROOF RUN-OFF COLLECTION SYSTEM, REF. LANDSCAPE PLANS

WINDOW KEY

A. 2'-9 3/8" x 5'-4 3/8"
B. 2'-9 3/8" x 5'-0 3/8"
C. 2'-5 3/8" x 3'-8 3/8"
D. 2'-1 3/8" x 4'-0 3/8"
E. 2'-9 3/8" x 6'-4 3/8"
F. 3'-4" x 2'-3 1/8"
G. 5'-1 3/8" x 5'-0 3/8"
H. 1'-9 3/8" x 3'-8 3/8"
J. 5'-0 3/8" x 6'-10"
K. 2'-9 3/8" x 4'-4 3/8"
L. 3'-2" x 0'-10"

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Concord, MA

MARK	DATE	DESCRIPTION
PS	4/24/09	PERMIT SET

ISSUE:

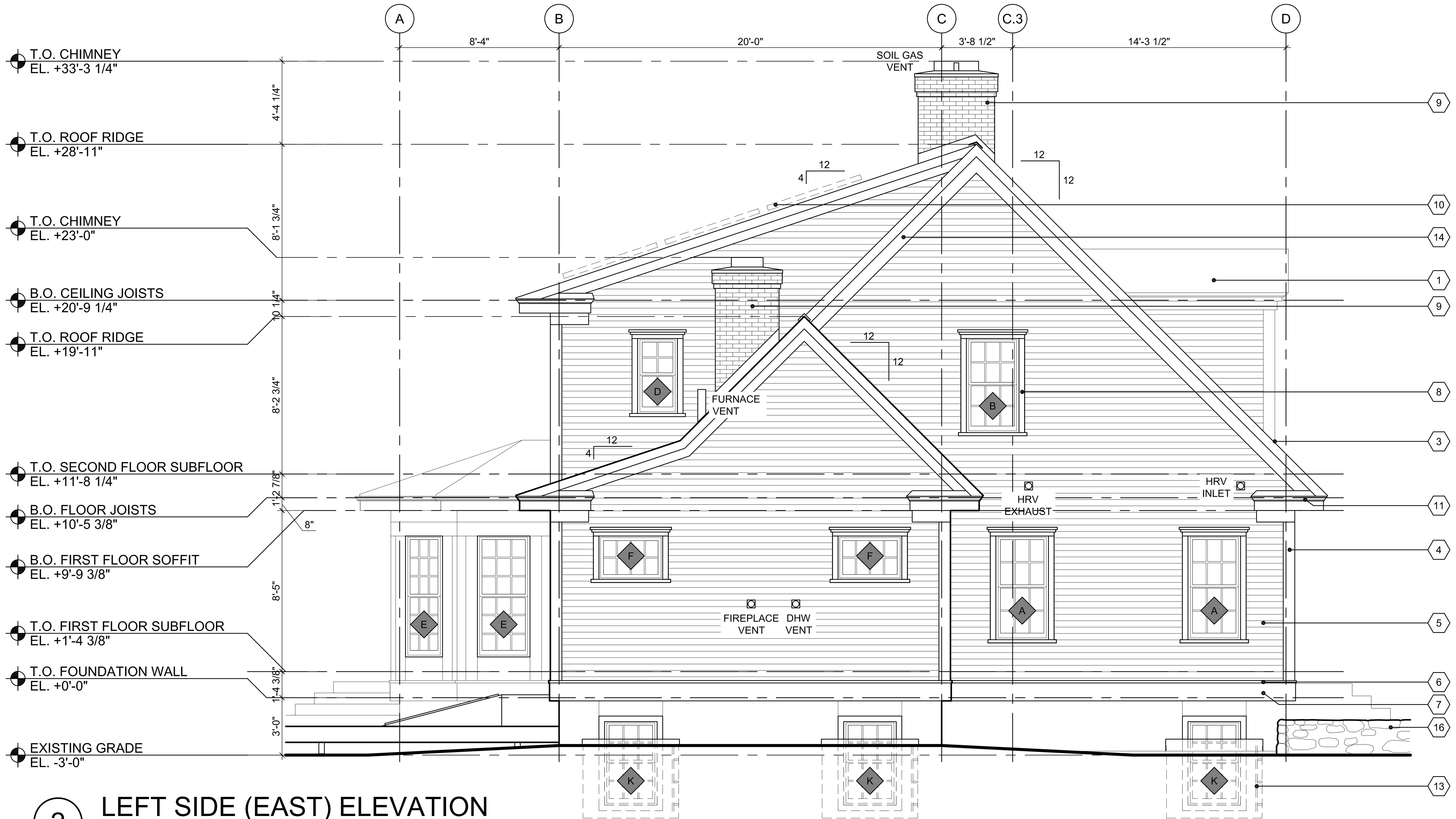
PROJECT NO: PS 099
CAD DWG FILE: PS 099–PLOT–Elevs
DRAWN BY: KG
CHECKED BY: BP

SHEET TITLE:

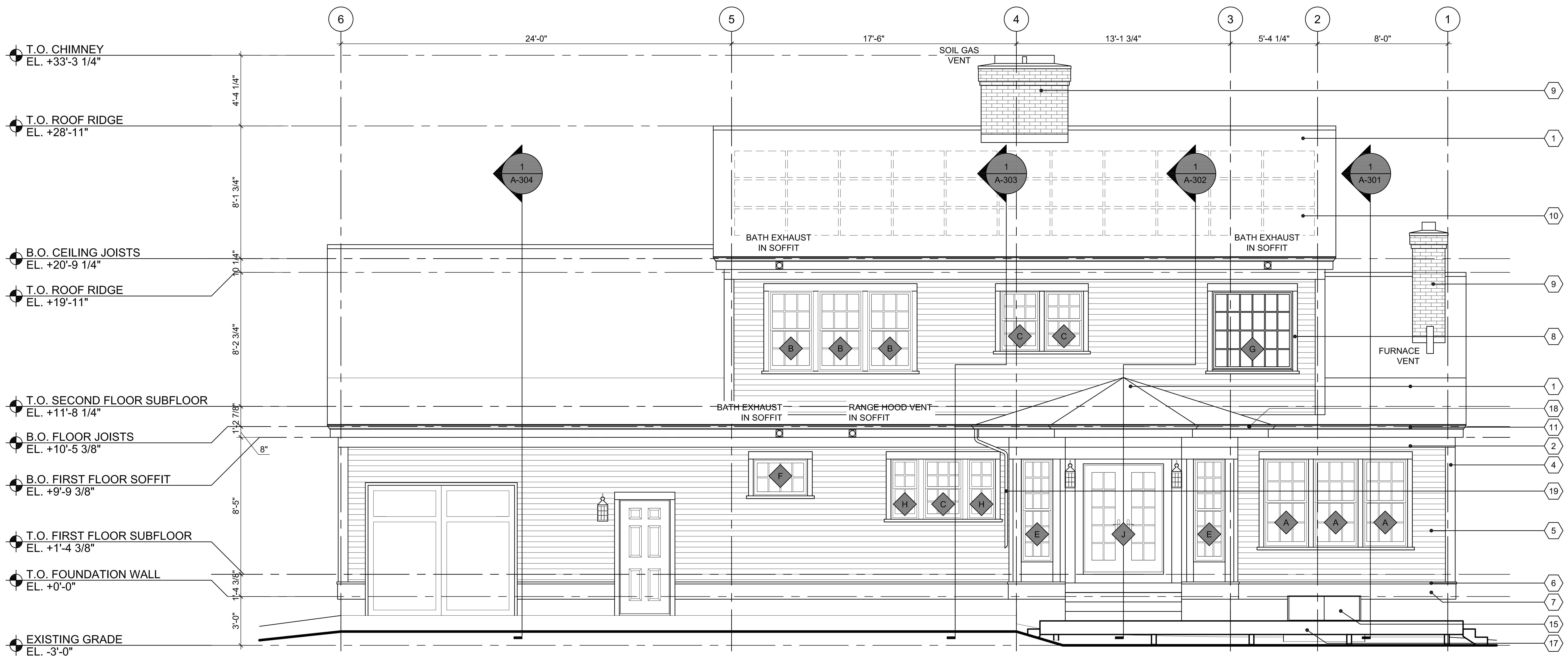
EXTERIOR ELEVATIONS

SCALE: AS NOTED

A-201



2 LEFT SIDE (EAST) ELEVATION
SCALE: 1/4" = 1'-0"



1 REAR (SOUTH) ELEVATION
SCALE: 1/4" = 1'-0"

GENERAL SHEET NOTES

1. FIRST FLOOR SOFFIT TO ALIGN AROUND PERIMETER OF HOUSE.

SHEET KEYNOTES

1. ASPHALT SHINGLES
2. $\frac{5}{4}$ x 8 FRIEZE BOARD TRIM
3. RAKE EDGE TRIM
4. $\frac{5}{4}$ x 8 TRIM
5. FIBER CEMENT SIDING - EXPOSURE TO HAVE "GRADIENT" - 4" EXPOSURE AT TOP OF WALL AND INCREMENTALLY SMALLER AS SIDING REACHES BOTTOM OF WALL.
6. 2 x 2 TRIM
7. $\frac{5}{4}$ x 12 TRIM
8. WINDOW TRIM
9. WOOD FRAMED MANUFACTURED BRICK VENEER CHIMNEY WITH CHIMNEY CAP
10. 5.75 kW PV ARRAY
11. $\frac{5}{4}$ x 8 TRIM WITH 3" CROWN MOULDING
12. BUILT-UP DOOR TRIM
13. EGRESS WINDOW WELL AND LADDER
14. APPLIED RAKE EXTENSION AND TRIM
15. BULKHEAD ENCLOSURE - DOOR AND EXTENSIONS
16. TERRACE AND STONE RETAINING WALL, REF. LANDSCAPE PLANS.
17. WOOD DECK, REF. LANDSCAPE PLANS.
18. ALUMINUM GUTTER
19. RAIN LEADER CONNECTS TO ROOF RUN-OFF COLLECTION SYSTEM, REF. LANDSCAPE PLANS

WINDOW KEY

A. 2'-9⅜" x 5'-4⅜"
B. 2'-9⅜" x 5'-0⅜"
C. 2'-5⅜" x 3'-8⅜"
D. 2'-1⅜" x 4'-0⅜"
E. 2'-9⅜" x 6'-4⅜"
F. 3'-4" x 2'-3⅛"
G. 5'-1⅜" x 5'-0⅜"
H. 1'-9⅜" x 3'-8⅜"
J. 5'-0⅜" x 6'-10"
K. 2'-9⅜" x 4'-4⅜"
L. 3'-2" x 0'-10"

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ISSUE:

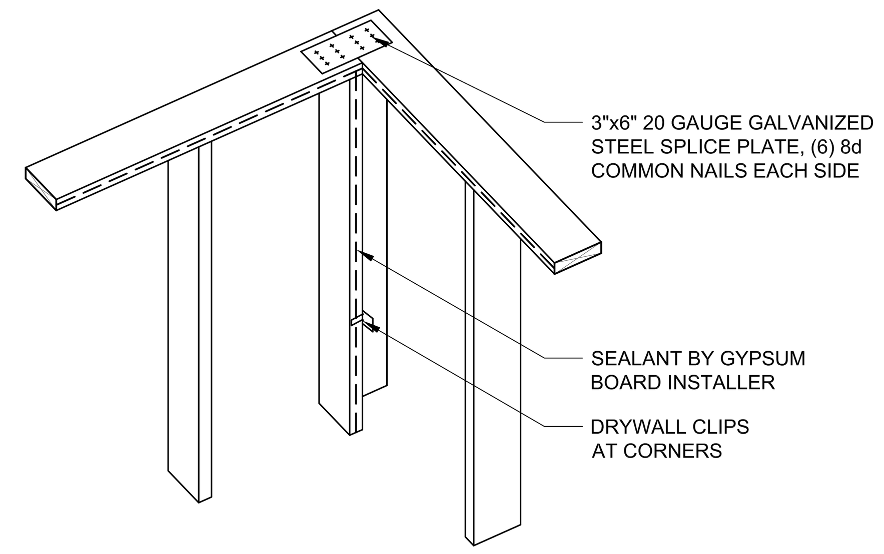
PROJECT NO:	PS 099
CAD DWG FILE:	PS 099–PLOT–Elevs
DRAWN BY:	KG
CHECKED BY:	BP

SHEET TITLE:

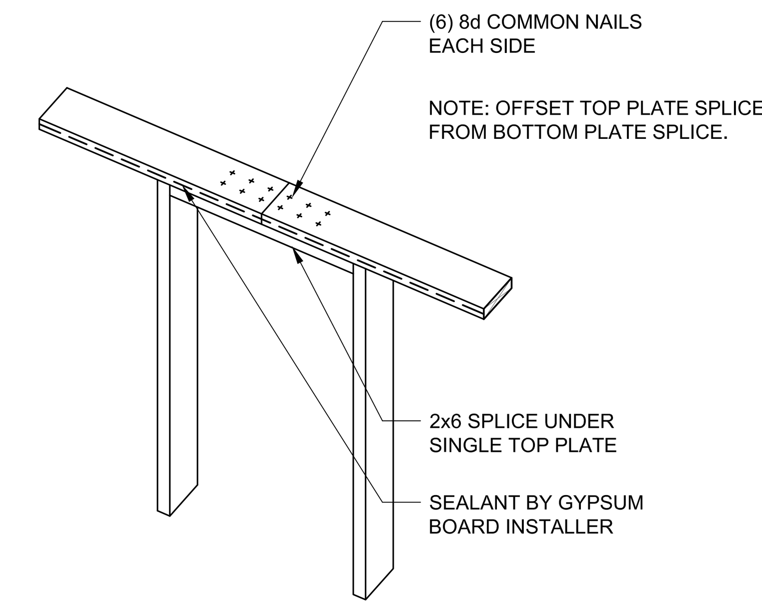
EXTERIOR ELEVATIONS

SCALE: AS NOTED

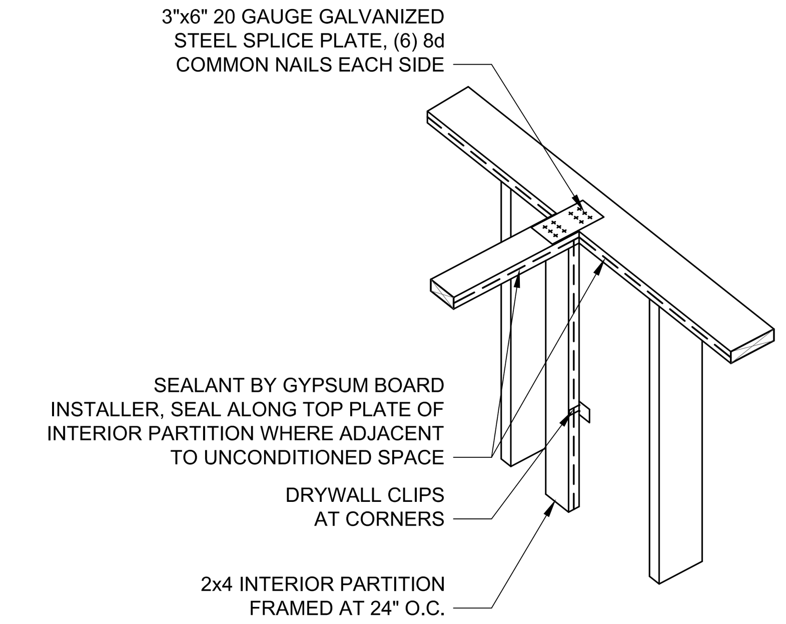
A-202



10 TWO-STUD CORNER - TOP
SCALE: N.T.S.



7 SINGLE TOP PLATE SPLICE
SCALE: N.T.S.



4 SINGLE TOP PLATE AT PARTITION
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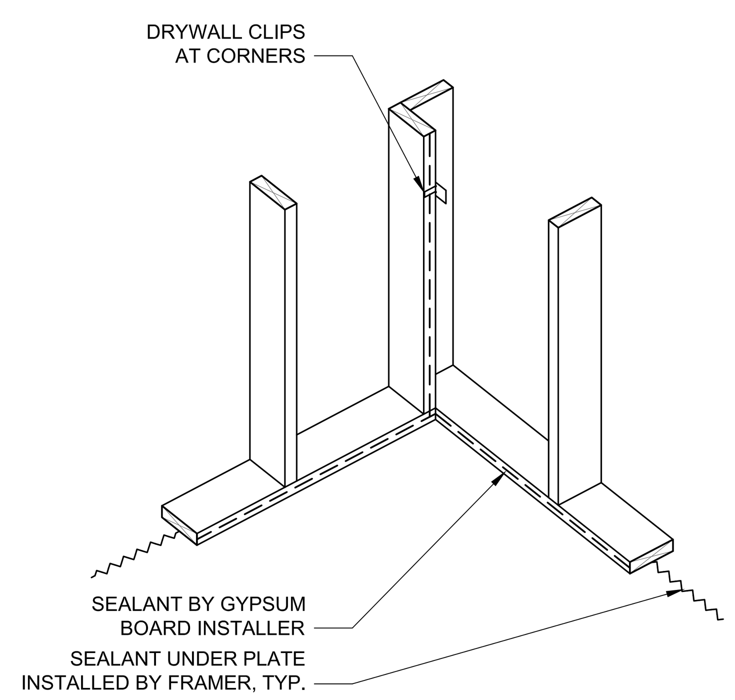
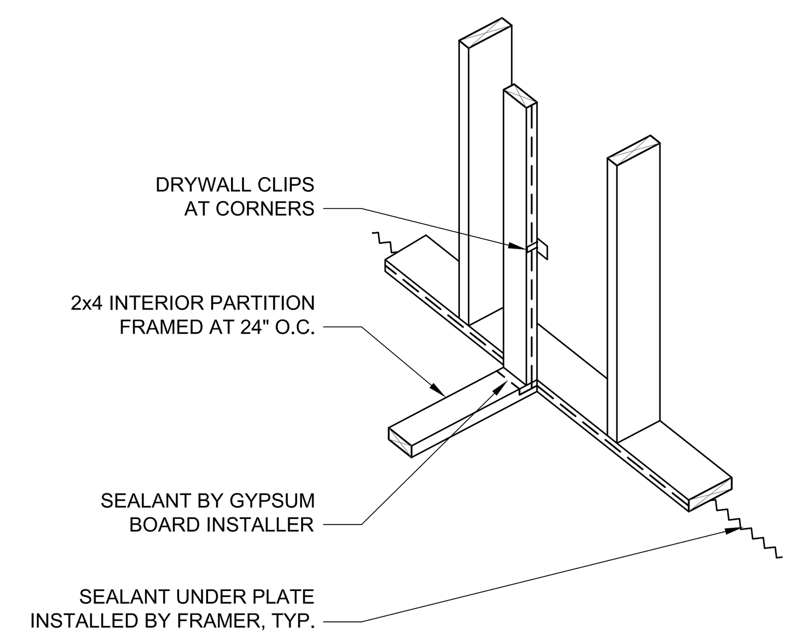
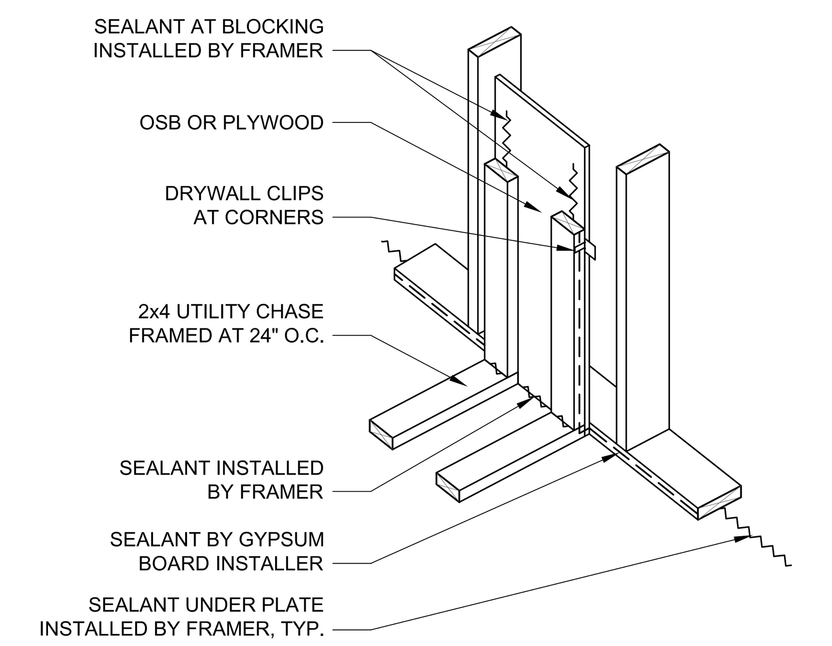


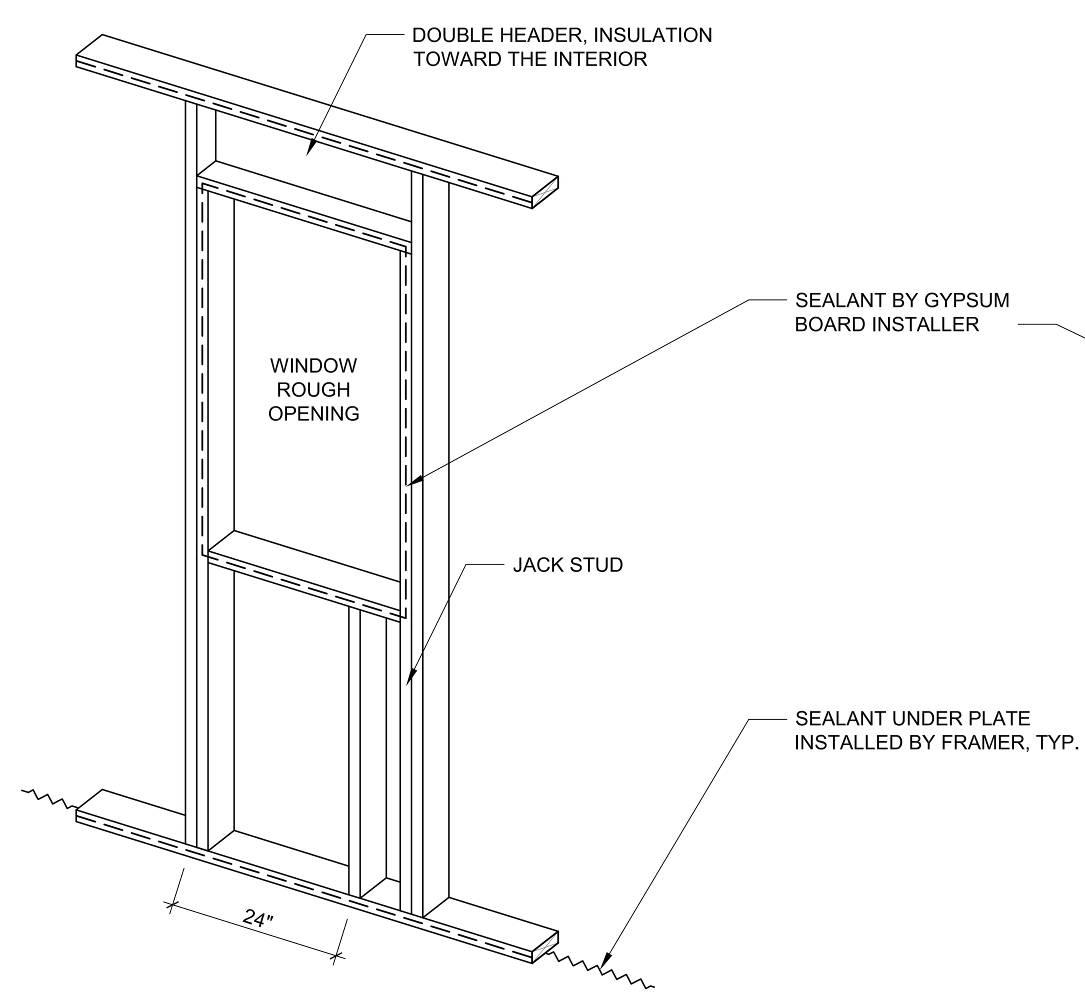
9 TWO-STUD CORNER - BOTTOM
SCALE: N.T.S.



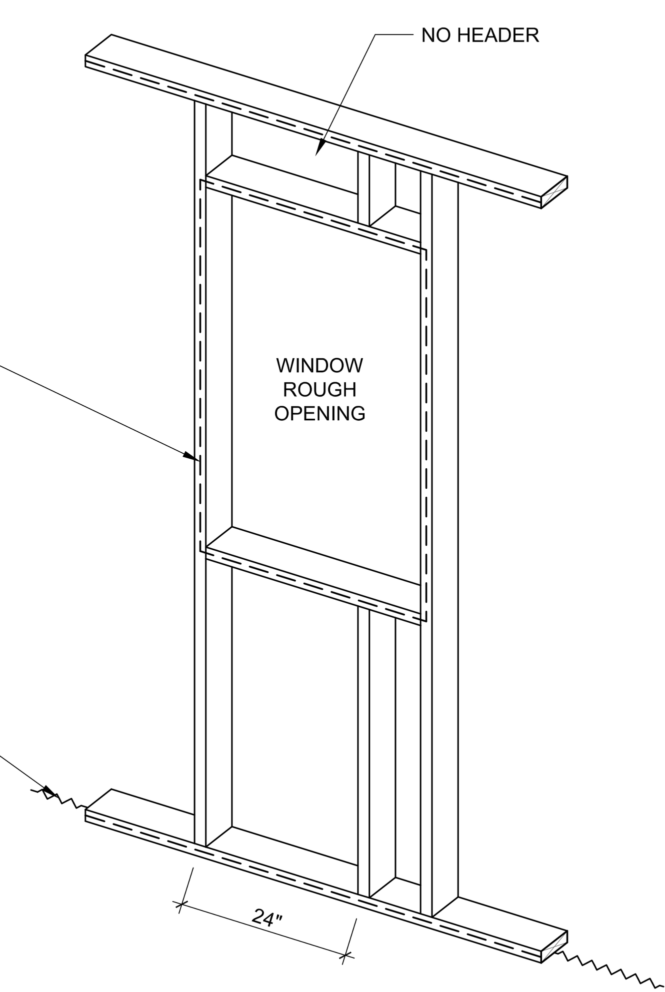
6 BOTTOM PLATE AT PARTITION
SCALE: N.T.S.



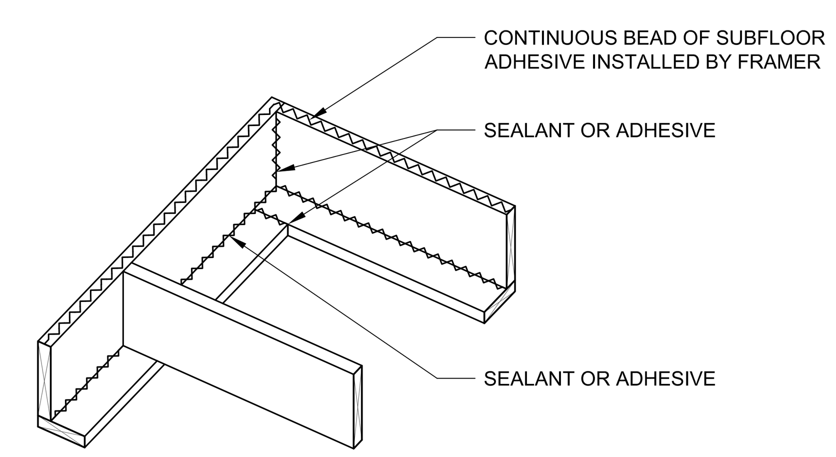
3 CHASE AIR SEALING
SCALE: N.T.S.



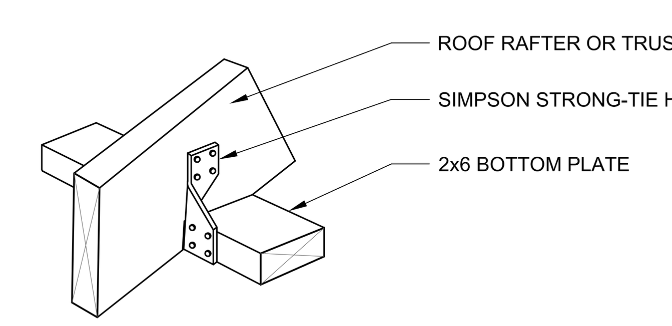
8 LOAD BEARING WALL
SCALE: N.T.S.



5 NON-LOAD BEARING WALL
SCALE: N.T.S.



2 RIM JOIST AIR SEALING
SCALE: N.T.S.



1 ROOF-WALL CONNECTION
SCALE: N.T.S.

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PS	4/24/09	PERMIT SET

ISSUE:

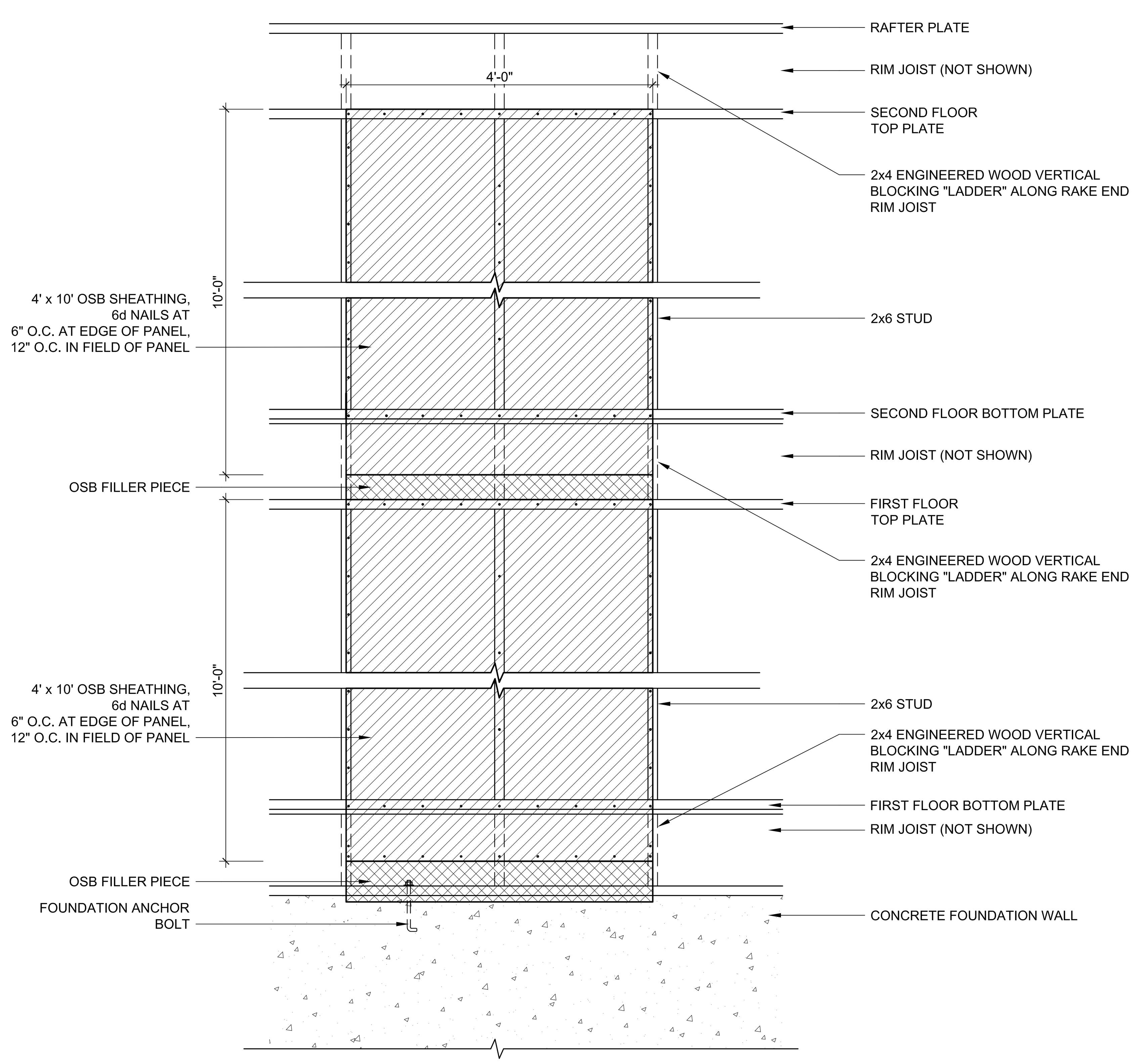
PROJECT NO:	PS 099
CAD DWG FILE:	PS 099–PLOT–Details
DRAWN BY:	KG
CHECKED BY:	BP

SHEET TITLE:

ADVANCED FRAMING & AIR SEALING DETAILS

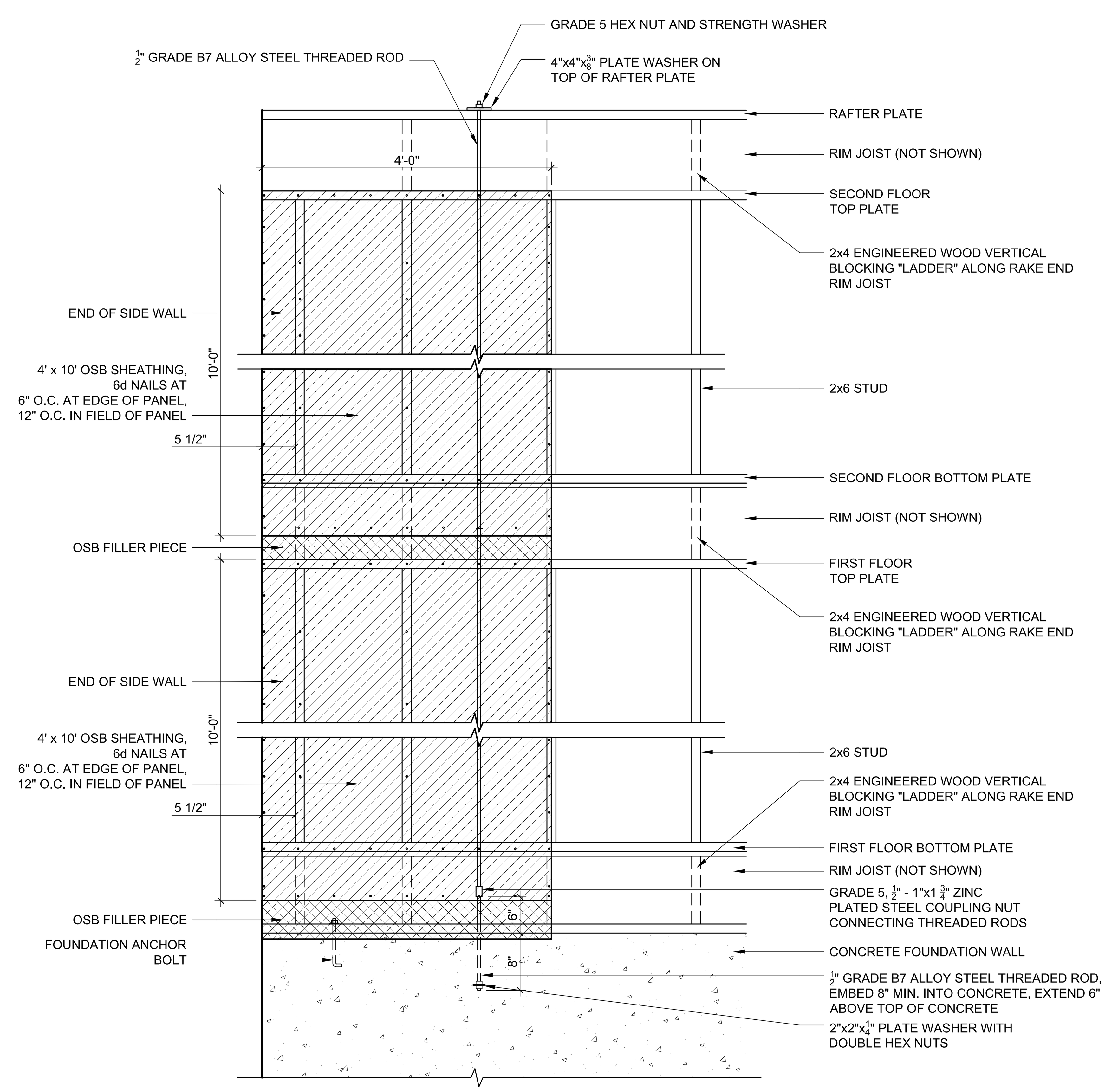
SCALE: AS NOTED

A-501



2 BRACED WALL ELEVATION ALONG WALL

SCALE: 3/4" = 1'-0"



1 BRACED WALL ELEVATION AT CORNER

SCALE: 3/4" = 1'-0"

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MARK	DATE	DESCRIPTION

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PROJECT NO:	PS 099
CAD DWG FILE:	PS 099–PLOT–Details
DRAWN BY:	KG
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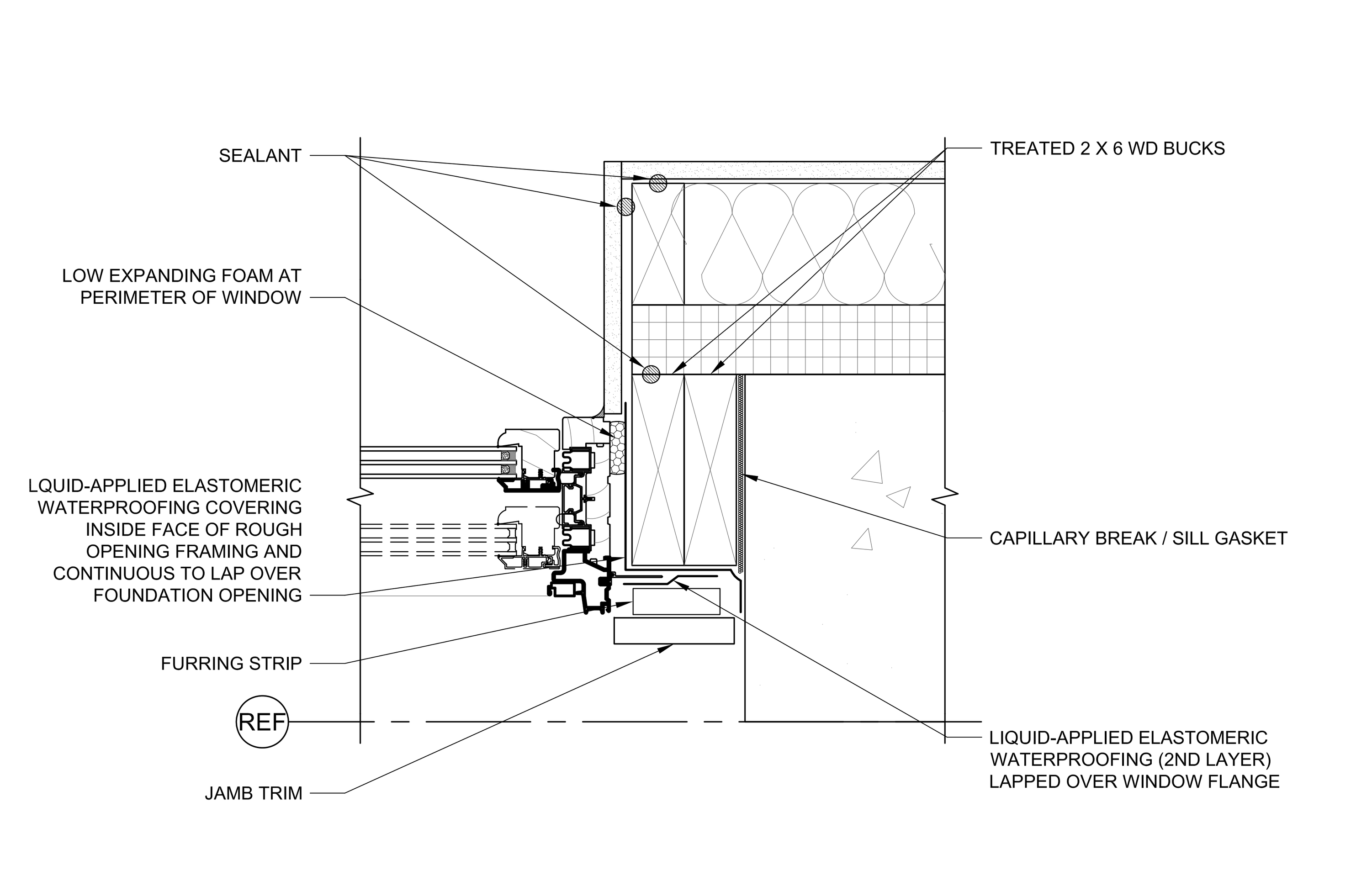
SHEET TITLE:

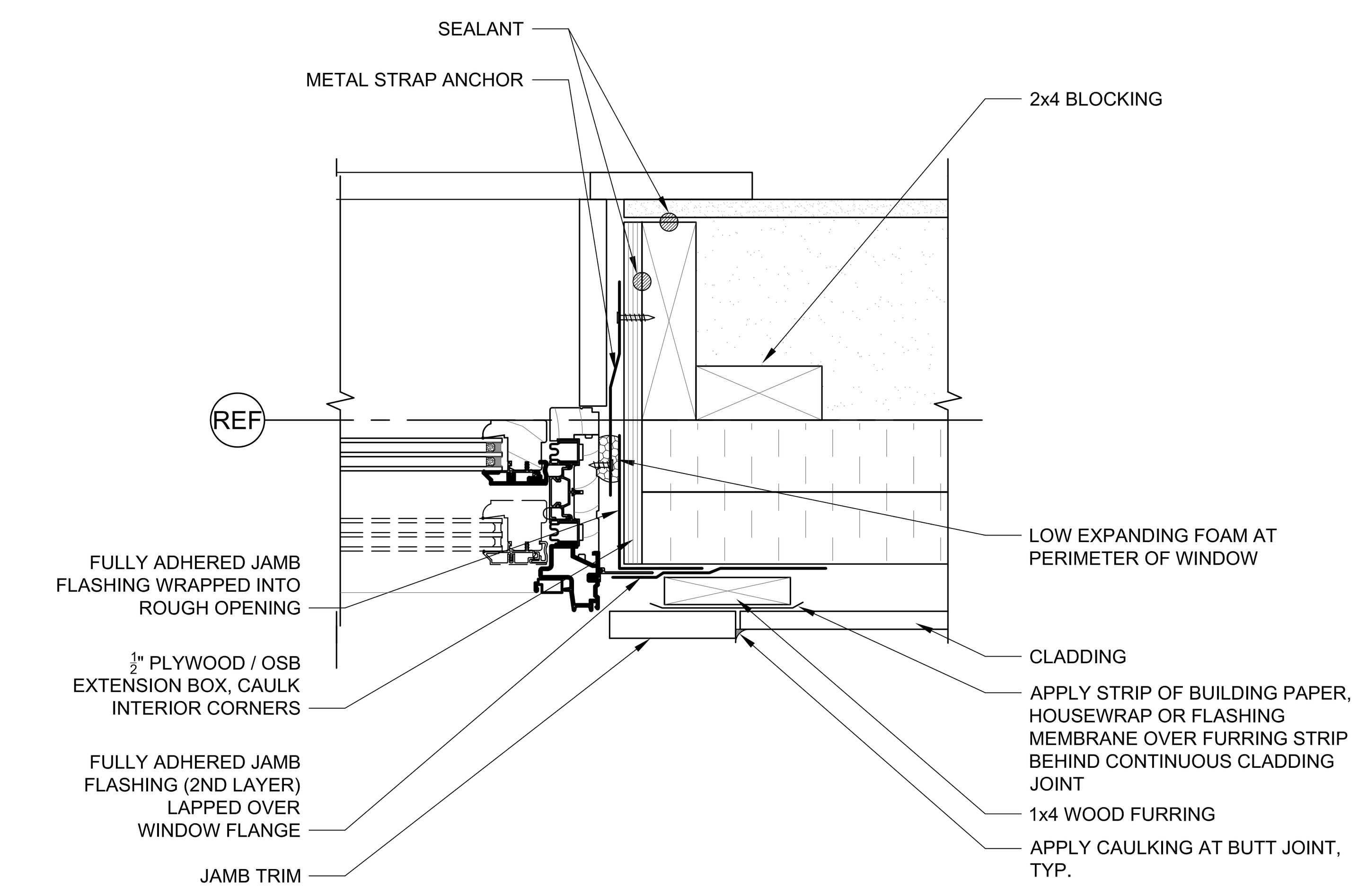
BRACED WALL ELEVATIONS

SCALE: AS NOTED

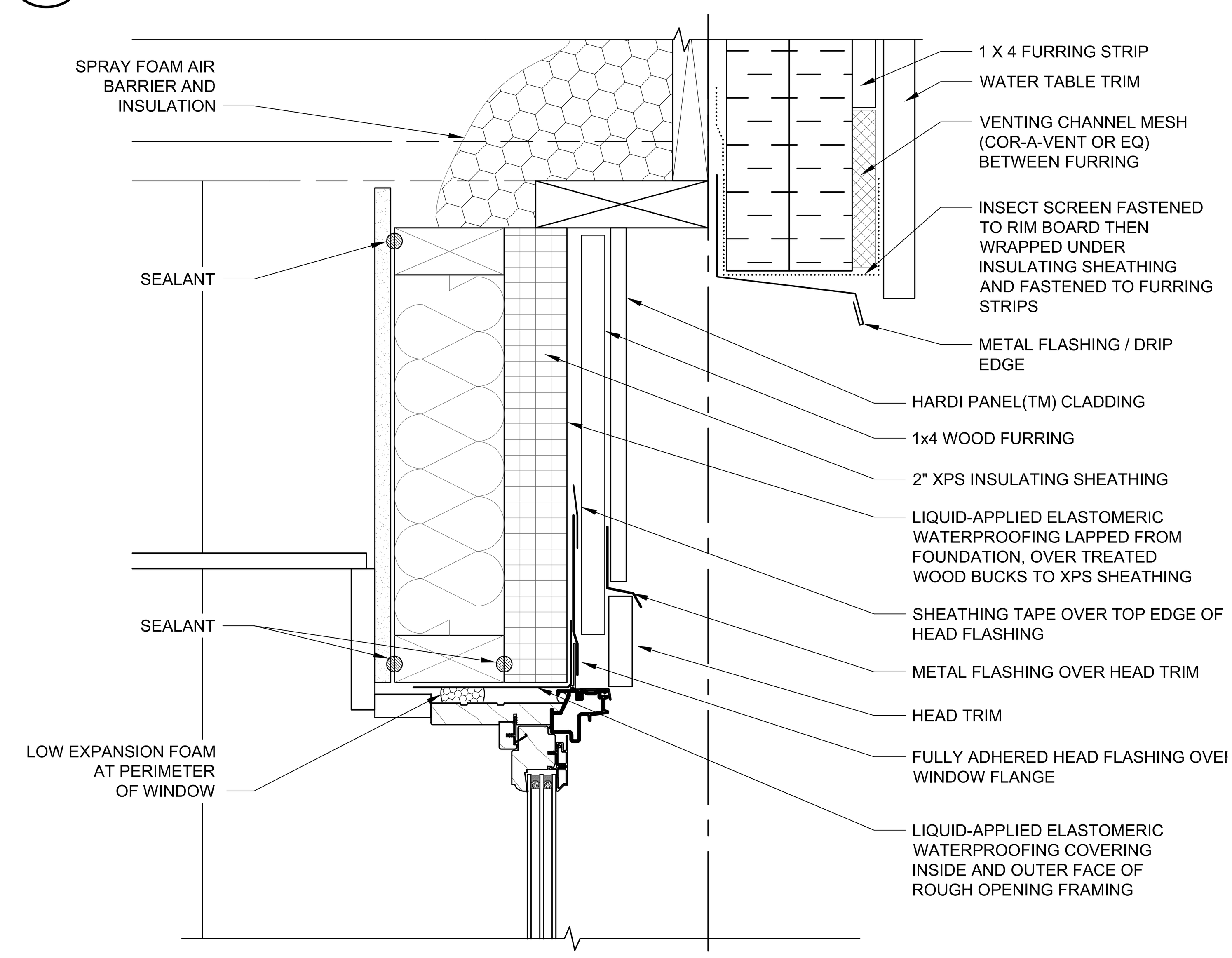
A-502



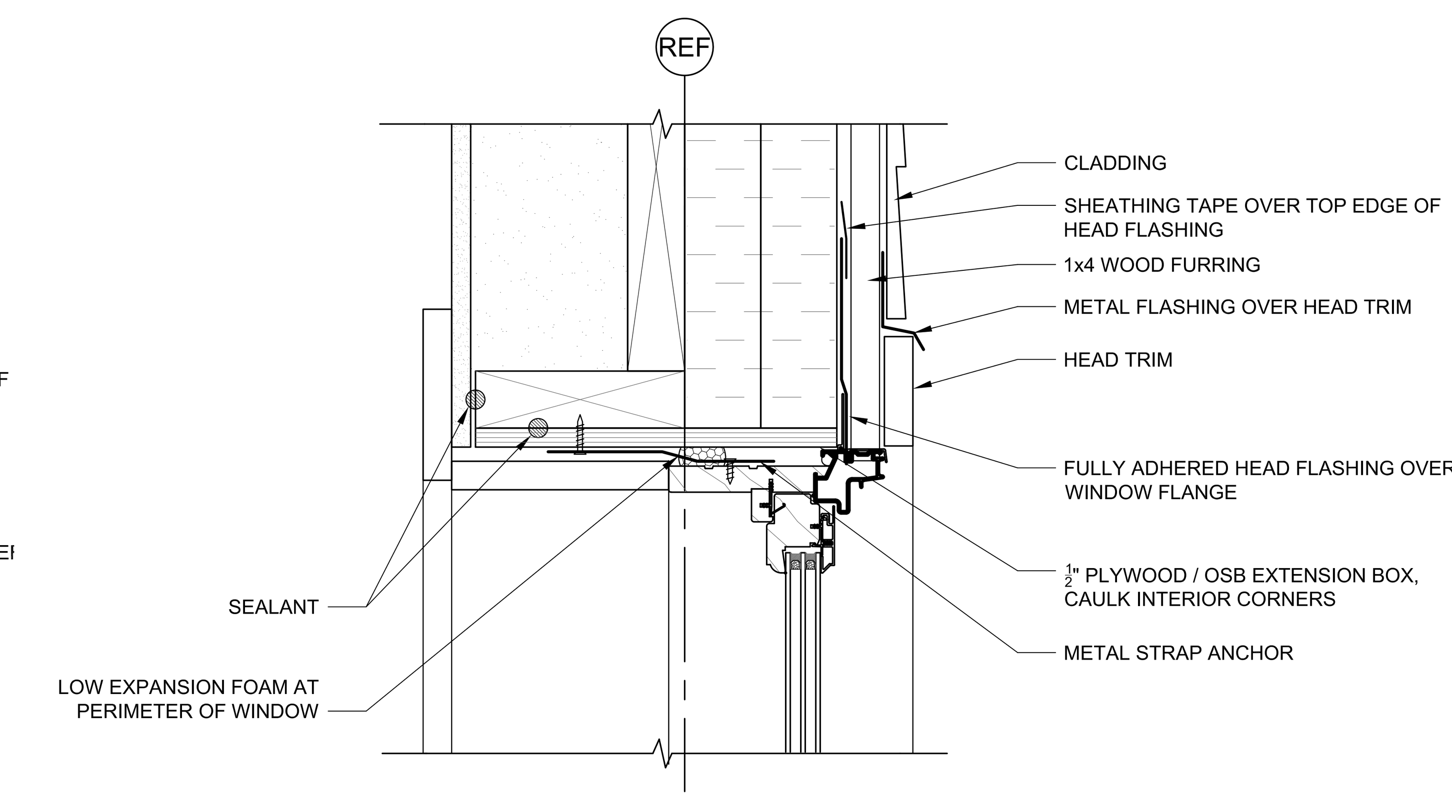
6 BASEMENT WINDOW JAMB DETAIL
SCALE: 3" = 1'-0"



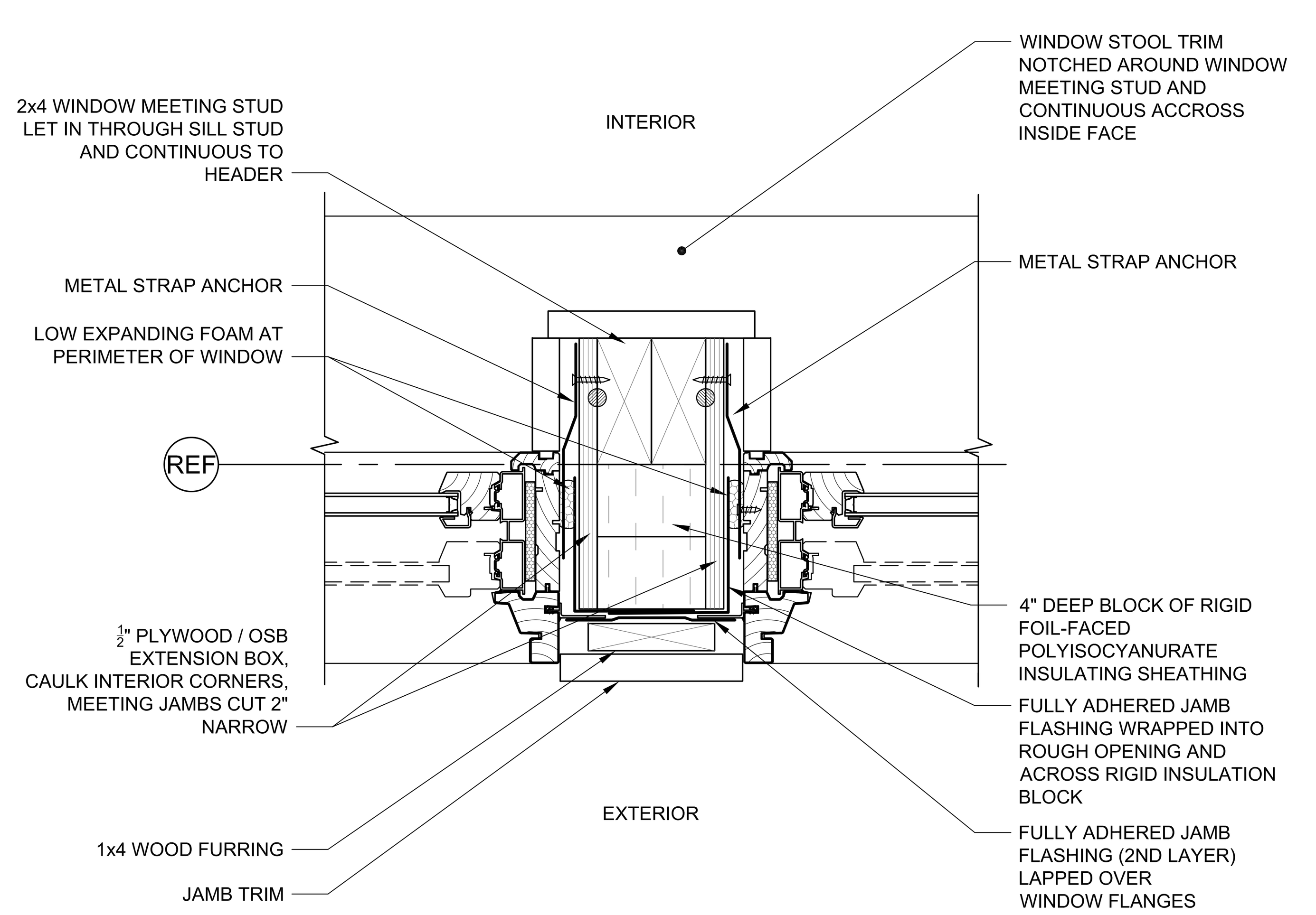
3 WINDOW JAMB DETAIL
SCALE: 3" = 1'-0"



5 BASEMENT WINDOW HEAD DETAIL
SCALE: 3" = 1'-0"



2 WINDOW HEAD DETAIL
SCALE: 3" = 1'-0"



7 GANGED WINDOW JAMB DETAIL
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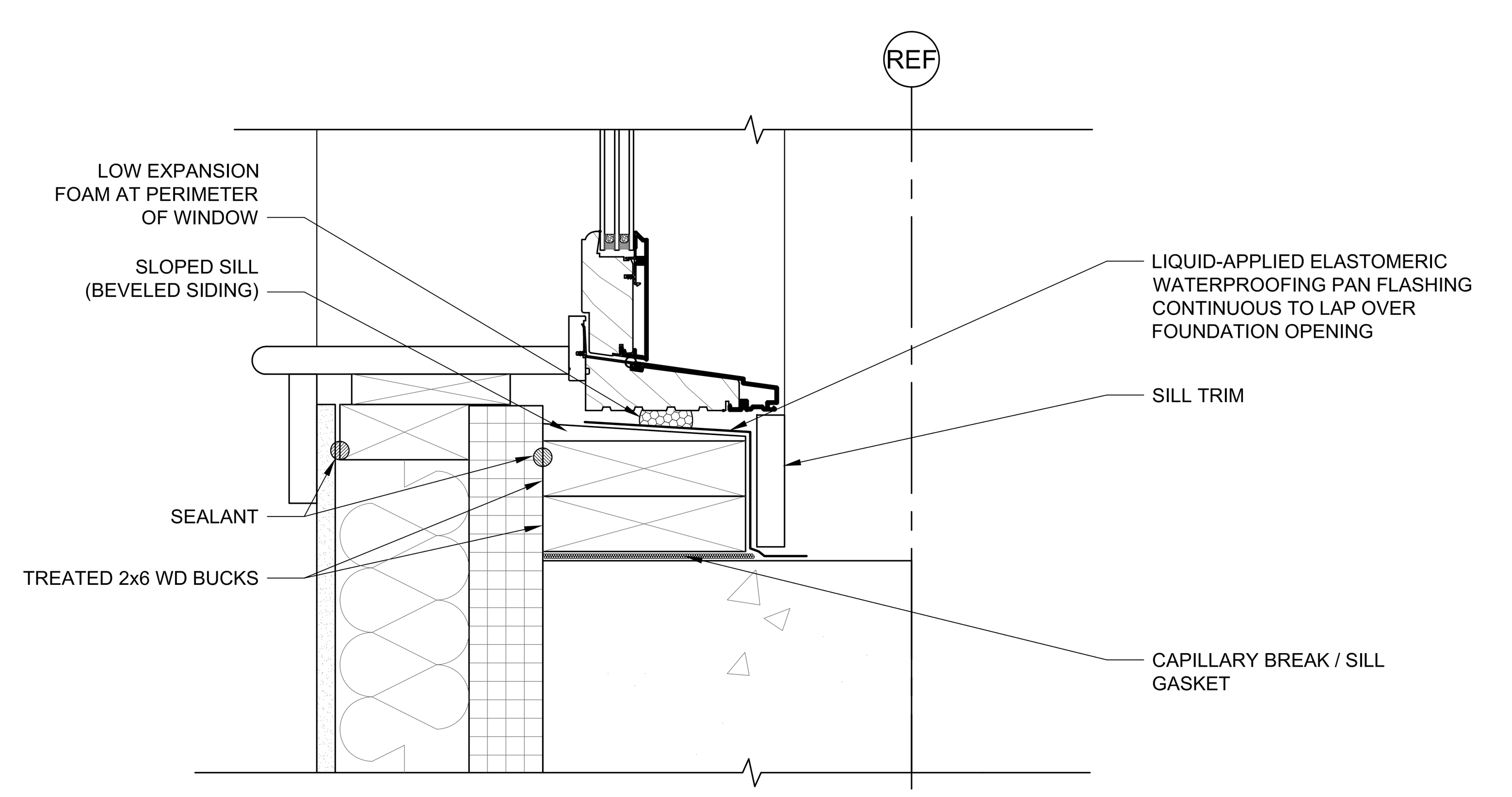
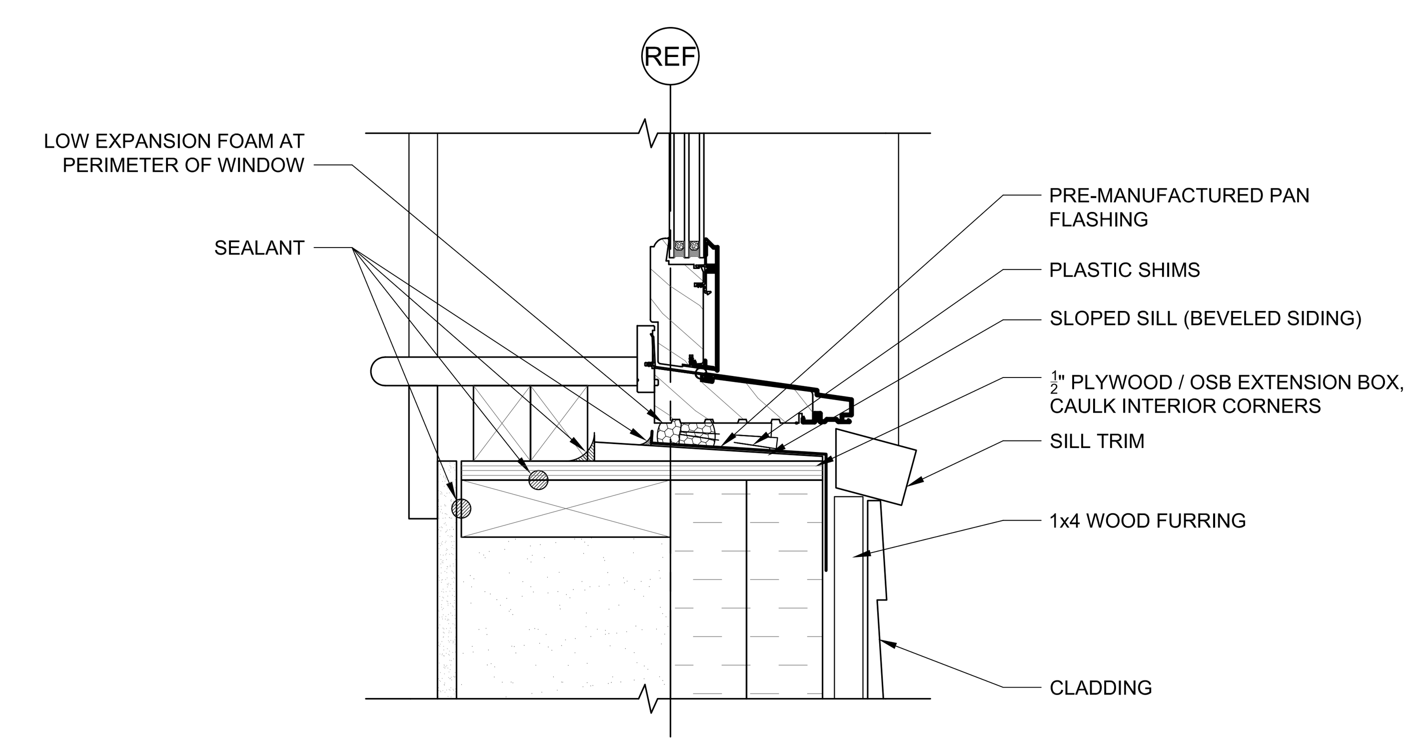


4 BASEMENT WINDOW SILL DETAIL
SCALE: 3" = 1'-0"



1 WINDOW SILL DETAIL
SCALE: 3" = 1'-0"

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MARK	DATE	DESCRIPTION

ISSUE:

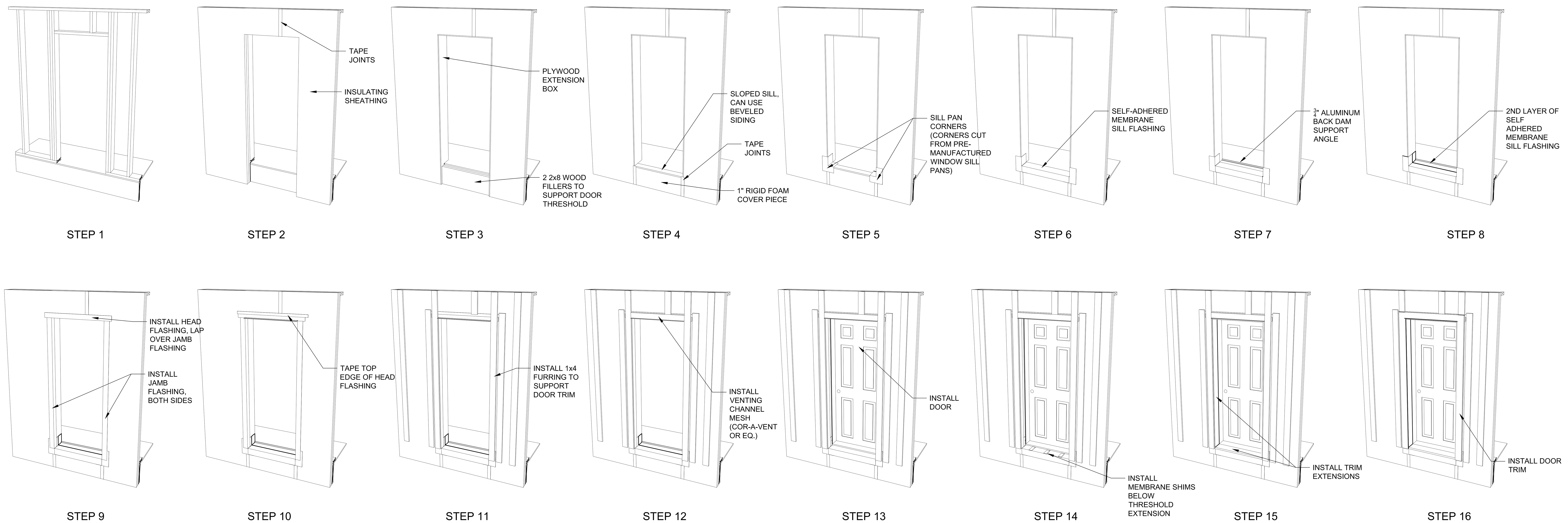
PROJECT NO:	PS 099
CAD DWG FILE:	PS 099—PLOT—Details
DRAWN BY:	KG
CHECKED BY:	BP

SHEET TITLE:

WINDOW DETAILS

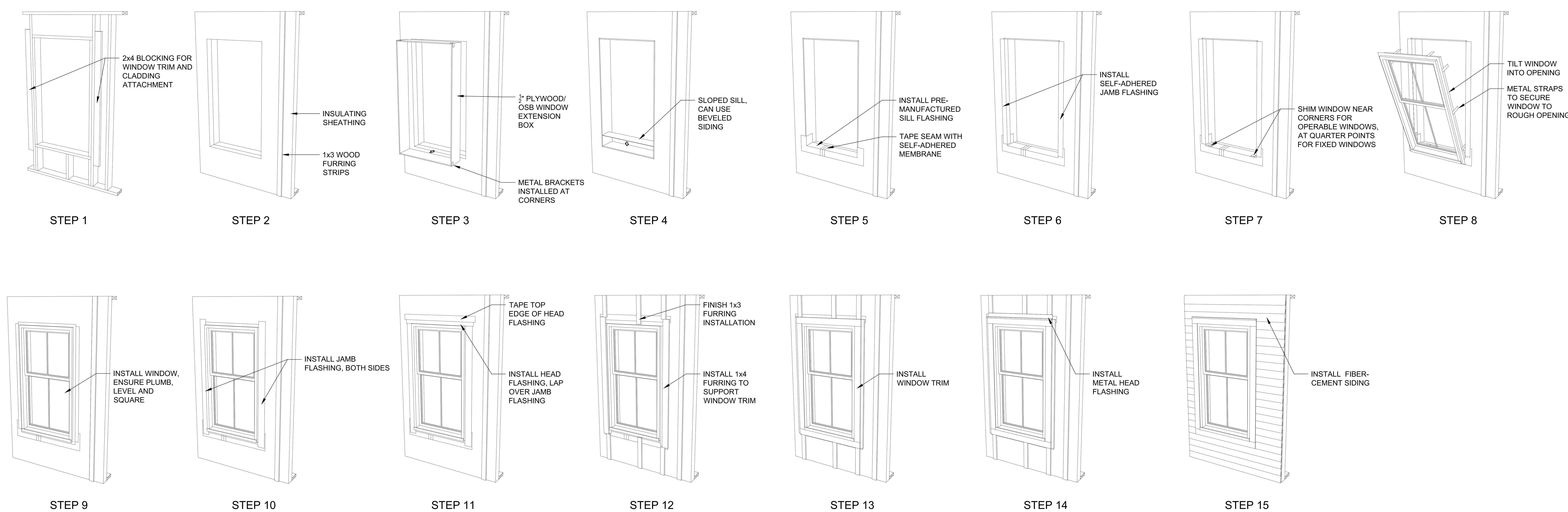
SCALE: AS NOTED

A-503



2 DOOR INSTALLATION SEQUENCE

SCALE: N.T.S.



1 WINDOW INSTALLATION SEQUENCE

SCALE: N.T.S.

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MARK	DATE	DESCRIPTION

ISSUE:

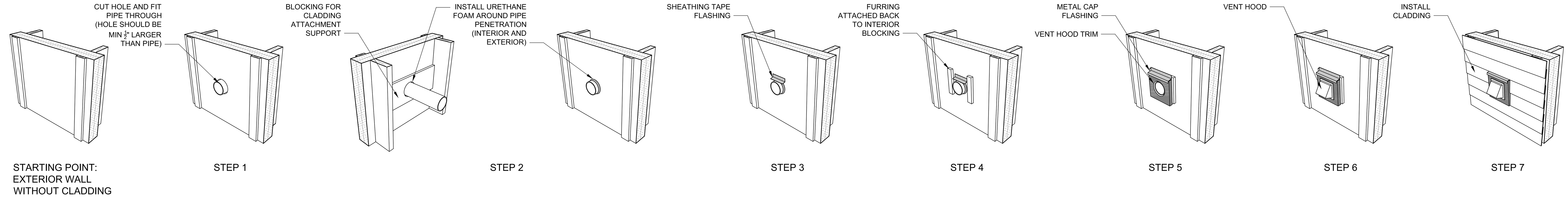
PROJECT NO:	PS 099
CAD DWG FILE:	PS 099–PLOT–Details
DRAWN BY:	KN, JM
CHECKED BY:	BP

SHEET TITLE:

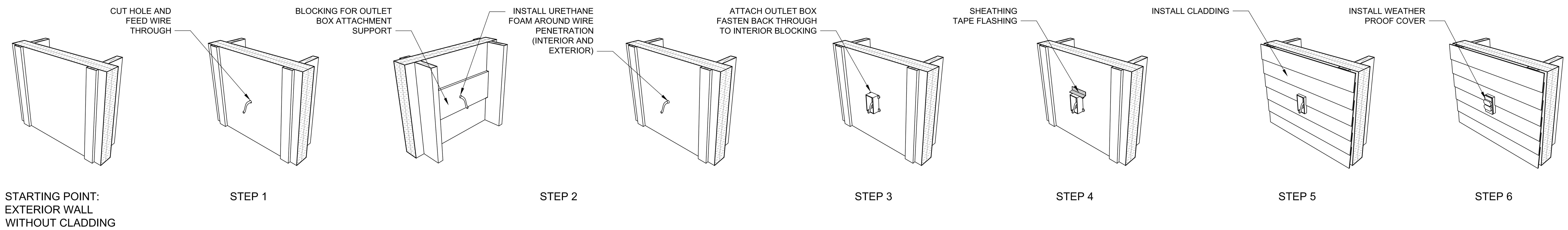
WINDOW & DOOR INSTALLATION SEQUENCES

SCALE: AS NOTED

A-504



PIPE / DUCT INSTALLATION SEQUENCE



EXTERIOR ELECTRICAL BOX INSTALLATION SEQUENCE

7 ENCLOSURE PENETRATION INSTALLATION SEQUENCES

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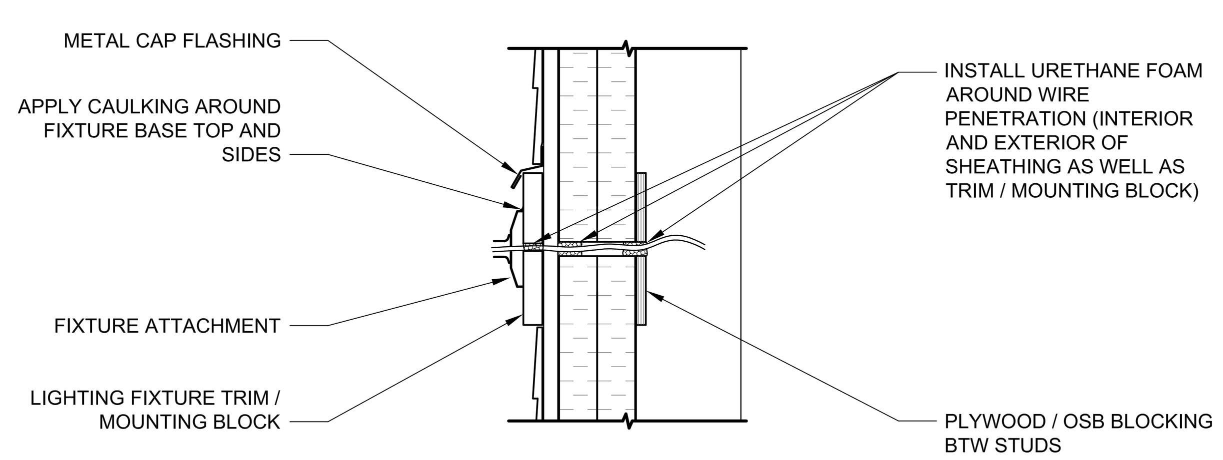
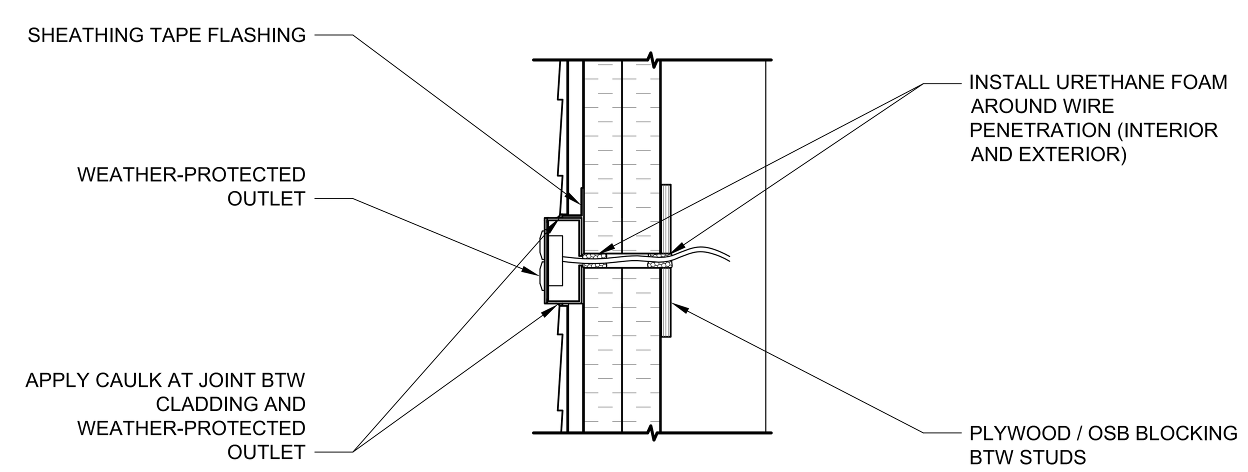


6 EXTERIOR LIGHT FIXTURE SECTION DETAIL

SCALE: 3" = 1'-0"



4 EXTERIOR ELECTRICAL BOX SECTION DETAIL

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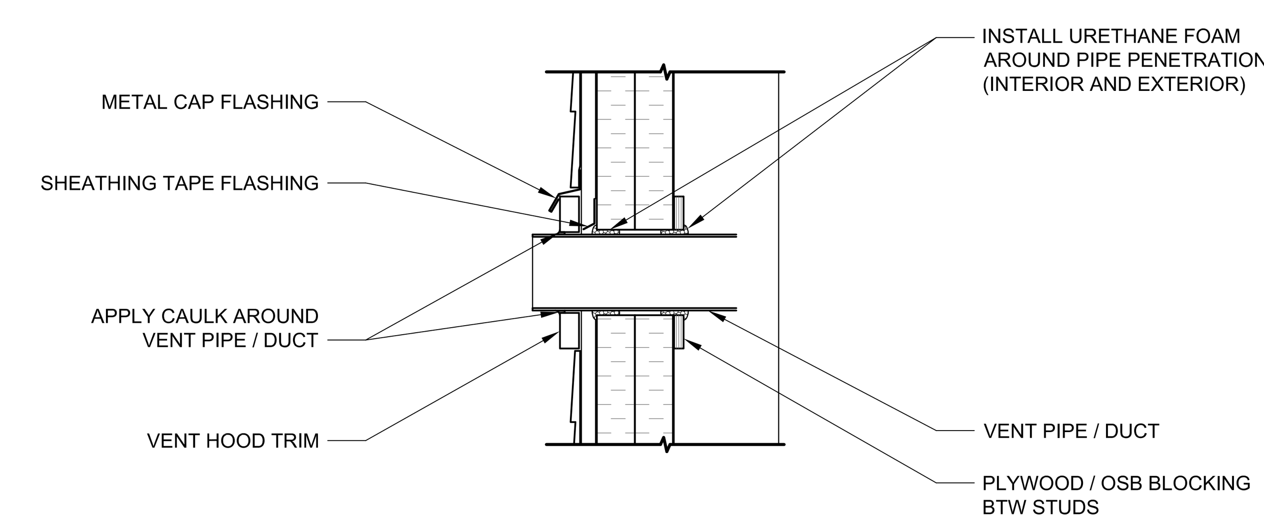

2 PIPE / DUCT SECTION DETAIL

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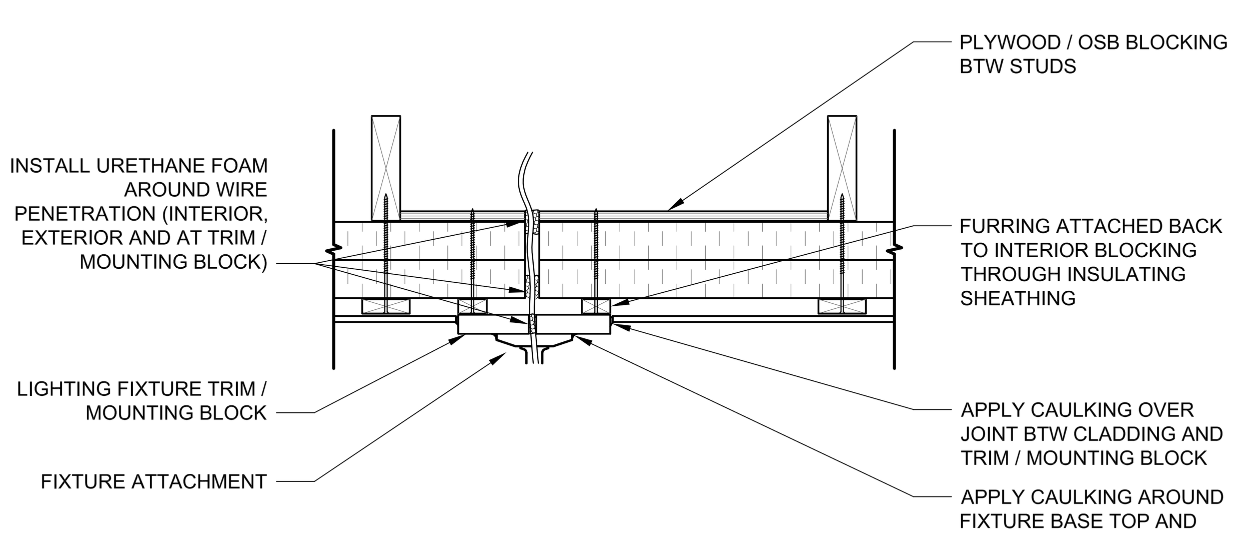
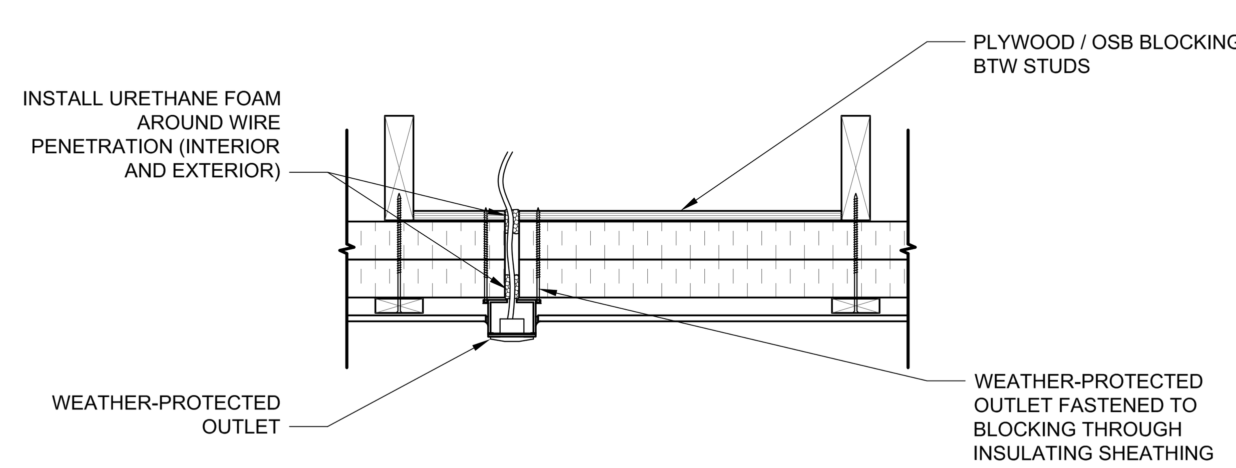


5 EXTERIOR LIGHT FIXTURE PLAN DETAIL

SCALE: 3" = 1'-0"



3 EXTERIOR ELECTRICAL BOX PLAN DETAIL

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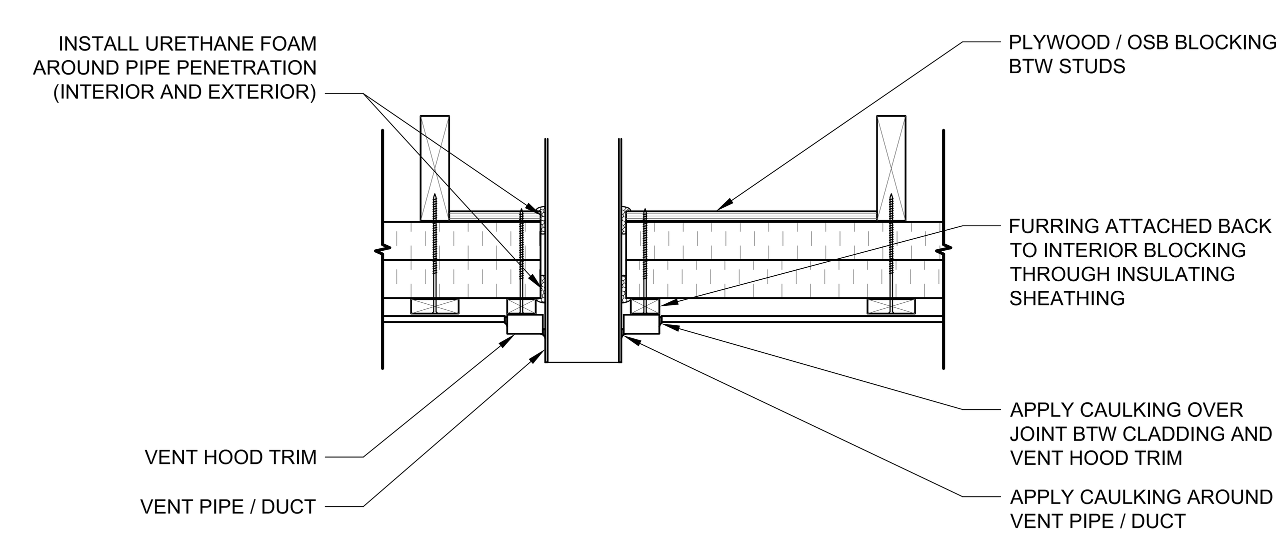

1 PIPE / DUCT PLAN DETAIL

SCALE: 3" = 1'-0"

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MARK	DATE	DESCRIPTION

ISSUE:

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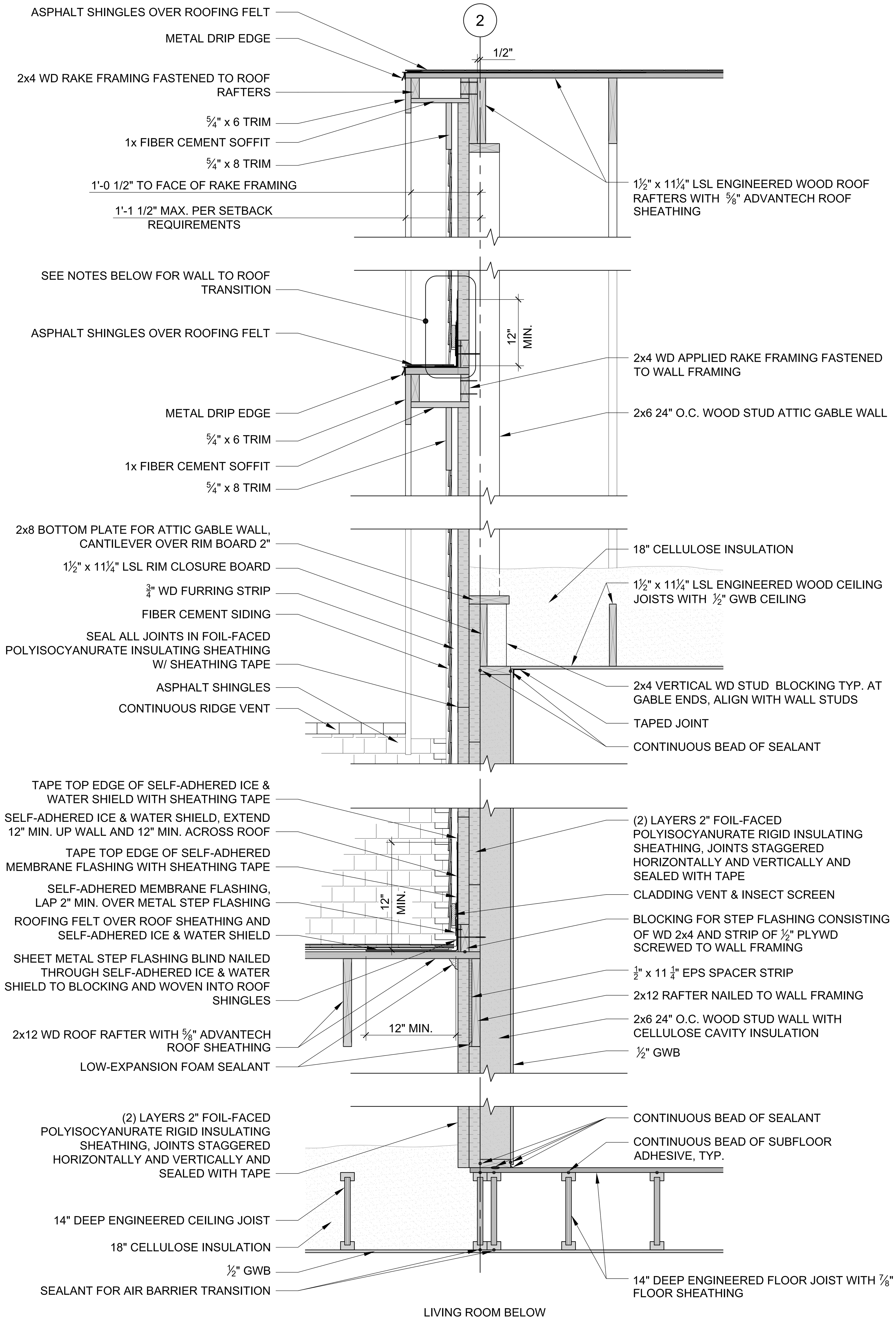
DRAWN BY:	KG
CHECKED BY:	BP

SHEET TITLE:

ENCLOSURE PENETRATION DETAILS & SEQUENCES

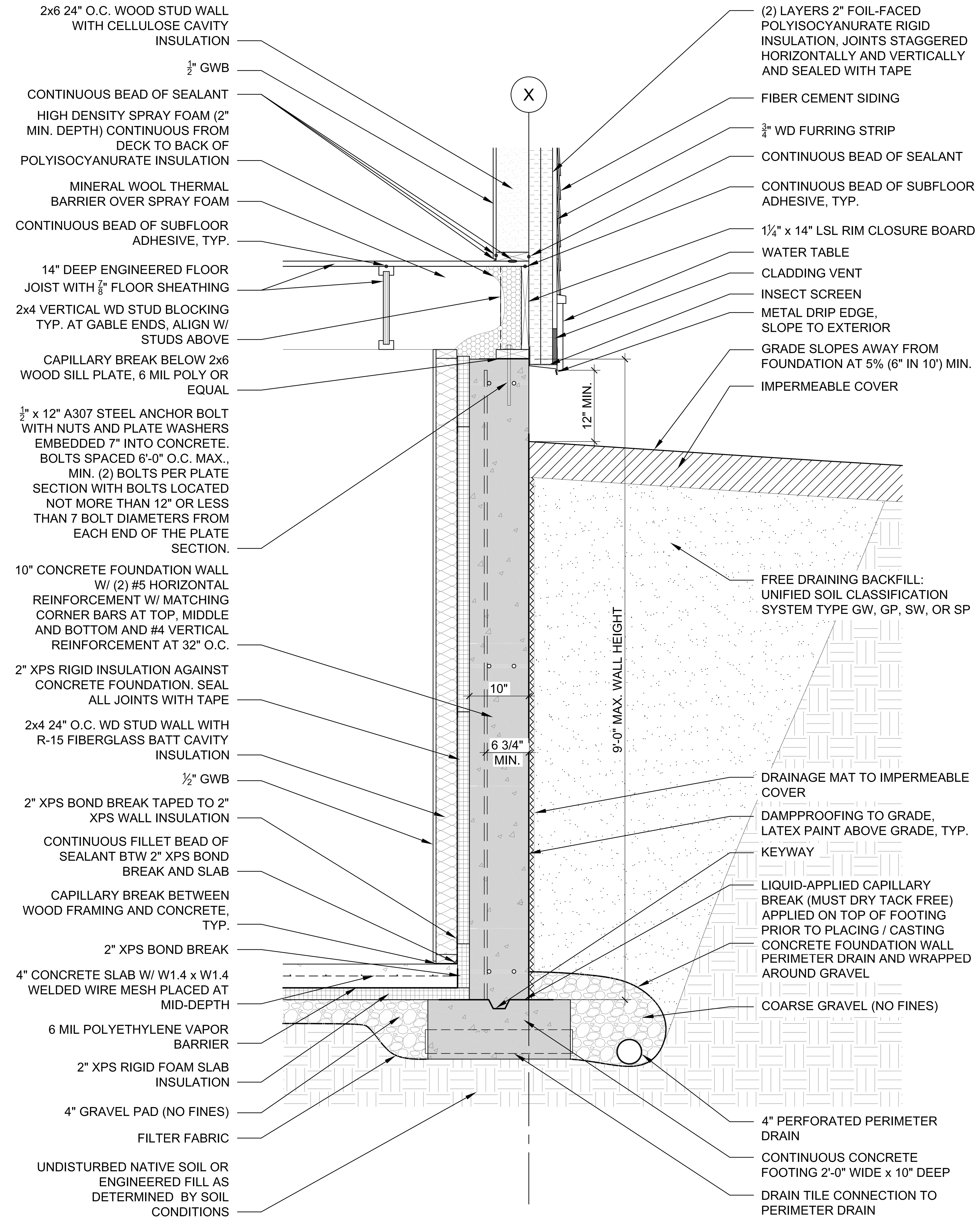
SCALE: AS NOTED

A-505



2 TYPICAL GABLE WALL DETAILS

SCALE: 1" = 1'-0"



1 TYPICAL FOUNDATION WALL DETAIL

SCALE: 1" = 1'-0"

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Building America — U.S. Department of Energy — Research Toward Zero Energy Homes

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ISSUE:

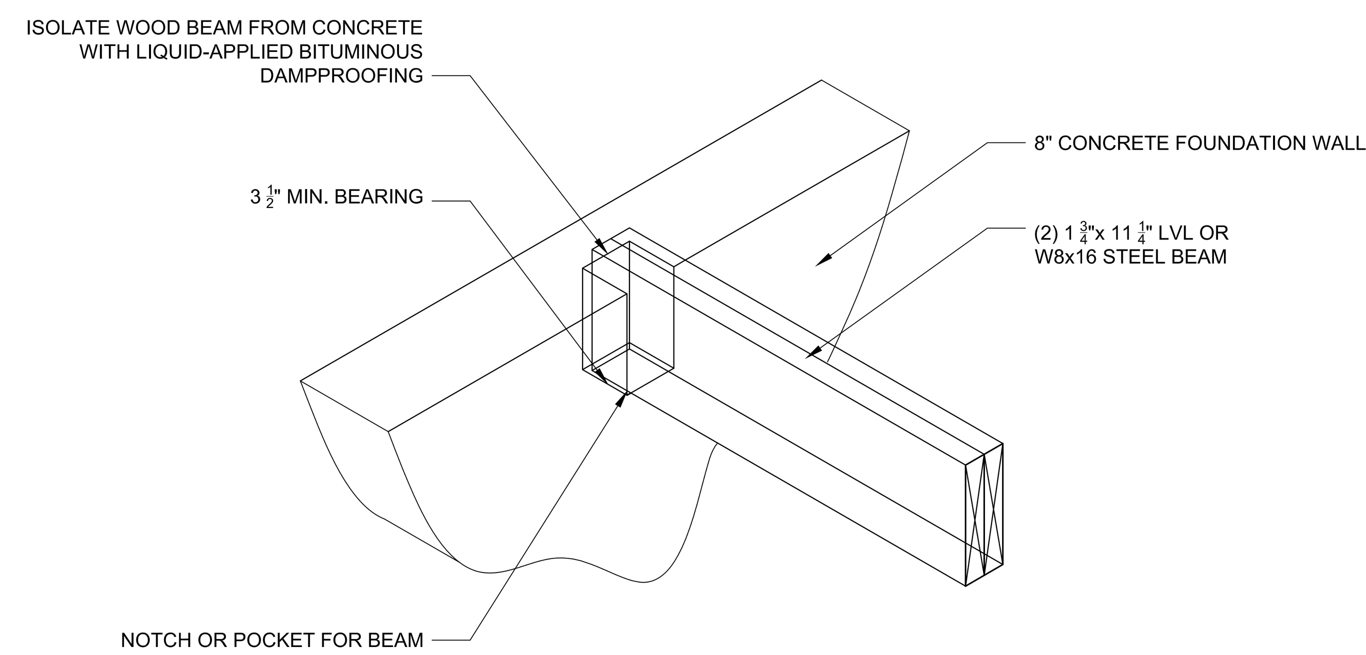
PROJECT NO:	PS 099
CAD DWG FILE:	PS 099–PLOT–Details
DRAWN BY:	KN
CHECKED BY:	BP

SHEET TITLE:

VERTICAL ENCLOSURE DETAILS

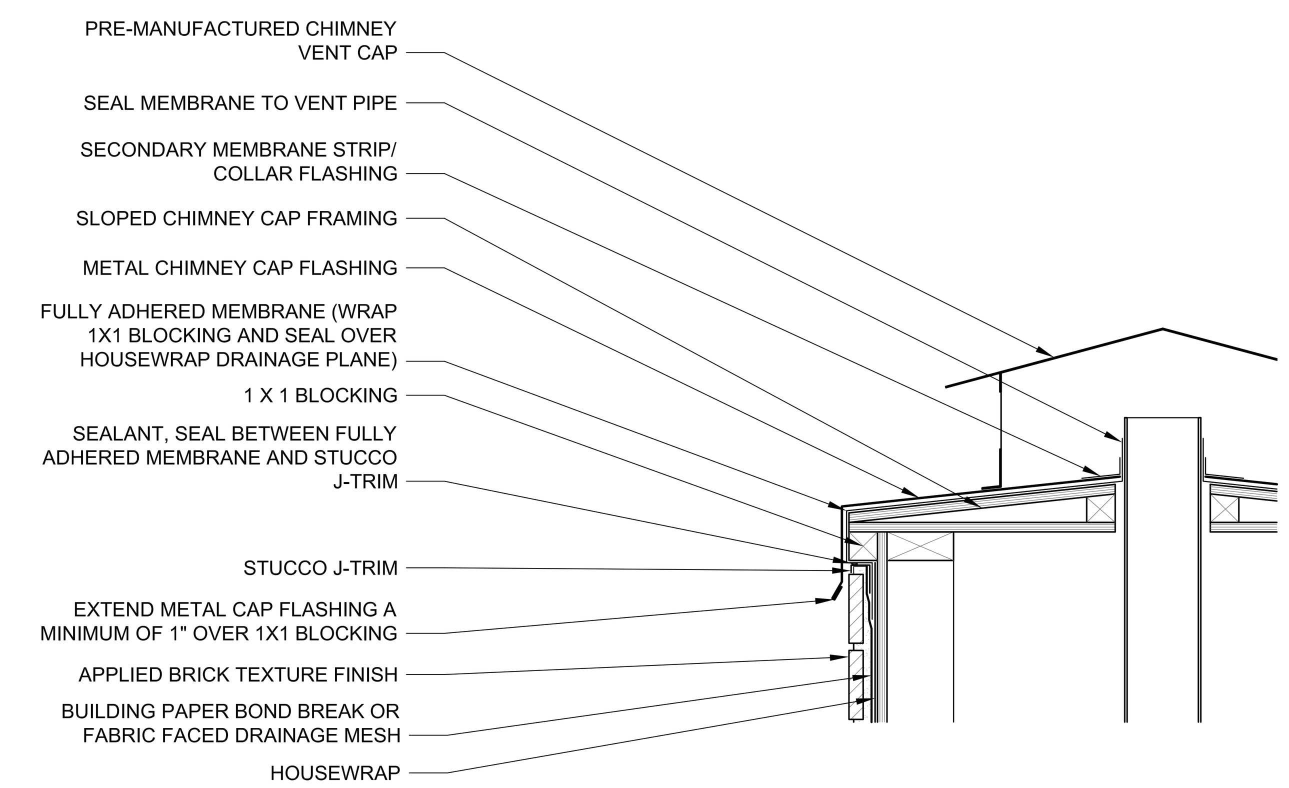
SCALE: AS NOTED

A-506



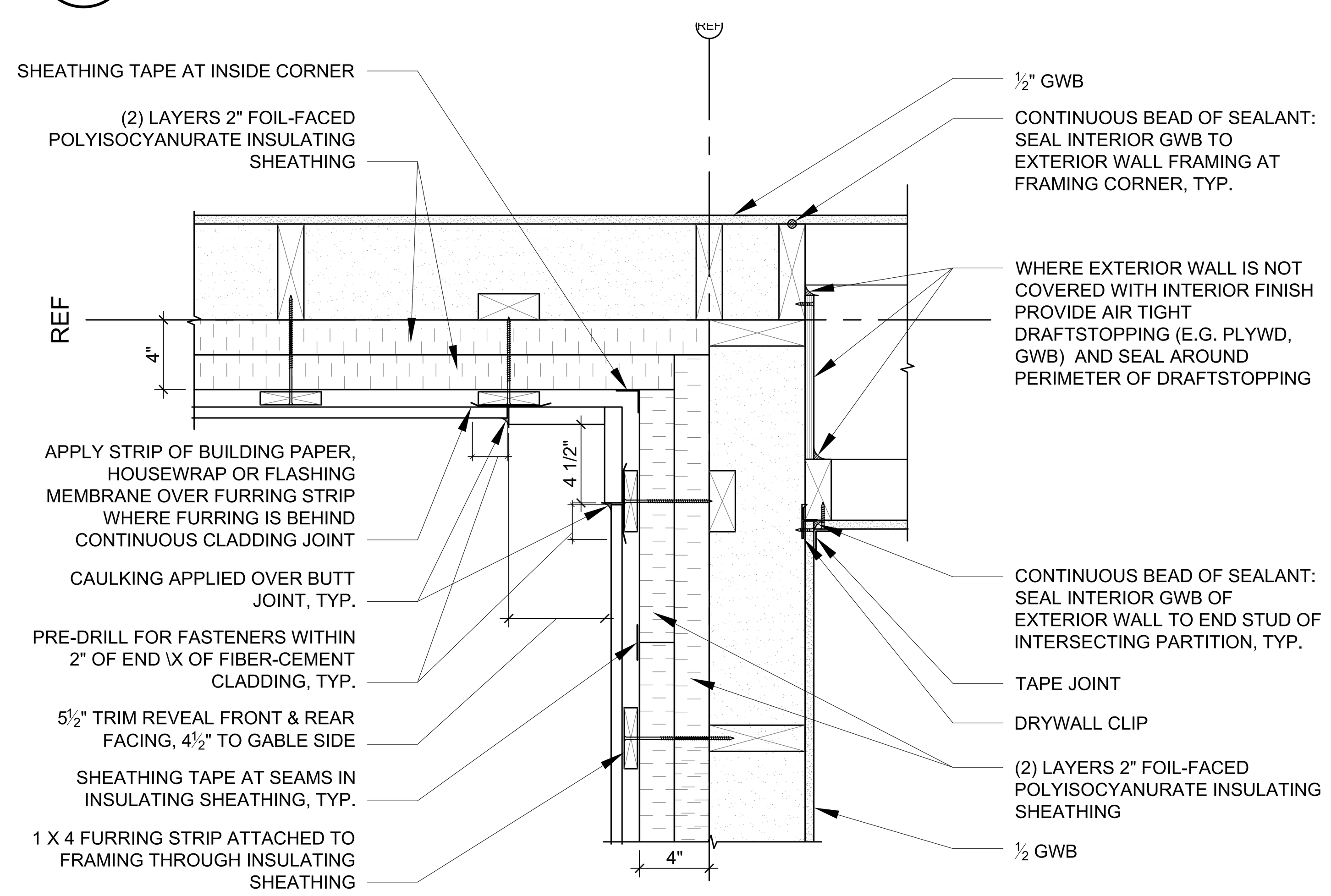
6 FOUNDATION WALL BEAM POCKET DETAIL

SCALE: 1 1/2" = 1'-0"



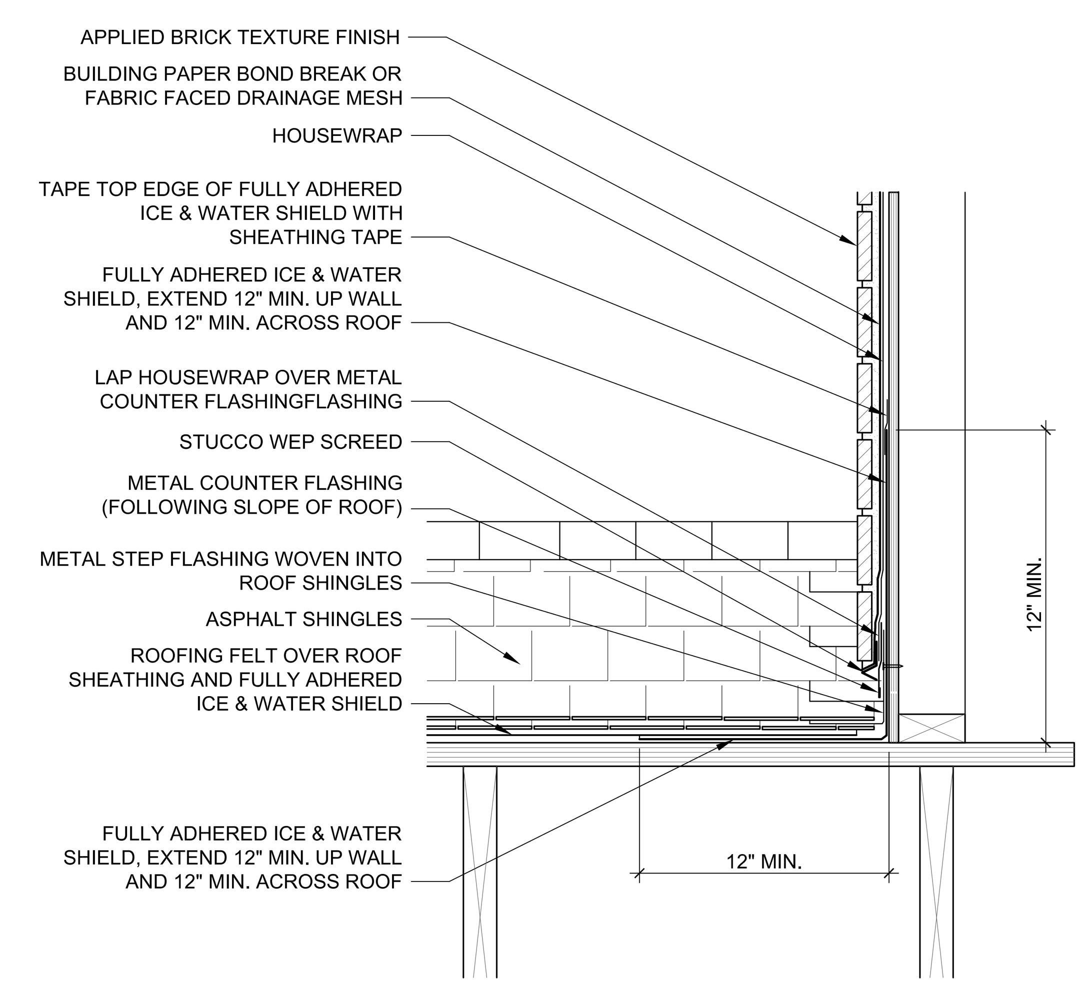
3 TOP OF CHIMNEY DETAIL

SCALE: 1 1/2" = 1'-0"



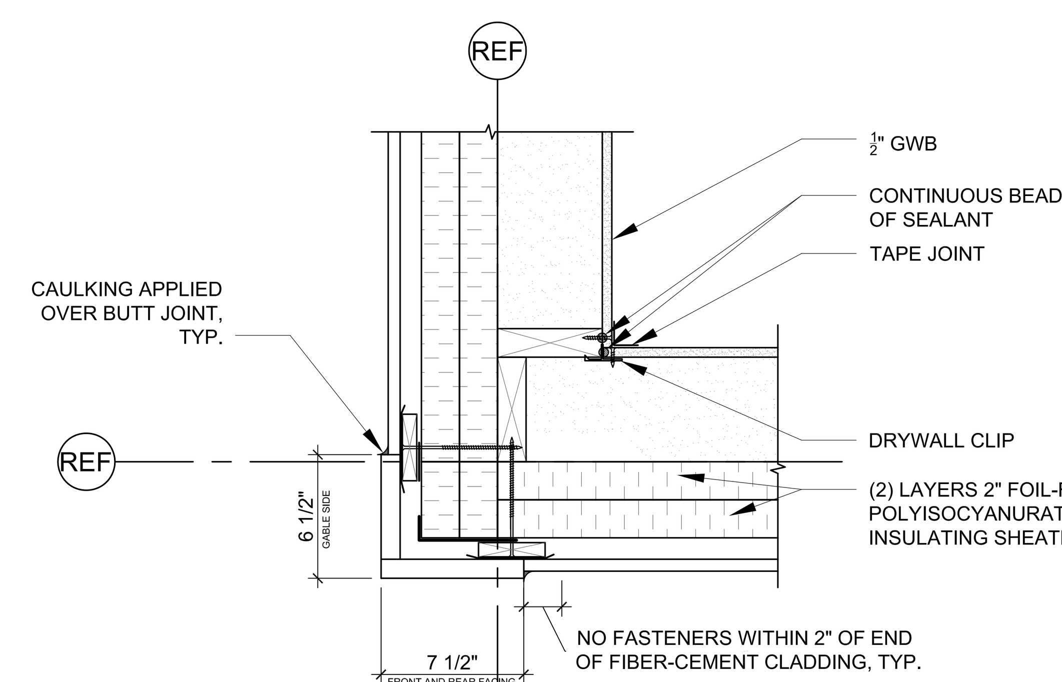
5 INSIDE CORNER DETAIL

SCALE: 1 1/2" = 1'-0"



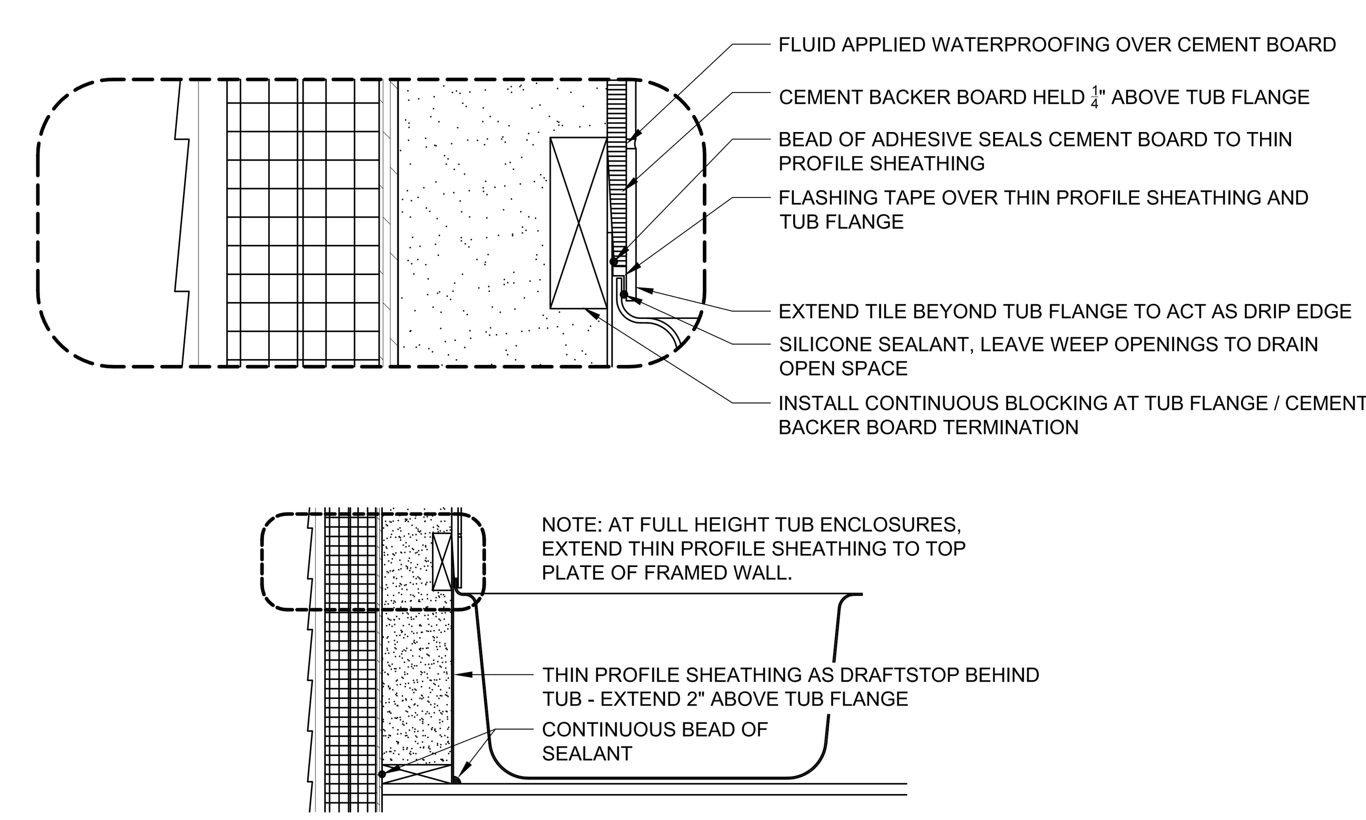
2 BOTTOM OF CHIMNEY DETAIL

SCALE: 1 1/2" = 1'-0"



4 OUTSIDE CORNER DETAIL

SCALE: 1 1/2" = 1'-0"



1 BATHTUB & SHOWER AT EXTERIOR WALL DETAIL

SCALE: 1" = 1'-0" BOTTOM, 3" = 1'-0" TOP

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CAD DWG FILE:	PS 099—PLOT—Details
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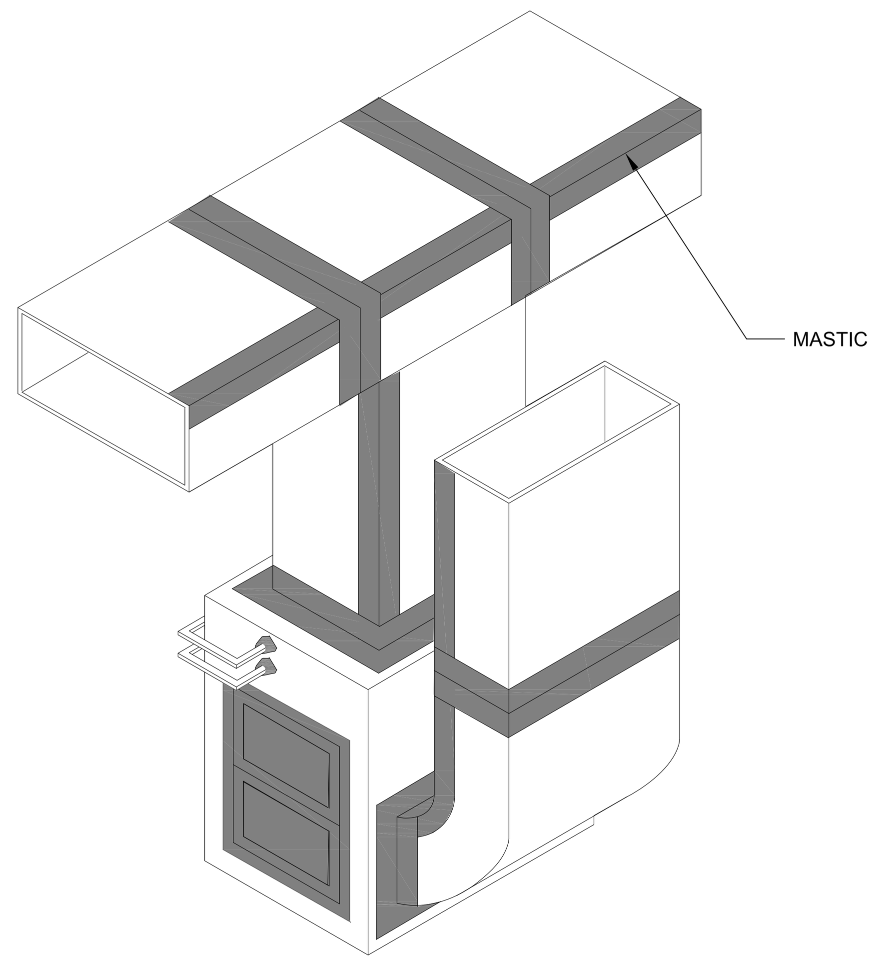
CHECKED BY:	BP

SHEET TITLE:

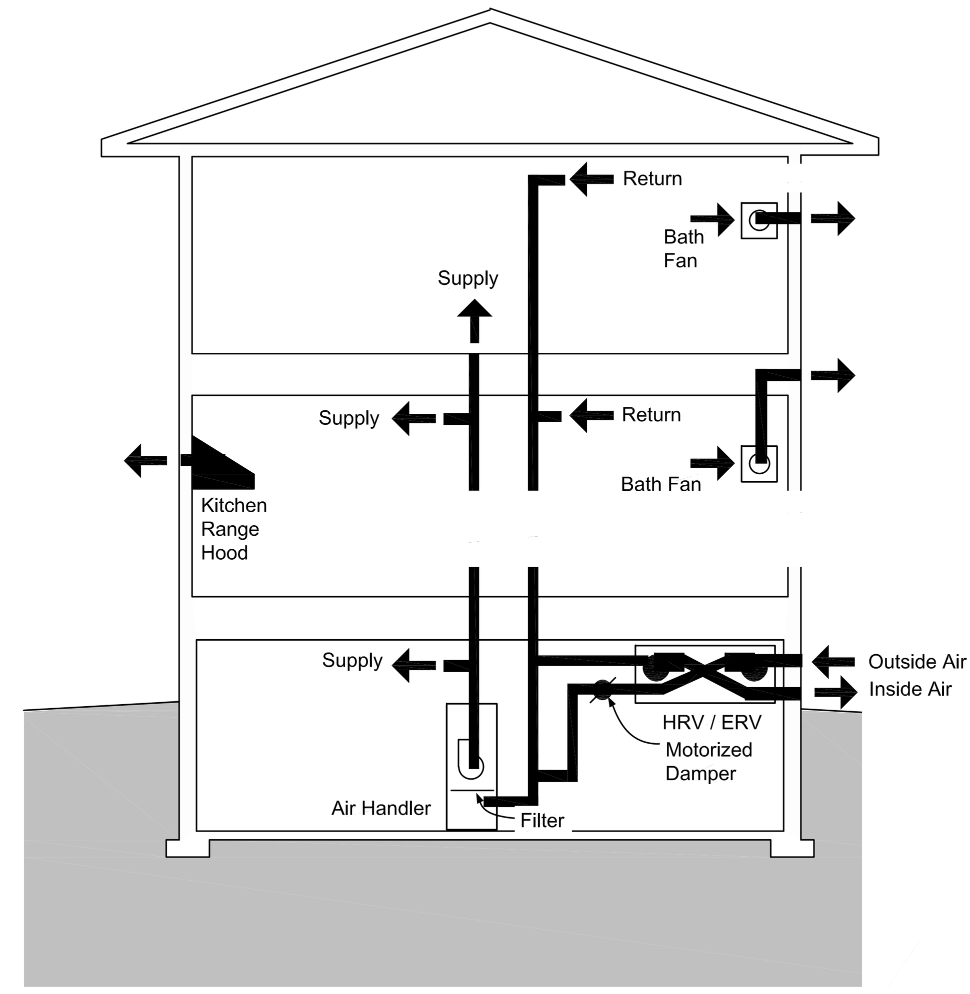
VERT. & HORIZ. ENCLOSURE DETAILS

SCALE: AS NOTED

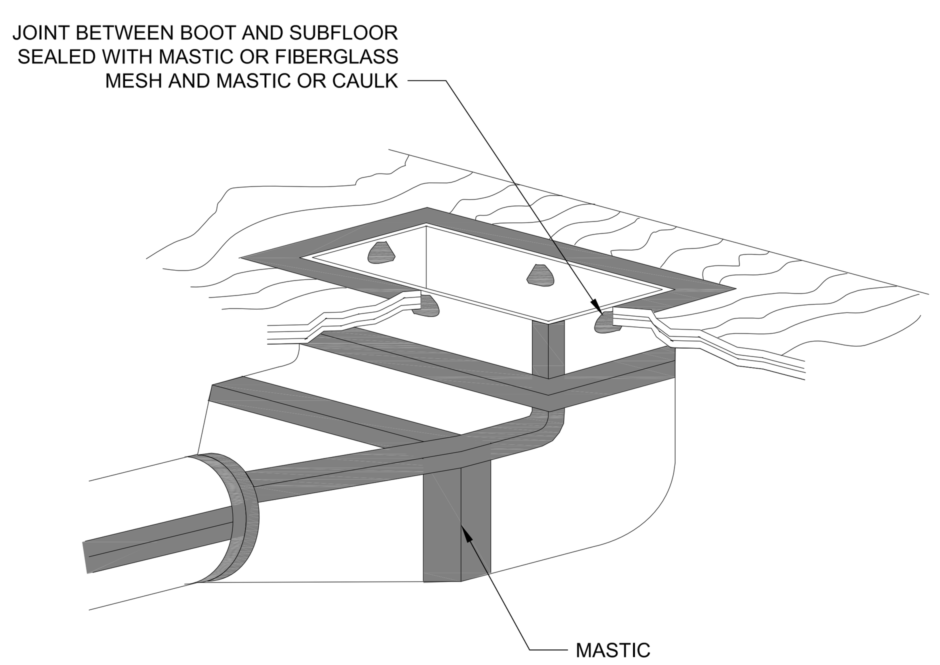
A-507



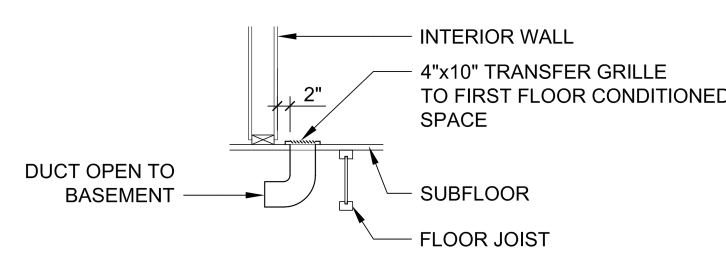
6 AIR HANDLER AIR SEALING DETAIL
SCALE: N.T.S.



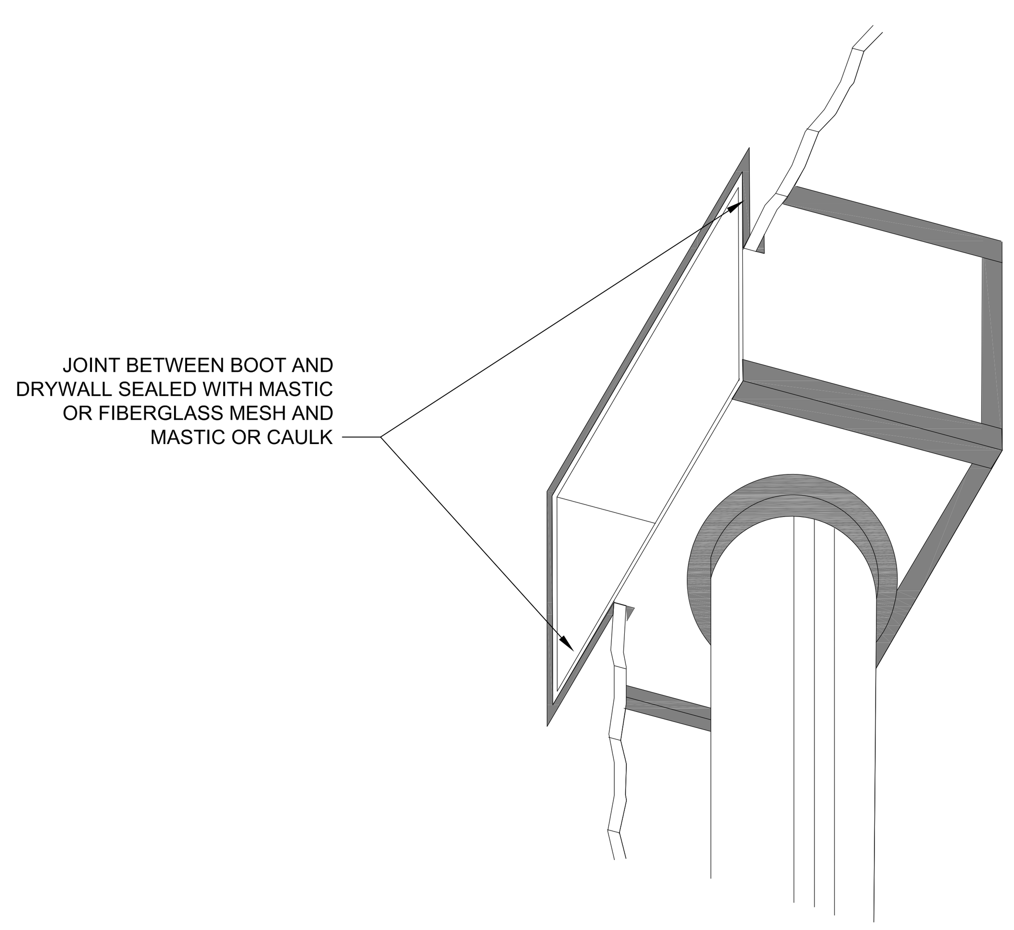
3 HRV SCHEMATIC
SCALE: N.T.S.



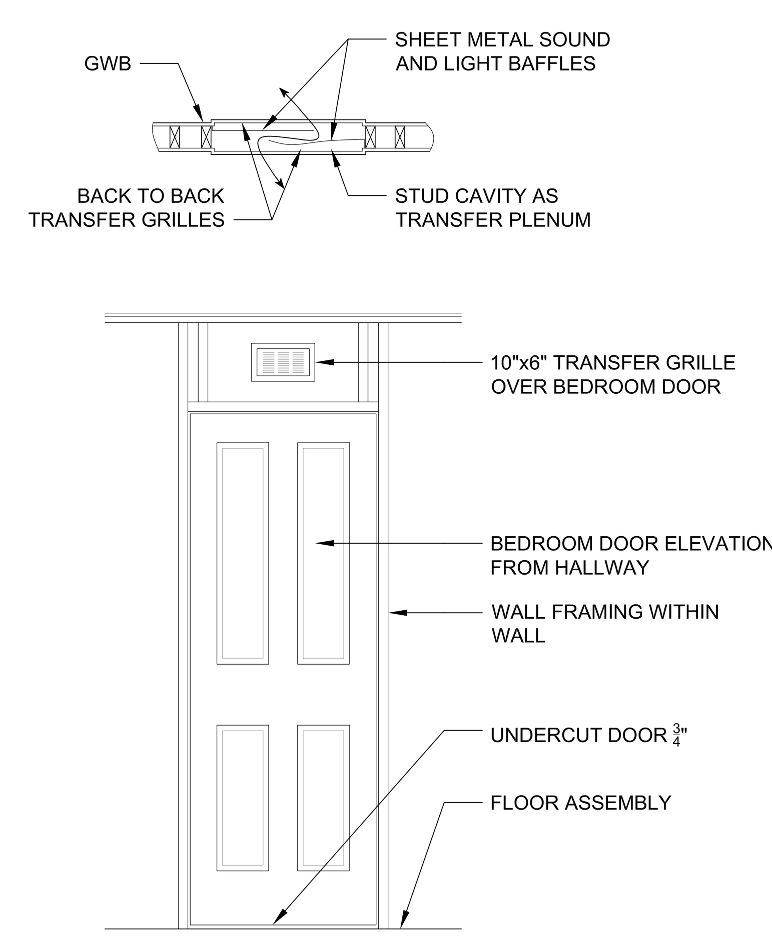
5 FLOOR BOOT AIR SEALING DETAIL
SCALE: N.T.S.



2 BASEMENT TRANSFER GRILLE DETAIL
SCALE: 1/2" = 1'-0"



4 WALL REGISTER AIR SEALING DETAIL
SCALE: N.T.S.



1 DOOR TRANSFER GRILLE DETAIL
SCALE: 1/2" = 1'-0"

GENERAL MECHANICAL NOTES

1. DUCTS ARE SIZED FOR COOLING TO ALLOW INSTALLATION OF CENTRAL COOLING IF SPECIFIED. SEE MECHANICAL SPECIFICATION FOR COOLING LOAD.
2. SIZES FOR BRANCH RUN-OUTS ARE GIVEN AS ROUND DUCT DIAMETER. WHERE OVAL SECTIONS ARE USED, THESE ARE TO BE SIZED EQUIVALENT TO THE GIVEN ROUND DUCT SIZES.
3. ALL DUCTS TO BE SEALED WITH MASTIC AND LOCATED IN CONDITIONED SPACE.
4. ALL DUCTS TO BE ARRANGED AND INSTALLED IN SUCH MANNER AS TO OFFER MINIMUM AIRFLOW RESISTANCE.
5. ALL REGISTERS TO HAVE ADJUSTABLE TURNING VANES AND CLOSE-OFF DAMPER.
6. A MANUAL DAMPER TO BE LOCATED AT EACH TAKE-OFF / MAIN TRUNK JUNCTION TO CONTROL FLOW.
7. TRANSFER GRILLES TO BE PROVIDED FOR PRESSURE RELIEF / PRESSURE EQUALIZATION BETWEEN CLOSED ROOMS AND COMMON AREAS.
8. DOORS TO BE UNDERCUT 3/4" BETWEEN TOP OF FINISH FLOOR AND UNDERSIDE OF DOOR.
9. FURNACE TO BE LOCATED AND ACCESSED WITHIN INTERIOR CONDITIONED SPACE.
10. RETURN DUCT TO BE BUILT WITH TWO OFFSET BENDS TO REDUCE SOUND TRANSMISSION AND A VIBRATION ISOLATION SECTION.
11. A FILTER WITH A MERV 13 RATING TO BE INSTALLED AT THE FURNACE.
12. HEAT RECOVERY VENTILATOR TO BE INSTALLED TO SUPPLY FRESH AIR TO INTERIOR. OUTDOOR AIR SUPPLY AND EXHAUST AIR TO BE CONNECTED TO THE RETURN DUCT UPSTREAM OF THE FILTER. EXHAUST AIR CONNECTION TO BE PLACED AT LEAST 3' UPSTREAM OF OUTDOOR AIR SUPPLY.
13. DUCTS TO OUTSIDE TO BE SLOPED TO THE OUTLET TO DRAIN ANY POTENTIAL INTERIOR CONDENSATION. AVOID USING LONG LENGTHS OF FLEX DUCT THAT MAY HAVE A DIP AND COULD CREATE A RESERVOIR FOR CONDENSATION.

HEAT RECOVERY VENTILATOR (HRV) NOTES

1. SUPPLY AND EXHAUST DUCTS BETWEEN HRV AND EXTERIOR TO BE INSULATED ALONG THE ENTIRE LENGTH TO CONTROL CONDENSATION.
2. SUPPLY AND EXHAUST DUCTS BETWEEN HRV AND EXTERIOR TO BE POSITIONED SO THAT THERE IS A FALL / SLOPE TOWARD THE OUTSIDE AIR INLET TO DRAIN ANY INCIDENT PRECIPITATION IN THE DUCT. SLOPE THE FIRST 4' OF DUCT RUN FROM THE EXTERIOR, OR THE ENTIRE FIRST SECTION IF SHORTER THAN 4'.
3. HRV AND CENTRAL FURNACE FAN TO BE CONTROLLED BY FAN CYCLING CONTROLLER WITH DAMPER CONTROL FUNCTION.
4. FAN CYCLING CONTROLLER TO BE SET UP AT 17% DUTY CYCLE (E.G., 5 MINUTES ON/25 MINUTE OFF), PROVIDING MIXING AND DISTRIBUTION OF VENTILATION AIR.
5. 24 V CONTROL LINE FROM MOTORIZED DAMPER TO BE USED TO SWITCH HRV ON AND OFF AT TWICE ASHRAE 62.2 VENTILATION RATE. USE RELAY IF NECESSARY TO ENERGIZE/CONNECT CONTROL TERMINALS ON HRV (E.G., "TIMER" TERMINALS). DURING CALLS FOR VENTILATION, AIR HANDLER AND HRV MUST RUN SIMULTANEOUSLY.
6. CONTROLLER CAN BE MOUNTED ON THE RETURN AIR TRUNK OR NEAR THE AIR HANDLER.
7. HRV TO BE PLACED ABOVE PLUMBED DRAIN PAN.

MECHANICAL SPECIFICATION

1. EQUIPMENT

FURNACE	YORK YP9C060B12MP11 OR COLEMAN CP9C060B12MP11 98% AFUE FURNACE
AIR CONDITIONER	CARRIER 24ABA430A31 14 SEER 2.5 TON OR EQUAL
HEAT RECOVERY VENTILATOR	FANTECH VHR1404 OR EQUAL
FAN CYCLING CONTROLLER	APRILAIRE 8126, FANCYCLER FR-V OR EQUAL

2. DESIGN LOADS

HEATING LOAD	23.7 kBTU/hr
COOLING LOAD	23.8 kBTU/hr
SYSTEM CFM	800 CFM
62.2 VENTILATION RATE	65 CFM

3. DUCT DESIGN

MAIN SUPPLY TRUNK	10" x 21"
SECOND FLOOR SUPPLY TRUNK	8" x 9"
FIRST FLOOR SUPPLY TRUNK (EAST)	8" x 10"
FIRST FLOOR SUPPLY TRUNK (WEST)	10" x 12"
MAIN RETURN DUCT	20" x 12" OR EQUIVALENT
FIRST FLOOR RETURN DUCT	8" x 22"
FIRST FLOOR RETURN GRILLE	18" x 20"
MASTER SUITE RETURN DUCT	5" x 8"
MASTER SUITE RETURN GRILLE	8" x 8"
SECOND FLOOR RETURN DUCT	3 1/2" x 10"
SECOND FLOOR RETURN GRILLE	6" x 10"
SUPPLY TRUNK DESIGN VELOCITY	650 FPM
RETURN TRUNK DESIGN VELOCITY	550 FPM
RETURN GRILLE DESIGN VELOCITY	350 FPM

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ISSUE:

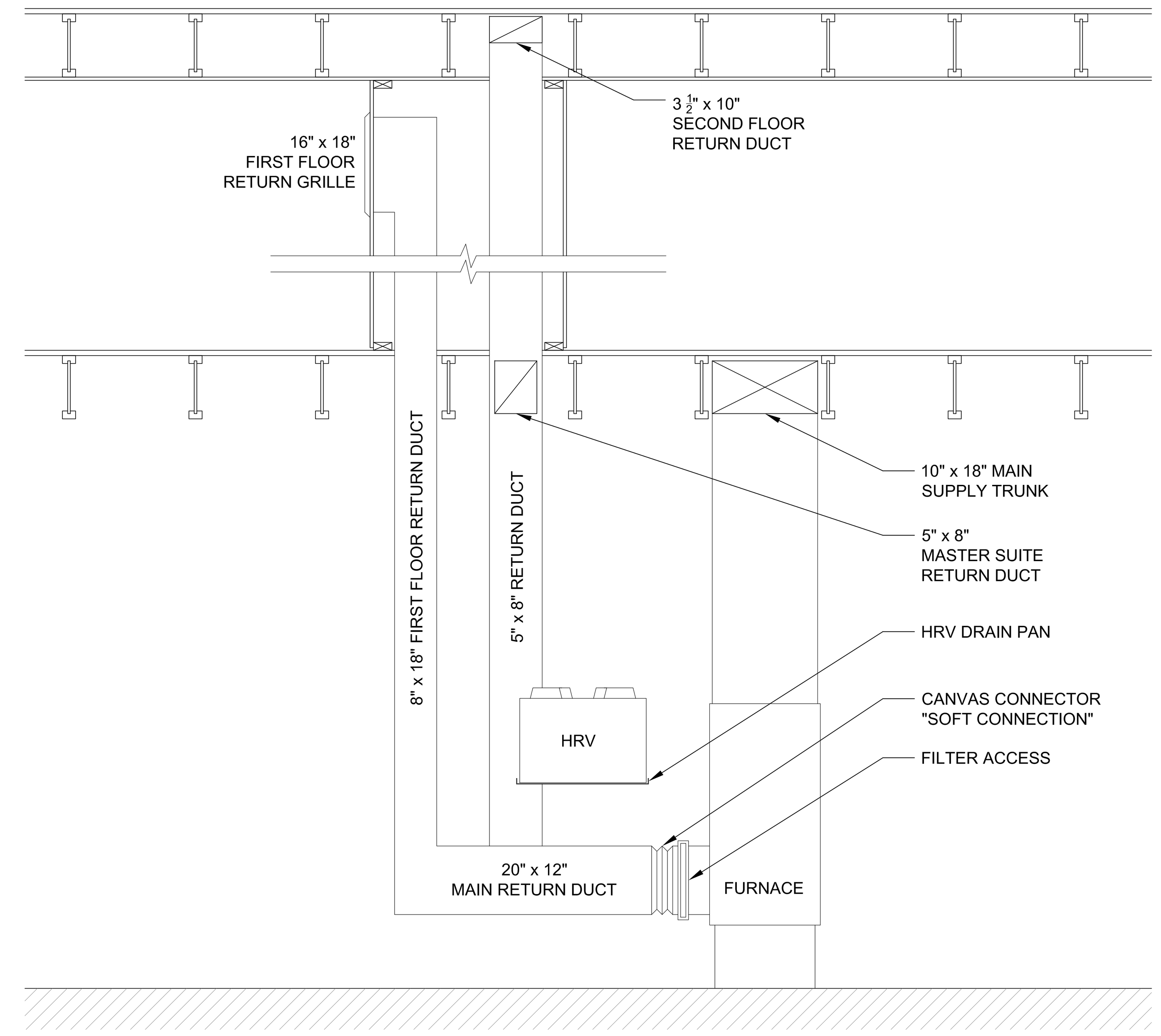
PROJECT NO:	PS 099
CAD DWG FILE:	PS 099–PLOT–Mech
DRAWN BY:	DB
CHECKED BY:	BP

SHEET TITLE:

MECH. NOTES, SPECIFICATIONS & STANDARD DETAILS

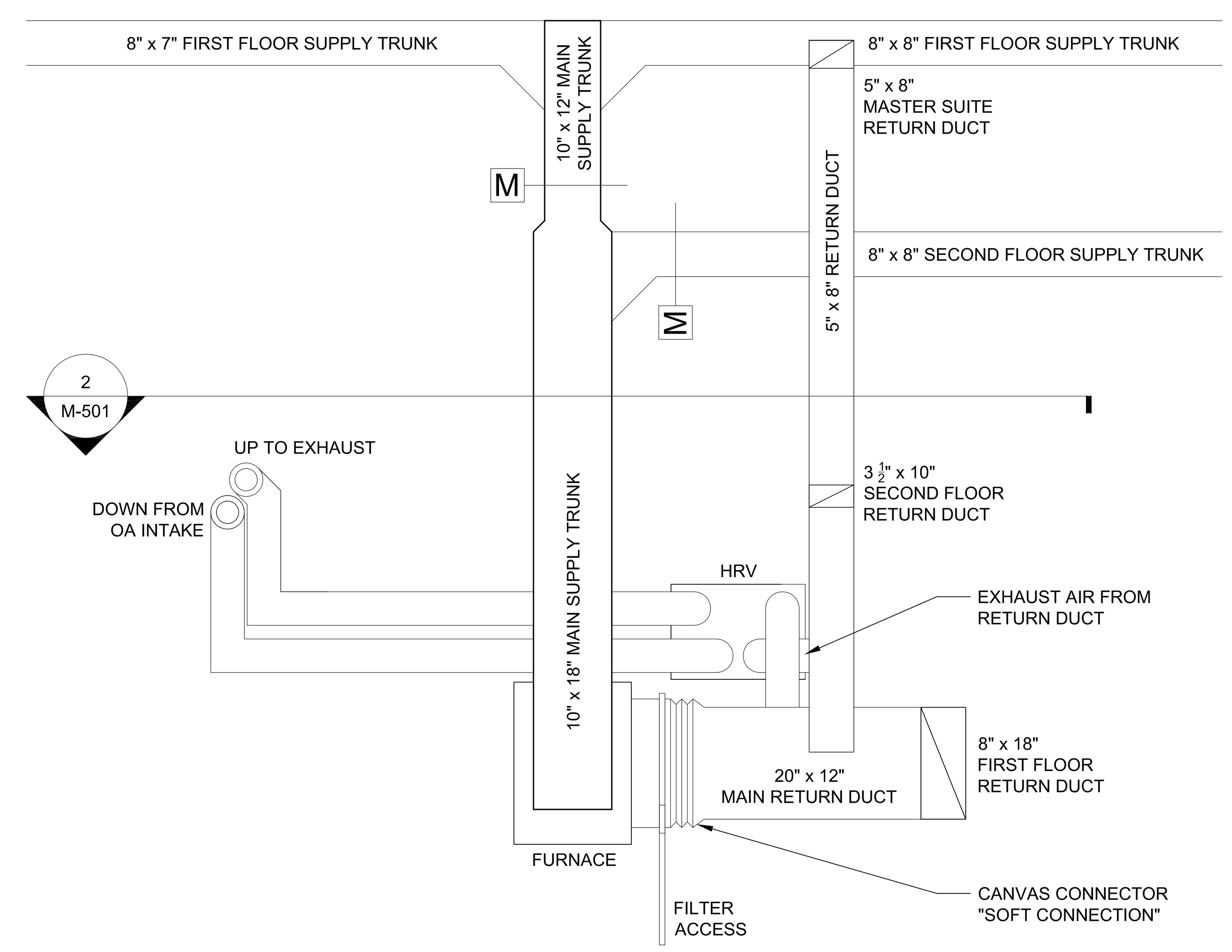
SCALE: AS NOTED

M-001



2 MECHANICAL AREA ENLARGED SECTION

SCALE: 1/2" = 1'-0"



1 MECHANICAL AREA ENLARGED PLAN

SCALE: 1/2" = 1'-0"

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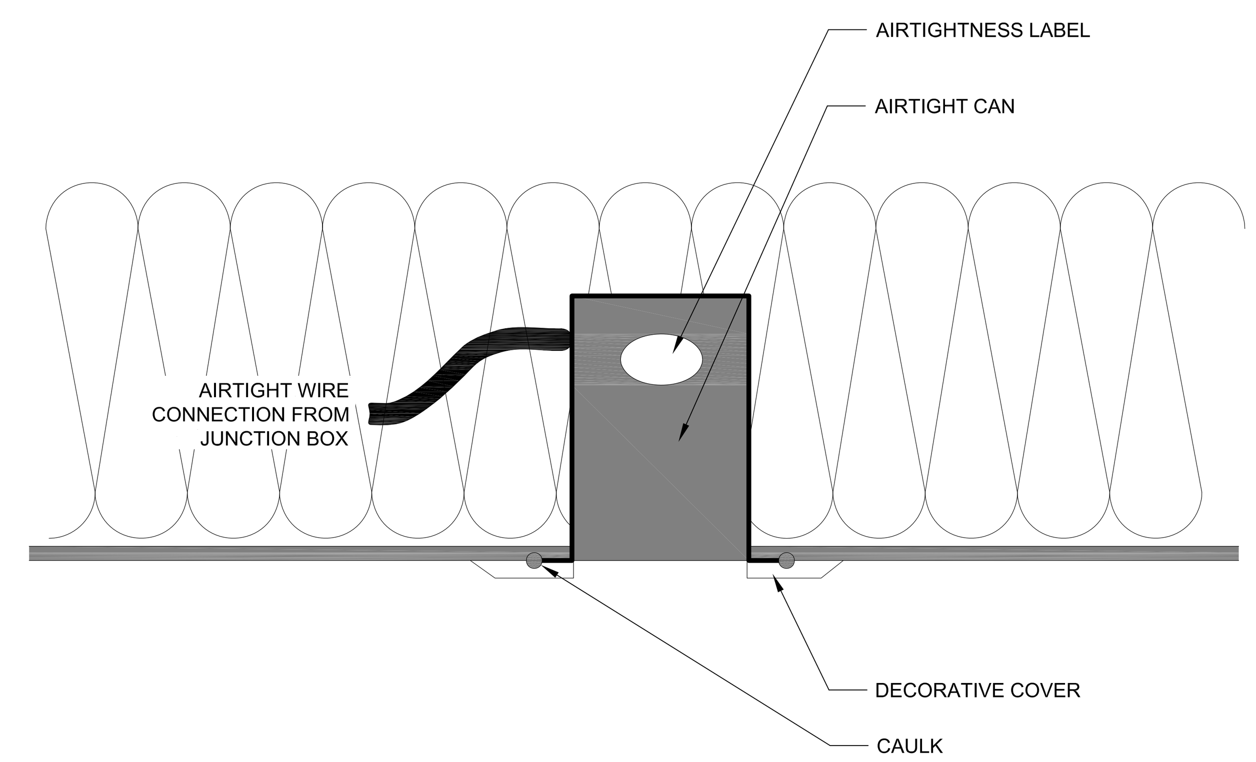
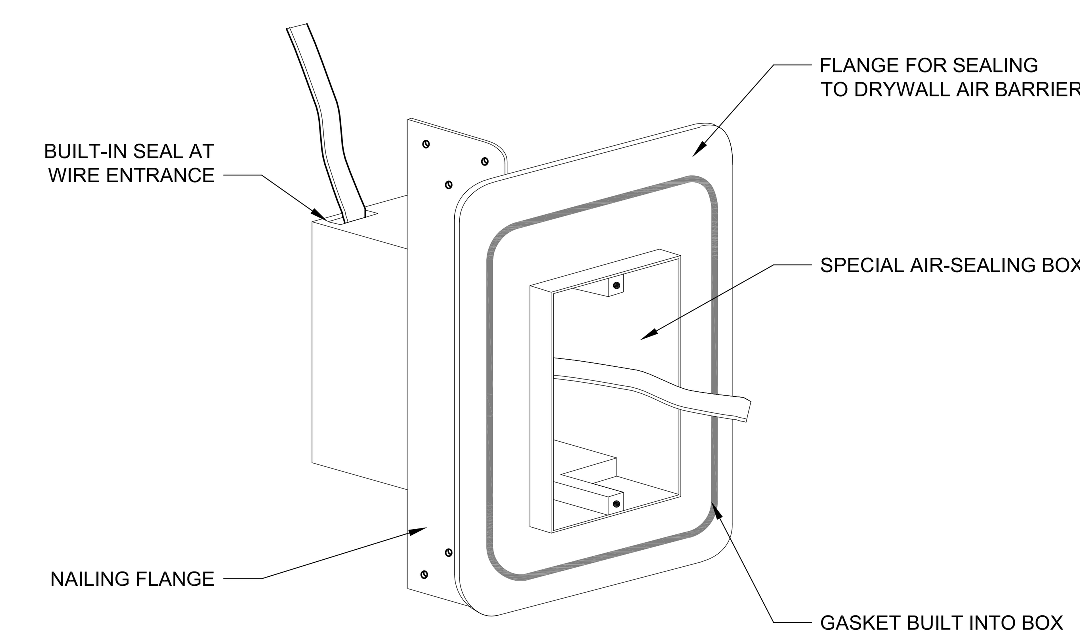
MECHANICAL DETAILS

SCALE: AS NOTED

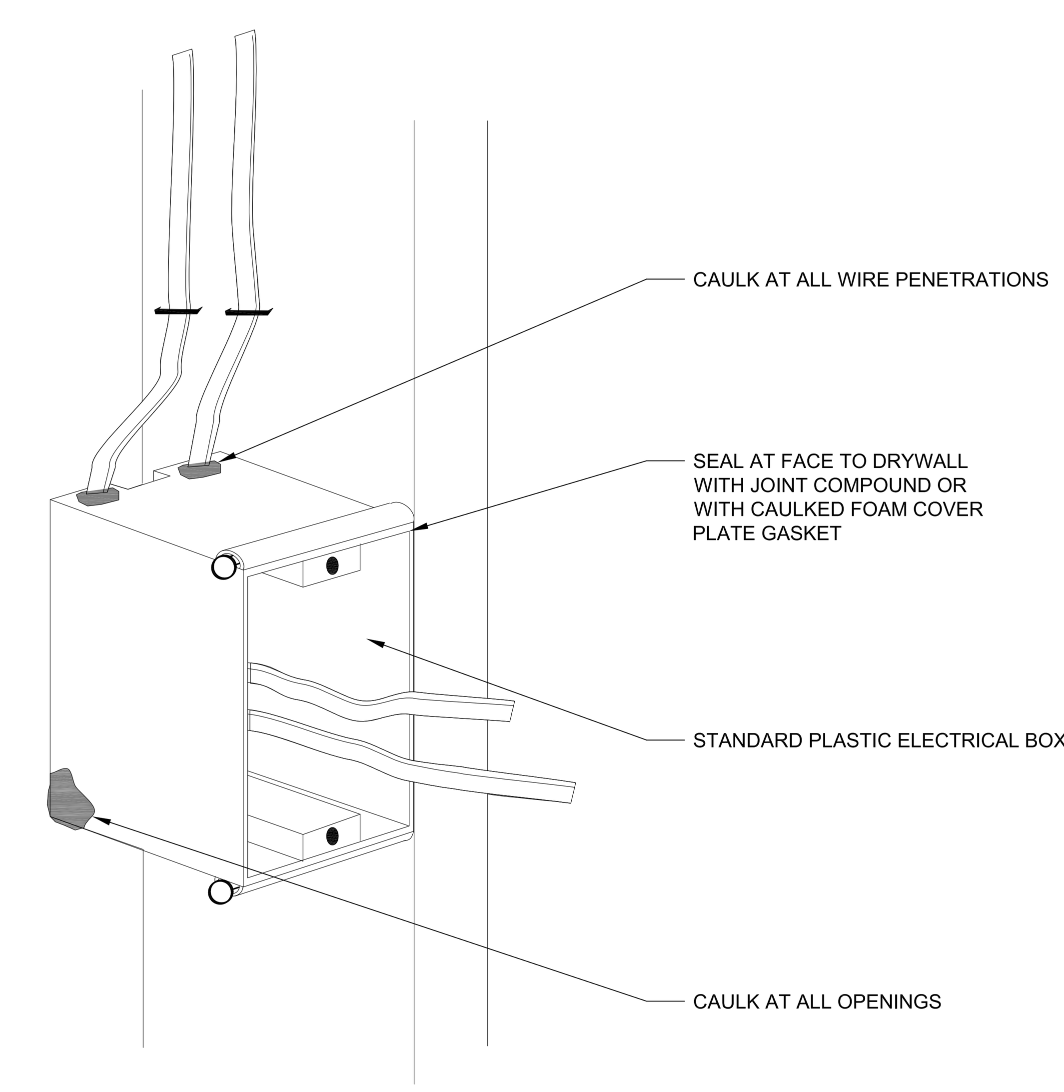
M-501



3 AIRTIGHT RECESSED LIGHT FIXTURE DETAIL
SCALE: N.T.S.



2 ELECTRICAL BOX AIR SEALING DETAIL - OPTION 2
SCALE: N.T.S.



1 ELECTRICAL BOX AIR SEALING DETAIL - OPTION 1
SCALE: N.T.S.

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ISSUE:

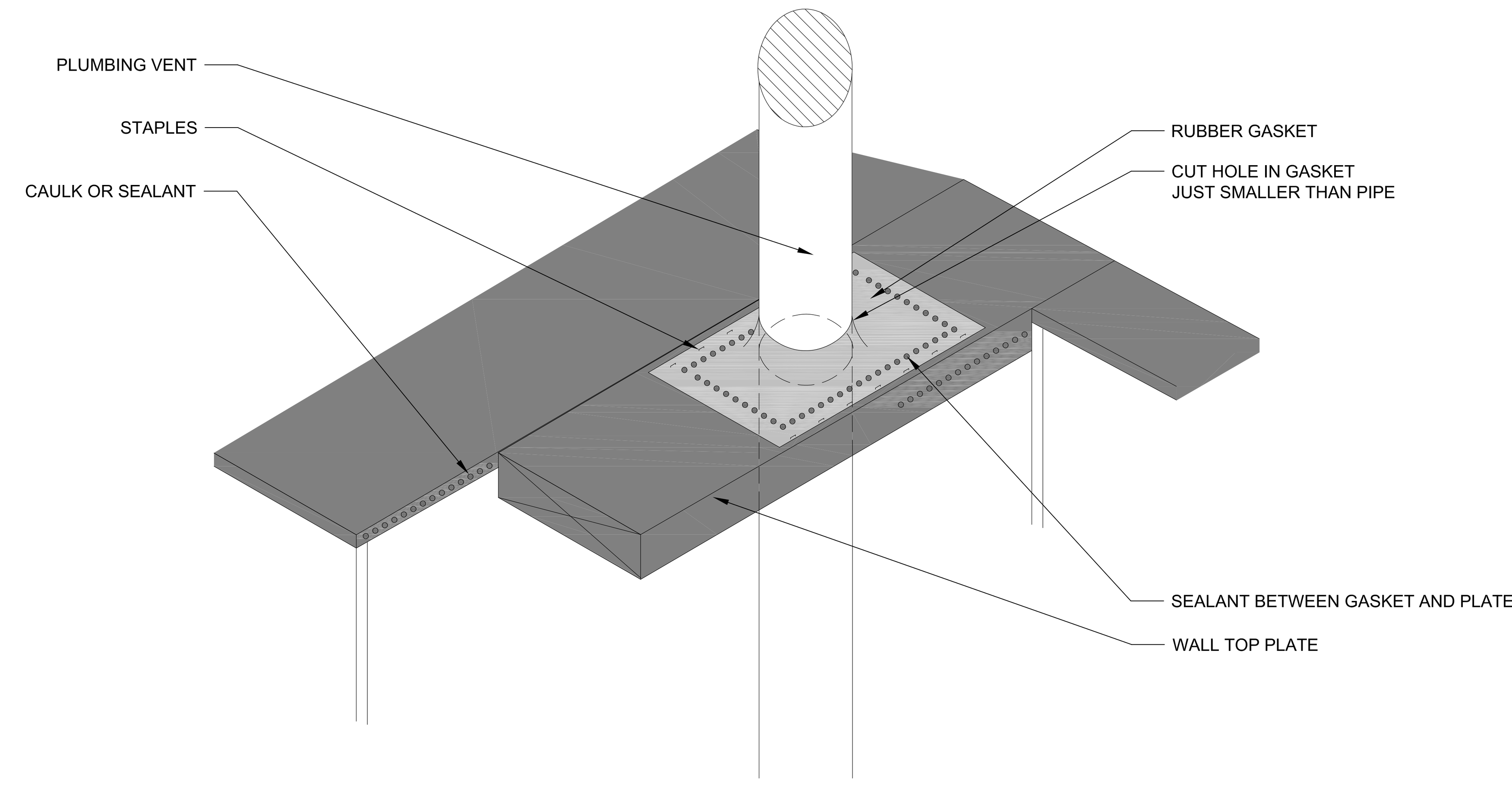
PROJECT NO: PS 099
CAD DWG FILE: PS 099-PLOT-Elec
DRAWN BY: DB
CHECKED BY: BP

SHEET TITLE:

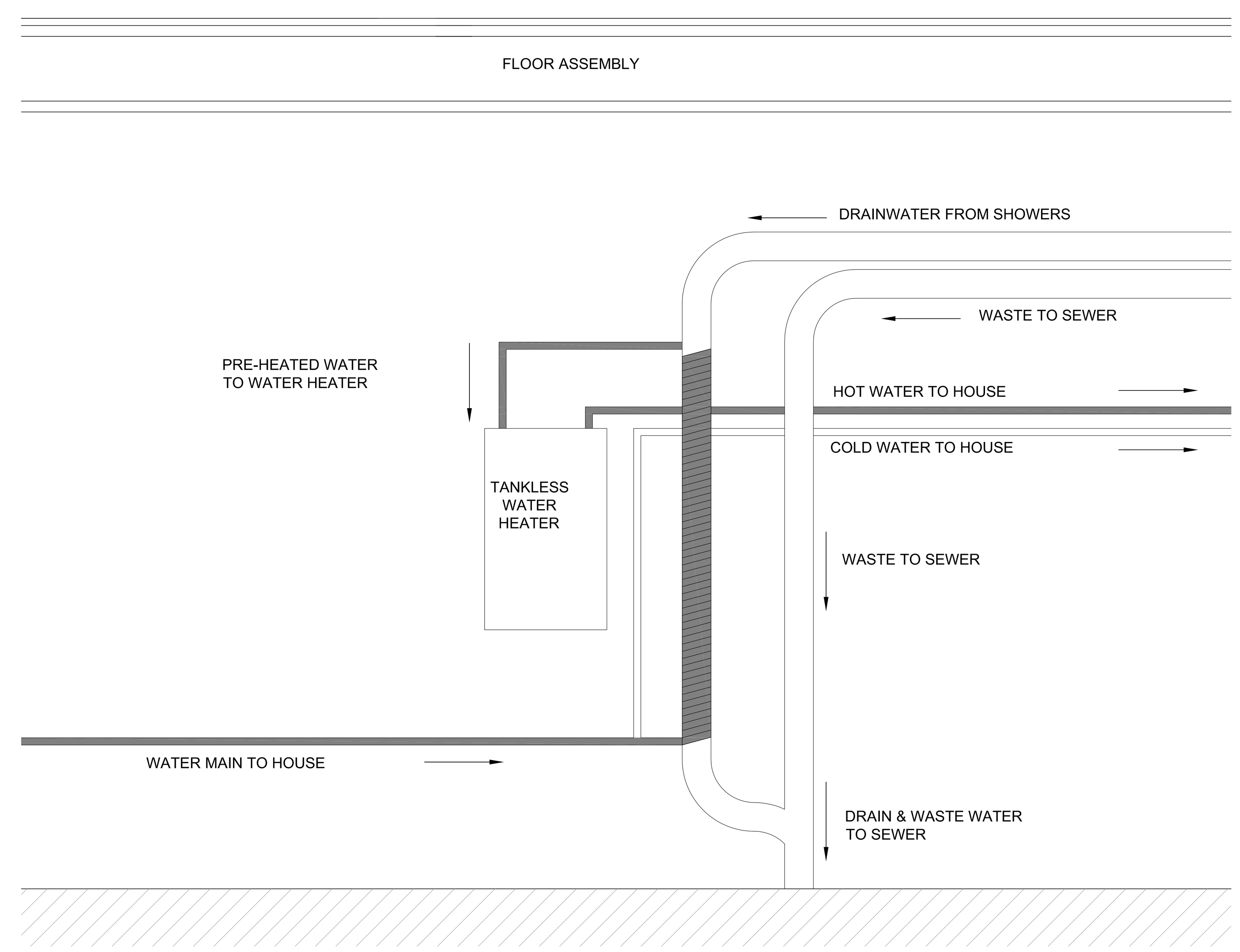
ELECTRICAL DETAILS

SCALE: AS NOTED

E-501



2 VENT STACK PENETRATION TO ATTIC DETAIL
SCALE: N.T.S.



1 DRAINWATER HEAT RECOVERY (DHR) SYSTEM SCHEMATIC
SCALE: N.T.S.

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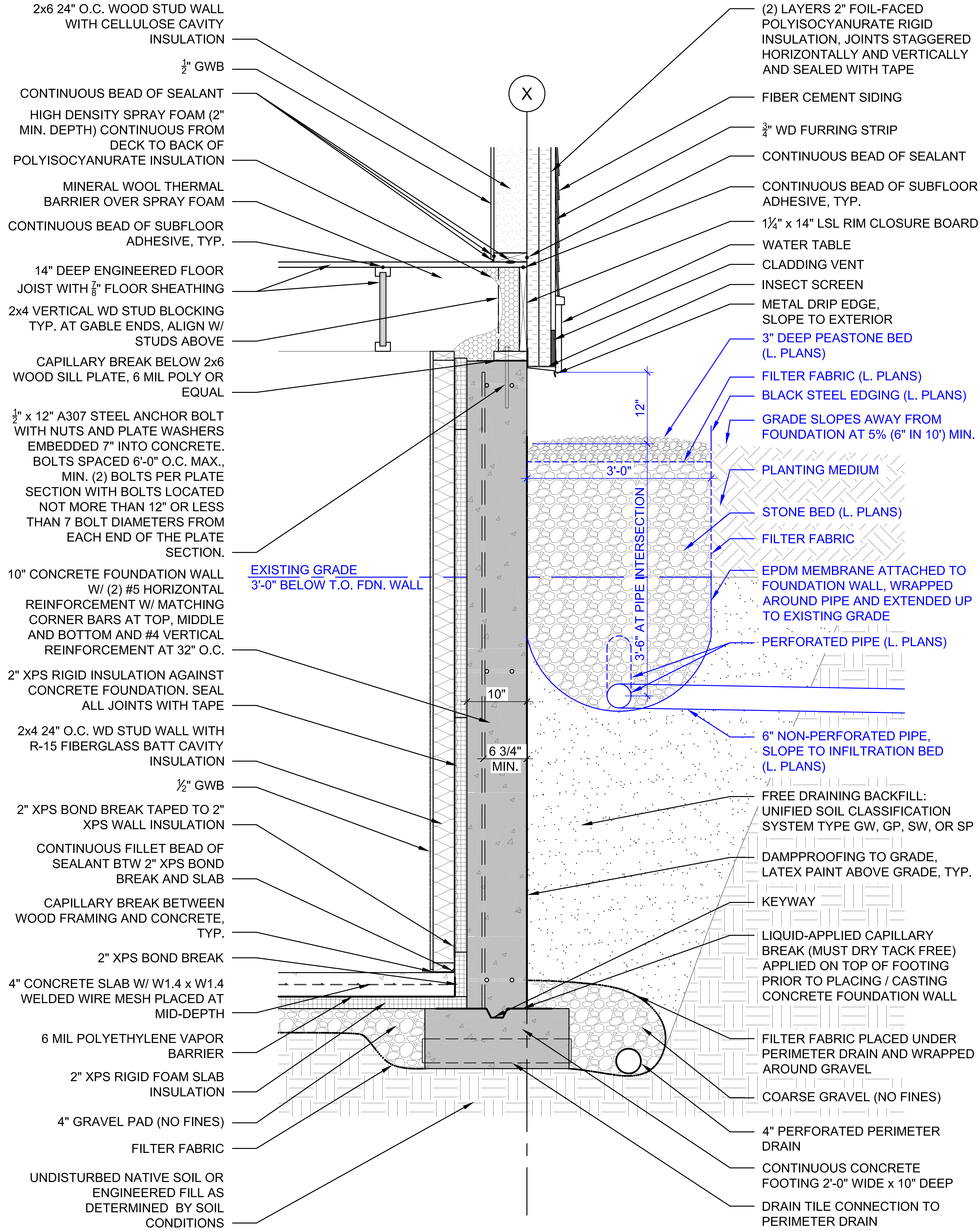
PLUMBING DETAILS

SCALE: AS NOTED

P-501

Appendix D.1.7.8
2009-07-17 Foulds Residence 3D Images

Appendix D.1.7.9
2009-09-02 Foulds Residence SK-03



bsc

Project: Foulds Residence
Date: 2009-09-02
Drawing Title: PERIMETER DRAINAGE AT FRONT FDN. WALL
Drawing File: WALL SECT_Foulds_SK_03.dwg
Drawing Scale: 3/4" = 1'-0"

Sheet Title:

SK-03

Appendix D.1.7.10
2009-10-21 Foulds Residence Site Visit Reports

2009-08-17 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-08-17 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-08-17.

Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-08-17
Time:	9:00 am – 10:00 am
Weather:	Sunny, hazy, 90 degrees
Workers on Site:	Crew installing fabric filter and perimeter drain
Work in Progress:	

1. Installing perimeter drain in gravel bed.
2. Installing filter fabric around gravel bed.

Figure 1.1 – Installing filter fabric

Figure 1.2 – Installing perimeter drain

2009-08-21 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
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Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-08-21.

Project Blog:
www.concordcape.posterous.com

Address: 33 Riverdale Road, Concord MA 01742

Date: 2009-08-21

Time: 9:00 am – 10:00 am

Weather: Sunny, hazy, 88 degrees

Workers on Site: None

Work in Progress:

1. House concrete foundation walls poured.
2. Dampproofing applied to concrete foundation walls.

Figure 1.1 – Foundation walls with dampproofing

Figure 1.2 – Inside view of foundation walls

2009-09-02 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-09-02 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-09-02.

Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-09-02
Time:	11:30 am – 12:30 pm
Weather:	Sunny, 75 degrees
Workers on Site:	Concrete crew
Work in Progress:	

1. Pouring garage foundation walls.
2. Prefabricated bulkhead to basement installed.
3. Perimeter of house has been backfilled.

Figure 1.1 – Garage foundation wall formwork

Figure 1.2 – Prefabricated bulkhead

2009-09-11 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-09-11 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-09-11.

Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-09-11
Time:	8:00 am – 8:15 am
Weather:	Cloudy, 60 degrees
Workers on Site:	None
Work in Progress:	

1. Formwork taken off garage foundation walls.
2. Perimeter of garage has been backfilled.

Figure 1.1 – House and garage foundation walls

Figure 1.2 – Gravel above backfill at garage

2009-09-29 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-09-29 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-09-29.

Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-09-29
Time:	2:30 pm – 3:30 pm
Weather:	Cloudy, 65 degrees
Workers on Site:	Framers
Work in Progress:	

1. Framing first floor with I-joists.
2. Digging trench for basement plumbing to run under concrete slab.

Figure 1.1 – Framing as seen from back of house

Figure 1.2 – Trench dug for basement plumbing

2009-10-02 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-10-02 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-10-02.

Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-10-02
Time:	8:30 am – 9:30 am
Weather:	Sunny, 50 degrees
Workers on Site:	Framers and concrete crew

Work in Progress:

1. Framing first floor walls.
2. Pouring basement concrete slab with welded wire mesh, 6 mil polyethylene below slab and 2" XPS below poly and turned up sides.

Figure 1.1 – First floor wall framing

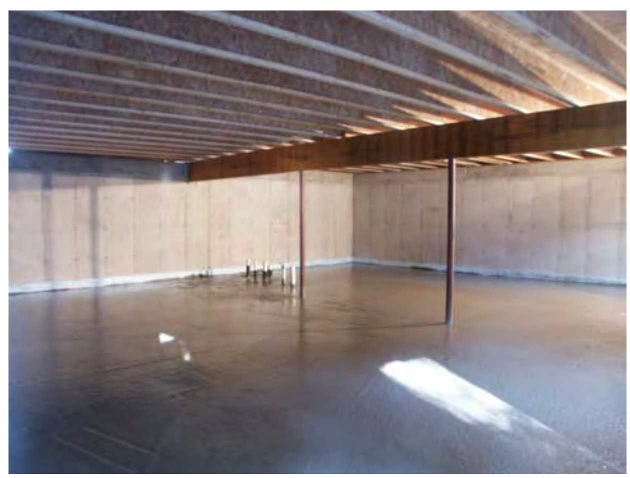

Figure 1.2 – Basement slab and perimeter foam

2009-10-08 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-10-08 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-10-08.

Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-10-08
Time:	8:30 am – 9:30 am
Weather:	Sunny, 50 degrees
Workers on Site:	Framers
Work in Progress:	

1. Framing second floor.
2. Installing ½" OSB sheathing lateral bracing panels.
3. Garage concrete slab poured and cured.

Figure 1.1 – Framing from back of house

Figure 1.2 – OSB sheathing

2009-10-14 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-10-14 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
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Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-10-14
Time:	11:00 am – 12:00 pm
Weather:	Sunny, 50 degrees
Workers on Site:	Framers
Work in Progress:	

1. Framing second floor walls.
2. Cutting roof rafters and preparing to frame roof.

Figure 1.1 – Framing from back of house

Figure 1.2 – Second floor walls and dormer wall

2009-10-21 Foulds Residence Site Visit Report

Written By: Katie Gunsch (BSC)

This report can be found in the following folder on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Admin/Site Visit Reports/2009-10-21 Foulds Residence Site Visit Report.pdf.

Additional site visit photos can also be found on the BSC server:
Building America/BA Communities/MA Concord Foulds House/Site Visit Photos/2009-10-21.

Project Blog:
www.concordcape.posterous.com

Address:	33 Riverdale Road, Concord MA 01742
Date:	2009-10-21
Time:	9:00 am – 11:00 am
Weather:	Sunny, 65 degrees
Workers on Site:	Framers
Work in Progress:	

1. Roof and dormers framed and sheathed.
2. Framing attic floor.
3. Installing threaded rods.
4. Exterior foam to be on site today – windows to be on site tomorrow.

Figure 1.1 – Framing from back of house

Figure 1.2 – Threaded rod tie-downs