lumenHAUS

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U.S. Department of Energy Solar Decathlon

Virginia Polytechnic Institute and State University

Project Manual Final - June 2, 2009

SUMMARY OF CHANGES

From the dates (04.01.09) to (06.02.09), the project manual has gone through drastic formatting and content changes. The table of contents has been updated, the design narratives have been updated and edited, and multiple additional specifications have been written.

The following are changes made to the project manual (03.31.09):

- Section Format and Page Format requirements have been applied.

The following are changes made to the project manual (03.26.09):

- Bookmarks have been added, reorganized, and renamed.
- The table of contents has been updated.
- A retail PV price quote has been added.
- A summary of reconfigurable features has been added.
- A list of drawing sheets has been provided.
- A header with the project name and location has been added to each page.
- The market viability narrative now contains the target market ID.

The following are changes made to the project manual (02.05.09):

- Links and bookmarks have been added to the PDF.
- It has been confirmed that the link to the specifications for Icynene (07 21 29 Sprayed Insulation) verifies a flame spread index of less than 20 and a smoke developed index of less than 400.
- Specifications have been provided for EcoVeil (13 31 23 Tensioned Fabric Structures) which include Fire-Test-Response Characteristics.

SD RULES COMPLIANCE CHECKLIST

Rule	Rule Description	Content Notes	DRAWING #	PROJECT MANUAL PAGE #
4-2	Construction Equipment	Forklift will be used for the unloading of prefabricated deck platforms	O-101	N/A
4-3	Ground Penetration	Photovoltaic Electrical system grounding rod.	A-101	N/A
4-4	Impact on the Turf	The Drawings contain the location, contact area, and schedule of weights for components resting on the turf.	S-111	N/A
4-5	Generators	The Project Manual contains generator specifications.	N/A	p. 287
4-6	Spill Containment	The site will incorporate tanks that contain potable water and wastewater for this project. Pond liners on the site will be prefabricated by a qualified roofing contractor and will be leak proof. on the site the project manual contains specifications for all equipment, tanks, and pipes that will contain fluids during the event.	P-101, A-101	N/A
4-6	Spill Containment	See specifications for water bladders, heat pump closed loop heat exchanger coil in the project manual	N/A	p. 187 p. 241
4-7	Lot Conditions	See structural calculations in the project manual		N/A
5-2	Solar Envelope Dimensions	See architectural drawings for the location of all house and site components relative to the solar envelope. PV system is adjustable to accommodate change in height	A-101, A-111, A-112, A-113 A-201 A-202 A-112a	N/A
6-1	Structural Design Approval	For structural design approval, see architectural drawings and the structural calculations in the Project Manual	S-111, S-112, S-311, S-312, S-511	p. 305
6-2	Max. Architectural Footprint	See architectural drawings for architectural footprint.	A-115	N/A
6-3	Min. Conditioned Space	See construction document for space conditioning means in primary living spaces.	A-116	N/A
6-4	House Entryways	See architectural drawings for the accessible public tour route and the ground surface area that will be covered by organizer-provided walkway material.	X-103	N/A
7-1	Placement	See the landscape drawings for the placement of all vegetation.	L-104 A-101	N/A
7-2	Watering Restrictions	We do not use a greywater irrigation system	N/A	N/A
8-1	PV Technology Limitations	See the Project Manual for photovoltaic component specifications.	N/A	p.301 p.285
8-1	PV Technology Limitations	See the Dabble D database DOE for retail pricing of photovoltaic components.	N/A	N/A
8-3	Thermal Energy Storage	See the Site plan for the location of the simulated geothermal exchange tank and water cooling tower.	A-101	N/A
8-4	Batteries	N/A	N/A	N/A

8-5	Desiccant Systems	No dessicant systems will be used.	N/A	N/A
8-6	Village Grid	See the Project Manual for completed Interconnection Application Form.	N/A	N/A
8-6	Village Grid	See the drawings for locations of the photovoltaics, inverters, terminal box, meter housing, service eqpt. and grounding means	Photovoltaics – A-101, Inverters – E-201 Terminal Box – E-601 Meter Housing- A101 Grounding – A101	N/A
8-6	Village Grid	See the Electrical specifications for the photovoltaics, inverters, terminal box, meter housing, service eqpt. and grounding means	N/A	p. 262 p. 285 p. 301
8-6	Village Grid	See the drawings for the three line electrical drawing	E-601	N/A
8-6	Village Grid	Calculations of service/feeder net computed load for NEC 220 can be found in the drawings	E-606	N/A
8-6	Village Grid	Site Plan showing the house, decks, ramps, tour paths and terminal box	A-101	N/A
8-6	Village Grid	Elevations showing the utility box, main utility disconnect and other service equipment.	A2	
9-4	Rainwater Collection	See the drawings for the location of the rainwater collection system.	A-101	N/A
9-6	Thermal Mass	The project drawings show the extent of the concrete slab-on-deck, the major element of the home's thermal mass.	S-111	N/A
10-2	Event Sponsor Recognition	Event sponsor recognition can be located on the display board on the site plan, in the communications plan and on the website.	X-201 A-101	N/A
10-3	Team Sponsor Recognition	Team sponsor recognition can be located on the display board on the site plan, in the communications plan and on the website.	X201 A-101	N/A
11-4	Public Exhibit	See the construction drawings for the accessible tour route.	X-103	N/A

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END OF SECTION

SECTION 01 31 23
PROJECT WEBSITE

LUMENHAUS website v3 was designed through a series of brainstorming sessions conducted in conjunction with a local Blacksburg design agency, Modea. A preliminary design was chosen from six alternatives and further developed by a small team of students in collaboration with a team of professionals at Modea's office. Through a series of meetings, the design of the site and its content were refined. The site is divided into two sections, *The Project* and *Experience LUMENHAUS. The Project* section features pages that present technical information about the house, the team, and our sponsors. *Experience LUMENHAUS* highlights the features and benefits of living in LUMENHAUS through an interactive 3D walkthrough of the house. This side of the site is intended to make the house accessible to a wide audience and draw interest in the specific technologies used within the house. Assistance in three-dimensional visualization and animation was provided by Spine 3D, located in Miami, Florida. The site was coded, tested, and launched by Modea.

www.lumenhaus.com

END OF SECTION

SECTION 01 32 19

SUBMITTALS SCHEDULE

06-03-08: graphics files, preliminary website, design development drawings, preliminary communications plan

08-19-08: compliant website

12-16-08: graphics files, stamped structural drawings and calculations, construction drawings, project manual, workshop preparation, health and safety plan

06-02-09: final communications plan, dinner party menus, final project manual draft, construction drawings

END OF SECTION

SECTION 03 24 00

FIBROUS REINFORCING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specifications for nylon fiber reinforcement to be included in concrete mix.

B. Products Furnished

1. High-performance reinforcement fibers for concrete.

1.02 REFERENCES

A. Abbreviations and Acronyms

1. PVA – Polyvinyl Alcohol
2. WWF – Welded Wire Fabric

B. American Society for Testing and Materials:

1. ASTM C1116, Standard Specification for Fiber-Reinforced Concrete
2. ASTM C1018, Standard Test Method for Flexural Toughness and First-Crack Strength of Fiber-Reinforced Concrete
3. ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
4. ASTM C78, Standard Test Method for Flexural Strength of Concrete
5. ASTM C496, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
6. ASTM C234, Standard Test Method for Comparing Concretes on the Basis of the Bond Developed with Reinforcing Steel

1.03 QUALITY ASSURANCE

A. Qualifications

1. Installation must comply with the requirements of applicable local, state and national code jurisdictions. Data on building code requirements and product compliance information can be obtained from Nycon, Inc.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Nycon fibers come in pre-measured bags containing the recommended dosage for 1, 5, 9 or 10 cubic yards of concrete. Custom packaging is available upon request.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. KURALON™ RSC15 – PVA Fibers for Long-Term Crack Control

2.02 MANUFACTURERS

A. Nycon, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. Tensile strength of 203,000 psi (1400 MPa).
2. Nycon fibers are not to be used as a structural element in concrete. Fiber reinforcing at 1-2 pounds per cubic yard is for secondary reinforcement only.
3. Confirm with the structural engineer if WWF is used in a structural capacity; if so, Nycon fibers can be added to, but cannot replace WWF.

2.04 SOURCE QUALITY CONTROL

A. Tests and Inspections

1. The plastic shrinkage crack method was adapted from Kraai, P.P., “A Proposed Test to Determine the Cracking Potential Due to Drying Shrinkage of Concrete,” *Concrete Construction* (September, 1985). Results show plastic shrinkage cracking was reduced by 83% as compared to non-fiber-reinforced concrete.
2. Permeability Tests conducted at ATEC Associates, in accordance with the U.S. Army Corps of Engineers Test EM 1110-2-1906, show that permeability of concrete is reduced by an average of 41% as compared to non-fiber-reinforced concrete.
3. Impact resistance testing was conducted using the procedure recommended by ACI Committee 544. Results show that blows to first crack increased by an average of 55%, and blows to failure increased by an average of 100%.
4. To determine long-term durability and fiber suitability in compliance with ASTM C1116, an accelerated aging test was employed that was adapted from Shah, P.P., et al., “Toughness of Glass Reinforced Concrete Panels Subjected to Accelerated Aging,” *PCI Journal* (September 1987). Fiber contribution was determined by measuring flexural toughness according to ASTM C1018 at various stages of accelerated aging. Changes in flexural toughness, as measured by the toughness index, provide a quantitative estimate of fiber integrity and its effectiveness as a reinforcement following aging. The data indicated no reduction in flexural toughness following accelerated aging over a 52-week period and, hence, no degradation of the Nycon fiber.
5. The compressive strength, flexural strength and the split tension compressive strength of Nycon fiber-reinforced concrete equal the performance of non-fiber-reinforced concrete based on tests conducted in accordance with ASTM C39, ASTM C78 and ASTM C496, respectively.
6. The behavior of Nycon fiber-reinforced concrete versus an un-reinforced control was determined per ASTM C234. The tests confirmed that the addition of 1 pound per cubic yard of Nycon fibers improves concrete’s bond strength to steel by an average of 16%.

PART 3 EXECUTION

3.01 INSTALLATION

A. Special Techniques – Manual Mixing

1. Add Nycon fibers at the rate of 1 pound per cubic yard of concrete. Fibers can be added to the aggregate in the weigh hopper, added to the aggregate on the belt, or added directly into the truck at the batch plant. Mix for a minimum of 4 minutes.

END OF SECTION

http://www.nycon.com/RSC15.htm
http://www.nycon.com/specs/SpecData2003.pdf
http://www.nycon.com/pdf/storktesting.pdf
http://www.nycon.com/pdf/MSDS_NyconPVA.pdf

SECTION 02 43 13

STRUCTURE RELOCATION

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specifications for heavy equipment to be used during initial construction completion on the site.

B. Products Furnished

1. 6000LB 21’ Straight Mast Forklift 2WD.

1.02 QUALITY ASSURANCE

A. Qualifications

1. Use of forklift limited to a trained and certified heavy equipment operator following good practice measurements and all required safety measures and precautions

1.04 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Delivery of forklift on site and date specified by distributor. While stored on site, all safety requirements must be followed through manufacturer’s instructions or local safety regulations, whichever is more stringent.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. 586G Series 3 6000LB lift capacity all-terrain forklift

2.02 MANUFACTURERS

A. Case Construction

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. Dependable, Tier III-certified Case Family engines deliver outstanding performance in the roughest environments.
2. Available load control provides smooth forklift operation and minimal chain stress for reduced maintenance cost.
3. Industry-leading lift speed means you’ll stay productive on the most demanding material handling jobs.
4. Zero tail swing and a narrow turning radius allow you to get in and out of the tightest spaces on the job.
5. Unmatched visibility due to the tapered hood and wide-channel dual-mast cylinders.
6. Easy-to-operate controls and a choice of seats provide a comfortable environment to get more work done.

7. Ground-level service access makes it easier to perform daily maintenance.
8. Roller mast design and self-adjusting wet disc brakes increase component life and reduce maintenance costs.
9. Operating Weight: 13,587 LB.

PART 3 EXECUTION

3.01 INSTALLATION

A. Special Techniques

1. To be used by certified and licensed heavy equipment operators in situations when manpower is insufficient to complete a job. All safety regulations and requirements must be followed.

END OF SECTION

http://www.casece.com/wps/portal/casece/model?product=Forklifts&brandsite_brand=CaseCE&brandsite_language=en&brandsite_geo=NA&model=Model_Forklifts_586G_S3

SECTION 03 31 00

STRUCTURAL CONCRETE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specifications for concrete slab.

B. Products Furnished

1. Furnish all labor, material, equipment and services necessary for the mixing and pouring of concrete for floors with the exception of formwork and reinforcement.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM C150, Type I, II Portland cement conformity, depending on soil conditions.
2. ASTM C309, Type I, Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.
3. ASTM E1155, Standard test method for determining floor flatness.

1.03 ACTION SUBMITTALS

A. Manufacturer's Instructions (specified for HTC Superfloor™)

1.04 DELIVERY, STORAGE, AND HANDLING

A. Storage and Handling Requirements

1. Protect areas to receive polished concrete finish at all times during construction to prevent oils, dirt, metal, excessive water and other potentially damaging materials from affecting the finished concrete surface. Protection measures listed below shall begin immediately after the concrete slab is poured:
   a. All hydraulic powered equipment shall be diapered to avoid staining of the concrete.
   b. All vehicle parking shall be prohibited on the finish slab area. If necessary to complete their scope of work, drop cloths shall be placed under vehicles at all times.
   c. No pipe cutting machine shall be used on the finish floor slab.
   d. Steel shall not be placed on the finish slab to avoid rusting.
   e. Acids and acidic detergents will not come in contact with slab.
   f. All painters will use drop cloths on the concrete. If paint gets on the concrete, it must be immediately removed.
   g. All trades will be informed that the slab must be protected at all times.

1.08 FIELD OR SITE CONDITIONS

A. Ambient Conditions

1. Comply with manufacturers written instructions for substrate temperature and moisture content, ambient temperature and humidity, ventilation and other conditions affecting chemical performance.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. LCJ Enterprises – Concrete Contractors

2.02 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. Concrete mixture shall be 3500 PSI or higher, non air entrained.

2.03 MIXES

A. Concrete Mix Design

1. The cement shall be Portland Cement Type I, conforming to ASTM C 150.
2. Any admixtures, plasticizers, slag, fly ash, or anything taking the place of Portland-based cement shall be kept to a minimum.
3. Color loads for integral color should never be smaller than 3 cubic yards.
4. Do not use calcium chloride-based admixtures. Non-chloride admixtures may be used.

B. Waterborne, Membrane-Forming Curing Compound: ASTM C 309, Type 1, Class B

1. For integrally colored concrete, curing compound shall be Deep Charcoal (A-21) by Scofield, approved by color pigment manufacturer.

PART 3 EXECUTION

3.01 PREPARATION

A. Protection of In-Place Conditions

1. Installer shall examine and approve concrete substrate for conditions affecting performance of finish. General contractor shall correct conditions that are found to be out of compliance with the requirements of this section. Repairs are not acceptable unless specifically approved on a case-by-case basis by the architect.

3.02 APPLICATION

A. Special Techniques

1. Maintain concrete temperature below 85 degrees. Keep concrete as cool and moist for as long as possible. In essence, decrease rate of hydration and drying to minimize cracking.
2. Place concrete to achieve as true and smooth a top surface as possible; mounds or dips are not acceptable. General contractor shall control overall flatness and levelness, including sloping areas to within tolerances permitted by specification – ASTM E 1155.
3. Slab shall be protected from indention and footprints during pour and curing.

3.03 CLEANING

A. Waste Management

1. All waste, equipment, and unused material is to be removed from the site by the concrete contractor.

END OF SECTION

SECTION 03 35 13

HIGH-TOLERANCE CONCRETE FLOOR FINISHING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Polished concrete finish in accordance with HTC Superfloor™ concept for interior concrete flatwork. Polished concrete finishes for pre-cast concrete, vertical cast-in-place concrete, and exterior concrete are specified in the sections for those types of concrete.
2. Concrete Sealant with color tinting sealant.

B. Products Furnished

1. Furnish all labor, material, equipment and services necessary for the dry diamond grinding and polishing of concrete floors in accordance with the HTC Superfloor™ concept.
2. Applying densifying impregnator/sealer and polishing to specified sheen level and aggregate exposure.
3. Use concrete tinting sealant to finish floor.

1.02 ACTION SUBMITTALS

A. Samples

1. For initial selection of finish color.

B. Manufacturer's Instructions

1. Concrete must be cured a minimum of 28 days prior to polishing.

1.03 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data

1. Clean with warm water as needed.
2. For information on maintenance procedures using the TWISTER™ Diamond Cleaning System by HTC, contact a Sales and Technical Support Representative at HTC, LLC 877-482-8700.

1.04 QUALITY ASSURANCE

A. Basis of design: HTC Superfloor™, manufactured by HTC LLC.

B. Qualifications

1. Installer/applicator shall be certified by concrete finish equipment and chemical manufacturer and shall provide adequate number of skilled workmen who are thoroughly trained and experienced in the necessary craft.

C. Certification

1. Provide a letter of certification from both the equipment and chemical manufacturer stating that the installer is a certified applicator and is familiar with proper procedures and installation requirements recommended by the manufacturer.

D. Mock-ups

1. Reserve portion of floor, for each color and floor finish, that will receive polish but will be covered with another material. Mock-up floor shall be placed on the same day, preferably the same pour as the floors to receive final polish.
2. Install mock-ups to verify selections made under sample submittal and to demonstrate methods and workmanship proposed for the project. If mock-up not possible, submitted samples will be accepted as demonstrated methods & workmanship.
3. Aggregate selected must be tested to ensure it will accept polish.
4. Control joints should be included in mock-up. Sawing performed by general contractor can begin as soon as the surface is firm enough not to displace any of the aggregate.
5. Approved mock-ups may become part of the completed work if undisturbed at time of substantial completion.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Storage and Handling Requirements

1. Protect areas to receive polished concrete finish at all times during construction to prevent oils, dirt, metal, excessive water and other potentially damaging materials from affecting the finished concrete surface. Protection measures listed below shall begin immediately after the concrete slab is poured:
   a. All hydraulic powered equipment shall be diapered to avoid staining of the concrete.
   b. All vehicle parking shall be prohibited on the finish slab area. If necessary to complete their scope of work, drop cloths shall be placed under vehicles at all times.
   c. No pipe cutting machine shall be used on the finish floor slab.
   d. Steel shall not be placed on the finish slab to avoid rusting.
   e. Acids and acidic detergents will not come in contact with slab.
   f. All painters will use drop cloths on the concrete. If paint gets on the concrete, it must be immediately removed.
   g. All trades will be informed that the slab must be protected at all times.
2. Finish concrete area shall be closed to traffic during finish floor application and after application, for the time as recommended by manufacturer.

1.06 FIELD OR SITE CONDITIONS

A. Ambient Conditions

1. Comply with manufacturers written instructions for substrate temperature and moisture content, ambient temperature and humidity, ventilation and other conditions affecting chemical performance.

PART 2 PRODUCTS

2.01 EQUIPMENT / COMPONENTS

A. Polishing Materials

1. Three-phase 480 Volt generator and step down transformer.
2. 3 head or 4 head counter rotating variable speed HTC Superfloor™ Approved Floor Grinder with at least 600 pounds down pressure. For example: HTC 950RX, HTC 800HDX, HTC 800 HD, HTC 650HDX, etc.
3. HTC Superfloor™ Dust extraction system, pre-separator, and squeegee attachments with minimum flow rating of 322 cubic feet per minute such as the HTC 75D.
4. Grinding Heads:
   a. HTC Superfloor™ Metal bonded: 16, 25, 40, 80, 150, and/or 300 grits.
   b. HTC Superfloor™ Resin bonded, phenolic diamonds: 100, 200, 400, 800, 1500, and 3000 grits.
5. Grinding Pads for Edges
   a. 40, 60, and 120 grits.
   b. 100, 200,400, 800, 1500, and 3000 grits.
6. Hand Grinder with dust extraction attachment and pads.
7. Penetrating Liquid Sealer Hardener Densifying Impregnator or as specified by construction manager with the following performance criteria: chemically reactive, waterborne solution of inorganic silicate or siliconate materials and proprietary components; odorless; colorless which hardens and densifies concrete surfaces to protect against abrasion, dusting, and absorption of liquids.
8. Control Joint and Saw Cut Filler, two part filler or polyurea as specified by construction manager.

2.02 CONCRETE SEALANT

A. Products

1. Ameripolish PROGUARD STAIN SHIELD Midnight Black Concrete Tinting Sealant or color as specified.
   a. Description: PROGUARD STAIN SHIELD is a penetrating stain repellant that was specifically formulated for the protection of polished/dyed concrete from oil and water-based stains.

PART 3 EXECUTION

3.01 PREPARATION

A. Protection of In-Place Conditions

1. Installer shall examine and approve concrete substrate for conditions affecting performance of finish. General contractor shall correct conditions that are found to be out

of compliance with the requirements of this section. Repairs are not acceptable unless specifically approved on a case-by-case basis by the architect.

B. Surface Preparation

1. Provide floor clean of materials and debris.
2. Protect adjacent surfaces as required to prevent damage by the concrete polishing procedure.
3. Ensure floor cured to accept polishing application.
4. Setup grinding machine, dust extraction system, tooling, and generator.

3.02 APPLICATION

A. Special Techniques

1. Applicator shall examine the areas and conditions under which work of this section will be provided and the general contractor shall correct conditions detrimental to the timely and proper completion of the work and the applicator shall not proceed until unsatisfactory conditions are resolved.
2. Grind the concrete floor to within 2 -3 inches of walls with 16, 25, 40, and 80 grit removing construction debris, floor slab imperfections and until there is a uniform scratch pattern and desired concrete aggregate exposure is achieved. Vacuum the floor thoroughly using a squeegee vacuum attachment.
3. Fill construction joints and cracks with filler products as specified in accordance with manufacturers instructions colored to match (or contrast) with concrete color as specified by architect.
4. Bull float cementitious grout coat onto surface to fill all voids, cement grout to match color of concrete, allow to cure overnight. Apply epoxy grout coat onto surface; allow to cure overnight, as specified by architect or construction manager.
5. Apply densifying impregnator undiluted at approximately 200 square feet per gallon using a stiff, long bristled broom. Cover the entire work area liberally and allow to sit for 10 minutes. Apply again to areas where the densifying impregnator has soaked in and allow to sit for an additional 30 minutes. Squeegee excess material off the floor. Allow 12 to 24 hours for full cure.
6. Grind the floor to within 2 - 3 inches of walls with metal bonded diamond grits of 150 and/or 300, grinding 90 degrees from each previous grind and removing all the scratches from the previous grit. Vacuum the floor thoroughly after each grind, using a squeegee vacuum attachment.
7. Grind the edges with 40, 60, and 120 grit grinding pads, removing all of the scratches from the previous grit. Vacuum the floor thoroughly after each grind, using a squeegee vacuum attachment.

8. Polish the floor, to desired sheen level, with phenolic resin bonded diamond grits of 100, 200, 400, 800, 1500, and 3000, first polishing the edges with pads of the same grit and then the field of the floor, removing all scratches from the previous grit. After each polish, clean the floor thoroughly using clean water and an auto-scrubber or a mop and a wet vacuum.
9. Apply PROGUARD STAIN SHIELD, buff with Green 300 grit Twister pad, as needed.

3.03 CLEANING

A. Waste Management

1. All waste, in addition to used and unused polishing materials, is to be removed from the site by the HTC Superfloor™ applicator.

3.04 PROTECTION

A. Protect the floors from damage until substantial completion.

END OF SECTION

http://www.htc-america.com/concepts/superfloor/
http://www.htc-sweden.com/ariadne/files/LLC/Superfloor_Brochure.pdf
http://www.htc-sweden.com/ariadne/files/LLC/Product_Catalog_2009.pdf
http://www.adcsc.com/products.htm

SECTION 05 12 23

STRUCTURAL STEEL FOR BUILDINGS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specifications for fabrication and delivery of structural steel frame.

B. Products Furnished

1. Furnish all labor, material, equipment and services necessary for the fabrication of the steel frame.

1.02 REFERENCES

A. Abbreviations and Acronyms

1. AISC – American Institute of Steel Construction

B. American Society for Testing and Materials:

1. ASTM A572, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
2. ASTM A500, Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
3. ASTM A325, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
4. ASTM A563, Standard Specification for Carbons and Alloy Steel Nuts
5. ASTM F436, Standard Specification for Hardened Steel Washers

1.03 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Manufacturer will incorporate transportation components into structural frame. The frame is to be picked up and delivered to the specified site by F.L. Moore and Sons, Inc.

1.04 QUALITY ASSURANCE

A. Qualifications

1. A qualified fabricator is one who participates in the AISC Quality Certification Program and is designated an AISC-Certified Plant, Category Sbd.
2. Welding: Qualify procedures and personnel according to AWS D1.1, “Structural Welding Code--Steel.”
3. Comply with applicable provisions of AISC's “Code of Standard Practice for Steel Buildings and Bridges.”

PART 2 PRODUCTS

2.01 MATERIALS / COMPONENTS

A. Steel Members

1. W8x10, ASTM A572
2. W12x25, ASTM A572
3. W12x26, ASTM A572
4. HSS 4x5/16 Round, ASTM A500
5. HSS 4x4x5/16 Rectangular, ASTM A500

B. Bolts, Connectors, and Anchors

1. High-strength bolts, nuts, and washers: ASTM A325, Type 1, heavy hex steel structural bolts; ASTM A563 heavy hex carbon-steel nuts; and ASTM F436 hardened carbon-steel washers.

2.02 MANUFACTURERS

A. United Steel, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. See structural calculations for more details on material properties, building code compliancy, and loading.

2.04 FABRICATION

A. Factory Assembly

1. Structural Steel: Fabricate and assemble in shop to greatest extent possible. Fabricate according to AISC's “Code of Standard Practice for Steel Buildings and Bridges” and AISC's.

2.05 FINISHES

A. Shop Finishing Methods

1. Fabricator's standard lead- and chromate-free, non-asphaltic, rust-inhibiting primer.
2. Clean surfaces to be painted. Remove loose rust and mill scale and spatter, slag, or flux deposits. Prepare surfaces according to the following specifications and standards:
   a. SSPC-SP 2, “Hand Tool Cleaning.”
   b. SSPC-SP 3, “Power Tool Cleaning.”

B. Immediately after surface preparation, apply primer according to manufacturer's written instructions and at rate recommended by SSPC to provide a dry film thickness of not less than 1.5 mils (0.038 mm). Use priming methods that result in full coverage of joints, corners, edges, and exposed surfaces.

PART 3 EXECUTION

3.01 INSTALLERS

A. Kullman Buildings Corp.

B. Virginia Tech Solar Decathlon Team

3.02 ERECTION

A. Special Techniques

1. Set structural steel accurately in locations and to elevations indicated and according to AISC's "Code of Standard Practice for Steel Buildings and Bridges" and "[Specification for Structural Steel Buildings--Allowable Stress Design and Plastic Design] [Load and Resistance Factor Design Specification for Structural Steel Buildings]."
2. Maintain erection tolerances of structural steel within AISC's "Code of Standard Practice for Steel Buildings and Bridges."

B. Field Connections

1. High-Strength Bolts: Install high-strength bolts according to RCSC's "Specification for Structural Joints Using ASTM A325 or A490 Bolts" for type of bolt and type of joint specified.
2. Weld Connections: Comply with AWS D1.1 for welding procedure specifications, tolerances, appearance, and quality of welds and for methods used in correcting welding work.
   a. Comply with AISC's "Code of Standard Practice for Steel Buildings and Bridges" and "[Specification for Structural Steel Buildings--Allowable Stress Design and Plastic Design] [Load and Resistance Factor Design Specification for Structural Steel Buildings]" for bearing, adequacy of temporary connections, alignment, and removal of paint on surfaces adjacent to field welds.

END OF SECTION

www.kullman.com/index.html

SECTION 05 31 13

STEEL FLOOR DECKING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Steel floor decking as a part of the fabrication of structural steel frame.

B. Products Furnished

1. Furnish all labor, material, equipment and services necessary for the fabrication of the steel frame.

1.02 MAINTENANCE MATERIAL SUBMITTALS

A. Extra Stock Materials

1. Additional decking material to be provided to support on-site modification of frame according to design revisions made by the architect.

PART 2 PRODUCTS

2.01 MATERIALS / COMPONENTS

A. Steel Floor Decking

1. 1 ½” – 20 gauge composite metal deck

2.02 MANUFACTURERS

A. United Steel, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. See structural calculations for more details on material properties, building code compliancy, and loading.

2.04 FABRICATION

A. Factory Assembly

1. Fabrication will take place in a conditioned manufacturing plant, protected from weather conditions that would prove to be undesirable for construction.

PART 3 EXECUTION

3.01 INSTALLERS

A. Kullman Buildings Corp.

B. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Steel floor decking to be installed according to architect’s drawings, stamped and approved by structural engineer.

3.03 ADJUSTING

A. On-site Installation

1. Extra stock material provided by Kullman Buildings Corp. to be added on-site upon further completion of house design as approved by architect. Modification of factory-built decking may be necessary.

3.04 CLEANING

A. Waste Management

1. Material left over from on-site modifications will be recycled.

END OF SECTION

www.kullman.com/index.html

SECTION 05 45 16

ELECTRICAL METAL SUPPORTS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Specification for photovoltaic array supports.

B. Products Finished
   1. Furnish SunFrame rail, cap strips, end caps, and fasteners.

1.02 ADMINISTRATIVE REQUIREMENTS

A. Pre-Installation Meetings
   1. Conduct a pre-installation meeting to verify project requirements, structural system conditions, and SunFrame manufacturer's installation instructions.

1.03 ACTION SUBMITTALS

A. Product Data
   1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions
   1. The product manufacturer shall provide a written installation guide along with maintenance data, including technical bulletins, load design charts, detail book, and shop drawings.

1.04 QUALITY ASSURANCE

A. Qualifications
   1. Obtain all SunFrame components through manufacturer or from a manufacturer recommended distributor.
   2. Installer(s) should be experienced in performing work of this sections and should have specialized in installation of work similar to that required for this project.

1.05 WARRANTY

A. Manufacturer Warranty
   1. Ten year limited product warranty and a five year limited finish warranty.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. SunFrame Shared Rail Photovoltaic Racking system

2.02 COMPONENTS

A. Cap Strips
   1. 6105-T5 aluminum extrusion
   2. Pre-punched cap strips designed to secure modules while accommodating varying module heights.

B. Rail

1. 6105-T5 aluminum extrusion
2. SunFrame Rail supports modules between the rails, not on top of them.
3. A threaded slot atop the rail allows securing module with cap strip.

C. End Caps

1. UV resistant plastic
2. Black caps to hide the rail end extrusion.

2.03 MANUFACTURERS

A. Unirac, Inc.

2.04 DESCRIPTION

A. Unirac's SunFrame system leads the PV market with its superior aesthetics. Its sleek design is engineered to sit low to the roof without gaps and implements shared rails for the best value.

B. Regulatory Requirements

1. SunFrame products, when installed in accordance with the provided installation guide, will be structurally adequate and will meet the structural requirements of the IBC 2006, IBC 2003, ASCE 7-02, ASCE 7-05 and California Building Code 2007.

2.05 PERFORMANCE / DESIGN CRITERIA

A. Characteristics

1. Modules are flush mounted in low-gap-free rows.
2. Visible components match clear or dark module frames.
3. End caps cover rail cross-section.
4. Optimized module performance, system spacing allows convection cooling for increased performance.
5. Minimized penetrations with longer attachment spans than competitive products.

2.06 ACCESSORIES

A. Splices: hidden splices re used to create long rows of modules.

B. Fasteners: corrosion resistant screws compatible with SunFrame system shall be provided by the SunFrame manufacturer.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment. Use provided installation guide.

B. Systems Integration

1. Insure clearances are adequate after installation of PV array. Use provided installation guide.

END OF SECTION

http://www.unirac.com/mounting-solutions/sunframe-rail-system.php?solution=roof-mount

SECTION 05 50 00

METAL FABRICATIONS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Steel weld plates and angles.
2. Metal floor plates.
3. Outrigger plates and sunscreen supports.

1.02 SUBMITTALS

A. Product data

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. ACE Steel, Inc.

2.02 METALS

A. Metal Surfaces, General: Provide materials with smooth, flat surface without blemishes.

B. Ferrous Metals:

1. Steel plates, shapes, and angles: ASTM A 36/A 36M
2. Steel Tubing: ASTM A 500, cold-formed steel tubing.
3. Steel Pipe: ASTM A53/ A 53M, standard weight, unless another weight is specified.

2.03 FASTENERS

A. General: Stainless –steel fasteners for exterior use. Select fasteners for type, grade, and class required.

2.04 FABRICATION

A. General: Preassemble items in the shop to the greatest extent possible. Use connections that maintain structural value of joined pieces.

1. Cut, drill, and punch metals cleanly and accurately. Remove burrs and ease edges. Remove sharp or rough areas on exposed surfaces.
2. Weld corners and seams continuously. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals. Obtain fusion without undercut or overlap. Remove welding flux immediately. Finish exposed welds smooth and blended.
3. Form exposed connections with hairline joints, flush and smooth, using concealed fasteners where possible. Locate joints where least conspicuous.
4. Fabricate seams and other connections that will be exposed to weather in a manner to exclude water. Provide weep holes where water may accumulate.

B. Miscellaneous Steel Trim: Fabricate units from steel shapes, plates, and bars of profiles shown with continuously welded joints and smooth exposed edges. Miter corners and use concealed field splices where possible. Provide cutout, fitting, and anchorages as needed to coordinate assembly and installation with other work.

2.05 FINISHES

A. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes. Finish metal fabrications after assembly.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. General: Perform cutting, drilling, and fitting required for installing metal fabrications. Set metal fabrications accurately in location, with edges and surfaces level, plumb, and true.

1. Fit exposed connections accurately together. Weld connections that are not to be left as exposed joints but cannot be shop welded. Do not weld, cut, or abrade surfaces of exterior units that have been hot-dip galvanized after fabrication.
2. Provide anchorage devices and fasteners where metal fabrications are required to be fastened to in-place construction.
3. Provide temporary bracing or anchors in formwork for items that are to be built into concrete, masonry, or similar construction.

B. Set bearing and leveling plates on cleaned surfaces using wedges, shims, or leveling nuts. After bearing members have been positioned and plumbed, tighten anchor bolts and pack solidly with non-shrink, nonmetallic grout.

C. Touch up surfaces and finishes after erection.

1. Painted Surfaces: Clean field welds, bolted connections, and abraded areas and touch up paint with the same material as used for shop painting.
2. Galvanized Surfaces: Clean field welds, bolted connections, and abraded areas and repair galvanizing to comply with ASTM A 780.

END OF SECTION

http://www.macraesbluebook.com/search/company.cfm?company=520396

SECTION 05 53 00

METAL GRATINGS

PART 1 GENERAL

1.01 SCOPE

A. The contractor shall provide all labor, materials, equipment and incidentals as shown, specified and required to furnish and install grating, stair treads and frames.

1.02 QUALITY ASSURANCE

A.01 Manufacturer Qualification: A company specializing in the manufacturing of metal bar gratings with not less than 10 years of documented experience.

A.02 Comply with applicable provisions and recommendations of the following: NAAMM Metal Bar Grating Manual designated ANSI/NAAMM MBG 531 (Aluminum and Light Duty Steel and Stainless Steel Grating) and MBG 532 (Heavy Duty Steel Grating).

A.03 Heavy Duty Steel: ASTM A1011 for hot rolled carbon steel sheet and strip. ASTM A510 for carbon steel wire rods and coarse round wire. ASTM A666 for stainless steel.

B.01 Take field measurements prior to preparation of final shop drawings and fabrication where required to ensure proper fitting of the work.

1.03 REFERENCES

A. ASTM A1011/A-04 Standard Specification for Steel Sheet and Strip

B. AISI 1008 Standard Low Carbon Steel

C. ANSI/NAAMM-MBG-531-00 Metal Bar Grating Manual

D. ASTM A-123 Standard Specification for Zinc Hot-Dip Galvanized Products.

1.04 SUBMITTALS

A. The contractor shall submit for approval shop drawings for the fabrication and erection of all work. Include plans, elevations, and details of sections and connections. Show type and location of all fasteners.

B. The contractor shall submit the manufacturer's specifications, load tables, anchor details and standard installation details.

C. Samples of grating and anchorage system shall be submitted for approval.

PART 2 PRODUCTS

2.01 GENERAL

A. Design is based upon use of carbon steel gratings as manufactured by Ohio Gratings, Inc. and terminology used herein may include reference to the specific performance or product of this manufacturer. Such reference shall be construed only as establishing the quality of materials, operational features and workmanship to be used under this Section and shall not, in any way, be construed as limiting competition.

1. Grating: Heavy Duty Welded Steel W Series by Ohio Gratings Inc., or equal.
2. Bearing Bars: Rectangular bar [1”, 1-1/4”, 1-1/2”,1-3/4”, 2”, 2-1/4”, 2-1/2”, 3”, 3-1/2”, 4”, 4-1/2”, 5”, 5-1/2”, 6”] depth x [1/4”, 5/16”, 3/8”, 1/2”] width on a maximum of [15/16”, 19/16”, 22/16”, 30/16”, 38/16”] centers. (Note other spacing may be specified at the discretion of the architect/engineer.)
3. Cross Bars: To be [size] welded at right angles to bearing bars at 4” centers maximum. (Note 2” cross bar centers may be specified at the discretion of architect/engineer.)
4. Surface: [Plain, Serrated].
5. Loading: Grating to carry a pedestrian loading equal to a uniform load of 100# per square foot over the required clear span with deflection not to exceed □”. (Note: alternate loading requirements may be specified at the discretion of the architect/engineer.)
6. Finish: The gratings shall be provided [Mill, Shop Black Pain, Galvanized after Fabrication].
7. Fabrication and Tolerances shall be in accordance with ANSI/ NAAMM Metal Bar Grating Manual.

PART 3 EXECUTION

3.01 INSTALLATION

A. Prior to grating installation, contractor shall inspect supports for correct size, layout and alignment. Any inconsistencies between contract drawings and supporting structure deemed detrimental to grating placement shall be reported in writing to the architect or owner’s agent prior to placement.

B. Install grating in accordance with shop drawings and standard installation clearances as recommended by ANSI / NAAMM Metal Bar Grating Manual.

C. Cutting, Fitting and Placement.
   1. Perform all cutting and fitting required for installation. Grating shall be placed such that cross bars align.
   2. Utilize standard panel widths wherever possible.

D. Protection of Aluminum from Dissimilar Materials:
   1. Where aluminum surfaces come into contact with dissimilar metals, surfaces shall be kept from direct contact by painting the dissimilar metal with one coat of bituminous paint or other approved insulating material.
   2. Where aluminum surfaces come into contact with dissimilar materials such as concrete, masonry or lime mortar, exposed aluminum surfaces shall be painted with one coat of bituminous paint or other approves insulating material.

3.02 GRATING ATTACHMENT

A. Use approved attachment system and fasteners to secure grating to supporting members as shown on plans.

END OF SECTION

http://www.ohiogratings.com/pdfs/Heavy%20Duty/3%20Part%20Spec%20W.pdf

SECTION 06 10 53

MISCELLANEOUS ROUGH CARPENTRY

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Framing with dimension lumber.
2. Wood blocking and nailers.
3. Wood furring and grounds.

1.02 REFERENCES

A. American Society for Testing of Materials:

1. ASTM A153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
2. ASTM C954, Standard Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs

1.03 ACTION SUBMITTALS

A. Product Data

1. Include data for [wood-preservative] [and] [fire-retardant] treatment from chemical treatment manufacturer and certification by treating plant that treated materials comply with requirements.

B. Research and Evaluation Reports

1. For the following, show compliance with building code in effect for project:
   a. Preservative-treated wood.
   b. Fire-retardant-treated wood.
   c. Power-driven fasteners.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. General Lumber

1. DOC PS 20 and applicable rules of grading agencies indicated. If no grading agency is indicated, provide lumber that complies with the applicable rules of any rules-writing agency certified by the ALSC Board of Review. Provide lumber graded by an agency certified by the ALSC Board of Review to inspect and grade lumber under the rules indicated.
   a. Factory mark each piece of lumber with grade stamp of grading agency.
   b. For exposed lumber indicated to receive a stained or natural finish, [mark grade stamp on end or back of each piece] [or] [omit grade stamp and provide certificates of grade compliance issued by grading agency].
   c. Provide dressed lumber, S4S, unless otherwise indicated.

B. Dimension Lumber Framing

1. Non-load-bearing interior partitions - grade of any species.
2. Other framing - the following species:
    a. Hem-fir (north); NLGA
    b. Southern pine; SPIB
    c. Douglas fir-larch; WCLIB or WWPA
    d. Mixed southern pine; SPIB
    e. Spruce-pine-fir; NLGA
    f. Douglas fir-south; WWPA
    g. Hem-fir; WCLIB or WWPA
    h. Douglas fir-larch (north); NLGA
    i. Spruce-pine-fir (south); NeLMA, WCLIB, or WWPA

2.02 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Maximum Moisture Content: 19 percent.

2.03 ACCESSORIES

A. General Fasteners

1. Where carpentry is exposed to weather, in ground contact, pressure-preservative treated, or in area of high relative humidity, provide fasteners [with hot-dip zinc coating complying with ASTM A153 / A153M] [of Type 304 stainless steel].

B. Power-Driven Fasteners

1. NES NER-272

C. Screws for Fastening to Cold-Formed Metal Framing

1. ASTM C954, except with wafer heads and reamer wings, length as recommended by screw manufacturer for material being fastened.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Set carpentry to required levels and lines, with members plumb, true to line, cut, and fitted. Fit carpentry to other construction; scribe and cope as needed for accurate fit. Locate [furring,] nailers, blocking, [grounds,] and similar supports to comply with requirements for attaching other construction.
2. Framing Standard: Comply with AF & PA's "Details for Conventional Wood Frame Construction," unless otherwise indicated.
3. Do not splice structural members between supports, unless otherwise indicated.

4. Comply with AWPA M4 for applying field treatment to cut surfaces of preservative-treated lumber.
5. Securely attach carpentry work to substrate by anchoring and fastening as indicated, complying with the following:
    a. NES NER-272 for power-driven fasteners.
    b. Table 2304.9.1, "Fastening Schedule," in ICC's International Building Code.
    c. Table 23-II-B-1, "Nailing Schedule," and Table 23-II-B-2, "Wood Structural Panel Roof Sheathing Nailing Schedule," in ICBO's Uniform Building Code.
    d. Table 2305.2, "Fastening Schedule," in BOCA's BOCA National Building Code.
    e. Table 2306.1, "Fastening Schedule," in SBCCI's Standard Building Code.
    f. Table R602.3(1), "Fastener Schedule for Structural Members," and Table R602.3(2), "Alternate Attachments," in ICC's International Residential Code for One- and Two-Family Dwellings.
    g. Table 602.3(1), "Fastener Schedule for Structural Members," and Table 602.3(2), "Alternate Attachments," in ICC's International One- and Two-Family Dwelling Code.

END OF SECTION

SECTION 06 12 00

STRUCTURAL PANELS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Structural Insulated Panels (SIPs)

B. Products Furnished

1. Furnish SIPs panels, adhesive, mechanical fasteners and related equipment specific to the structural steel frame in Section 05 12 23.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM C578, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation
2. ASTM D3273, Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber

B. ICC Evaluation Service:

1. ICC ES AC04, Acceptance Criteria for Sandwich Panels
2. ICC ES AC05, Acceptance Criteria for Sandwich Panel Adhesives
3. ICC ES AC12, Acceptance Criteria for Foam Plastic Insulation
4. ICC ES AC239, Acceptance Criteria for Termite-Resistant Foam Plastics

C. National Institute of Standards and Technology

1. DOC PS2, Performance Standard for Wood-based Structural-Use Panels

D. Greenguard Environmental Institute

1. Standard for Low-Emitting Products

E. American Wood Protection Association

1. AWPA E-1, Standard Testing for Resistance to Formosan Termite

1.03 ADMINISTRATIVE REQUIREMENTS

A. Pre-installation Meetings

1. Conduct pre-installation meeting to verify project requirements, foundation/structural system/substrate conditions, SIP manufacturer’s installation instructions, and SIP manufacturer’s warranty requirements.

1.04 ACTION SUBMITTALS

A. Shop Drawings

1. Submit shop drawings for SIPs showing layout, elevations, product components, and accessories.

B. Manufacturer's Instructions

1. Comply with manufacturer's ICC ES report, load design charts, detail book, shop drawings, and product data, including product technical bulletins, for installation.
2. Plans shall be reviewed by a qualified architect/engineer and shall be signed and/or sealed. Deviations from standard detail and load design values shall be calculated and signed and/or sealed by a qualified architect/engineer.

1.05 QUALITY ASSURANCE

A. Qualifications

1. Obtain all SIPs through one source. All accessories are to be as furnished or recommended by the SIP manufacturer.
2. Installer should be experienced in performing work of this section and should have specialized in installation of work similar to that required for this project.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Deliver materials from SIP manufacturer with identification labels or markings intact.
2. Off-load SIPs from truck using fork lift or other means to prevent damage to SIPs.

B. Storage and Handling Requirements

1. SIPs shall be fully supported in storage and prevented from contact with the ground. Stack SIPs on pallets or a minimum of three stickers for every 8 feet of SIP length.
2. SIPs shall be fully protected from weather. Protect against exposure to rain, water, dirt, mud, and other residue that may affect SIP performance. Cover stored SIPs with breathable protective wraps.

1.07 WARRANTY

A. Manufacturer Warranty

1. Submit SIP manufacturer's standard warranty document. SIP manufacturer's warranty is in addition to, and not a limitation of, other rights owner may have under contract documents.

PART 2 PRODUCTS

2.01 OWNER-SUPPLIED PRODUCTS

A. Dimensional lumber, SPF #2 or better or pre-engineered equivalent, to frame out edges of SIPs.

2.02 PRODUCT TYPES / SYSTEM DESCRIPTION

A. R-Control® Structural Insulated Panels

1. Structural Insulated Panels (SIPs) consist of oriented strand board (OSB) laminated with structural adhesives to a termite resistant EPS insulation core, an EPA registered treatment for mold, mildew, and termites, and SIP manufacturer-supplied connecting splines, sealants, and SIP screws.

2.03 MANUFACTURERS

A. List of Licensed R-Control® SIP Manufacturers / Suppliers

1. ACH Foam Technologies, LLC
2. Big Sky Insulations, Inc.
3. Branch River Plastics, Inc.
4. NoArk Enterprises, Inc.
5. Team Industries, Inc.
6. Therma Foam, Inc.
7. Thermal Foams, Inc.
8. AFM Corporation

2.04 DESCRIPTION

A. Regulatory Requirements

1. Provide SIPs which have been manufactured, fabricated, and installed to withstand loads and to maintain performance criteria stated by SIP manufacturer without defects, damage, or failure.
2. SIPs shall be recognized for compliance with International Building Code, International Residential Code in a current ICC ES evaluation report.

2.05 MATERIALS

A. SIPs consist of the following:

1. UL certified EPS core with Perform Guard treatment, minimum of 0.95 pcf (15.2 kg/m^3) complying with ASTM C578 Type I and having ICC ES recognition of termite resistance. Insulation manufacturer shall provide Third Party UL certificate. ICC ES report shall be provided for recognition of termite resistance in compliance with ICC AC239.
2. OSB identified with APA or TECO performance mark with Exposure I durability rating and performance in accordance with DOC PS-2 span rating 24/16 or greater.
3. Adhesives shall be in conformance with ICC ES AC05.
4. Frame Guard treatment for mold, mildew, and termite resistance meeting the following requirements:
    a. Registered with EPA.
    b. Indoor air quality certified under GEI standard for low-emitting products.
    c. Mold growth: 0 rating, tested to ASTM D3273 for 8 weeks at 77 degrees F and 100% relative humidity.
    d. Termite resistance rating of 7.0, tested to AWPA E-1.
    e. Equivalent lateral resistance and tooth holding capacity as untreated wood.

2.06 FABRICATION

A. Factory Assembly

1. SIPs shall be fabricated in accordance with approved shop drawings.

2.07 ACCESSORIES

A. Splines: OSB, block splines, or I-beam for use in joining SIPs shall be supplied by SIPs manufacturer.

B. Fasteners: corrosion resistant SIP screws compatible with SIP system shall be provided by the SIPs manufacturer.

1. Wood screws for attachment to wood members.
2. Heavy duty metal screws for attachment to metal members (16 gauge to 3/16”).

C. SIP Sealant: shall be specifically designed for use with SIPs. Sealant must be compatible with all components of the SIP. Sealant shall be provided by the SIP manufacturer.

D. Vapor Barrier SIP Tape: 40 mil thick, butyl adhesive suitable for indoor use, min. 6 inch wide for use on SIP joints as specified by designer. SIP Tape shall be supplied by the SIP manufacturer.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Verification of Conditions

1. Verify substrate conditions (which have been previously installed under other sections) are acceptable for product installation in accordance with manufacturer’s instructions.
2. Verify conditions of foundation/structural system/substrate and other conditions which affect installation of SIPs. Any adverse conditions shall be reported in writing. Do not proceed with installation until adverse conditions are corrected.

3.03 INSTALLATION

A. SIP Supports

1. Provide level and square foundation/structural system/substrate that support wall and/or roof SIPs. For wall SIPs, hold sill plate back from edge of rim board 7/16" (11 mm) to allow full bearing of OSB skins. Provide 1 1/2" (38 mm) diameter access holes in plating to align with electrical wire chases in SIPs. Provide adequate bracing of SIPs during erection. Remove debris from plate area prior to SIP placement.

B. SIP Fastening

1. Connect SIPs by nails or staples as shown on drawings. Screws of equal strength may be substituted for nails and staples as specified by engineer. SIP sealant must be used together with each fastening techniques. Where SIP Screw Fasteners are used, provide a minimum of 1" (25.4 mm) penetration into support. Join SIPs using plates and splines. Secure attachment with nails, staples, or screws, and SIP sealant. Apply SIP sealant following SIP manufacturer recommendations.

C. SIP Tape

1. Provide SIP Tape at joints between SIP roof panels and at intersection of roof and wall.

D. Vapor Retarders

1. Provide vapor retarders mandated by building code. Provide a vapor retarder, such as 6 mil (0.006") (0.15 mm) polyethylene on SIP applications which are connected using methods other than surface splines.

E. Thermal Barriers

1. Interior surfaces of SIPs shall be finished with a minimum 15-minute thermal barrier, such as 1/4" (4 mm) gypsum wallboard, nominal 1" (25 mm) wood paneling, or other approved materials. Apply code approved thermal barriers according to SIP manufacturer’s recommendations.

F. Restrictions

1. Do not install SIPs directly on concrete.
2. Do not put plumbing in SIPs without consulting SIP manufacturer. Do not over-cut skins for field-cut openings and do not cut skins for electrical chases.
3. SIPs shall be protected from exposure to solvents and their vapors that damage the EPS foam core.
4. Remove and replace insulated wall or roof SIPs which have become excessively wet or damaged before proceeding with installation of additional SIPs or other work.

3.04 PROTECTION

A. Protect roof SIPs from weather by roofing materials to provide temporary protection at the end of the day or when rain or snow is imminent.

B. After installation, cover SIPs to prevent contact with water on each exposed SIP edges and faces.

END OF SECTION

http://www.r-control.com/
http://www.r-control.com/downloads/brochure/R-Control%20SIP%20Load%20Design%20Chart.pdf
http://www.r-control.com/downloads/codereport/ESR-2233.pdf

SECTION 06 15 33

WOOD PATIO DECKING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Wood used for exterior patio decking.
2. Hardware used for railings, handrails, and fasteners.
3. Stainless steel drainage grates.

1.02 REFERENCES

A. American Society for Testing of Materials:

1. ASTM A153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

1.03 ACTION SUBMITTALS

A. Product Data

1. Include data for thermal treated, fire-retardant treatment from chemical treatment manufacturer and certification by treating plant that treated materials comply with requirements.
2. Include data for stainless steel profile bar screen floor drain.

B. Research and Evaluation Reports

1. For the following, show compliance with building code in effect for project:
   a. Thermal treated wood.
   b. Power-driven fasteners.
   c. Stainless steel floor drains.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Thermal treated lumber products.

1. Description: Thermally modified wood uses high heat in a controlled atmosphere to improve dimensional stability and decay resistance of wood in an environmentally responsible and sustainable manner.
2. Resource Efficient: Thermal treated wood is long lasting, adding value and utility to wood to promote responsible and sustainable forestry practice. The enhanced performance of thermal treated wood rivals exotic species from tropical rain forests, providing an alternate to rain forest removal. Up to 80% of the energy required for thermal modification comes from the wood itself, and wood scrap can be burn or land filled without adverse environmental impact. Finishes last longer, promoting less VOCs in the environment.

3. Uniform coloration throughout of one of the following wood types:
    a. Ash
    b. Birch
    c. Poplar
    d. Red Oak

B. Custom Fabricated Steel Tube Handrail with Stainless Steel Wire Balusters
    1. Description: Custom designed and fabricated by the Virginia Tech Solar Decathlon team.

C. Stainless Steel floor drain.
    1. Description: Non-welded Mechanically interlocked stainless steel screens that have both the benefits of strength and flexibility while lying completely flat. The highly durable material is perfect for floor drains, screen conveyors, fish diversion systems, and hammer mills.
    2. ADA Compliant for heavy duty and pedestrian traffic.
    3. Available in a wide variety of sizes and colors.

2.02 MAUNFACTURERS

A. Cambia *by* Greenleaf.

B. ACE Steel, INC.

C. Hendrick Screen Co.

2.03 ACCESSORIES

A. General Fasteners
    1. Where carpentry is exposed to weather, in ground contact, pressure-preservative treated, or in area of high relative humidity, provide fasteners [with hot-dip zinc coating complying with ASTM A153 / A153M of Type 304 stainless steel.

B. Power-Driven Fasteners
    1. NES NER-272

C. Screws for Fastening to Cold-Formed Metal Framing
    1. ASTM C954, except with wafer heads and reamer wings, length as recommended by screw manufacturer for material being fastened.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques
    1. Set carpentry to required levels and lines, with members plumb, true to line, cut, and fitted. Fit carpentry to other construction; scribe and cope as needed for accurate fit. Locate nailers, blocking, and similar supports to comply with requirements for attaching other construction.

2. Comply with AWPA M4 for applying field treatment to cut surfaces of preservative-treated lumber.
3. Securely attach carpentry work to substrate by anchoring and fastening as indicated, complying with the references sited in 2.03 ACCESSORIES section of this specification.
4. Follow manufacturer’s provided installation guide.

END OF SECTION

SECTION 06 20 23

INTERIOR FINISH CARPENTRY

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Interior standing and running trim.
2. Plywood paneling
3. Shelving

1.02 ACTION SUBMITTALS

A. Product data: For each type of process and factory-fabricated product.

B. Samples: For each type of paneling indicated.

1.03 QUALITY ASSURANCE

A. Forest Certification: For the following wood products, provide materials produced from wood obtained from forests certified by an FSC-accredited certification body to comply with FSC 1.2, "Principles and Criteria":

1. Interior 3/4" thick plywood paneling.

PART 2 PRODUCTS

2.01 MATERIALS, GENERAL

A. Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer.

2.02 FIRE-RETARDANT-TREATED MATERIALS

A. Comply with performance requirements in AWPA C27, Interior Type A. Kiln dry after treatment to maximum moisture content of 15 percent.

2.03 PANELING

A. Hardwood Veneer Plywood Paneling: Manufacturer's stock hardwood plywood panels complying with HPVA HP-1 made with 0.3 ppm urea-formaldehyde adhesive.

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
2. Manufacturers: Subject to compliance with requirements, provide products by Columbia Forest Products, Inc.
3. Face Veneer Species Cut: Rift Sliced Maple
4. Veneer Matching: Select for similar color and grain.
5. Thickness: 1/28 inch

2.04 ACCESSORIES

A. Panel Clip Z-Clip Alloy 6063 Aluminum Model # NYM111M

1. Description: 2.5" Z Panel Clip with holes designed for attaching plywood panels to interior walls.

2. Finished: Milled extruded aluminum

3. Dimension: 2.5" length x .176" width

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 PREPARATION

A. Before installing interior finish carpentry, condition materials to average prevailing humidity in installation areas for a minimum of 24 hours.

3.03 INSTALLATION, GENERAL

A. Install interior finish carpentry level, plumb, true, and aligned with adjacent materials. Use concealed shims where necessary for alignment.

1. Scribe and cut interior finish carpentry to fit adjoining work.

2. Countersink fasteners, fill surface flush, and sand where face fastening is unavoidable.

3. Install to tolerance of 1/8 inch in 96 inches (3 mm in 2438 mm) for level and plumb. Install adjoining interior finish carpentry with 1/32-inch (0.8-mm) maximum offset.

3.04 PANELING INSTALLATION

A. Plywood Paneling: Select and arrange panels on each wall to minimize noticeable variations in grain character and color between adjacent panels. Leave 1/4-inch (6-mm) gap to be covered with trim at top, bottom, and openings. Install with uniform tight joints between panels.

1. Attach panels to supports with manufacturer's recommended panel adhesive and fasteners. Space fasteners as recommended by panel manufacturer.

2. Conceal fasteners to greatest practical extent.

END OF SECTION

http://www.columbiaforestproducts.com

SECTION 07 21 13.13

Foam Board Insulation

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Tapered Foam-Control Expanded Polystyrene (EPS) rigid board plastic thermal insulation.

B. Products Furnished

1. Pre-cut foam plastic insulation sections.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM C 578, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation
2. ASTM E 2430, Standard Test Method for Acceptable Criteria for EIFS Boards

B. ICC Evaluation Service:

1. ICC ES AC12, Acceptance Criteria for Foam Plastic Insulation

1.03 ADMINISTRATIVE REUIREMENTS

A. Pre-installation Meetings

1. Conduct pre-installation meeting to verify project requirements, manufacturer's installation instructions, and manufacturer's warranty requirements.

1.04 ACTION SUBMITTALS

A. Shop Drawings

1. Submit shop drawings for Foam-Control Expanded Polystyrene (EPS) board showing layout location, elevations, product components, and accessories.

B. Manufacturer's Instructions

1. Comply with manufacturer's detail book, shop drawings, product data, technical bulletins, and installation instructions.

1.05 QUALITY ASSURANCE

A. Regulatory Agency Approvals

1. Foam-Control EPS meets or exceeds the requirements of ASTM C578, "Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation." Foam-Control EPS is monitored for quality Control and Listed by Underwriters Laboratories Inc. The International Code Council Evaluation Service recognizes Foam –Control EPS for building code compliance.

B. Qualifications

1. Obtain all Foam-Control Expanded Polystyrene (EPS) boards through one source. All accessories are to be furnished or recommended by manufacturer.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Deliver materials from manufacturer with identification labels or markings intact.
2. Off-load plastic foam board insulation with means to prevent damage to product.

B. Storage and Handling Requirements

1. Foam-Control Expanded Polystyrene (EPS) shall be fully supported in storage and prevents from contract with the ground.

1.07 WARRANTY

A. Product Warranty

1. Foam-Control EPS Licensees offer a product warranty ensuring thermal performance, physical properties, and termite resistance.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Roof-specific tapered Foam-Control Expanded Polystyrene (EPS) rigid board plastic thermal insulation.

B. FOAMULAR 150 2” Rigid Expanded Polystrene rigid board plastic thermal insulation.

2.02 MANUFACTURERS

A. AFM Corporation

B. Owens Corning

2.03 Description

A. Cost-effective thermal design is among the highest priorities in construction. Thermal resistance (R-value) of an insulation assembly is the determining factor in thermal performance. Foam-Control EPS provides optimum cost value when compared to other rigid insulations of the same R-value design.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Thermal Performance: The R-value of Foam-Control EPS remains constant and does not suffer from R-value loss. The closed cell structure of Foam-Control EPS contains air and not blowing agents, which deplete over time.
2. Exposure to Water and Water Vapor: The mechanical properties of EPS are unaffected by moisture. Exposure to water or water vapor does not cause swelling.
3. Temperature Exposure/Flame Retardants: EPS is able to withstand the rigors of temperature cycling, assuring long term performance. The maximum recommended long-term exposure temperature for Foam-Control EPs is 165 degrees F.
4. Resistance to mold and mildew: EPS will not decompose and will not support mold or mildew growth. EPS provides no nutrient value to plants or animals.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Roof-specific tapered Foam-Control EPS sections are to be tamped on place to insure removal of water to prevent leaks while adding thermal insulation. Follow manufacturer's instructions.

END OF SECTION

http://www.foam-control.com/Insulation.asp
http://www.foam-control.com/

SECTION 07 21 23

LOOSE-FILL INSULATION

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Aerogel as loose-fill insulation for glass and polycarbonate assemblies.

B. Products Furnished

1. Aerogel and equipment/facilities necessary to fill assemblies.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM D1929, Standard Test Method for Determining Ignition Temperature of Plastics

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Nanogel® is Cabot Corporation's trade name for its family of silica aerogels.

2.02 MANUFACTURERS

A. Cabot Corporation

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Low thermal conductivity, 9-12mW/mK.
2. High porosity, (95% air, 5% solid) with a pore size of 20-40 nanometers.
3. Low tap density, 30-100kg/m^3.
4. Completely hydrophobic surface chemistry.
5. Specific heat capacity of Kj/Kg .7-1.15.
6. Corrosion resistant.

PART 3 EXECUTION

3.01 INSTALLERS

A. Members of the Virginia Tech Solar Decathlon Team will fill glass and polycarbonate assemblies with aerogel under the supervision of employed professionals at Cabot Corporation.

3.02 INSTALLATION

A. Special Techniques

1. Aerogel is poured from a hopper while a tamping mechanism moves the glass or polycarbonate assembly below, helping fine particles to settle.

<u>END OF SECTION</u>

http://www.cabot-corp.com/wcm/download/en-us/ae/NG_Fine_Particle_Aerogel1.pdf
http://www.cabot-corp.com/wcm/download/en-us/ae/Nanogel%20Daylighting%20brochure.pdf

SECTION 07 21 29

SPRAYED INSULATION

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Self-supported, spray-applied cellulosic insulation.

1.02 ACTION SUBMITTALS

A. Product Data

B. Samples

1. Full-size units for each type of exposed insulation indicated.

C. Test and Evaluation Reports

D. Sustainable Design Submittals

1. Credit MR 4.1 [and MR 4.2]: Product data indicating percentages by weight of post-consumer and pre-consumer recycled content for products having recycled content.

1.03 QUALITY ASSURANCE

A. Preconstruction Testing

1. Retain ASTM test method below based on product and kind of fire-resistance characteristic specified for each product in Part 2. Fire-Test-Response Characteristics: Provide insulation and related materials with the fire-test-response characteristics indicated, as determined by testing identical products per [ASTM E 84 for surface-burning characteristics] [and] [other methods indicated with product], by UL or another testing and inspecting agency acceptable to authorities having jurisdiction. Identify materials with appropriate markings of applicable testing and inspecting agency.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Honeywell Enovate Blowing Agent, closed-cell polyurethane spray foam insulation

2.02 MANUFACTURERS

A. Honeywell Specialty Materials, Fluorine Products

2.03 DESCRIPTION

A. Regulatory Requirements

1. Self-supported, spray-applied cellulosic Insulation: ASTM C 1149, [Type I (materials applied with liquid adhesive; suitable for either exposed or enclosed applications),] [Type II (materials containing a dry adhesive activated by water during installation; intended only for enclosed or covered applications),] [Type III (materials containing an adhesive mixed with water during application; intended for application on attic floors),] chemically treated for flame-resistance, processing, and handling characteristics.

PART 3 EXECUTION

3.01 INSTALLERS

A. Honeywell, local installer.

3.02 INSTALLATION

A. Special Techniques

1. Apply self-supported, spray-applied cellulosic insulation according to manufacturer's written instructions.

2. Do not apply insulation until installation of pipes, ducts, conduits, wiring, and electrical outlets in walls is completed and windows, electrical boxes, and other items not indicated to receive insulation are masked. After insulation is applied, make it flush with face of studs by using method recommended by insulation manufacturer.

B. Interface with Other Work

1. Water-Piping Coordination: If water piping is located within insulated exterior walls, coordinate location of piping to ensure that it is placed on warm side of insulation and insulation encapsulates piping.

3.03 CLEANING

A. Waste Management

1. All waste is to be removed from the site by Honeywell installer.

END OF SECTION

http://www51.honeywell.com/sm/chemicals/enovate/common/documents/enovate.pdf
http://sc.leadix.com/24/70/live/files/Enovate%20Fact%20Pack%2007_full%20NEW.pdf

SECTION 07 25 00

WEATHER BARRIERS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Weather Barrier membrane
2. Seam Tape
3. Fasteners for Weather Barrier Assembly

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM C920, Standard Specification for Elastomeric Joint Sealants
2. ASTM C1193; Standard Guide for Use of Joint Sealants
3. ASTM D882; Test Method for Tensile Properties of Thin Plastic Sheeting
4. ASTM D1117; Standard Guide for Evaluating Non-woven Fabrics
5. ASTM E84; Test Method for Surface Burning Characteristics of Building Materials
6. ASTM E96; Test Method for Water Vapor Transmission of Materials
7. ASTM E1677; Specification for Air Retarder Material or System for Framed Building Walls
8. ASTM E2178; Test Method for Air Permeance of Building Materials

B. AATCC – American Association of Textile Chemists and Colorists

1. Test Method 127 Water Resistance: Hydrostatic Pressure Test

C. TAPPI

1. Test Method T-410; Grams of Paper and Paperboard (Weight per Unit Area)
2. Test Method T-460; Air Resistance (Gurley Hill Method)

1.03 ADMINISTRATIVE REUIREMENTS

A. Pre-installation Meetings

1. Conduct pre-installation meeting to verify project requirements, manufacturer's installation instructions, and manufacturer's warranty requirements.

1.04 ACTION SUBMITTALS

A. Product Data: Submit manufacturer current technical literature for each component.

B. Samples: Weather Barrier membrane, minimum 8.5" x 11".

C. Quality Assurance Submittals

1.05 QUALITY ASSURANCE

A. Qualifications

1. Installer shall have experience with installation of similar weather barrier assemblies under similar conditions.

2. Installation shall be in accordance with manufacturer's installation guidelines and recommendations.

3. Source Limitations: Provide weather barrier and accessory materials produced by single manufacturer.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver weather barrier materials and components in manufacturer's original, unopened, undamaged containers with identification labels intact.

B. Store weather barrier materials as recommended by system manufacturer.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. DuPont™ Tyvek® HomeWrap®

B. DuPont™ Tyvek® Tape

2.02 MANUFACTURERS

A. DUPONT, Inc.

2.03 MATERIALS

A. Basis of Design: spunbonded polyolefin, non-woven, non-perforated, weather barrier is based upon DuPont™ Tyvek® HomeWrap® and related assembly components.

B. Performance Characteristics:

1. Air Penetration: <.004 cfm/ft^2 at 1.57 psf, when tested in accordance with ASTM E2178. Type I per ASTM E1677.

2. Water Vapor Transmission: 56 perms, when tested in accordance with ASTM E96-05, Method A.

3. Water Penetration Resistance: 250 cm when tested in accordance with AATCC Test Method 127.

4. Basis Weight: 1.8 oz/yd^2, when tested in accordance with TAPPI Test Method T-410.

5. Air Resistance: 1200 seconds, when tested in accordance with TAPPI Test Method T-460.

6. Tensile Strength: 30/30 lbs/in., when tested in accordance with ASTM D882.

7. Tear Resistance: 8/6 lbs, when tested in accordance with ASTM D1117.

8. Surface Burning Characteristics: Class A, when tested in accordance with ASTM E84. Flame Spread: 15, Smoke Developed: 15

2.04 ACCESSORIES

A. Seam Tape 2” wide, DuPont Tyvek Tape as distributred by Dupont Building Innovations.

B. Fasteners:

1. DuPont™ Tyvek® Wrap Cap Screws, as distributed by DuPont: 1-5/8 inch rust resistant screw with 2-inch diameter plastic cap or manufacturer approved 1-1/4” or 2” metal gasketed washer.

2. DuPont™ Tyvek® Wrap Caps, as distributed by DuPont: #4 nails with large 1-inch plastic cap fasteners, or 1-inch plastic cap staples with leg length sufficient to achieve a minimum penetration of 5/8-inch into the wood stud.

C. Sealants

1. Provide sealants that comply with ASTM C 920, elastomeric polymer sealant to maintain watertight conditions.

D. Adhesive:

1. Provide adhesive recommended by weather barrier manufacturer.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify substrate and surface conditions are in accordance with weather barrier manufacturer recommended tolerances prior to installation of weather barrier and accessories.

3.02 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Install weather barrier over exterior face of exterior wall substrate in accordance with manufacturer recommendations.

B. Start weather barrier installation at a building corner, leaving 6-12 inches of weather barrier extended beyond corner to overlap.

C. Install weather barrier in a horizontal manner starting at the lower portion of the wall surface. Maintain weather barrier plumb and level.

D. Extend bottom roll edge over sill plate interface 2” to 3” minimum. Seal weather barrier with sealant or tape. Shingle weather barrier over back edge of thru-wall flashings and seal weather barrier with sealant or tape. Ensure weeps are not blocked.

E. Subsequent layers shall overlap lower layers a minimum of 6 inches horizontally in a shingling manner.

F. Window and Door Openings: Extend weather barrier completely over openings.

G. Weather Barrier Attachment:

1. Attach weather barrier to studs through exterior sheathing. Secure using weather barrier manufacturer recommended fasteners, spaced 12 -18 inches vertically on center along stud line, and 24 inch on center, maximum horizontally

H. Seal seams of weather barrier with seam tape at all vertical and horizontal overlapping seams.

I. Seal any tears or cuts as recommended by weather barrier manufacturer.

3.03 PROTECTION

A. Protect installed weather barrier from damage.

END OF SECTION

http://www2.dupont.com/Tyvek/en_US/

SECTION 07 42 13

METAL WALL PANELS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for highly resilient synthetic rubber floor tiling.

1.02 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design metal wall panel assembly, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

1.03 SUBMITTALS

A. Product Data: For each type of product indicated.

B. Shop Drawings: Show fabrication and installation layout of metal wall panels; details of edge conditions, joints, panel profiles, corners, anchorages, attachemtn systems, trim, flashings, closures, and accessories; and special details. Distinguish between factory-, shop-, and field-assembled work.

C. Maintenance Data.

D. Warranties.

1.04 QUALITY ASSURANCE

A. Pre-installation Conference: Conduct conference at site or by phone.

1.05 WARRANTY

A. Submit providers standard, 30-year limited warranty covering the following defects:

1. By the zinc manufacturer for zinc material quality defects
2. By the panel or panel system fabricator of the wall panel assembly for their material fabrication and system design defects.
3. By the installer agreeing to repair or replace systems or components as a result of workmanship defects.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering metal wall panel materials that may be incorporated in the work include: RHIENZINK America, Inc.

B. Panel Fabricator: Select wall panel fabricator that has the equipment and personnel capable of providing quality zinc wall panel profiles as indicated on the drawings

1. A. Zahner Co.

2.02 FRAMING

A. Provide additional subframing components, hats, zees or similar light-gauge metal profile to provide air-space ad indicated on drawings. All framing member and components shall be fabricated from ASTM A525 G90 galvanized sheet steel. Provide all secondary framing members as required for panels installation whether indicated or not on the architectural drawings.

2.03 ACCESSORIES

A. Provide all components necessary for a complete, functional, weatherproof assembly including, but not limited to, trim, copings, fascias, sills, flashing, counter flashing, door frame trim, corner units, clips, wall caps, copings, sealants, closures and fillers. Metal materials shall match panels and be zinc compatible.

B. Clips & Fasteners: Provide stainless steel concealed clips and fasteners (corrosion free); supplied in accordance with manufacturer's recommendations and to meet the load requirements as specified by architect and confirmed by Engineering calculations. Attachment clips shall permit expansion and contraction of the panel system throughout the specified temperature range. When permeable air barrier sheets are used and as required by the architect to resist liquid water penetration at the fastener penetration, provide fasteners with watertight washer gaskets (such as self-adhered membrane).

PART 3 EXECUTION

3.01 INSTALLERS

A. A. Zahner Co.

B. Virginia Tech Solar Decathlon Team

3.02 INSPECTION

A. Installer shall inspect all surfaces, areas and other contingent construction in or to which his work is to be installed and insure himself that they are in proper condition to receive the work to be performed under this Section.

3.03 PREPARATION

A. Verify field dimensions before fabrication.

B. Place permeable underlayment membrane on substrate surfaces to receive metal panels; comply with manufacturer's instructions.

3.04 INSTALLATION

A. Manufacturer's Recommendations: Except as otherwise shown or specified, comply with recommendations and instructions of manufacturer of sheet metal being fabricated and installed.

1. Do not install in inclement weather
2. Do not install over a damp substrate

B. Install work to be truly straight and square or conform to geometry indicated on drawings.

1. Fabricate and install work with lines and corners of exposed units true and accurate.
2. Shim and align panel units within installed tolerance of ¼ inch in 20' –0"
3. All seams shall be of uniform appearance and dimensions, straight and level with minimum exposure of solder and sealant.

C. Conceal fasteners and expansion provision where possible in exposed work, and locate so as to minimize possibility of leakage. Cover and seal fasteners and anchors as required for a tight installation.

D. Provide work as indicated on approved shop drawings

F. Install work to meet specified performance requirements.

3.05 CLEANING AND PROTECTION

A. Remove protective film (if any) from exposed surfaces of metal panels promptly upon installation (or prior if film covers any concealed seam areas) with care to avoid damage to finish.

B. Clean exposed metal surfaces of substances that would interfere with uniform oxidation and weathering and as recommended by panel manufacturer and maintain in a clean condition during construction. Never apply cleaner directly to zinc surface.

C. Ensure that cleaning by other trades working in proximity to zinc installation is in accordance with the recommendations of the zinc manufacturer.

3.06 CLEAN-UP

A. During the progress of the work, keep premises clear of debris resulting from this operation and remove surplus and waste materials from the site as soon as possible.

B. Upon completion of the work, installer shall remove from the site all equipment and materials used on the work as well as any debris resulting from the operations.

END OF SECTION

http://www.azahner.com/

http://us.rheinzink.de/

SECTION 07 53 23

ETHYLENE-PROPYLENE-DIENE-MONOMER ROOFING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Ethylene-Propylene Membrane and Vented Roof System.

B. Products Furnished

1. Furnish and install the Stevens EP Vented Roof System in accordance with drawings and specifications approved by Stevens Roofing Systems.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM D6878-03, Standard Specification for Thermoplastic Polyolefin Based Sheet Roofing.

1.03 ACTION SUBMITTALS

A. Product Data

1. Data sheets for all materials not supplied or approved by Stevens shall be submitted to Stevens for written approval prior to the start of installation.

B. Shop Drawings

1. VRS Authorized Applicators must submit a roof drawing indicating which details will be employed in the project as well as all accurate existing construction conditions. These drawings shall be approved by Stevens prior to the start of work. These must include: exact deck construction, outline and size of the roof, location and type of penetrations, perimeter (including any overhang or soffit conditions) and penetration flashing detail references as well as a layout of any substantial above deck piping or mechanical screens, and a copy of any non-SR details to be used. Details which do not conform to Stevens standard SR Detail Drawings must be shown as to their anticipated construction.

C. Samples

1. Samples of all materials not supplied or approved by Stevens shall be submitted to Stevens for written approval prior to the start of installation.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Apply roofing system using a Stevens authorized roofing applicator. Applicator must have written certification from Stevens for approval to install the VRS System.
2. Stevens EP membrane is classified by Underwriters Laboratories as a Class A sheathing material for use in construction of Class A roofing assemblies. See UL's *Roofing Materials & Systems Directory* for specific assemblies.

3. Stevens EP Membranes meet the ASTM D6878-03 specification for TPO-based roofing material.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. All materials provided by Stevens shall be delivered with appropriate packaging labels indicating warnings, storage conditions, lot numbers, and usage instructions.

B. Storage and Handling Requirements

1. Materials shall be stored in their original undamaged packaging and storage conditions shall be maintained in accordance with the manufacturer's requirements.

1.06 WARRANTY

A. Manufacturer Warranty

1. No installation will be accepted for Stevens VRS Warranty unless the complete Request for Warranty (RFW) has been received and approved by Stevens prior to job start.
2. A Stevens representative shall inspect the installation for compliance with applicable Stevens specifications upon completion of the roofing system.
3. Upon acceptance of the roofing system installation, a Stevens standard or Total System Warranty will be issued for a five (5), ten (10) or fifteen (15) year period covering wind damage up to 60 mph.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Stevens, mechanically-attached ethylene-propylene membrane and Vented Roof System.

2.02 MANUFACTURERS

A. Dow Roofing Systems

2.03 DESCRIPTION

A. Regulatory Requirements

1. This specification is intended to be applied to building roofs that have deck structures meeting guidelines herein and have no abnormally severe or unknown environmental exposures, e.g. coastal winds or certain chemicals, except as specifically authorized herein.
2. Metal work other than Stevens Edge Metal Systems is not covered by Stevens for Warranty. Metal work must be secured in a manner approved by Stevens and/or in accordance with SMACNA guidelines to prevent damage from buckling or wind exposure. All metal work that is part of the waterproofing envelope must be sealed, structurally sound, and appropriately anchored to prevent leakage.
3. All Stevens EP Membrane is manufactured in an ISO-9001:2000 facility.

2.04 MATERIALS

A. Membrane shall be .045-in., .060-in. or .080-in. (Stevens EP-XL) nominal thickness overall, scrim-reinforced, Ethylene Propylene-based sheet 76.5-in. wide by appropriate length conforming to the minimum physical properties in Table 1, *Physical Properties Chart.* (Factory fabricated 10-ft. and 12-ft. widths are also available for .045 and .060 thick materials only.)

B. Stevens EP membrane is available in White, Light Slate Gray, Pewter, Buckskin, Terra Cotta, Patina, Dark Ivy Green, or Neon Blue. (White was chosen for its reflective quality.)

C. All air-seal terminations shall be made per Stevens approved details utilizing fasteners supplied by Stevens.

PART 3 EXECUTION

3.01 INSTALLERS

A. An installer will be provided by Stevens.

3.02 EXAMINATION

A. Evaluation and Assessment

1. Job start training by a Stevens Technical Representative is mandatory for ALL VRS installations. Upon completion of the installation, an inspection shall be performed by a representative of Stevens to ascertain that the roofing membrane system has been installed according to Stevens approved specifications and details. Upon approval of the project, a Warranty shall be written.

3.03 PREPARATION

A. Surface Preparation

1. The applicator shall be responsible for the suitability of the substrate to accept Stevens EP membrane. Surfaces to be bonded shall be dry, clean and free of debris. Suitable surfaces are usually considered to be smooth; solid masonry, wood, and metal, plus insulation board fastened to the specific manufacturers recommendations.

2. The applicator is responsible for determining the suitability of the substrate for the Stevens EP membrane. The substrate shall be smooth and free of sharp edges and other surface irregularities that prevent the flashing membrane from being 100% adhered.

3.04 INSTALLATION

A. Special Techniques

1. Block off or shut down positive pressure building ventilation systems during application to prevent sheet from billowing during application.

2. The Stevens EP membrane shall be sealed and mechanically attached with appropriate Stevens fastener at all perimeters and through-deck penetrations.

3. Fasteners should be installed with a depth-sensing screw gun to prevent overdriving or underdriving. Insulation may be loose laid with a minimum of 1/2-in. thick moisture resistant gypsum board overlayment. If the job specification requires insulation attachment, an approved insulation board shall be mechanically attached with Stevens fasteners and approved insulation plates or bonded to the structural concrete deck with a Stevens-supplied insulation adhesive.
4. At all perimeters which are to receive a gravel stop or metal edging after installing approved air seal, the Stevens EP membrane must be brought over the outside edge and terminated 12-in. o.c. *(Reference specific SRV Detail Drawings)*. All field areas of membrane must overlap adjacent sheet by minimum 2-in. and be hot-air welded as in section 3.02.C.
5. Stevens VRS Valves are to be installed as per Stevens detail SRV-1E at pre-specified locations determined by Stevens Technical Review Dept.
6. Membrane shall be overlapped 2-in. and hot-air welded without any contaminants (adhesive, dirt, debris, etc.) in the seam.
7. The entire lap edge must be probed with approved seam probing tool (i.e. Sears cotter pin extractor) after it has cooled completely to verify seam consistency. Probing before the seam area has cooled will damage the membrane. In addition there should be destructive tests performed daily on a 3-in. wide area of seam weld to verify sufficient peel strength. A properly welded seam will have membrane de-lamination from scrim prior to weld failure. Destructive test welds should be done for the first seam of the day, first seam after the robot welder has been allowed to cool down, and after any extreme changes in weather conditions. Cut edges shall be caulked by applying Stevens EP Cut-edge Sealant from a squeeze bottle.
8. Consideration should be given in the project design to potential safety problems that can precipitate from the smooth surface characteristic of the Stevens EP sheet. The membrane surface becomes slippery when wet. If access to roof is required, walkway surfaces are highly recommended. In northern climates, sliding snow could create a hazard below and adjacent to the perimeter if a retarding system is not installed on roofs with slopes greater than 2-in. per foot.

3.05 RE-INSTALLATION

A. At the discretion of Stevens, excessive patching as a result of damage to the Stevens EP membrane or caused by faulty installation may require total recover in those areas.

END OF SECTION

http://www.dowroofingsystems.com/System_Info/stevensVrs.html
http://www.dowroofingsystems.com/Technical_Info/Specs/Specs_PDF/epvrs2.pdf

SECTION 07 62 00

SHEET METAL FLASHING AND TRIM

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Fully adhered or mechanically attached single-ply standard fascia.

B. Products Furnished

1. Factory fabricated and finished roof edging.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for all materials in this specification.

B. Shop Drawings

1. Show profiles, joining method, location of accessory items, anchorage and flashing details, adjacent construction interface, and dimensions.

C. Samples

1. Available on request; size to adequately represent material.

D. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide.

1.03 QUALITY ASSURANCE

A. Qualifications

1. The fascia product shall be listed in current Factory Mutual Research Corporation Approval Guide approved for [FM-1-645].

B. Preconstruction Testing

1. High performance roof edge system shall be CERTIFIED by the manufacturer to comply with ANSI/SPRI Standard ES-1. Roof edge shall meet performance design criteria according to the following test standards:

    a. ANSI/SPRI ES-1 Test Method RE-1 Test for Roof Edge Termination of Single-Ply Roofing Membranes: The fascia system shall be tested to secure the membrane to minimum of 100 lbs/ft in accord with the ANSI/SPRI ES-1 Test Method RE -1. Use the current edition of ANSI/SPRI ES-1 Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems.

    b. ANSI/SPRI ES-1 Test Method RE-2 Pull-Off Test for Fascia: The fascia system shall be tested in accord with the ANSI/SPRI ES-1 Test Method RE -2. Use the current edition of ANSI/SPRI ES-1 Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. All material shall arrive in the manufacturer's original sealed, labeled containers.

B. Storage and Handling Requirements

1. Store materials in a dry, protected, well-vented area. The contractor shall report damaged material immediately to the delivering carrier and note such damage on the carrier's freight bill of lading.
2. Remove protective plastic surface film only immediately before installation.

1.05 FIELD OR SITE CONDITIONS

A. Verify that other trades are complete before installing the roof edging.

B. Mounting surfaces shall be straight and secure; substrates shall be of proper width.

C. Observe all appropriate OSHA safety guidelines for this work.

1.06 WARRANTY

A. Manufacturer Warranty

1. Provide a lifetime warranty for the roof edge system, when installed per manufacturer's instructions, covering blow-off from winds up to 170 mph. The warranty is not to exceed the life of the roof membrane on which the product was originally installed.
2. Provide a lifetime warranty for manufacturer approved 70% Kynar colors for the painted finish covering color fade, chalk, and film integrity. The warranty is not to exceed the life of the roof membrane on which the product was originally installed.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Anchor-Tite Roof Edging System

1. Decorative metal fascia with continuous extruded aluminum bar. Terminate adhered or mechanically attached single-ply roofing at perimeter. The system shall be watertight with no exposed fasteners. Model(s) shall be (choose from the following sizes): AF-40, AF-55, AF-70, AF-85. The rise above the nailer for all models is 1-1/4". Fascia model number denote inches; (i.e. AF-55 has a 5-1/2" face height).

2.02 MANUFACTURERS

A. Metal-Era, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Extruded bar shall lock membrane, prevent wind pullback.
2. Injection molded EPDM splices to allow thermal expansion of extruded aluminum anchor bar.
3. Fascia shall freely thermal cycle on extruded bar, preventing periodic maintenance.
4. Fascia may be factory modified for true radius application.

2.04 MATERIALS

A. Fascia Metal

1. 24 gauge galvanized steel with Kynar 500 finish.

B. Extruded Bar

1. Shall be continuous 6063-T6 alloy aluminum at 12'-0" (3.65 m) standard lengths. All bar miters are welded.

C. Fasteners

1. #9 x 2" stainless steel fasteners provided with drivers. No exposed fasteners permitted.

2.05 ACCESSORIES

A. Miters, downspout scuppers, spill out scuppers shall be fabricated by manufacturer.

B. Welded base assembly shall be used to maintain watertight integrity.

C. Provide matching brick wall cap, downspout, extenders, or other special fabrications as detailed.

2.06 FINISHES

A. Finish Materials

1. For 24 gauge galvanized steel, choose Kynar 500 standard color from manufacturer's standard colors.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Verification of Conditions

1. Verify that the roof edging installation will not disrupt other trades. Verify that the substrate is dry, clean and free of foreign matter. Report and correct any defects prior to any installation.

3.03 INSTALLATION

A. Special Techniques

1. Installing contractor shall check as-built conditions and verify the manufacturer's roof edge details for accuracy to fit the wall assembly prior to fabrication. The installer shall comply with the roof edging manufacturer's installation guide when setting edging.

2. Installer shall use provided fasteners consistent with manufacturer's instructions, suitable for the substrate to which it is being installed.

3. Install water cut-off, as recommended by the membrane manufacturer, under the anchor bar.

END OF SECTION

http://www.metalera.com/Product.aspx?id=416

SECTION 07 72 00
ROOF ACCESSORIES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Roof Vent

1.02 ACTION SUBMITTALS

A. Product Data

1. Furnish and install the Acrylife 3500 V²T Venturi Vent Technology in accordance with drawings and specifications approved by Acrylife, Inc. Good roofing practices must be used at all times with these specifications.

B. Manufacturer's Instructions

1. Included in the system are labor, materials, equipment, accessories, and related services to complete the application in accordance with requirements established by Acrylife, Inc. All V²T projects require review by Acrylife before any specification becomes valid.

1.03 QUALITY ASSURANCE

A. Testing

1. Acrylife, Inc., will furnish, upon request, certification that the materials meet the requirements as stated in the specification.

1.03 WARRANTY

A. Manufacturer Warranty

1. Acrylife warrants the V²T Roof Vent System for a period of 10 years from the time of installation. Acrylife will repair or cause to be repaired leaks which are a result of materials or workmanship supplied by Acrylife subject to the cost of the original installation.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Roof Vent

1. Basis of Design Product: V²T Venturi Vent System

2.02 MANUFACTURERS

A. Acrylife

PART 3 EXECUTION

3.01 INSTALLERS

A. Acrylife

3.02 INSTALLATION

A. Manufacturer Installation Instructions

1. Follow each manufacturer’s provided installation instruction manual.

END OF SECTION

SECTION 07 92 00

JOINT SEALANTS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes joint sealants for the following applications:

1. Exterior joints in vertical surfaces

1.02 PERFORMANCE REQUIREMENTS

A. Provide joint protection for exterior applications that establish and maintain weatherproofing and reduce unconditioned air exchange through continuous joint protection without staining or deteriorating joint substrates.

1.02 SUBMITTALS

A. Product Data: For each joint-sealant product indicated.

B. Shop Drawings

C. Compatibility and adhesion test reports.

D. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide.

1.03 QUALITY ASSURANCE

A. Preconstruction Compatibility and Adhesion Testing: Submit samples of materials that will contact or affect joint sealants to joint-sealant manufacturers for testing according to ASTM C 1087 to determine whether priming and other specific joint preparation techniques are required to obtain rapid, optimum adhesion of joint sealants to joint substrates.

B. Preconstruction Field Testing

1. Preconstruction Field-Adhesion Testing: Before installing joint protection, field test their adhesion to Project joint substrates according to the method in ASTM C 1193 that is appropriate for the types of Project joints.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. All material shall arrive in the manufacturer’s original sealed, labeled containers.

B. Storage and Handling Requirements

1. Store materials in a dry, protected, well-vented area. The contractor shall report damaged material immediately to the delivering carrier and note such damage on the carrier’s freight bill of lading.

1.05 FIELD OR SITE CONDITIONS

A. Observe all appropriate OSHA safety guidelines for this work.

1.06 WARRANTY

A. Special Installer's Warranty: Installer's standard form in which installer agrees to repair or replace joint protection that do not comply with performance and other requirements specified in this section within specified warranty period.

1. Warranty Period: Two years from date of substantial completion.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Therm-L-Brush Joint Protection for Vertical Sliding Doors

1. Therm-L Brushes provides a broad range of products specifically designed to improve the thermal efficiency of buildings, reduce pest problems, and improve personnel comfort and safety.

2.02 MANUFACTURERS

A. Sealeze Industrial Brush Products

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Reduce heating and cooling costs by closing gaps up to 7 inches wide
2. Reduce pest problems by reducing access, blocking light and smells that attract pests.
3. Effective in hot and cold conditions, even to 70° F below zero.
4. Lifecycle Cost Reduction: independent tests show that Sealeze Therm-L-Brush® doesn't degrade after 2 million door operations.
5. UL labeled for use on 3-hour fire doors (Therm-L-Brush with filament 4 inches and less)

2.04 MATERIALS

A. Compatibility: Provide joint sealants, backings, and other related materials that are compatible with one another and with joint substrates under conditions of service and application, as demonstrated by sealant manufacturer, based on testing and field experience.

B. Colors of Exposed Joint Sealants: As indicated.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 PREPARATION

A. Surface Cleaning of Joints: Clean out joints immediately before installing joint sealants.

1. Remove all foreign material from joint substrates that could interfere with adhesion of joint protection.

a. Clean by brushing, grinding, blast cleaning, mechanical abrading or a combination of these methods to produce a clean, sound substrate capable of developing optimum bond with joint protection. Remove loose particles remaining after cleaning operations above by vacuuming or blowing out joints with oil-free compressed air.

B. Joint Priming: Prime joint where recommended in writing by manufacturer based on preconstruction joint-substrate tests or prior experience. Apply primer to comply with manufacturers written instructions. Confine primers to areas of joint-protection-bond; do not allow spillage or migration onto adjoining surfaces.

C. Masking Tape: Use masking tape where required to prevent contact of sealant with adjoiing surfaces that otherwise would be permanently stained or damaged by suchg contact or by methods required to remove sealant smears. Remove tape immediately after tooling without disturbing joint protection.

3.03 INSTALLATION

A. Sealant Installation Standard: Comply with recommendations in ASTM C 1193 for use of joint sealants as applicable to materials, applications, and conditions indicated.

B. Manufacturer’s Installation: Follow the manufacturer’s written installation guide as necessary.

END OF SECTION

http://www.sealeze.com/therm.htm

SECTION 08 10 00

DOORS AND FRAMES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for custom designed and fabricated front door, front door threshold, door handle and hardware.
2. Specification for custom designed and fabricated bathroom door, bathroom door hardware, and door track.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM E330, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

1.03 ACTION SUBMITTALS

A. Shop Drawings

1. Sets of blue-line shop / fabrication drawings, showing all internal and surrounding details and conditions of the door handle hardware installation.

B. Test and Evaluation Reports where applicable.

C. Manufacturer's Instructions for installation, use, and care.

1.04 QUALITY ASSURANCE

A. Preconstruction Testing

1. Complete testing in accordance with ASTM E330, at a static air pressure of 45.00 PSF positive load and 45.00 PSF negative load (SGD-C30). At the conclusion of the test there shall be no glass breakage, permanent damage to fasteners, hardware parts or actuating mechanisms, nor any other damage that would render the operating portion(s) of the sliding glass door inoperable.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Front Door

1. Custom designed and fabricated front glass door and door handle.
2. Door hardware, pivots, and accessories.
3. Front door threshold.

B. Bathroom Door

1. Custom designed and fabricated sliding bathroom glass door.
2. Hafele Hardware and Accessories.

2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

B. Rixson Specialty Door Hardware and Pivots

C. Glass Dynamics, INC.

D. Hafele

2.03 PRODUCTS

A. 1” Enviro-Seal insulated glass or comparable product

B. Center Hung Threshold Model # PH800

1. Requirements: Ansi 117.1 and A.D.A Compliant
2. Dimensions: 8” W x 36” L x ½” H
3. Materials: Stainless Steel

C. Rixson Pivot Set with M19 Intermediate Pivot Model # 147

1. Full weight of door is borne by floor pivot, providing long pivot life and trouble-free operation.
2. All pivot sets are required to meet ANSI grade one standard as listed in ANSI 156.4

D. Hafele Sliding Glass Door Hardware and Accessories

1. Glass Holding Profile Model # 941.13.091
2. Drilling and Mortise jig Model # 941.12.090
3. Eku Flush Handle Kit Model # 941.12.050
4, Upper Running Track Model # 941.00.253
5. Spacer profile for running track Model # 941.13.220
6. Clip-On fascia for upper tack model # 941.12.425
7. Any other comparable product or necessary addition s required by the drawings.

2.04 MATERIALS

A. GLAZING

1. Lisec Enviro-Seal Laminated Glass
   a. Thickness: 1”.
   b. Color: Colorless, Transparent.
   c. Single glazing profile as indicated on drawings

B. Stainless Steel Hardware

1. Fasteners: Same metal as metal being fastened, nonmagnetic stainless steel, or other non-corrosive metal as recommended by manufacturer.

2.04 ACCESSORIES

A. Rollers

1. Each roller is to be adjustable, steel stainless steel, ball bearing, tandem carriage.

B. Roller Track

1. The roller track is to be twenty-four gauge stainless steel specially designed to seat securely in the sill.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Furnish and apply sealants in accordance with the manufacturers published installation instructions to provide a weather tight installation. Remove all excess sealants to leave all exposed surfaces and joints clean and smooth.

3.03 FIELD / SITE QUALITY CONTROL

A. Field Tests and Inspections

1. For standard field testing procedures please refer to ASTM 1105 or AAMA 502.

END OF SECTION

http://www.rixson.com/library/catalogs/
http://www.glassdynamics.com/

SECTION 08 11 66.23

ALUMINUM SCREEN DOORS AND FRAMES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for multi-panel sliding glass door system, with screens, designed for exterior use.

B. Products Furnished

1. Aluminum architectural multi-panel sliding glass doors complete with hardware and other related components as shown on the project drawings and as specified within this or other related specification sections.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM E330, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

1.03 ACTION SUBMITTALS

A. Shop Drawings

1. Sets of blue-line shop / fabrication drawings, showing all internal and surrounding details and conditions of the sliding glass door installation.

B. Test and Evaluation Reports

C. Manufacturer's Instructions

1.04 QUALITY ASSURANCE

A. Preconstruction Testing

1. Complete testing in accordance with ASTM E330, at a static air pressure of 45.00 PSF positive load and 45.00 PSF negative load (SGD-C30). At the conclusion of the test there shall be no glass breakage, permanent damage to fasteners, hardware parts or actuating mechanisms, nor any other damage that would render the operating portion(s) of the sliding glass door inoperable.

1.05 WARRANTY

A. Manufacturer Warranty

1. The responsible installation contractor shall assume full responsibility and warrant for a period of year(s), the satisfactory performance and installation of the materials specified within this section.
2. Any deficiencies or failures of the materials or installation, during the warranty period, will be repaired or replaced by the responsible installing contractor at no cost to the general contractor or the owner.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. All aluminum screen doors to be furnished are to be NORWOOD Series 3070-EX.

2.02 MANUFACTURERS

A. FLEETWOOD Aluminum Products, Inc.

2.03 MATERIALS

A. Aluminum

1. All aluminum frame sections shall be extruded 6063-T6 aluminum alloy.

B. Screen Mesh

1. 18 x 16 "Charcoal" fiberglass (standard) 18 x 14 Aluminum Wire 18 x 14 Coated (Black) Aluminum Wire

2. Screen mesh is to be held in place with a vinyl spline, easily removable for field replacement of the mesh.

3. Screen corner keys are to be of extruded aluminum specially designed to maintain screen corner integrity without use of mechanical fasteners and eliminate electrolytic action. Corner keys other than extruded aluminum are unacceptable.

2.04 ACCESSORIES

A. Rollers

1. Each roller is to be adjustable, steel stainless steel, ball bearing, tandem carriage.

B. Roller Track

1. The roller track is to be twenty-four gauge stainless steel specially designed to seat securely in the sill.

2.05 FABRICATION

A. General

1. Frame head and jamb and sash panel horizontal extrusions shall have a nominal minimum wall thickness of 0.094". Master frame sill and sash panel vertical extrusions shall have a nominal minimum wall thickness of 0.094".

B. Frame and Sash

1. Frame and operating sash components shall be accurately coped and mechanically fastened. All joints shall be hairline.

2.06 FINISHES

A. Anodized

1. Finish all exposed aluminum with electrolytically deposited color, in accordance with the standards of the Aluminum Association designation number:
AA-M12-C22-A31 Clear Class II Anodized (607.1)

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Bring all discrepancies between the project plans and field conditions to the attention of the general contractor prior to commencement of any work in the area in question.
2. Erect the aluminum sliding glass doors and components square and true, in strict accordance with the manufacturers published installation instructions. The installer is to furnish adequate anchoring to maintain position and integrity of the sliding glass doors when subjected to normal building movement and the specified wind load.
3. Furnish and apply sealants in accordance with the manufacturers published installation instructions to provide a weather tight installation. Remove all excess sealants to leave all exposed surfaces and joints clean and smooth.

3.03 FIELD / SITE QUALITY CONTROL

A. Field Tests and Inspections

1. Field testing results will not achieve laboratory testing results. To field test and achieve laboratory results, Fleetwood recommends adding ½” to the sill pan height. For standard field testing procedures please refer to ASTM 1105 or AAMA 502.
2. Field test results will not be considered valid unless performed within four weeks of specimen installation.

END OF SECTION

http://www.fleetwoodusa.com/PRODUCTS/sliding-door-exterior-norwood-3070EX.php
http://www2.fleetwoodusa.com/PRODUCTS/subprod_spec_frame.asp?sproduct=3070

SECTION 08 32 13

SLIDING ALUMINUM-FRAMED GLASS DOORS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for multi-panel sliding glass door system designed for exterior use.

B. Products Furnished

1. Aluminum architectural multi-panel sliding glass doors complete with hardware and other related components as shown on the project drawings and as specified within this or other related specification sections.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM E283, Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
2. ASTM E1105, Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls
3. ASTM E331, Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
4. ASTM E547 Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference
5. ASTM E330, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference
6. ASTM E987, Standard Test Methods for Deglazing Force of Fenestration Products

B. National Fenestration Rating Council:

1. NFRC 100, Procedure for Determining Fenestration Product U-Factors

C. American Architectural Manufacturers Association:

1. AAMA/NWWDA 101/I.S.2-97, Voluntary Specification for Aluminum, Vinyl (PVC) and Wood Windows and Glass Doors
2. AAMA 502, Voluntary Specification for Field Testing of Newly Installed Fenestration Products

1.03 ACTION SUBMITTALS

A. Shop Drawings

1. Sets of blue-line shop / fabrication drawings, showing all internal and surrounding details and conditions of the sliding glass door installation.

B. Test and Evaluation Reports

C. Manufacturer’s Instructions

1.04 QUALITY ASSURANCE

A. Preconstruction Testing

1. All aluminum sliding glass doors to be furnished under this section are to have been previously tested and certified in accordance with the criteria of AAMA/NWWDA 101/I.S.2-97, to the minimum standards of a SGD-C30 rating.
2. Thermal test specimen sizes and configurations are to be in accordance with the National Fenestration Rating Council, Inc., NFRC 100 procedure.
3. Complete testing in accordance with ASTM E283, at a static air pressure of 1.57 PSF (SGD-C30).
4. Complete testing in accordance with ASTM E331 & ASTM E547, at a static pressure difference of 4.50 PSF (SGD-C30) with 1-7/16" high sill pan.
5. Complete testing in accordance with ASTM E330, at a static air pressure of 45.00 PSF positive load and 45.00 PSF negative load (SGD-C30). At the conclusion of the test there shall be no glass breakage, permanent damage to fasteners, hardware parts or actuating mechanisms, nor any other damage that would render the operating portion(s) of the sliding glass door inoperable.
6. Conduct testing in accordance with ASTM E987. The stiles shall not deglaze to a maximum pressure of 70 PSF. The rails shall not deglaze to a maximum pressure of 50 PSF.

1.05 WARRANTY

A. Manufacturer Warranty

1. The responsible installation contractor shall assume full responsibility and warrant for a period of year(s), the satisfactory performance and installation of the materials specified within this section.
2. Any deficiencies or failures of the materials or installation, during the warranty period, will be repaired or replaced by the responsible installing contractor at no cost to the general contractor or the owner.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. All aluminum sliding glass doors to be furnished are to be NORWOOD Series 3070-EX.

B. Motor used to move sliding glass doors to be NemaTrue Right Angle Gear head, 2:1 ratio.

2.02 MANUFACTURERS

A. FLEETWOOD Aluminum Products, Inc.

B. Thomson Linear Motion Co. by DANAHER Motion Co.

2.03 MATERIALS

A. Aluminum

1. All aluminum frame sections shall be extruded 6063-T6 aluminum alloy.

B. Glass

1. Furnish only sliding glass doors that have a rabbet specifically designed to accommodate 3/16", 1/4" tempered single glaze, 1" tempered insulated glass products.
2. All glass and glazing materials are to be factory field glazed.
3. All factory field glazed materials shall be glazed with a specially designed marine type glazing vinyl, in strict accordance with the manufacturers published glazing instructions.

2.04 ACCESSORIES

A. Rollers

1. Each roller is to be adjustable, steel stainless steel, ball bearing, tandem carriage.

B. Roller Track

1. The roller track is to be twenty-four gauge stainless steel specially designed to seat securely in the sill.

C. Locking Mechanism

1. The operating sash lock is to be located within the lock stile and is to consist of a heavy duty steel stainless steel hook bolt. When locked, the hook bolt is to engage a steel reinforced lock slot in the lock jamb.

D. Screens

1. Specifications for screens can be found in Section 08 11 66.23 of the project manual.

E. Weather-stripping and Glazing Gaskets

1. All glazing gasket is to be marine type vinyl, specifically designed for a tight seal between the glass and the sash extrusion.
2. Pile weather-stripping is to be a minimum of .170" tall with a center polypropylene fin.

2.05 FABRICATION

A. General

1. Frame head and jamb and sash panel horizontal extrusions shall have a nominal minimum wall thickness of 0.094". Master frame sill and sash panel vertical extrusions shall have a nominal minimum wall thickness of 0.094".

B. Frame and Sash

1. Frame and operating sash components shall be accurately coped and mechanically fastened. All joints shall be hairline.

2.06 FINISHES

A. Anodized

1. Finish all exposed aluminum with electrolytically deposited color, in accordance with the standards of the Aluminum Association designation number:
AA-M12-C22-A31 Clear Class II Anodized (607.1)

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Bring all discrepancies between the project plans and field conditions to the attention of the general contractor prior to commencement of any work in the area in question.
2. Erect the aluminum sliding glass doors and components square and true, in strict accordance with the manufacturers published installation instructions. The installer is to furnish adequate anchoring to maintain position and integrity of the sliding glass doors when subjected to normal building movement and the specified wind load.
3. Furnish and apply sealants in accordance with the manufacturers published installation instructions to provide a weather tight installation. Remove all excess sealants to leave all exposed surfaces and joints clean and smooth.

3.03 FIELD / SITE QUALITY CONTROL

A. Field Tests and Inspections

1. Field testing results will not achieve laboratory testing results. To field test and achieve laboratory results, Fleetwood recommends adding ½" to the sill pan height. For standard field testing procedures please refer to ASTM 1105 or AAMA 502.
2. Field test results will not be considered valid unless performed within four weeks of specimen installation.

3.04 ADJUSTING

A. Adjust the aluminum sliding glass doors for proper operation, after installation and cleaning has been completed.

3.05 CLEANING

A. Upon completion of the entire scope of the work specified within this section, the aluminum sliding glass doors and components are to be cleaned of dirt and manufacturer's identification marks. DO NOT REMOVE THE PERMANENT ANSI/AAMA or NFRC LABELS.

END OF SECTION

http://www.fleetwoodusa.com/PRODUCTS/sliding-door-exterior-norwood-3070EX.php
http://www2.fleetwoodusa.com/PRODUCTS/subprod_spec_frame.asp?sproduct=3070
http://www.danahermotion.com/website/com/eng/products/gearheads/nematrue/right_angle.php

SECTION 08 45 13

STRUCTURED POLYCARBONATE PANEL ASSEMBLIES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes aluminum-framed assembles glazed with multi-walled (structured) polycarbonate panels as follows:

1. Wall Assemblies.

1.02 PERFORMANCE REUIREMENTS

A. Provide assemblies, including anchorage, capable of withstanding, without failure, the effects of the following:

1. Thermal movements.
2. Movements of supporting structure.
3. Dimensional tolerance of building frame.

B. Failure includes:

1. Deflection exceeding specified limits.
2. Water leakage.
3. Noise or vibration created by wind and thermal and structural movements.
4. Loosening or weakening of fasteners, attachments, and other components.

1.03 QUALITY ASSURANCE

A. Installer Qualifications

1. Installer(s) should be experienced in performing work of this sections and should have specialized in installation of work similar to that required for this project.

1.04 PROJECT CONDITIONS

A. Field Measurements: indicated measurements on shop drawings/construction documents

1.05 WARRANTY

A. Manufacturer Warranty

1. Polycarbonate Sheet Warranty: Gallina sheets are warranted for 10 years against loss of light transmission in excess of 6 percent when tested according to ASTM D1003 and yellowing in excess of 10 Delta units according to ASTM D1925. In addition, Gallina sheets are warranted for 10 years against breakage due to hail. Warranty is non-prorated for 10 years when Gallina sheets are properly installed and maintained.
2. Special Aluminum Finish Warranty: Ten years on weatherization starting on date of substantial completion.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Duo-Gard 1500 Series aluminum extrusion channels

B. Gallina polycarbonate sheet (policarb and arcoPlus)

2.02 MANUFACTURERS

A. Duo-Gard Industries, Inc

B. Gallina USA, LLC

2.03 DESCRIPTION

A. Polycarbonate structured wall assembly using Gallina polycarbonate sheets and Duo-Gard 1500 Series 10 mm aluminum channeling.

B. Regulatory Requirements

1. American Society for Testing & Materials (ASTM): ASTM D635 Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-supporting Plastics in a Horizontal Position, ASTM D1929 Standard Test Method for Determining Ignition Temperature of Plastics, ASTM E84 Standard Test Method for Surface Burning Characteristics of Building Materials, ASTM E822 Standard Practice for Determining Resistance of Solar Collector Covers to Hail by Impact With Propelled Ice Balls

2. Environmental Considerations: Use of high performance glazing can improve natural lighting in buildings, resulting in reduced lighting electrical loads. High thermal performance systems can reduce building thermal energy consumption when compared to lower performance glazing systems.

3. Physical/Chemical Properties: Impact resistance - Gallina sheets withstand the impact of 16 lb (7.3 kg) dropped 25' (7.6 m) without breakage. Impact tests - Exceeds Gardner Falling Dart limits; no rupture from 1/2" (12.7 mm) radius tip at 220 ft/lb (299.2 NÂ·m). No penetration, 100 ft/lb (136 NÂ·m) involving air cannon with 1 1/2" (38 mm) diameter tip at 95 mph (153 kph)

4. Light Transmitting Plastic Classification - Plastic Gallina sheets are classified as a Light Transmitting Plastic. Horizontal Burn Rate is per ASTM D635. Light Transmitting Plastics are classified as either CC-1, extent of burn 1" (25.4 mm) or less, or CC-2, burn rate less than 2 1/2" (64 mm) per minute. Gallina Sheets of 1/4" (6 mm), 5/16" (8 mm), 3/8" (10 mm) and 5/8" (16 mm) thickens are classified CC-1.
Smoke Density - Gallina sheets are tested in accordance with ASTM E84 or ASTM Codes commonly require a Smoke Density Rating of not greater than 450 per ASTM E84 test or not greater than 75 per ASTM D2843. Gallina Sheets meets these requirements.
Ignition Properties - Gallina sheets are tested in accordance with ASTM D1929. Model codes typically require Light Transmitting Plastic to have a self-ignition temperature of 650 degrees F (343 degrees C) or greater. Gallina sheets meet this requirement with a self-ignition temperature of 986 degrees F (530 degrees C). Gallina sheets melt at 800 degrees F (427 degrees C).

Flame spread - Gallina sheets are tested in accordance with ASTM E84. Model building codes typically do not specify a flame spread requirement. Values for Gallina sheets vary with thickness and range from 10 - 80. Gallina sheets meet National Fire Protection Association (NFPA) Class A and UBC Class 1.

2.04 PERFORMANCE/DESIGN CRITERIA

A. Aluminum Framing System

1. Aluminum: Anodized Channels 1.5 in. x 2.5 in.

a. System Attachment: Attaches to structure using perimeter channels and intermediate clips, which are not visible.

b. Construction: Interlocking tongue and groove continuous façade without mullions or visual breaks. Low-profile aluminum (10 mm) perimeter base features snap-cap for easy installation and continuous flowing façade. No visible fasteners.

B. Polycarbonate Glazing Sheets

1. General: a tough, lightweight, insulating glazing sheet extruded from high performance polycarbonate. Its many advantages make polycarbonate sheets an attractive, economical alternative for a wide variety of exterior glazing applications, including skylights and roof windows, atria, sports halls, industrial plants, pool enclosures, greenhouses, solar collectors, canopies and window renovations

2. Capacities:

a. Virtually unbreakable: impact strength tested at 200 times that of glass and eight times that of acrylic.

b. Energy efficient: U-values comparable to glass.

c. Lightweight: weight 1/6 as much as glass and 1/3 as much as acrylic.

d. Flame retardant: sheets melt without igniting and will not support combustion.

e. Flexible: bending radius for ¼” thickness panel is 3’ 5”.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 PREPARATION

A. Special Techniques

1. Handle and store product according to manufacturer’s recommendations. Examine crates for evidence of damage. Prior to installation examine each sheet for damage. Treat open ends of each sheet immediately upon opening shipping crates so no dirt, debris or other foreign matter becomes lodged in the glazing. Immediately prior to installation, expose the glazing edges by peeling back the protective film in an amount sufficient for the edge bite. Verify openings are correct size.

B. Systems Integration

1. Polycarbonate sheets can be easily drilled, cut, punched, sheared and bent using simple hand tools or sheet metal fabricating equipment. A razor knife can be used to cut most thickens. For heavier gauges, a hand-held circular saw with fine teeth is recommended. Chips and dust can be removed from the cellular structure with compressed air. When drilling holes, it is necessary to allow for thermal expansion. Holes should be at least 1 1/2" (38 mm) from the edge of the sheet. Edge engagement or bite should be at least 1/2" (12.7 mm) for sheet thickness up to 3/8" (9.5 mm). For 5/8" (15.9 mm) sheets, edge engagement should be 3/4" (19 mm). Rabbet depth of frame is calculated as edge engagement plus thermal expansion for the size of sheet being used. This value is 1/8" per 3' (3.2 mm per 0.9 m) of length or width per 100 degrees F (37.8 degrees C) temperature differential. Remove the protective release film immediately after installation.

END OF SECTION

http://www.gallinausa.com/spec.data.html

www.duo-gard.com/pdf/1500-TIW-Summary.pdf

SECTION 08 62 00

UNIT SKYLIGHTS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Self-flashing unit skylights with integral curb.
2. Unit skylights mounted on site-built curbs.

1.02 SUBMITTALS

A. Product Data: For each type of unit skylight indicated.

B. Shop Drawings: For unit skylight work. Include plans, elevations, sections, details, and connections to supporting structure and other adjoining work.

C. Samples for Verification: For each type of exposed finish required, in a representative section of each unit skylight in manufacturer's standard size.

D. Product Schedule: For unit skylights.

E. Qualification Data

F. Product test reports.

H. Maintenance Data.

1.03 QUALITY ASSURANCE

A. Manufacturer's Qualifications: A manufacturer capable of fabricating unit skylights that meet or exceed performance requirements indicated and of documenting this performance by inclusion in lists and by labels, test reports, and calculations.

B. Installer Qualifications: An installer acceptable to unit skylight manufacturer for installation of units required for this project.

C. Unit Skylight Standard: Comply with AAMA/WDMA 101/I.S.2/NAFS, "North American Fenestration Standard Voluntary Performance Specification for Windows, Skylights and Glass Doors," for minimum standards of performance, materials, components, accessories, and fabrication. Comply with more stringent requirements if indicated.

1.04 WARRANTY

A. Manufacturer Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of unit skylights that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years from date of substantial completion.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, product indicated on drawings, Glass Dynamics, INC. 1" Enviro-Seal insulated glass or comparable product.

2.03 MATERIALS

A. Aluminum Components

1. Sheets: ASTM B 209/209M, alloy and temper to suit forming operations and finish requirements but with not less than the strength and durability of alclad Alloy 3005-H25.
2. Extruded Shapes: ASTM B 221/221M, alloy and temper to suit structural and finish requirements but with not less than the strength and durability of Alloy 6063-T52.

B. Fasteners: Same metal as metal being fastened, nonmagnetic stainless steel, or other non-corrosive metal as recommended by manufacturer. Finish exposed fasteners to match material being fastened.

2.04 GLAZING

A. Lisec Enviro-Seal Laminated Glass

1. Thickness: 1”.
2. Color: Colorless, Transparent.
3. Single-Glazing Profile: as indicated on drawings.

2.05 INSTALLATION MATERIALS

A. Bituminous Coating: SSPC-Paint 12, solvent-type, bituminous mastic, nominally free of sulfur and containing no asbestos fibers, formulated for 15-mil dry film thickness per coating or other comparable coating compatible with roof system designated on plans.

B. Mastic Sealant: Polyisobutylene or similar; non-hardening, non-skinning, non-drying, non-migrating sealant.

C. Roofing Cement: ASTM D 4586, asbestos free, designed for trowel application or other comparable adhesive designed for roofing system.

2.06 UNIT SKYLIGHTS

A. General: Provide factory-assembled unit skylights that include glazing, extruded aluminum glazing retainers, gaskets, and inner frames that are capable of withstanding performance requirements indicated.

B. Site-Built Curb: As indicated on drawings.

C. Unit Shape and Size: As indicated on drawings.

D. Condensation Control: Fabricate unit skylights with integral internal gutters and non-clogging weeps to collect and drawing condensation to the exterior.

E. Thermal Break: Fabricate unit skylights with thermal barrier separating exterior and interior metal framing.

2.07 ALUMINUM FINISHES

A. Mill Finish: Manufacturer’s standard.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. After completion of installation to manufacturer's specification and nominal curing of sealant and glazing compounds, but before installation of interior finishes, test for water leaks according to AAMA 501.2.

B. Perform test for total area of each unit skylight.

C. Work will be considered defective if it does not pass tests and inspections.

3.03 CLEANING

A. Clean exposed unit skylight surface according to manufacturer's written instructions.

END OF SECTION

http://www.glassdynamics.com/

SECTION 08 71 13

AUTOMATIC DOOR OPERATORS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Rapidtrak, belt-driven linear actuators.
2. LinearRace shafting assembly.

1.02 ACTION SUBMITTALS

A. Shop Drawings

B. Manufacturer's Instructions

1. Instructions for installation, adjustments, and maintenance are provided by the manufacturer in the Rapidtrak Manual.

1.03 WARRANTY

A. Manufacturer Warranty

1. Thomson warrants that it will repair or replace any product manufactured and sold by it which proves to be defective in material or workmanship within a period of one year from the date of original purchase for consumer, commercial, or industrial use.
2. The warranty covers normal use and does not cover damage or defect which results from alteration, accident, neglect, or improper installation, operation, or maintenance.
3. The warranty extends only to the original purchaser and is not transferable or assignable without Thomson's prior consent.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Rapidtrak (TG07B130-C137X438) M55, prism-guided, belt-driven, linear motion system.

B. Rapidtrak (TG07B130-C274X849) M75, prism-guided, belt-driven, linear motion system.

C. LinearRace (LSRA 10 SM) corrosion resistant, zinc-plated, steel rail and butt joints.

D. 440C stainless steel shafting

2.02 MANUFACTURERS

A. Thomson

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Place the unit on the mounting surface. Shims are placed at the mounting point so that the unit keeps its shape, and is not bent or twisted in any direction. The distance

between each mounting point must not exceed the maximum permissible mounting distance for the maximum load being moved by the unit.

2. See the Rapidtrak Manual for illustrations and more details on installation.

3.03 MAINTENANCE / REPAIR

A. The customer can perform service and maintenance as described in the Rapidtrak Manual. Some steps, however, require special tools which can be ordered from Warner Linear. Other maintenance should be performed by service personnel from the Warner Linear Service Center.

3.04 ADJUSTING

A. Instructions for the adjustment of the belt position and tension, as well as adjustment of saddle play, can be found in the Rapidtrak Manual.

END OF SECTION

http://www.danahermotion.com/website/common/download/document/Rapidtrak_Manual.pdf
http://www.danahermotion.com/website/com/eng/download/document/60_Case_Shafting_Catalog_Section_Inch_Metric.pdf

SECTION 08 88 00

SPECIAL FUNCTION GLAZING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes SageGlass® electrically tint-able insulating glass units for dynamic light and heat control.

1.02 DEFINITIONS

A. 2-ply Laminated Glass: 2-sheets of monolithic glass bonded together with plastic interlayer by heat and pressure.

B. Bite: Dimension by which edge of glass product is engaged into glazing channel.

C. Fenestration: Openings in building's envelope including windows, doors, and skylights.

D. Framing System: Basic rigid supporting structure of window.

E. Frame Wire Harness: Wire that runs through framing system and connects IGU pigtail to low-voltage wiring on interior of building.

F. Glazing System: Soft material used in framing system.

G. IGU Pigtail: Wire that extends from individual insulated glass units.

H. IGU: Insulated Glass Unit.

I. Inboard Lite: Pane of IGU that faces interior of building.

J. Laminate Inner-Ply: Glass pane in laminated glass construction that faces exterior of building.

K. Laminate Outer-Ply: Glass pane in laminated glass construction that faces interior of building.

L. Outboard Lite: Pane of IGU that faces exterior of building.

M. Tinted: On state, with lowest visible light transmission.

N. Untinted: Off state, with highest visible light transmission.

1.03 SYSTEM DESCRIPTION

A. Design Requirements:

1. SageGlass® electrically tintable insulating glass units shall be operated by a SageGlass® control system.
2. Framing and Glazing provided by SageGlass®

1.04 SUBMITTALS

A. Product Data: Manufacturer's Product Data sheets including installation instructions.

B. Documentation indicating compliance with ASTM E2141-02, Chromogenic fenestration standard as verified by third party test laboratory such as National Renewable Energy Laboratory (NREL). SHOP DRAWINGS NOT PROVIDED BY SAGE ELECTROCHROMICS. THESE NEED TO BE PROVIDED BY OTHERS.

C. Shop Drawings: Indicate framing system and accommodations for wiring paths, connectors, routing, and exit from framing system.

D. Structural Calculations: Provide structural calculations for framing system certified by structural engineer licensed in the state in which Project is located.

1.05 QUALITY ASSURANCE

A. Comply with published recommendations of glass product manufacturers and organizations below, except where more stringent requirements are indicated. Refer to these publications for glazing terms not otherwise defined in this section or referenced standards: GANA Publications, AAMA Publications, IGMA Publications.

B. Safety glass products in the US are to comply with CPSC 16 CFR Part 1201 for Category II materials.

C. Glass thermal and optical performance properties shall be based on calculations from the current LBNL WINDOW 5.2 computer program.

D. Provide glass that is heat-treated by horizontal (roller hearth) process with inherent roller wave distortion parallel to short edge of glass as installed when specified.

E. Installer Qualifications: Acceptable to SAGE Electrochromics and capable of preparing data for glazed framing systems, based on testing and engineering analysis of SAGE Electrochromics' standard units in assemblies similar to those indicated for this Project.

F. Pre-Installation Meetings: Conduct pre-installation meeting/teleconference with the following parties in attendance:

1. Architect, Contractor, glazing contractor, framing manufacturer, SageGlass® IGU and Controls manufacturer, electrical contractor, and other parties related to Work of this Section, to review procedures, schedules, safety, and coordination with other elements of Project.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Comply with manufacturer's instruction for receiving, handling, storing, and protecting materials.

B. Deliver materials in manufacturer's original, unopened, undamaged containers with identification labels intact.

C. Store materials in original packaging, protected from exposure to harmful environmental conditions, including static electricity, and at temperature and humidity conditions recommended by manufacturer.

D. Exercise care to prevent edge damage to glass, wire, and coatings on glass.

E. Where insulating glass units will be exposed to substantial altitude changes, avoid hermetic seal ruptures by complying with manufacturer's recommendations for venting and sealing.

1.07 WARRANTY

A. Warrant SageGlass® IGUs against defects in material or workmanship causing material obstruction of vision as a result of fogging or film formation of the internal glass as a result of failure of the hermetic seal for a period of ten years from the date of shipping of the SageGlass® IGUs from the Manufacturer.

B. Warrant SageGlass® electrochromic glass against defects in material or workmanship for a period of five years from the date of shipping of the SageGlass® electrochromic glass from the Manufacturer.

C. Warrant SageGlass® Controls against defects in material or workmanship for a period of five years from the date of shipping of the SageGlass® Controls from the Manufacturer.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. SAGE Electrochromics, Inc.

2.02 MATERIALS

A. SageGlass® Classic™ Laminated Sealed Insulating Glass Units (IGUs) (or comparable product):

1. Outboard Lite:
   a. Glass Type: SageGlass® coated clear float glass.
   b. Glass Tint: Variable.
   c. Nominal Thickness: 0.25 in (6 mm) per industry standards.
   d. Heat Treatment: Tempered.
   e. Coating Orientation: Surface No. 2.

2. Air Space:
   a. Spacer Material: Austenitic standard stainless steel.
   b. Nominal Thickness: 0.50 plus/minus 0.02 in (12.5 mm plus/minus 0.5mm).
   c. Wall Thickness: 0.008 inch (0.2 cm).
   d. Gas Fill: 90 percent Argon.
   e. Desiccant: 4 sides filled with 100 percent molecular sieve and silica gel blend desiccant.

3. Laminated Inboard Lite:
   a. Outer Ply (Surface 4): 1) Glass Type: Clear float glass. 2) Glass Tint: Clear. 3) Nominal Thickness: 0.125 inch (3 mm). 4) Heat Treatment: Heat-strengthened.
   b. Interlayer: 1) Interlayer Type: Polyvinyl Butyral. 2) Interlayer Tint: None. 3) Nominal Thickness: 0.06 inch (1.52 mm).
   c. Inner Ply (Surface 3): 1) Glass Type: Clear float glass. 2) Glass Tint: Clear. 3) Nominal Thickness: 0.125 inch (3 mm). 4) Heat Treatment: Heat-strengthened.

4. Pigtail:
   a. 2-conductor sheathed cable type CM/CL2, 0.15 inch nominal OD.
   b. Molex 52213-0211 2-pin connector.

5. Untinted Performance Characteristics (Center of Glass):
   a. Visible Transmittance: 62 percent.
   b. Interior Visible Reflectance: 14 percent.
   c. Exterior Visible Reflectance: 21 percent.

d. Summer U-factor (U-value): 0.28.

e. Winter U-factor (U-value): 0.28.

f. Krochman Damage Function (KDF): 15 percent.

g. Solar Heat Gain Coefficient (SHGC): 0.48.

6. Tinted Performance Characteristics (Center of Glass):

a. Visible Transmittance: 3.5 percent.

b. Interior Visible Reflectance: 10 percent.

c. Exterior Visible Reflectance: 6 percent.

d. Summer U-factor (U-value): 0.28.

e. Winter U-factor (U-value): 0.28.

f. Krochman Damage Function (KDF): 1.7 percent.

g. Solar Heat Gain Coefficient (SHGC): 0.09.

PART 3 EXECUTION

3.01 EXAMINATION

A. Site Verification and Conditions:

1. Verify that site conditions are acceptable for glass installation.

2. Verify openings for glazing are correctly sized and within tolerance.

3. Verify that functioning weep system is present.

4. Verify that minimum required face and edge clearances are being met.

5. Verify that glazing channels and recesses are clear and free of obstructions, weeps are clear, and channels and recesses are ready for glazing.

B. Do not proceed with glazing until unsatisfactory conditions have been corrected.

3.02 PREPARATION

A. Surface Preparation: Clean and prepare glazing channels and other framing members to receive glass and wire. Remove coatings and other harmful materials that will prevent glass and glazing installation required to comply with performance criteria specified.

3.03 INSTALLATION

A. Install products using recommendations of manufacturers of glass, sealants, gaskets, and other glazing materials, except where more stringent requirements are indicated, including those in the "GANA Glazing Manual".

B. Verify that IGU secondary seal is compatible with glazing sealants.

C. Install glass in prepared glazing channels and other framing members.

D. Install glass per framing manufacturer’s wiring diagram showing IGU orientation and wire exit point into building. Comply with glass manufacturer’s labels and instructions for glass orientation.

E. Use grommets during installation to protect wire when routing through frame.

F. Verify glazing pocket where IGU Pigtail and Frame Wire Harness connection is made is a dry location.

G. Install setting blocks in rabbets as recommended by referenced glazing standards in GANA Glazing Manual and IGMA Glazing Guidelines and manufacturer's Glazing Guidelines.

H. Use edge blocks for all installed panes to prevent glass from walking post installation.

I. Provide bite on glass, minimum edge and face clearances, and glazing material tolerances recommended by GANA Glazing Manual and as approved by glass manufacturer.

J. Provide weep system as recommended by GANA Glazing Manual.

K. Distribute weight of glass unit along edge rather than at corners.

L. Comply with framing manufacturer's and referenced industry recommendations on expansion joints and anchors, accommodating thermal movement, glass openings, use of setting blocks, use of glass spacers, edge blocks, and installation of weep systems.

M. Protect glass from edge damage during handling and installation.

N. Prevent glass from contact with contaminating substances that result from construction operations, such as weld spatter, fireproofing, or plaster.

O. Once electronically tintable IGUs have been removed from SAGE Electrochromics' packaging, remove protective film within 90 days of exposure to sunlight or other UV light sources.

3.04 CLEANING

A. Clean glass inside and outside, immediately after installation and sealants have cured, per SAGE Electrochromics' written recommendations.

B. Do not use scrapers or other metal tools to clean glass.

END OF SECTION

http://www.sage-ec.com/

SECTION 09 65 19

RESILIENT TILE FLOORING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for highly resilient synthetic rubber floor tiling.

1.02 ACTION SUBMITTALS

A. Samples

1. Samples for verification and approval available upon request. Accepted and approved samples shall constitute the standard materials which represent the materials installed on the project.

B. Manufacturer's Instructions

1.03 DELIVERY, STORAGE, AND HANDLING

A. Storage and Handling Requirements

1. Floor tiles and adhesives must be site conditioned at room temperature for 72 hours prior to, during, and after installation. Room temperature must be maintained between 65°F and 75°F and relative humidity of 50%.
2. In rooms that are exposed to intense or direct sunlight, the product must be protected during the conditioning, installation, and adhesive curing periods by covering the light source.
3. Floor tiles are not recommended for exterior use. Exposure to excessive UV rays can result in fading and/or color variation.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Johnsonite Roundel Rubber Floor Tile

2.02 MANUFACTURERS

A. Johnsonite, Inc.

2.03 MATERIALS

A. Synthetic rubber floor tile.

B. Johnsonite's #965 acrylic latex adhesive.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 PREPARATION

A. Surface Preparation

1. All sub-floors must be clean, smooth, and dry. Dust, scale, and loose particles must be removed. The surface must be free of solvents, paint, grease, oil, wax, alkali, sealing/curing compounds, and any other foreign material which could affect adhesive bonding.

3.03 INSTALLATION

A. Special Techniques

1. Floor tiles must be dry laid prior to adhesive installation. Start at the center of the room and position the tiles point-to-point and lay the tiles with the directional arrows, on the back of each tile, running parallel to the adjacent tile. Make all final cuts around room perimeter, alcoves, offsets, and other obstructions.
2. After proper mixing, apply adhesive to sub-floor. See adhesive label for mixing directions, trowel recommendations, and sub-floor porosity conditions. Remove wet adhesive at seams or off tile surface with a cloth dampened with rubbing alcohol or water.
3. Install the tile point-to-point and align the arrows, on the back side of the tile, parallel to the adjacent tiles and butt the edges tightly. Lower the tiles into the adhesive. Periodically, lift the corner of an installed tile to ensure proper transfer of adhesive.
4. After tiles have been installed, roll the floor, in both directions, with a 100 lb. 3-section roller. Roll a second time one hour later. Inspect the floor 2 ½ hours after installation and roll a third time, if necessary. Use a hand roller in areas which cannot be reached with a large roller. Remove any adhesive on the surface.
5. Avoid all traffic for at least 12 hours and only limited light traffic for a period of 72 hours after the installation. Avoid cold or excessive heat, including direct sunlight during this 72 hour period.

3.04 MAINTENANCE

A. 72 hours after installation is completed, initial maintenance procedures must be implemented. Refer to Johnsonite Rubber Floor Tile Maintenance Instructions for complete maintenance instructions.

END OF SECTION

http://www.johnsonite.com/Portals/8/files/RTPS012108.pdf

SECTION 09 91 13

EXTERIOR PAINTING

PART 1 GENERAL

1.01 SUMMARY

A. This section includes surface preparation and the application of paint systems on the following interior substrates:

  1. Steel

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Samples: For each finish and for each color and texture required.

1.03 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials described below that are from same production run (batch mix) as materials applied and that are packaged for storage and identified with labels describing contents.

  1. Quantity: Furnish an additional 5 percent, but not less than 1 gal. (3.8 L) of each material and color applied.

1.04 QUALITY ASSURANCE

A. Qualifications

  1. Product shall comply with MPI standards indicated and listed in “MPI Approved Products List.”
  2. Preparation and workmanship shall comply with requirements in “MPI Architectural Painting Specification Manual” for products and paint systems indicated.

B. Mock-ups

  1. Apply benchmark samples of each paint system indicated and each color and finish selected to verify preliminary selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Pro Industrial Pro-Cryl Universal Acrylic Primer

  1. Gray (B66 A 310)

2.02 MANUFACTURERS

A. Sherwin Williams

2.03 CHEMICAL COMPONENTS OF FIELD-APPLIED INTERIOR PAINTS AND COATINGS

A. Provide products that comply with the following limits for VOC content, exclusive of colorants added to a tint base, when calculated according to 40 CFR 59, Subpart D (EPA Method 24) and the following chemical restrictions; these requirements do not apply to primers or finishes that are applied in a fabrication or finishing shop.

  1. Flat Paints and Coatings: VOC content of not more than 50 g/L.

2. Non-flat Paints and Coatings: VOC content of not more than 150 g/L.
3. Aromatic Compounds: Paints and coatings shall not contain more than 1.0 percent by weight of total aromatic compounds (hydrocarbon compounds containing one or more benzene rings).

2.04 PERFORMANCE / DESIGN CRITERIA

A. Alkyd Anticorrosive Metal Primer: MPI #79.
   1. VOC Content: <100g/L; <0.83 lb/gal.

PART 3 EXECUTION

3.01 APPLICATORS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Examine substrates and conditions, with applicator present, for compliance with requirements for maximum moisture content and other conditions affecting performance of work.
B. Verify suitability of substrates, including surface conditions and compatibility with existing finishes and primers.
C. Begin coating application only after unsatisfactory conditions have been corrected and surfaces are dry.

3.03 PREPARATION

A. Surface Preparation
   1. Clean substrates of substances that could impair bond of paints, including dirt, oil, grease, and incompatible paints and encapsulates.

3.04 APPLICATION

A. Apply paints to produce surface films without cloudiness, spotting, holidays, laps, brush marks, roller tracking, runs, sags, ropiness, or other surface imperfections. Cut in sharp lines and color breaks.
B. Protect work of other trades against damage from paint application. Correct damage to work of other trades by cleaning, repairing, replacing, and refinishing, as approved by Architect, and leave in an undamaged condition.
C. At completion of construction activities of other trades, touch up and restore damaged or defaced painted surfaces.

END OF SECTION

http://www.paintdocs.com/webmsds/webPDF.jsp?SITEID=STORECAT&prodno=640322681&doctype=PDS&lang=E

SECTION 09 91 23

INTERIOR PAINTING

PART 1 GENERAL

1.01 SUMMARY

A. This section includes surface preparation and the application of paint systems on the following interior substrates:

   1. Wood

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Samples: For each finish and for each color and texture required.

1.03 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials described below that are from same production run (batch mix) as materials applied and that are packaged for storage and identified with labels describing contents.

   1. Quantity: Furnish an additional 5 percent, but not less than 1 gal. (3.8 L) of each material and color applied.

1.04 QUALITY ASSURANCE

A. Qualifications

   1. Product shall comply with MPI standards indicated and listed in “MPI Approved Products List.”
   2. Preparation and workmanship shall comply with requirements in “MPI Architectural Painting Specification Manual” for products and paint systems indicated.

B. Mock-ups

   1. Apply benchmark samples of each paint system indicated and each color and finish selected to verify preliminary selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Duration Home Interior Latex Coating

   1. Real Red (A97 R 158)

B. PrepRite ProBlock Interior/Exterior Latex Primer/Sealer

   1. White (B51 W 20)

2.02 MANUFACTURERS

A. Sherwin Williams

2.03 CHEMICAL COMPONENTS OF FIELD-APPLIED INTERIOR PAINTS AND COATINGS

A. Provide products that comply with the following limits for VOC content, exclusive of colorants added to a tint base, when calculated according to 40 CFR 59, Subpart D (EPA Method 24) and the following chemical restrictions; these requirements do not apply to primers or finishes that are applied in a fabrication or finishing shop.

1. Flat Paints and Coatings: VOC content of not more than 50 g/L.
2. Non-flat Paints and Coatings: VOC content of not more than 150 g/L.
3. Aromatic Compounds: Paints and coatings shall not contain more than 1.0 percent by weight of total aromatic compounds (hydrocarbon compounds containing one or more benzene rings).

2.04 DESCRIPTION

A. Sustainability Characteristics

1. Sherwin Williams GreenSure Initiative
   a. Use of sustainable raw materials, like soy and sunflower oil in paint.
   b. Reduction of the amount of solvent in formulations, so the vapors being emitted into the atmosphere are more environmentally friendly.
   c. New techniques in manufacturing processes have helped produce less waste.
   d. Streamlined national distribution processes, helping to conserve fuel, energy and other natural resources.
   e. Formulated many of our coatings to clean easily and to resist mildew and harmful bacteria improving the indoor and outdoor environments.

2.05 PERFORMANCE / DESIGN CRITERIA

A. Interior Latex (Satin): MPI #43 (Gloss Level 4).

1. VOC Content: <100g/L; <0.83 lb/gal.
2. Environmental Performance Rating: [EPR 1.5] [EPR 2] [EPR 2.5] [EPR 3.5].

B. Interior Latex Primer/Sealer: MPI #50.

1. VOC Content: <100g/L; <0.83 lb/gal.
2. Environmental Performance Rating: [EPR 1] [EPR 2] [EPR 3].

PART 3 EXECUTION

3.01 APPLICATORS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Examine substrates and conditions, with applicator present, for compliance with requirements for maximum moisture content and other conditions affecting performance of work.

B. Maximum moisture content of substrates when measured with an electronic moisture meter as follows:

1. Wood: 15 percent.
2. Gypsum Board: 12 percent.

C. Verify suitability of substrates, including surface conditions and compatibility with existing finishes and primers.

D. Begin coating application only after unsatisfactory conditions have been corrected and surfaces are dry.

3.03 PREPARATION

A. Surface Preparation

1. Clean substrates of substances that could impair bond of paints, including dirt, oil, grease, and incompatible paints and encapsulates.

3.04 APPLICATION

A. Apply paints to produce surface films without cloudiness, spotting, holidays, laps, brush marks, roller tracking, runs, sags, ropiness, or other surface imperfections. Cut in sharp lines and color breaks.

B. Protect work of other trades against damage from paint application. Correct damage to work of other trades by cleaning, repairing, replacing, and refinishing, as approved by Architect, and leave in an undamaged condition.

C. At completion of construction activities of other trades, touch up and restore damaged or defaced painted surfaces.

END OF SECTION

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http://www.paintdocs.com/webmsds/webPDF.jsp?SITEID=STORECAT&prodno=6006258&doctype=PDS&lang=E

SECTION 09 97 13.13
INTERIOR STEEL COATINGS

PART 1 GENERAL

1.01 SUMMARY

A. This section includes surface preparation and the application of a bluing compound on the following interior substrates:

1. Steel

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Samples: For each finish and for each color and texture required.

1.03 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials described below that are from same production run (batch mix) as materials applied and that are packaged for storage and identified with labels describing contents.

1. Quantity: Furnish an additional 5 percent, but not less than 1 gal. (3.8 L) of each material and color applied.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Product shall comply with MPI standards indicated and listed in “MPI Approved Products List.”

B. Mock-ups

1. Apply benchmark samples of each paint system indicated and each color and finish selected to verify preliminary selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Bluing Solution

1. STEEL BLUE Opaque Staining Fluid - 1 gallon #2131A73

2.02 MANUFACTURERS

A. McMaster-Carr Supply Company

2.03 CHEMICAL COMPONENTS OF FIELD-APPLIED INTERIOR COATINGS

A. Description: Product is a mixture of hazardous and non-hazardous ingredients compounded in a polymer.

1. Hazardous Components:

a. Selenious Acid 1-3%

b. Cupric Sulfate 1-3%

c. Nitric Acid 1-3%

2.04 PHYSICAL AND CHEMICAL PROPERTIES

A. Form: Light blue liquid.

B. Color: According to product specifications.

C. Odor: Nearly odorless.

PART 3 EXECUTION

3.01 APPLICATORS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Examine substrates and conditions, with applicator present, for compliance with requirements for maximum moisture content and other conditions affecting performance of work.

B. Verify suitability of substrates, including surface conditions and compatibility with existing finishes and primers.

C. Begin coating application only after unsatisfactory conditions have been corrected and surfaces are dry.

3.03 PREPARATION

A. Surface Preparation

1. Clean substrates of substances that could impair bond of paints, including dirt, oil, grease, and incompatible paints and encapsulates.

3.04 APPLICATION

A. Apply powder coating to produce surface films without cloudiness, spotting, holidays, laps, runs, sags, or other surface imperfections. Cut in sharp lines and color breaks.

B. Correct damage to work of other trades by cleaning, repairing, replacing, and refinishing, as approved by Architect, and leave in an undamaged condition.

END OF SECTION

http://www.mcmaster.com/#bluing-fluids/=258x4x

SECTION 09 97 13.23

EXTERIOR STEEL COATINGS

PART 1 GENERAL

1.01 SUMMARY

A. This section includes surface preparation and the application of powder-coating systems on the following exterior substrates:

1. Steel

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Samples: For each finish and for each color and texture required.

1.03 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials described below that are from same production run (batch mix) as materials applied and that are packaged for storage and identified with labels describing contents.

1. Quantity: Furnish an additional 5 percent, but not less than 1 gal. (3.8 L) of each material and color applied.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Product shall comply with MPI standards indicated and listed in “MPI Approved Products List.”

B. Mock-ups

1. Apply benchmark samples of each paint system indicated and each color and finish selected to verify preliminary selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Drylac Powder Coatings

1. Blue (RAL 5012)
2. Any other color to be specified in the TIGER color library.

2.02 MANUFACTURERS

A. TIGER Drylac USA, Inc.

2.03 CHEMICAL COMPONENTS OF FIELD-APPLIED EXTERIOR COATINGS

A. Description: Product is a mixture of hazardous and non-hazardous ingredients compounded in a polymer.

1. Hazardous Components:

a.	Barium Sulfate	5-10%
b.	T-Glycid-T-Cyanurate	5-10%
c.	Titanium Dioxide	5-10%

2.04 PHYSICAL AND CHEMICAL PROPERTIES

A. Form: Solid, finely divided powder

B. Color: According to product specifications

C. Odor: Nearly odorless.

PART 3 EXECUTION

3.01 APPLICATORS

A. A. Zahner Company

3.02 EXAMINATION

A. Examine substrates and conditions, with applicator present, for compliance with requirements for maximum moisture content and other conditions affecting performance of work.

B. Verify suitability of substrates, including surface conditions and compatibility with existing finishes and primers.

C. Begin coating application only after unsatisfactory conditions have been corrected and surfaces are dry.

3.03 PREPARATION

A. Surface Preparation

1. Clean substrates of substances that could impair bond of paints, including dirt, oil, grease, and incompatible paints and encapsulates.

3.04 APPLICATION

A. Apply powder coating to produce surface films without cloudiness, spotting, holidays, laps, runs, sags, or other surface imperfections. Cut in sharp lines and color breaks.

B. Correct damage to work of other trades by cleaning, repairing, replacing, and refinishing, as approved by Architect, and leave in an undamaged condition.

END OF SECTION

http://www.tiger-coatings.us/

SECTION 10 14 00

SIGNAGE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for signage for house numbers.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Neutra House Numbers - Aluminum

2.02 MANUFACTURERS

A. Design Within Reach

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Precision crafted in weather- and corrosion-resistant aluminum.
2. Each number weighs half a pound and installs without visible hardware.
3. Designed for visibility, these numbers measure 4" tall and float approximately .75" off the wall to cast subtle shadows.
4. Bead-blasted extruded aluminum finish further enhances visibility.
5. Each number comes with mounting hardware, extensive installation instructions and a full-scale drilling template that eliminates any guesswork during installation.

2.04 FINISHES

A. Finish Materials

1. Bead-blasted extruded aluminum.
2. Stainless steel threaded rod
3. Aluminum spacers.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Follow manufacture’s supplied installation guide

END OF SECTION

http://www.dwr.com/product/neutra-house-numbers-aluminum.do?keyword=house+numbers&sortby=ourPicks

SECTION 10 71 13.19

ROLLING EXTERIOR SHUTTERS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Custom fabricated rolling exterior shutters.
2. Pillow block for shutter track.
3. Custom belt-driven linear rodless actuator
4. Support Rail for rolling exterior shutters

1.02 ADMINISTRATIVE REQUIREMENTS

A. Coordination with manufacturer.

1. Clarification for possible assemblies and potential design limits.

B. Pre-installation meetings.

1. Conduct pre-installation meeting to verify project requirements, manufacturer’s installation instructions, and manufacturer’s warranty requirements.

1.03 ACTION SUBMITTALS

A. Product data

B. Shop drawings

1. Submit shop drawings for rolling exterior shutters showing layout, elevations, product components, and accessories.

C. Samples

D. Manufacturer’s instructions

1. Comply with manufacturer’s detail book, shop drawings, and product data, including product technical bulletins, for installation.
2. Deviations from standard detail and load design values shall be calculated by a qualified architect/engineer.

1.04 QUALITY ASSURANCE

A. Qualifications

1. All accessories are to be as furnished or recommended by the manufacturer.
2. Installer should be experienced in performing work of this section and should have specialized in installation of work similar to that required for this project.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Stainless steel metal screen

B. Super Smart Pillow Block

C. Rapidtrak M75 prism-guide belt drive

D. 60 Case Steel Lower Support Rail Assembly with Carbon Steel Shaft

2.02 MANUFACTURERS

A. A. Zahner Co.

B. Thomson

C. Danaher Motion Co.

2.03 PERFORMANCE/DESIGN CRITERIA

A. Capacities for stainless steel panels

1. A custom designed and fabricated laser-jet cut shutter system using manufacturer-specified angel-hair (SPF-001) finished stainless steel.

2. Low non-directional, reflectivity.

B. Capacities for pillow block

1. Nominal diameters: 0.625 in

2. Recommended shaft: 5/8 L

3. Dynamic load capacity (lbF): 620

C. Capacities for Rapidtrak M75

1. Maximum Torque (lbF in): 708

2. Maximum Speed (In/Sec): 40

3. Maximum Lenght (in): 196

4. Maximum Load (lbs): 484

D. Capacities for 60 Case Steel Lower Rail Assembly

1. Straightness: .001”/foot

2. Finish: Stainless Steel; Solid Stainless Steel construction

3. Tolerance Class: ‘L’

2.04 METALS

A. Metal Surfaces, General: Provide materials with smooth, flat surface without blemishes.

B. Ferrous Metals:

1. Steel plates, shapes, and angles: ASTM A 36/A 36M

2.05 FASTENERS

A. General: Stainless –steel fasteners for exterior use. Select fasteners for type, grade, and class required.

2.06 FABRICATION

A. General: Preassemble items in the shop to the greatest extent possible. Use connections that maintain structural value of joined pieces.

1. Cut and punch metals cleanly and accurately. Remove burrs and ease edges. Remove sharp or rough areas on exposed surfaces.

2. Form exposed connections with hairline joints, flush and smooth, using concealed fasteners where possible. Locate joints where least conspicuous.

3. Fabricate seams and other connections that will be exposed to weather in a manner to exclude water. Provide weep holes where water may accumulate.

2.07 FINISHES

A. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes. Finish metal fabrications after assembly.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Stainless steel panels

1. General: Perform cutting, drilling, and fitting required for installing metal fabrications. Set metal fabrications accurately in location, with edges and surfaces level, plumb, and true.

a. Fit exposed connections accurately together.

b. Provide anchorage devices and fasteners where metal fabrications are required to be fastened to in-place construction.

2.. Touch up surfaces and finishes after erection.

a. Painted Surfaces: Clean bolted connections and abraded areas and touch up coating with the same material as used for manufacturer's painting.

B. Super smart pillow block

1. General: Follow manufacturer provided installation guidelines.

C. Rapidtrak M75 prism-guide belt drive

1. General: Follow manufacturer provided installation guidelines.

D. 60 Case Steel Lower Rail Assembly

1. General: Follow manufacturer provided installation guidelines.

END OF SECTION

http://www.azahner.com

http://www.danahermotion.com/website/com/eng/index.php

www.danahermotion.com/website/com/eng/download/document/60_Case_Shafting_Catalog_Section_Inch_Metric.pdf

SECTION 11 24 19

VACUUM CLEANING SYSTEMS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for vacuum cleaner.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

B. Testing

1. Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Residential appliances shall comply with NAECA standards.

1.04 WARRANTY

A. Manufacturer Warranty

1. 1 Year Parts and Labor: This limited warranty begins on the original date of purchase, and is valid only on products purchased and used in North America, and does not include installation, removal or reinstallation. Warranty repairs must be performed by iRobot Corporation's authorized service center.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. iRobot Roomba 500 Series with On-Board Scheduling

2.02 MANUFACTURERS

A. iRobot

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Basis of Design Product: iRobot Roomba 500 Series Model # 405-793
   a. On-board scheduling system: Roomba leave its home base at the time user schedules, cleans and returns to charge; easy to use with clearly marked buttons scheduling interface.
   b. Virtual Wall Lighthouses: Restrict the Roomba from off-limit areas.

c. 4 Cleaning Behaviors: Spiraling, wall following, room crossing, and dirt detection.

d. Self-adjusting cleaning heads: Automatically detects and adjusts from carpet to hard floors

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Follow manufacturers “Instruction and Use Guide’.

END OF SECTION

SECTION 11 28 13

COMPUTERS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for computers and computing equipments.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product and complete installation data for products in this specification.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

B. Testing

1. Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Residential appliances shall comply with NAECA standards.

1.04 WARRANTY

A. Manufacturer Warranty

1. iMac and iPhone are covered by Apple’s One-Year Limited Warranty. Warranty service for eligible repairs is available at no charge for twelve months from the date of original retail purchase (”date of purchase”).
2. Lifebook Tablet is covered by one or three-year International Limited Warranty; 24/7 technical support; Fujitsu extended service plans available.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Lifebook Tablet Laptop Computer

B. 24” Desktop Computer

C. Internet-enabled smart-phone.

2.02 MANUFACTURERS

A. Fujitsu

B. Apple

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Basis of Design Product: 12” Fujitsu Lifebook T2010 Tablet PC Notebook

a. 1.2 GHz Intel Core 2 Duo Processor Ultra Low Voltage U7600

b. Four GB Memory

c. 120 GB 5400 rpm hard drive

d. Mobile Intel GMA X3100 with Intel Clear Video Technology enabling DX10 and MPEG-2 graphics card

2. Basis of Design Product: 24” 2.66 GHz iMac Desktop Computer Model #MB418LL/A

a. 2.66 GHz Intel Core 2 Duo Processor

b. Four GB memory

c. 640 GB hard drive

d. NVIDIA GeForce 9400M graphics card

3. Basis of Design Product: iPhone 3G Cellular Phone with 3.5” multi-touch screen

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Place units in final locations after finishes have been completed in each area.

2. Follow manufacturer’s supplied installation guide.

END OF SECTION

http://solutions.us.fujitsu.com/images/swf/T2010/T2010(us).swf

http://www.apple.com/imac/specs.html

http://www.apple.com/iphone/specs.html

SECTION 11 31 13

RESIDENTIAL KITCHEN APPLIANCES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Cooking equipment including cooktops and microwave ovens.
2. Refrigerators/freezers.
3. Dishwashers.
4. Espresso machines.

1.02 SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

A. Installer Qualifications

1. An employer of workers trained and approved by manufacturer for installation and maintenance of units is required for this project.

B. Testing

1. Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Residential appliances shall comply with NAECA standards.

1.04 WARRANTY

A. Manufacturer Warranty

1. Refrigerator/Freezer: For two years from the date of original purchase, warranty covers all parts and labor to repair or replace any part of the product, which proves to be defective in materials or workmanship.
2. Dishwasher: One-year major appliance under $2,500 service protection plan. A comprehensive one-year plan that covers repairs. Coverage is in addition to manufacturer's one-year parts and labor warranty.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Cooktop

1. Basis of Design Product: 24” Residential Induction Cooktop Model #DDP-3 or a comparable product from one of the following manufacturers:
    a. Bosch
    b. Electrolux
    c. G.E.
2. Description: 24” 3 Burner Electromagnetic Induction Cooktop.
    a. Color: Black, Frameless
    b. Energy Star Compliant
    c. Over-Heat Safety and Over-Flow Safety Sensors
    d. Efficiency: 90% of heat transferred to cooking utensil; compared to 50% for gas and 60% for other electric technologies.

B. Microwave

1. Basis of Design Product: G.E. Profile Advantium 120V Above-the-Cooktop Oven Model # SCA1001KSS or a comparable product from on of the following manufacturers:
    a. Whirlpool
    b. Kenmore
2. Description: 120V Above-the-Cooktop Microwave Oven with two-speed, 300 CFM venting system and halogen cooktop lighting system.
    a. Speedcook technology: Delivers oven-quality food up to four times fasten than a conventional oven.
    b. Multiple cooking modes: Combine four ovens in one with speedcook, traditional, sensor microwave and warming options.
    c. Sensor cooking controls: Automatically adjust time and power for exceptional performance.
    d. Auto and Time Defrost: Automatically defrosts for a specified amount of time.

C. Refrigerator/Freezer

1. Basis of Design Product: Liebherr 24” Fully Integrated Refrigerator Freezer Model # HC-1011 Right Hinge Without Ice Maker or a comparable product from one of the following manufacturers:
    a. Fagor USA
    b. Sub-Zero

2. Description: 24” Fully Integrated Refrigerator Freezer
   a. Finish: Custom Paneled
   b. System: Dual Refrigeration featuring SoftClose
   c. Energy Star Compliant
   d. LED lighting systems

D. Dishwasher
1. Basis of Design Product: Fisher & Paykel Custom Panel Standard Single DishDrawer Model # DD24SI6 or a comparable product from one of the following manufacturers:
   a. ASKO
   b. DCS
2. Description: Single Integrated Dish Drawer Dishwasher
   a. Finish: Custom Paneled
   b. Capacity: 6 Plate settings for plates as large as 12” and long stemmed wine glasses.
   c. Energy Star Compliant featuring ‘Eco Option’ wash program using as little as 1.95 gallons of water per use.
   d. Flow through detergent dispenser.
   e. Load sensors for optimum performance.

E. Espresso Machine
1. Basis of Design Product: Nespresso Essenza D100 GS or a comparable product from one of the following manufacturers:
   a. Gaggia
   b. Delonghi
2. Description: On-counter residential espresso machine with pre-packaged capsule brewing system.
   a. Compact Brewing Unit technology using Thermoblock heating element and 19 Bar pressure pump.
   b. Capsule container for up to 14 used capsules.
   c. Automatic and programmable coffee quality with backlit buttons.

2.02 MANUFACTURERS

A. Diva Induction
B. G.E. Appliances
C. Liebherr Appliances
D. Fisher & Paykel
E. Nespresso, U.S.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Manufacturer Installation Instructions

1. Follow each manufacturer's provided installation instruction manual.

B. Special Techniques

1. Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment.

END OF SECTION

http://www.liebherr-appliances.com/products/fully_integrated/24_fully_integrated.html

http://www.homedepot.com/webapp/wcs/stores/servlet/ProductDisplay?storeId=10051&langId=-1&catalogId=10053&productId=100398706&N=10000003+500753+10401019

http://www.divainduction.com/products.php?product=7

http://www.fisherpaykel.com/dishwashing/?productUid=C8D58221-0E9B-ACC5-91078BFCEB92BFAA

http://nespresso.com/precom/sima/fiche__Essenza_D100_GS__N_ESS_D100GS_1_pt_en.html

SECTION 11 31 23

RESIDENTIAL LAUNDRY APPLIANCES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for combination clothes washer and dryer.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

A. Qualifications

1. An employer of workers trained and approved by manufacturer for installation and maintenance of units is required for this project.

B. Testing

1. Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Residential appliances shall comply with NAECA standards.

1.04 WARRANTY

A. Manufacturer Warranty

1. One year for parts and labor, two years on the control board, seven years on the motor, and lifetime coverage on the drum.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Full-size all-in-one SteamWasher™ and dryer combination (WM3988HWA).

2.02 MANUFACTURERS

A. LG – Life's Good

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Largest capacity front load combo (4.2 cu. ft. IEC) with NeveRust™ stainless steel drum.
2. Direct Drive Motor for the ultimate in durability and reliability.
3. TilTub™ is designed with a 10° tilt for easy reach of clothing in the rear of the drum.
4. 1320 RPM powerful spin for efficient water extraction.

4. Measurements:
   a. Diameter Top: 7.9”
   b. Daimeter Base: 5.5”
   c. Capacity: 2.1 qt
5. Measurements:
   a. Diameter Top: 11”
   b. Daimeter Base: 8.7”

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle cookware carefully to avoid breaking or chipping.

END OF SECTION

SECTION 11 42 00

FOOD PREPERATION EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Casserole Pot
2. Stockpot
3. Saucepan
4. Sauté Pan
5. Frying Pam

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written use and care guide for owner.

1.03 QUALITY ASSURANCE

1.04 WARRANTY

A. Manufacturer Warranty

1. 30 year limited guarantee. This guarantee does not cover any damage resulting from an accident, abuse or misuse (overheating included), discoloration, and deposition of lime or other substances. Scratches to the inside or outside of the stainless steel are not considered production errors.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. John Pawson Line

2.02 MANUFACTURERS

A. Demeyere

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Measurements:
   a. Diameter: 8.7"
   b. Capacity: 4.2 qt
2. Measurements:
   a. Diameter: 9.4"
   b. Capacity: 8.5 qt
3. Measurements:
   a. Diameter: 7.1"
   b. Capacity: 2.3 qt

4. Measurements:
   a. Diameter Top: 7.9”
   b. Daimeter Base: 5.5”
   c. Capacity: 2.1 qt
5. Measurements:
   a. Diameter Top: 11”
   b. Daimeter Base: 8.7”

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques
   1. Handle cookware carefully to avoid breaking or chipping.

END OF SECTION

SECTION 11 52 00

AUDIO-VISUAL EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section includes audio/visual equipment for the following:

1. Samsung 8000 46” 1080p LED HDTV
2. Samsung 6000 32” 1080p LED HDTV
3. HT-BD8200 Receiver and Speaker Home Theater System

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product and complete installation data for products in this specification.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

A. Qualifications

1. An employer of workers trained and approved by manufacturer for installation and maintenance of units is required for this project.

B. Testing

1. Residential appliances shall comply with NAECA standards.

1.04 WARRANTY

A. Manufacturer Warranty

1. Samsung: One year for parts and labor, backed by manufacturer’s toll-free support.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. 46” LED High Definition TV with 1080p Resolution (UN46B8000).

B. 32” LED High Definition TV with 1080p Resolution (UN32B6000).

C. Home Theater Sound Bars (HT-BD8200) equipped with an integrated Blu-ray player,

2.02 MANUFACTURERS

A. Samsung Electronics America, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Televisions:

   a. 5,000,000:1 Dynamic Contrast Ratio.

   b. AutoMotion Plus 240Hz.

   c. Full HD 1080p resolution.

d. Ultra-slim (1.2” deep) Touch of Color design.
e. Energy Star compliant; LED TVs use up to 40% less power than conventional LCD TVs.
f. Fast 2ms response time minimizes blurring of fast motion in high action programs.

2. Home Theater System
a. Fully integrated Blu-ray player with Full HD 1080p playback and virtual 5.1-channel surround sound for a life-like audio presence.
b. 2.6 inches deep and accented with Samsung’s Touch of Color (ToC) design.
c. “Smart Volume” technology for automatic volume level adjustments and the ability to change audio sources without the need to continually pick up the remote.
d. Each speaker has built in I-pod Dock.
e. "Bio kelp speaker" eco-friendly and improves sound production
f. Integrated connectivity and can connect to wireless networks for streaming internet radio.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment.

END OF SECTION

http://www.samsung.com/us/consumer/detail/detail.do?group=televisions&type=televisions&subtype=ledtv&model_cd=UN55B8000XFXZA

SECTION 11 67 53

GAME ROOM EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section includes specifications for the following:

1. Game Console/ Blu-Ray Player
2. Game Console
3. Game Console Accessory

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product and complete installation data for products in this specification.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.04 WARRANTY

A. Manufacturer Warranty

1. Game Console/ Blu-Ray Player : The manufacturer warrants to the original purchaser that the product hardware shall be free from material defects in material and workmanship for a period of one (1) year from the original date of purchase (the "Warranty Period").

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. PLAYSTATION®3 80GB System (CECHP01)

B. Nintendo® Wii™ (ABC)

C. Nintendo® WiiFit with Wii Balance Board™

2.02 MANUFACTURERS

A. Sony Computer Entertainment America Inc.

B. Nintendo of America Inc.

C. Nintendo of America Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. PLAYSTATION®3:
   a. Hard Drive: 2.5’ Serial ATA (80GB)
   b. Ethernet (10BASE-T, 100BASE-TX, 1000BASE-T) IEEE 802.11 b/g Wi.Fi
   c. Bluetooth 2.0 (EDR)
   d. Wireless Controller Bluetooth (up to 7)

e. Screen size: 480i, 480p, 720p, 1080i, 1080p
f. HDMI: HDMI out – (x1 / HDMI)
g. Analog: AV MULTI OUT x 1
h. Digital audio: DIGITAL OUT (OPTICAL) x1
i. Blu-ray/DVD/CD DRIVE “read only”
j. I/O: USB 2.0 x 2
k. Dimensions: Approximately 325mm (W) x 98mm (H) x 274mm (D)
l. Weight: Approximately 5 kg
m. CPU: Cell Broadband Engine™
n. GPU: RSX
o. Memory: 256MB XDR Main RAM, 256 GDDR3 VRAM

2. Nintendo® Wii™:
a. Accessories: Remote x 1, Nunchuk, AC Adaptor, A/V Cable, Batteries x 2
b. Size: 44mm (W) x 157mm (H) x 215.4mm (D)
c. Wireless LAN IEEE802.11b/g or LAN Adapter Optional
d. Disc: 12cm Wii Disc or 8cm Game Cube Disc
e. USB 2.0 x 2
f. SD Card Slot x 1
g. Game Cube Controller Port x 4
h. Game Cube Memory Slot x 2
i. A/V Multi Output x 1

3. Nintendo® WiiFit with Wii Balance Board™:
a. WiiFit Disc
b. WiiFit Balance Board™
c. AAA Batteries x 4

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Install according to manufacturers’ provided instructions.

END OF SECTION

http://www.us.playstation.com/PS3/Systems/TechSpecs/default.html

http://www.nintendo.co.jp/wii/console/index.html

http://wii.com/jp/articles/wii-fit/index.html

SECTION 12 22 00

CURTAINS AND DRAPES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Electronic drive drapery track systems.
2. Drapery control system.
3. Drapery.

1.02 REFERENCES

A. Association of Electrical and Medical Imaging Equipment Manufacturers (NEMA)WD1-1999(R2005) - General Color requirements for Wiring Devices.

B. ASTM International (ASTM) D4674-89 - Standard Test Method for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Fluorescent Lighting and Window-Filtered Daylight.

C. National Fire Protection Association (NFPA)70 (2008) - National Electrical Code.

1.03 SYSTEM DESCRIPTION

A. Drapery System: Ultra-quiet, precision-controlled electronic drive unit hidden behind draperies, controlling drapery movement.

B. Track System: Single drapery track.

C. Track Configuration: Straight.

D. Track Operation: Left draw, left-mounted electronic drive unit.

E. Track System Capacity: 145 pounds.

F. Drapery Style: Pinch pleat.

G. Controls: Wall mounted.

1.04 ACTION SUBMITTALS

A. Submittals for Review:

1. Shop Drawings: Include following for each drapery track required:
    a. Drapery locations by room name and number using Architect’s plan numbers.
    b. Description of track system, direction of draw, and track operation.
    c. Attachments and accessories.
    d. Electronic drive unit and control locations.
    e. Low voltage wiring diagrams with system components.
    f. Power supply locations.
2. Product Data: Include product descriptions, electronic drive unit attributes, control station descriptions, and operational characteristics.
3. Samples: 6 inch long drapery track samples showing profile and finish.

B. Closeout Submittals:

1. Operation and Maintenance Data.

1.05 QUALITY ASSURANCE

A. Manufacturer Qualifications:

1. Minimum 5 years experience in manufacture of low-voltage motorized shading systems.
2. Provide single source for shading system and control systems.

B. Installer Qualifications: Qualified by factory training and previous experience to install and commission specified products.

C. Perform work in accordance with NFPA 70.

D. Mockup:

1. Provide mockup of one typical drapery system.
2. Show drapery tracks and accessories, electronic drive units, and controls.
3. Approved mockup may remain as part of the work.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Include installation, programming, and maintenance instructions in product packaging.

1.07 PROJECT CONDITIONS

A. Do not install drapery track systems until overhead and adjacent work is completed.

1.08 WARRANTY

A., Provide manufacturer's 2 year warranty covering parts and labor and 8 year limited parts warranty covering repair or replacement of defective equipment.

B. Provide manufacturer's 10 year warranty covering repair or replacement of defective equipment.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. *Sivoia* QS D105 Drapery Track System.

B. Verosol Fabrics 812

2.02 MANUFACTURERS

A. Contract Documents are based on Sivoia QS Drapery Systems by Lutron Electronics Co., Inc.

B. Specialty Drapery

2.03 COMPONENTS

A. Electronic Drive Drapery Track System:

1. Tracks:
   a. Extruded aluminum with drive belts, idler gear housings, master carriers, auxiliary carriers, covers, and mounting brackets to suit system layout.
   b. Color-matched end caps.
   c. Concealed splicing bars.
   d. Optional manual-open master carrier with field-adjustable spring release.
2. Electronic drive units:
   a. Operate independently, without use of external group controllers.
   b. Audible noise: Maximum 44 dBA measured 3 feet from operator drive unit.
   c. Power: 24 VDC, approved power supply via NEC Class 2 power source.
3. Controls: Low voltage keypad powered from electronic drive unit.

4. System Performance:
    a. One-touch control of draperies by means of keypad or infrared remote.
    b. Store up to 250 programmable stop points including open, close, and any other position.
    c. Presets set by 5-second button push and hold from keypad, contact closure input, or handheld remote control.
    d. Presets recalled by keypad, contact closure input, infrared receiver, or other lighting control system interface.
    e. Keypad adjustment of presets disabled using lockout feature on keypad.
    f. Open and close limits programmable from electronic drive unit, wall-mounted keypad, or handheld remote control.
    g. 10 year power failure memory.
    h. System components electro static discharge protected.
5. Grouping:
    a. Keypads and contact closure inputs can control any electronic drive unit without separate group controller.
    b. System groups and subgroups configured at point of control without rewiring and without access to electronic drive unit.
    c. System may contain multiple electronic drive units.
    d. Keypads and interfaces able to operate any group or subgroup of electronic drive units.
    e. Controls able to operate any group or subgroup of electronic drive units regardless of window or drapery treatment type.
6. Integration:
    a. Electronic drive units integrate with lighting controls without separate interface.
    b. Contact closure, RS232, and Ethernet interfaces available to interface with audio/visual equipment and security systems.

B. Drapery Control Systems:
1. Drapes controlled by built-in shading columns on lighting control or by keypad.
2. Electronic drive units, keypads, and lighting controls contain microprocessors, allowing high level programming from any source.
3. Drapery tracks, skylight shades, window shades, lighting controls, and keypads wired together on same communications link.
4. Wall Mounted Controls:
    a. Low voltage keypads:
    a. Electronically set and reconfigure drapery track open and close limits, drapery preset positions, system groups, and system subgroups without rewiring or access to electronic drive unit.

b. Fit into standard electrical box.

5. Face plates:
   a. Attach without visible means of attachment.
   b. Engraved artwork.
6. Product color: Match NEMA WD1.
7. Provide immediate local LED response upon button activation.
8. Backlit buttons.
9. Removable button assemblies allowing field changes.
10. Capable of simultaneously controlling one or more draperies or shades.
11. Type: Two button with raise/lower.
12. Infrared Receivers:
    a. Available on system keypads, or as attachment to electronic drive unit.
    b. Electronically set and reconfigure drapery open and close limits, drapery preset points, system groups, and system subgroups without rewiring and without access to electronic drive unit.
    c. Include circuitry to reduce degraded performance.
13. Remote Controls:
    a. Infrared handheld type.
    b. Type: Lighting and drapery control on/off and favorite preset for lights and open/close and favorite preset for draperies.
14. Infrared Interfaces:
    a. Interface to other control system via dry contact closure input device.
15. Power Supplies:
    a. Electronic drive units powered with 24 VDC from approved power supply; power supply via NEC Class 2 power source.
    b. Provide individual transformer for each electronic drive unit.

C. Verosol Fabrics:

1. Metalized fabrics provide excellent sunshading and anti-glare properties. Different transparency types alter the view through the window. The heat reflecting and insulating values of the fabrics make a sizable contribution to comfort levels in areas close to the windows as well as to overall energy efficiency
2. The ratio or solar energy reflected by the metalized side of the fabric: 58%.
3. Color rendering index: 99%.
4. Solar transmission: 6%.
5. Solar heat gain coefficient: 30%.
6. Product color: white #999.

2.04 FINISHES

A. Finish Materials

1. Track and Accessories: White baked enamel, clear anodized, bronze.
2. Keypads: Designer gloss, designer Satin, Architectural Matte, Metal, color (to be selected from manufacturer’s full color range).

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Install in accordance with manufacturer's instructions and approved shop drawings.

B. Install drapery systems to provide smooth operation.

C. Locate controls.

D. Connect to power supply and control wiring.

E. Connect to lighting control system.

3.03 DEMONSTRATION

A. Demonstrate proper operation and maintenance of drapery systems to owner.

END OF SECTION

http://www.lutron.com/cms400/page.aspx?id=8183&mn=757
http://www.lutron.com/cms400/page.aspx?id=8175&mn=767
http://www.specialtydrapery.com/drapery/shadeworks/Sun_Control/Sun_Control_Draperies.aspx

SECTION 12 35 30

RESIDENTIAL CASEWORK

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for custom fabricated bedroom area built-in casework.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.04 WARRANTY

A. Manufacturer Warranty

1. Hafele Hardware: Products have a 1-year, full replacement warranty if product fails unless otherwise specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Custom fabricated bedroom area casework, built-in closets, and storage areas designed and manufactured by the Virginia Tech Solar Decathlon Team.

1. Material: Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer. (See specification 06 20 23 - Interior Finish Carpentry).

B. All hardware, hanging racks, accessories, door handles, and hinges.

1. Synergy Collection Wardrobe Closet Rod & Wardrobe Rail Support Model # 801.42.900
   a. Description: Two pins for 5 mm holes, 32 mm (1 1/4") spacing with an additional screw hole for mounting on the side panel material: zinc, plated.
2. Synergy Collection Belt Rack Model # 807.54.931
   a. Length: 6 hook length: 358 mm (14 1/8")
   b. Material: Aluminum, anodized or epoxy coated
3. Synergy Collection Shoe Rail Model # 805.87.900
   a. Length: 36"
   b. Material: Aluminum anodized

4. Ironfix ® Ironing Board Model # 568.60.681
   a. Description: Drawer mounted and wall mounted ironing boards are the ultimate in convenience. Ironfix drawer mounted ironing board rotates 180 degrees and our slide-less design keeps clothing free from roller bearing grease.
   b. Dimensions: 24” W x 14” L
   c. Material: White epoxy-coated steel with natural white cotton with gray stripes and foam backing cover.
5. Concealed ‘A-Series’ Clip Full Overlay Straight Arm Hinge Model # 311.60.500
   a. Description: Self closing, clip mounted.
6. Metal Shelf Support Pin Model # 282.04.720
   a. Material: Nickel-plated Steel
   b. Length: 3 mm
7. Dialock Electronic Furniture Locking System (EFLS) Model # 911.71.010
8. Magnetic Screw Mounted Pressure Catcher and Matching Strike Model # 245.90.320
   a. Color: Black
   b. Material: plastic with steel strike

2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

B. Hafele America Co.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Follow manufacturer’s supplied assembly instructions when installing all hardware, hanging racks, accessories, door handles, and hinges

END OF SECTION

http://www.hafele.com/us/products/97.asp

SECTION 12 35 30.13

KITCHEN CASEWORK

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for custom fabricated kitchen area built-in casework.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. Hafele Hardware: Products have a 1-year, full replacement warranty if product fails unless otherwise specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Custom fabricated kitchen area casework, built-in cabinets, and storage areas designed and manufactured by the Virginia Tech Solar Decathlon Team.

1. Material: Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer. (See specification 06 20 23 – Interior Finish Carpentry).

B. All hardware, drawer organizers, accessories, door handles, and hinges.

1. Arena Champagne Spice Rack Model # 54.34.800
   a. Material: Steel, apoxy coated
   b. Dimensions: ¾" W x 10" D x 23.5"
2. Metal Shelf Support Pin Model # 282.04.720
   a. Material: Nickel-plated Steel
   b. Length: 3 mm
3. Magnetic Screw Mounted Pressure Catcher and Matching Strike Model # 245.90.320
   a. Color: Black
   b. Material: plastic with steel strike

4. Triangle Post Kitchenware and Plate Organizer Model # 557.46.001
   a. Description: Customizable drawer organizer with pre-drilled holes allowing for any combination of beech post and divider sections. Posts are secured with fastening nut.
   b. Dimensions: 36” x 24”
   c. Material: Veneered beech
5. Wood Inserts Drawer Organization Model # 556.91.304 and Model # 556.91.312
   a. Description: Solid wood, fully assembled wood kitchen utensil organizers.
   b. Dimensions: 19.5” L x 11.5” W x 2” H
   c. Material: 4 mm solid beech
6. Rapid Pull Out Table System Item # 505.58.703
   a. Material: wood; melamine plastic coated (table top); beech wood (telescopic guides)
   b. Color: white/gray dotted
   c. Width: 20.5”
7. Pull Down Shelf Mechanism Item # 504.58.200
   a. Material: stainless steal
   b. Length: 17 5/8”
8. Under-sink storage unit Item # 545.48.239
   a. Material: steel
   b. Color: chrome-plated
   c. Dimension: 9" x 181/2" x 16"
9. 3-tier base cabinet pull-out 90º Item # 545.61.233
   a. Material: steel
   b. Color: chrome-plated
   c. Dimensions: (minimum of) 4 ½” x 19” x 29 ¾”
10. Base Pull-Out Towel Rail 90º Item # 545.61.262
    a. Material: steel
    b. Color: chrome-plated
    c. Dimensions: (minimum of) 4 1/2" x 19 " x 23 1/4"
11. 2-tier Base Cabinet Pull-out Item # 545.17.200
    a. Material: steel
    b. Color: chrome
    c. Dimensions: 18 7/8” x 4 5/16” x 19 5/16”

12. Tandem Chef's Pantry Pull-Out Frame Set Item # 546.64.802
    a. Material: steel, epoxy-coated
    b. Color: champagne
    c. Height: 45"

2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

B. Hafele America Co.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques
   1. Follow manufacturer's supplied assembly instructions when installing all hardware, hanging racks, accessories, door handles, and hinges

END OF SECTION

http://www.hafele.com/us/products/97.asp

SECTION 12 35 30.23

BATHROOM CASEWORK

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for custom fabricated bathroom sink, vanity, and drawers.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.04 WARRANTY

A. Manufacturer Warranty

1. Hafele Hardware: Products have a 1-year, full replacement warranty if product fails unless otherwise specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Custom fabricated bathroom sink, vanity, and drawers designed and manufactured by the Virginia Tech Solar Decathlon Team.

1. Material: Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer. (See specification 06 20 23 - Interior Finish Carpentry).
2. Tile: Keystone Shapes ColorBody Porcelain Tile Oblong
    a. 2" L x 1" W
    b. Color: Black D311

B. All hardware, accessories, door handles, and hinges.

1. Synergy Collection Wardrobe Closet Rod & Wardrobe Rail Support Model # 801.42.900
    a. Description: Two pins for 5 mm holes, 32 mm (1 1/4") spacing with an additional screw hole for mounting on the side panel material: zinc, plated.
2. Concealed 'A-Series' Clip Full Overlay Straight Arm Hinge Model # 311.60.500
    a. Description: Self closing, clip mounted.
3. Metal Shelf Support Pin Model # 282.04.720
    a. Material: Nickel-plated Steel
    b. Length: 3 mm

4. Magnetic Screw Mounted Pressure Catcher and Matching Strike Model # 245.90.320
    a. Color: Black
    b. Material: plastic with steel strike
5. Axor Towel holder, single arm Model # 42020
    a. Solid Stainless Steel
    b. 433 mm L
6. Axor Roll holder Model # 42036
    a. Solid stainless steel

2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team
B. Hafele America Co.
C. Daltile Products
D. Axor Design

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques
    1. Follow manufacturer’s supplied assembly instructions when installing all hardware, hanging racks, accessories, door handles, and hinges

END OF SECTION

http://www.hafele.com/us/products/97.asp
http://pageflip.hansgrohe.com/pageflip/axor/collections09/en-gb/index.html
http://www.daltileproducts.com/series.cfm?series=240%E0%B9%80

SECTION 12 36 00
COUNTERTOPS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Kitchen countertop.

1.02 ACTION SUBMITTALS

A. Product data: For each type of process and factory-fabricated product.

B. Shop Drawings: prior to fabrication, the contractor shall furnish and submit detailed shop drawings for the approval of the architect/designers, showing accurate dimensions and details of manufacture's panel work

1.03 QUALITY ASSURANCE

A. Qualifications: fabrication and installation of all manufacturer's surfaces shall be performed by an approved fabrication shop in accordance with the manufacturers' printed instructions and final drawings

B. Sustainability Standards Certifications

1. LEED V2.1 recycled content, local regional materials, rapidly renewable materials, certified wood materials, and low emitting materials, are all standards that can be applied
2. Only solid surface material certified by the Forest Stewardship Council, Smartwood, and the Rainforest Alliance

1.04 WARRANTY

A. Manufacturer warrants that products permanently and properly installed after November 15, 2007 and purchased through approved distributors will be free from material defects for a period of 15 years

B. Manufacturer will replace any area of installation that is found to have a manufacturing defect if the panel was installed properly and will pay the cost of the required product.

PART 2 PRODUCTS

2.01 MATERIALS, GENERAL

A. PaperStone™ Certified heavy-duty solid surface made from 100% post-consumer recycled paper and a proprietary petroleum-free resin using color slate.

B. PaperStone finish made from natural waxes (bee and carnauba) and vegetable products (soybean oil)

2.02 MANUFACTURER

A. Paneltech International

2.03 DESCRIPTION

A. Sustainability Characteristics:

1. PaperStone Certified is made from 100% recycled materials.

2. Made from manufacturer's proprietary, petroleum-free resin that contains natural ingredients like cashew nut shell liquid.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 PREPARATION

A. Cut PaperStone dry. Slow the blade speed or increase the feed rate if you detect excess heat. Fully support PaperStone before you begin cutting since the blade could bind when the slab shifts as the cut proceeds. We recommend using a triple chip carbide-tipped saw blade if possible and carbide-tipped router bits.

3.03 INSTALLATION, GENERAL

A. On a sturdy On a sturdy, level surface, set out spacer bars of uniform thickness and place the PaperStone sections on them. Leave a gap between the two sections that is slightly less than the width of a straight-edge router bit.

1. Use a biscuit joiner, cut slots for standard wood biscuits. Or
2. Rout necessary holes for the type of tight-joint fasteners typically used to connect section of post-form laminate counters
3. Glue joint using a slow-drying two-part epoxy. CA5 adhesive may also be used
4. Once the joint has cured, lightly sand it to blend the seam with surrounding area

3.04 PROTECTION

A. Sanding: sanding should be minimal as to not wear through the top layer to expose the bonded sheets of paper. 180 grit sandpaper may be used as a first step finishing with fiber abrasive pad.

B. Finishing: place PaperStone finish bottle under a stream of warm water to make the fluid mix and flow more easily. Apply think coat to the surface with a soft cloth. Let stand for 20 minutes then wipe off any excess. Finish up using a clean, soft cloth to give an even, rich luster. Do no use finished area for at least 12 hours to allow the finish to harden.

END OF SECTION

http://www.paperstoneproducts.com/ps_properties_applications.php

SECTION 12 41 13
DESK ACCESSORIES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Paperclip holder
   2. Letter opener
   3. Paper holder
   4. Pen holder
   5. Magnetic board

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer’s Instructions
   1. The product manufacturer shall provide a written use and care guide for owner.

1.03 QUALITY ASSURANCE

1.04 WARRANTY

A. Manufacturer Warranty
   1. Distributor to offer 1-year limited warranty on breaking or damaging of flatware.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Designation
   1. Wave by Steve McGugan
   2. Letter Opener by Allan Scharff
   3. Wave by Steve McGugan
   4. Wave by Steve McGugan
   5. Memory board by DesignIt

2.02 MANUFACTURERS

A. Georg Jensen

2.03 PERFORMANCE / DESIGN CRITERIA

A. Characteristics
   1. Materials: Stainless steel
   2. Materials: Stainless steel
   3. Materials: Stainless steel and plastic
   4. Materials: Stainless steel and plastic
   5. Materials: Stainless steel, magnets and plastic

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle flatware carefully to avoid breaking or chipping.

END OF SECTION

SECTION 12 42 16

FLATWARE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for flatware.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written use and care guide for owner.

1.03 QUALITY ASSURANCE

1.04 WARRANTY

A. Manufacturer Warranty

1. Distributor to offer 1-year limited warranty on breaking or damaging of flatware.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Heller Dinnerware Set by Massimo Vignelli

2.02 MANUFACTURERS

A. Heller Co.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Measurements:

   a. Plate Height 1” Diameter 9.75”

   b. Salad Plate Height .75” Diameter 7.5”

   c. Bowl Height 2.25”, Diameter 7.5”

   d. Mug Height 4.25”, Diameter 3.13”

2. Materials:

   a. Melamine plates and bowls.

   b. Polycarbonate mugs.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle flatware carefully to avoid breaking or chipping.

END OF SECTION

SECTION 12 42 16.13

SILVERWARE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for silverware.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written use and care guide for owner.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Caravel cutlery pattern by Henning Koppel

2.02 MANUFACTURERS

A. Georg Jensen

2.03 PERFORMANCE / DESIGN CRITERIA

A. Characteristics

1. Materials:

a. Stainless Steel

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle silverware carefully to avoid scratching or bending.

END OF SECTION

SECTION 12 42 19

HOLLOWWARE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Salad Bowl & Servers
2. Salt Cellar & Scoop
3. Salt & Pepper Set
4. Cocktail Shaker
5. Pitcher

1.02 ACTION SUBMITTALS

A. Manufacturer's Instructions

1. The product manufacturer shall provide a written use and care guide for owner.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Designation

1. Caravel by Henning Koppel
2. Twist by Phillip Bro Ludvigsen
3. Castors by Henning Koppel
4. Cocktail Shaker by Helle Damkjaer
5. Koppel Pitcher by Henning Koppel

2.02 MANUFACTURERS

A. Georg Jensen

2.03 PERFORMANCE / DESIGN CRITERIA

A. Characteristics

1. Materials: Stainless steel and black polycarbonate
2. Materials: Stainless steel
3. Materials: Stainless steel
4. Materials: Stainless steel and silicon
5. Materials: Stainless steel

B. Dimensions

1. Capacity: 60 cl
2. H 330 mm, W 150 mm, D 12 mm

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle flatware carefully to avoid scratching or denting.

END OF SECTION

SECTION 12 42 23

GLASSWARE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for glassware.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written use and care guide for owner.

1.03 QUALITY ASSURANCE

1.04 WARRANTY

A. Manufacturer Warranty

1. Distributor to offer 1-year limited warranty on breaking or damaging of glassware.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Set of 5 Usuhari Stacking Glasses

2.02 MANUFACTURERS

A. Shotoku Glass Company

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Measurements: Height 3-5.75", Diameter 1.75-3"
2. Material: Glass

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle thin glass carefully to avoid breaking or chipping.

END OF SECTION

SECTION 12 44 13

BATH LINENS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for bath linens and towels to be provided by Solar Decathlon.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. None specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Standard White Towels.

2.02 MANUFACTURERS

A. Consumer Contact Company

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Weight: 1.09 lbs each.
2. Dimensions: 30” x 60”

2.04 MATERIALS

A. 100% Cotton 2 ply terry velour.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

SECTION 12 45 13

BED LINENS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for bed linens, pillow shams, and sheets.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. None specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Tamara Bed Linens

2.02 MANUFACTURERS

A. Marimekko ®

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Designer Maija Isola's ornamental 1960 classic, inspired by eastern European wood-block prints and folk art handicrafts. Crate & Barrel's exclusive reissue in three new color-saturated hues flourishes positive-negative on ultra-soft 300-thread-count cotton percale. Duvet cover and comforter are printed color on antique white. Reversible duvet cover is tailored with a hidden button closure at bottom. Reversible comforter has quilting on the inside for a crisp look. Shams are finished with a deep 2" flange and generous overlapping closure on back.

2.04 MATERIALS

A. 100% Cotton

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.crateandbarrel.com/Family.aspx?c=1624&f=31820

SECTION 12 45 16

PILLOWS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for bed pillows.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product data.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide written maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. None specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Feather-down Bed Pillows

2.02 MANUFACTURERS

A. Crate & Barrel

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. The core support of feather is wrapped in the fluffy luxury of domestic down for a superior-quality pillow with nothing but pure white fill. The preshrunk cambric cotton shell is closely woven to keep the fill inside.

2.04 MATERIALS

A. 100% Cotton Pillow Shell

B. 80% white duck feather, 20% snow-white domestic down.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

<u>END OF SECTION</u>

http://www.crateandbarrel.com/family.aspx?c=1627&f=11504

SECTION 12 42 16

BOWLS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Nesting Bowls 3 pc
2. Nesting Bowls 2 pc

1.02 ACTION SUBMITTALS

A. Manufacturer's Instructions

1. The product manufacturer shall provide a written use and care guide for owner.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Designation

1. Leaf by Helle Damkjaer
2. Bloom by Helle Damkjaer

2.02 MANUFACTURERS

A. Georg Jensen

2.03 PERFORMANCE / DESIGN CRITERIA

A. Characteristics

1. Materials: Stainless steel
2. Materials: Stainless steel

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle bowls carefully to avoid scratching or denting.

<u>END OF SECTION</u>

SECTION 12 42 29

VASES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Vase

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written use and care guide for owner.

1.03 QUALITY ASSURANCE

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Flora by Todd Bracher

2.02 MANUFACTURERS

A. Georg Jensen

2.03 PERFORMANCE / DESIGN CRITERIA

A. Characteristics

1. Measurements:

a. Height 230mm

2. Materials:

a. Stainless Steel

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Handle vase carefully to avoid scratching or denting.

END OF SECTION

SECTION 12 46 33

WASTE RECEPTACLES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Kitchen waste receptacles.
2. Bedroom, bathroom, and office waste receptacles

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

A. Qualifications

1. An employer of workers trained and approved by manufacturer for installation and maintenance of units is required for this project.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Pull-Out Door Mounted, Double Waste Bin, US Cargo 15 or comparable product.

B. Garbino Trash Can – translucent white or comparable product.

2.02 MANUFACTURERS

A. Hafele

B. Umbra®

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics for Double Waste Bin

1. Inside cabinet area: 14" wide x 21" high
2. Cabinet depth cannot be less that 22 1/2"
3. Minimum inside face frame clearance 308 mm (12 1/8")
4. 1 x 40 liter (10.57 gallons) and 1 x 8.5 liters (2.25 gallons)

B. Capacities / Characteristics for Garbino

1. 13" tall x 10 1/4" wide.
2. 10 quart maximum storage capacity

2.04 MATERIALS

A. Double Waste Bin, US Cargo 15:

1. Frame and cove: steel, powder-coated

2. Pails: plastic

B. High-impact virgin polypropylene construction

2.05 FINISHES

A. Powder-coated steel

B. High-gloss, translucent white finish

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Install according to manufacturers' written instructions, using fasteners appropriate to substrate indicated and recommended by unit manufacturer. Install units level, plumb, and firmly anchored in locations and at heights indicated.

END OF SECTION

http://www.umbra.com/ustore/product/082855/c040/garbino_can__matte_.html
https://hachol02.hafeleonline.com/OA_HTML/ibeCCtpItmDspRte.jsp?item=23567&oracledb_prod=39HxNSaIqbuPgGTXMq01pD2R:S&oracledb_prod_pses=ZGCBF70150F80445EF6B371EFDB1CE3743998B9387DC57D35DBCA05EF856DA044FE7C43F628EF10F969B970D518749FF8C8B84E73824FE4DFFB8B468291806D7D7

SECTION 12 48 53

RUGS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for rugs.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product data.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide written maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. None specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Velvet Designer Rug

2.02 MANUFACTURERS

A. Nani Marquina

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Homemade and hand loomed to a density of 6.600-knots/sq. meter.
2. Pile length of 10mm and total height of 12mm.
3. Dimensions: 67” W x 94.5” D
4. Color: Ivory

2.04 MATERIALS

A. 100% New Zealand wool.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.spacify.com/modern_contemporary_velvet_designer_rug_by_nani_marquina-572-474-Nani.Velvet.html#tabs

SECTION 12 51 83

CUSTOM OFFICE FURNITURE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for custom fabricated bathroom sink, vanity, and drawers.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.04 WARRANTY

A. Manufacturer Warranty

1. Hafele Hardware: Products have a 1-year, full replacement warranty if product fails unless otherwise specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Custom fabricated bathroom sink, vanity, and drawers designed and manufactured by the Virginia Tech Solar Decathlon Team.

1. Material: Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer. (See specification 06 20 23 - Interior Finish Carpentry).

B. All hardware, accessories, door handles, and hinges.

1. Concealed 'A-Series' Clip Full Overlay Straight Arm Hinge Model # 311.60.500
   a. Description: Self closing, clip mounted.
2. Metal Shelf Support Pin Model # 282.04.720
   a. Material: Nickel-plated Steel
   b. Length: 3 mm
3. Magnetic Screw Mounted Pressure Catcher and Matching Strike Model # 245.90.320
   a. Color: Black
   b. Material: plastic with steel strike
4. Flush Drawer Pull Model # 161.15.613
   a. Solid Stainless Steel

2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

B. Hafele America Co.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Follow manufacturer's supplied assembly instructions when installing all hardware, hanging racks, accessories, door handles, and hinges

END OF SECTION

http://www.hafele.com/us/products/97.asp

SECTION 12 52 23

OFFICE SEATING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for office seating.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. 12 year, all encompassing warranty also covers electrical components, casters, pneumatic cylinders, tilts, and all moving mechanisms. All labor is included in the warranty when work is performed in U.S. or Canada.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Aeron Chair with lumbar support

2.02 MANUFACTURERS

A. Herman Miller

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Basis of Design Product: Aeron® Chair (1994)

   a. Apotheosis of ergonomic seating, conceived to conform not only to different human shapes and weights but also to movement.

   b. Kinemat® tilt

   c. Pellicle web upholstery: evenly distributes weight over the seat and back and permits air circulation

   d. Greenguard Certified

2.04 MATERIALS

A. Pellicle fabric seat and adjustable back; die-cast aluminum arms, frame and base with black or titanium finish.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Assembly required.

2. Follow manufacturer’s supplied assembly instructions.

END OF SECTION

http://www.dwr.com/product/classics/view-all-licensed-classics/aeron-chair.do?sortby=ourPicks

SECTION 12 58 13

COUCHES AND LOVESEATS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for living room furniture.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

1.03 WARRANTY

A. Manufacturer Warranty

1. None specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Park Sofa by Jsper Morrison (2004)

2.02 MANUFACTURERS

A. VITRA

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Basis of Design Product: Park Sofa (2004)

a. Fabric: Fabric Credo 06 Antracite/Elephant

b. 75.5" L x 31" H x 33.5" D

c. All covers are removable.

2.04 MATERIALS

A. Polished aluminium feet, solid wood frame, polyurethane foam and polyester/wool upholstery.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Assembly required.

2. Follow manufacturer's supplied assembly instructions.

END OF SECTION

http://www.vitra.com/en-us/home/products/park-sofa/

SECTION 12 58 16

RESIDENTIAL CHAIRS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for living room chairs.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product and complete installation data for products in this specification.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. None specified.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Park Armchair by Jasper Morrison (2004)

2.02 MANUFACTURERS

A. Vitra

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Basis of Design Product: Park Armchair (2004)

a. Fabric: Fabric Credo 06 Antracite/Elephant

b. 30” L x 31” H x 33.5” D

c. All covers are removable.

2.04 MATERIALS

A. Park Armchair: Polished aluminum feet, solid wood frame, polyurethane foam and polyester/ wool upholstery.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Assembly required.
2. Follow manufacturer's supplied assembly instructions.

END OF SECTION

http://www.vitra.com/en-us/home/products/park-armchair-park-swivel-ar-1/

SECTION 12 58 19

DINING TABLES AND CHAIRS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for dining area tables, chairs, and barstools.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. Series 7 Chair: A five-year guarantee against manufacturing defects in standard products (materials and workmanship). Wear, tear and damage to the product is not covered under this warranty. Claims from end users under the guarantee must be submitted to the vendor from whom the product was purchased.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Fritz Hansen Series 7 Chair by Arne Jacobsen Model # 3107

B. Onda Counter Stool

C. Custom fabricated dining room table designed and manufactured by the Virginia Tech Solar Decathlon Team.

2.02 MANUFACTURERS

A. Republic of Fritz Hansen

B. Stua

C. Virginia Tech Solar Decathlon Team

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Basis of Design Product: Series 7 Chair
   a. Laminated walnut veneer with a steel base.
   b. 20.5" L x 31" H x 20" D
2. Basis of Design Product: Onda Counter Stool by Jesus Gasca (2006)
   a. Finish: Matte White Stone and Stainless Steel
   b. 33" H x 16" W x 14" D

c. Components are completely recyclable.

3. Custom fabricated dining room table designed and manufactured by the Virginia Tech Solar Decathlon Team.

a. Approximately 30” W x 64” L

2.04 MATERIALS

A. Series 7 Chair: The shell is in laminated, molded veneer. The outer veneer is sliced cherry, walnut, maple, ash, beech or dark-stained oak. The base is 14 mm steel tubes with 4 legs with leg ferrules of black-grey synthetic material.

B. Matte stainless steel frame; molded plastic seat shell with soft rubber skin.

C. Dining Table: Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer. (See specification 06 20 23 – Interior Finish Carpentry).

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Follow manufacturer’s supplied assembly instructions.

END OF SECTION

http://www.fritzhansen.com/content/us/architects/product_facts/product_fact_sheets_uk

http://www.dwr.com/product/classics/stua/onda-counter-stool-chrome.do?sortby=ourPicks

SECTION 12 58 23

COFFEE TABLES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for living area table.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Custom fabricated living area table designed and manufactured by the Virginia Tech Solar Decathlon Team.

B. Furniture feet by Hafele.

2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

B. Hafele

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Custom fabricated dining room table designed and manufactured by the Virginia Tech Solar Decathlon Team.
    a. Dimensions: Approximately 32” W x 32” L
2. Furniture Feet Model # 634.47.203
    a. Static Load rating approximately 55 lbs per foot.
    b. Furniture can be mounted on both sides.

2.04 MATERIALS

A. Coffee Table: Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer. (See specification 06 20 23 – Interior Finish Carpentry).

B. Brushed Steel, plated.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

SECTION 12 58 29

BEDS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for bed and mattress.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1. The product manufacturer shall provide maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. Tempur Production USA, LLC ("Tempur-Pedic") guarantees that we will, at Tempur-Pedic's option, replace or repair purchaser's Tempur-Pedic® mattress if it is defective due to faulty workmanship or materials. This warranty covers: deterioration causing the mattress to have a visible indentation greater than three-fourths (0.75) of an inch that is not associated with a sag in the foundation or adjustable bed base; and any physical flaw in the mattress that causes the TEMPUR material to split or crack, despite normal usage and proper handling (as outlined in the Mattress Use & Care Instructions).

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. PrimaBed by Tempur-pedic®

B. Custom fabricated bed frame designed and manufactured by the Virginia Tech Solar Decathlon Team.

2.02 MANUFACTURERS

A. Tempur Production USA, LLC

B. Virginia Tech Solar Decathlon Team

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. PrimaBed Queen Sized Bed
   a. Dual AirFlow System™
   b. Suede-trimmed, allergen-resistant cover
   c. Extra thick TEMPUR material Comfort Layer
   d. 60” W x 80” L
2. Custom fabricated bed frame designed and manufactured by the Virginia Tech Solar Decathlon Team.
   a. Approximately 62” W x 82” L

2.04 MATERIALS

A. Mattress: Comfort TEMPUR material Comfort

B. Bed Frame: Europly™ hardwood plywood consisting of domestic and imported urea-formaldehyde or phenol formaldehyde bonded unfinished or UV (clear, prime, pigment) coated hardwood industrial stock panels with veneer.
(See specification 06 20 23 – Interior Finish Carpentry).

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Follow manufacturer's supplied assembly instructions.

END OF SECTION

http://www.tempurpedic.com/mattresses/the_primabed_by_tempur_pedic/overview/

SECTION 12 58 90

EXTERIOR RESIDENTIAL FURNITURE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for exterior tables and lounge chairs.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 WARRANTY

A. Manufacturer Warranty

1. Repair or replace any frame, sling or top that has failed structurally or powdercoat that has blistered or peeled for a period of 10 years from the original purchase date under normal use and maintenance.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Lounge Chair With Arms

B. Adjustable Chaise Lounge

C. End Table With Porcelain Top

2.02 MANUFACTURERS

A. Richard Schultz Design

B. Richard Schultz Design

C. Richard Schultz Design

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Basis of Design Product: 1966-25 WWS Lounge Chair (or comparable product)
   a. Silver frame with a white mesh seat.
   b. 26" W x 26" H x 28.25" D
   c. Frame constructed from 95% recycle aluminum.
2. Basis of Design Product: 1966-42 WWW Adjustable Chaise Lounge (or comparable product)
   a. White frame with a white mesh seat.
   b. 25.5" W x 14" H x 76" D

c. Frame constructed from 95% recycle aluminum.

3. Basis of Design Product: 1966-18 WW End Table (or comparable product)

a. White table top with a white frame.

b. 18” W x 15.5” H x 18” D

c. Frame constructed from 95% recycle aluminum.

2.04 MATERIALS

A. Frame constructed from cast and extruded aluminum. Mesh seat consists of a woven vinyl coated polyester mesh.

B. Frame constructed from cast and extruded aluminum. Mesh seat consists of a woven vinyl coated polyester mesh.

C. Table top is made from porcelain enamel and placed on the steel frame that is constructed from cast and extruded aluminum.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Follow manufacturer’s supplied assembly instructions.

END OF SECTION

http://www.richardschultz.com/products/1966/index.asp

SECTION 13 31 23

TENSIONED FABRIC STRUCTURES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes specification for the following:

1. Tensioned fabric illuminated ceilings.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product and complete installation data for products in this specification.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

C. Product Samples

1. Before installation begins, manufacturer to provide material sample.

1.03 QUALITY ASSURANCE

A. Qualifications

1. An employer of workers trained and approved by manufacturer for installation and maintenance of units is required for this project.

1.04 WARRANTY

A. Manufacturer Warranty

1. 10 + 5: Manufactuer to provide an additional 5 years to an existing 10 year warranty on all professionally installed stretched fabric ceilings.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Daylight Illuminated Ceiling Translucent Stretch Fabric Ceiling System

2.02 MANUFACTURERS

A. EXTENZO®

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. The capacity of Stretch Ceilings to transmit light makes it possible to create remarkable atmospheres, either by using natural daylight, as in the case of a sky-dome for example, or by using other light sources whose effects can be controlled: variation in intensity, variation in colors, time control or sequencing.
2. Color: White unless otherwise specified.
3. Quick to fit, easy to take down and perfectly taut: Each ceiling, with its anchors welded to the edge, is made to measure in one of manufacturer factories.

4. Lamps, spotlights, air vents, speakers, all accessories can be integrated discreetly. Cables and piping are totally hidden.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

B. Manufacturer approved installation team.

3.02 INSTALLATION

A. Special Techniques

1. Taking measurements: provide shop drawings and construction documents to manufacturer for order specification.
2. Fitting Tracks: Peripheral tracks are fixed by screwing or stapling onto the wall or ceiling. Manufactuer to provide multi-purpose tracks.
3. Fitting Accessories: Custom fit posts, columns, integrated spotlights, chandeliers, light fixtures, sprinklers of any other accessory on-site.
4. Installation of the stretch ceiling: Prior to installation, the thermo-expandable stretch ceiling is softened by slightly raising the ambient temperature for the time needed to lock the anchors into the track. The stretch ceiling automatically becomes taut as it cools.
5. Follow manufacturer's supplied installation instructions and guides.

END OF SECTION

http://www.extenzo.com/index.php/Technical-applications/Illuminated-Ceiling-Backlit-Ceiling.html

SECTION 22 11 16

DOMESTIC WATER PIPING

PART 1 GENERAL

1.01 SUMMARY

A. This section includes

1. Specifications for water-distribution piping
2. Fittings and valves
3. Manifolds

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Installation

1.03 QUALITY ASSURANCE

A. Piping materials shall bear label, stamps, or other markings of specified testing agency.

B. Comply with ASTM F 645 for selection, design, and installation of thermoplastic water piping.

C. Comply with NSF 61 for materials for water-service piping and specialties for domestic water.

1.04 PROJECT CONDITIONS

A. Coordinate with Solar Decathlon Organizers to request amount of water needed during competition.

B. Coordinate connection to water main with utility company in permanent situations.

PART 2 PRODUCTS

2.01 PIPE

A. PEX Plumbing

1. Comply with NSF/ANSI 14/61 Listed for Use in potable water systems.
2. Explicitly approved in the Uniform Plumbing Code, International Plumbing Code, and International Residential Code. Listed by ICC, IAPMO, and CSA

B. MANUFACTURERS

1. REHAU AG & Co.

2.02 FITTINGS AND VALVES

A. BRASS FITTINGS

1. Comply with ASTM F 2080, ASTM F 877, NSF 61, CSA B 137.5

B. MANUFACTURERS

1. REHAU AG & Co.

2.03 MANIFOLDS

A. COPPER MANIFOLD

1. Accommodates 2 gpm per circuit up to 16 gpm per manifold

B. MANUFACTURERS

1. REHAU AG & Co.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Tools: To be done with manufacturer recommended and provided tools

B. Instructions: To be done in a manufacture approved manner

END OF SECTION

http://www.paintdocs.com/webmsds/webPDF.jsp?SITEID=STORECAT&prodno=640363958&doctype=PDS&lang=E
http://www.paintdocs.com/webmsds/webPDF.jsp?SITEID=STORECAT&prodno=6006258&doctype=PDS&lang=E
http://na.rehau.com/files/Radiant_Heating_Systems_Product_Catalog_7.07.pdf

SECTION 22 11 23

DOMESTIC WATER PUMPS

PART 1 GENERAL

1.01 SUMMARY

A. This section includes

1. UP15-10SU7P/TLC
2. J5S
3. Taco 005-F

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Installation

1.03 QUALITY ASSURANCE

A. Use only approved liquids by manufactures recommendations

PART 2 PRODUCTS

2.01 PUMPS

A. UC17

1. Requirements
    a. ANSI/ NSF61 and IAPMO listed
2. Performance
    a. Max flow- 3.4 GPM
    b. Max head- 3.5 ft head
    c. Temperature Range- 36° – 150° F
    d. Max Operating Pressure- 145 PSI

B. J5S

1. Requirements
    a. UL778 listed
    b. NEMA standard motor
    c. ISO 9001 listed
    d. FDA compliant
2. PERFORMANCE
    a. Max flow- 17.5 GPM
    b. Max Operational Pressure- 63 PSI
    c. Max Temperature- 150° F

C. TACO 005-F

1. Requirements
    a. UL listed

2. PERFORMANCE
   a. Flow range- 0-18 gallons
   b. Head range- 0- 9.5 feet
   c. Minimum fluid temperature- 40° F
   d. Maximum temperature- 230° F
   e. Maximum pressure- 125 psi

2.02 MANUFACTURERS

A. Grundfos

B. Goulds Pumps

C. TACO

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Will be done with approved tools and in a manner consistent with proper pipe joining methods

END OF SECTION

http://www.watertanks.com/images/pdf/watertankscom-goulds-boosterpumps.pdf
http://www.plumbersurplus.com/pdf/01208.pdf
http://www.kingsolar.com/catalog/mfg/taco/005.pdf

SECTION 22 12 19

FACILITY GROUND-MOUNTED, POTABLE-WATER STORAGE TANKS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for energy efficient hot water storage tank.
2. Specification for the diaphragm pressure tank

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1.03 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Bring in the entire tank in its original packaging to the final installation location. This will protect the tank better during transport.
2. One can move the solar water heater tank SM300/1 with a hand dolly also with a lifting crane or device.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Logalux SM300

2.02 MANUFACTURERS

A. Buderus

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. 77 gallon tank.
2. Maximum water temperature of 203°F.
3. Maximum operating pressure of 145 psi.

2.04 MATERIALS

A. Solar hot water tank consists of:

1. Tank shell with corrosion protection.
   a. The cathodic corrosion protection consists of hygienic Buderus Thermoglaze Duo-Clean and a magnesium anode protection system.
2. Tank insulation made from non FCKW insulation material that is directly attached to the tank shell.
3. Two smooth high output heat transfer coils that transfer the energy from the solar and/or heating system to the domestic water inside the tank shell.
4. Dry well for installation of DHW tank temperature sensor.

a. The DHW temperature control of the boiler system controls the DHW temperature.

5. Hand hole cover for service and maintenance access.
6. Dual magnesium anodes.
7. Jacket cover.

B. Tank kit fittings:

1. Tee piece with P & T relief valve.
2. Bracket for mounting of aquastat.
3. Spacer set for securing DHW tank sensor.
4. Cover cap for DHW recirculation connection.
5. Tee piece with tank drain valve.

2.05 PRODUCT TYPE

A. H2 Pro WWT

2.06 MANUFACTURER

A. Flexicon

2.07 PERFORMANCE/ DESIGN CRITERIA

A. Capacities

1. 33.4 gallon tank
2. Maximum water temperature- 140°F.
3. Maximum operating pressure 125 psi.

2.08 MATERIALS

A. Pressure tank consists of

1. 16 gage rolled steel tank.
2. Butyl rubber upper chamber diaphragm.
3. copolymer polypropylene lower chamber diaphragm

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Verification of Conditions

1. Minimum 12" overhead space is required for the removal of the magnesium anode rod as well as some side clearance.
2. Maintain 2" clearance from heated pipes to combustible surfaces.
3. Place the solar tank in a frost free room.
4. Place solar tank on a level and sufficiently strong floor.

3.03 INSTALLATION

A. Follow all specific state and local codes regarding the installation and operation of the equipment.

B. Special Techniques

1. See the Installation and Maintenance Manual for instructions on solar tank assembly, system start-up and shut-down, and the installation of:
   a. Tank temperature sensor.
   b. Aquastat.
   c. Water side piping connections.
   d. Tank kit components.

3.04 MAINTENANCE

A. Recommendation for end customer: Please sign up for an annual service and maintenance contract with your installer. Make sure to have annual maintenance performed on your boiler and solar system.

B. Use shorter service intervals in case of hard or extremely hard water conditions and high temperature operation.

C. Use only original replacement parts. See the Installation and Maintenance Manual for a list of replacement parts.

D. See the Installation and Maintenance Manual for instructions on checking and replacing the magnesium anode rod, and cleaning the hot water tank.

3.05 CLEANING

A. Waste Management
   1. The Bosch Group is dedicated to adhere to country specific disposal standards as it relates to packaging to ensure optimum recycling. All packaging materials are environmental friendly and can be recycled.
   2. Obsolete products contain raw materials that can be recycled. The components are easily separated and are clearly marked. In this manner the individual components are easily sorted and added into the recycling and disposal stream.

END OF SECTION

http://www.buderus.net/OurProducts/DomesticHotWaterTanks/LogaluxSM300SM400/MechanicalThermalSpecifications/tabid/588/Default.aspx
http://www.buderussolar.com/LinkClick.aspx?fileticket=2iPerrti7GQ%3d&tabid=285&mid=1041

SECTION 22 13 16

SANITARY WASTE AND VENT PIPING

PART 1 GENERAL

1.01 SUMMARY

A. This section includes specifications for waste water removal piping

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Installation

1.03 QUALITY ASSURANCE

A. Piping materials shall bear label, stamps, or other markings of specified testing agency.

PART 2 PRODUCTS

2.01 PIPE

A. PVC PIPE AND FITTINGS

1. Pipes shall comply with one of the following per the ICC
    a. ASTM D 2665
    b. ASTM D 2949
    c. ASTM F 1488
    d. CSA B 1 & 1.2
2. Pipe fittings shall comply with
    a. ASTM D 2665
    b. ASTM D 3311
    c. ASTM F1866

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Tools: To be done with manufacturer recommended tools and/ or chemicals

B. Instructions: To be done in a manufacture approved manner

C. Installation is to comply with ICC 705.14

<u>END OF SECTION</u>

International Plumbing Codes

SECTION 22 13 19.36

Air-Admittance Valve

PART 1 GENERAL

1.01 SUMMARY

A. This section includes the specifications of air admittance valves

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Installation

1.03 QUALITY ASSURANCE

A. Used only in a manufacturer and ICC approved manner

B. Lifetime warranty

C. Listed by

1. ASSE seal of approval
2. National Evaluation Service
3. NSF national (NSF Standard 14)
4. NSF national (ANSI/ASSE Performance Standard 1051 and ASSE 1050)
5. IAMPO Classified Marking, file no. C3803
6. Warnock Hersey (ITS-Intertek Test Service

PART 2 PRODUCTS

2.01 Air-admittance valves

A. Mini-vent or similar model

1. 1 ½” to 2” NPT adapter
2. Max DFU- 3 to 6
3. Accommodates negative pressure in the drainage system

B. Manufacturer

1. Studor

C. Approving codes

1. IPC- 2003
2. SBCCI- 1994
3. BOCA- 1993
4. IRC- 2003
5. UPC

D. Materials

1. polystyrene
2. ABS (acrylonitrile butadinene styrene
3. ABS or PVC adaptor

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Will be done with approved tools and in a manner consistent with proper pipe joining methods

B. The installment of the air admittance valve will be done in a manner allowing the valve to be at least 4" above the branch or weir of the trap

END OF SECTION

http://www.ipscorp.com/pdf/studor/StudorSpec_MiniVent.pdf

SECTION 22 14 26.13

ROOF DRAINS

PART 1 GENERAL

1.01 SUMMARY

A. This section includes specifications for roof drain

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Installation

1.03 QUALITY ASSURANCE

A. Product will comply with manufacturer’s recommended usage

PART 2 PRODUCTS

2.01 PIPE AND FITTINGS

A. Roof Drains

1. The roof drain shall comply with ASME A112.21.2M or ASME A112.3.1

B Fittings

2. Fittings shall comply with ICC 1102.7

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Instructions: The team will install the drains in a manufacture approved manner

B. Roof drains that pass through the interior of the building will be sealed to the building with an approved flashing material

<u>END OF SECTION</u>

International Plumbing Codes

SECTION 22 41 13

RESIDENTIAL WATER CLOSETS, URINALS, AND BIDETS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for residential water closet fixture.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

A. Qualifications

1. An employer of workers trained and approved by manufacturer for installation and maintenance of units is required for this project.

B. Testing

1. Specified model meets or exceeds the following: ASME A112.19.2, CSA B45, ASME A112.19.14, EPA WaterSense®

1.04 WARRANTY

A. Manufacturer Warranty

1. Manufacturer's plumbing products are warranted to be free of defects in material and workmanship for one year from date of installation. Manufacturer will, at its election, repair, replace or make appropriate adjustment where Manufacturer's inspection discloses any such defects occurring in normal usage within one (1) year after installation. Manufacturer is not responsible for removal or installation costs.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Saile® elongated one-piece toilet with dual flush technology (K-3564)

1. Manufacturer's Product Specification: The one-piece toilet with elongated bowl shall be made of vitreous china. Toilet shall be 28-1/2″ in length, 14-1/4" in width, and 28-3/4" in height. Toilet shall feature a required minimum 12" rough-in and 2-1/8″ fully glazed trapway. Toilet shall feature a dual flush flushing system. Toilet shall be high efficiency with 1.6 gpf (6 lpf) or 0.8 gpf (3 lpf). Toilet shall feature a skirted bowl design. Toilet shall include a polished chrome top-mount flush actuator. Toilet shall include a Saile seat and cover [K-4748]. Toilet shall be less supply. Toilet shall be Kohler Model K-3564.

2.02 MANUFACTURERS

A. Kohler, Co.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Elongated bowl.
2. Dual flush flushing system.
3. Skirted bowl design.
4. One-piece.
5. Less supply; 0.8 gpf

2.04 ACCESSORIES

A. Dual flush actuator (K-9384) included.

2.05 FINISHES

A. Finish Materials

1. Vitreous china available in white
2. Polished Chrome trip lever

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Install according to manufacturer's installation guide.

END OF SECTION

http://www.us.kohler.com/onlinecatalog/detail.jsp?item=13150202&section=2&category=13&subcategory=117

SECTION 22 41 40

Residential Plumbing Fixtures

PART 1 GENERAL

1.01 SUMMARY

A. This section includes the following:

1. Kitchen and lavatory sinks.
2. Faucets for kitchen and lavatory sinks.
3. Shower head.
4. Shower valve.
5. Shower drain.

1.02 SUBMITTALS

A. Product Data: For each type of product indicated.

B. Operation and maintenance data.

1.03 QUALITY ASSURANCE

A. Regulatory Requirements: Comply with requirements in ICC A117.1, “Accessible and Usable Buildings and Facilities” for plumbing fixtures for people with disabilities.

B. Regulatory Requirements: Comply with requirements in Public Law 102-486, “Energy Policy Act,” about water flow and consumption rates for plumbing fixtures.

C. NSF Standard: Comply with NSF 61, “Drinking Water System Components-Health Effects,” for fixture materials that will be in contact with potable water.

D. Select combinations of fixtures and trim, faucets, and other components that are compatible.

E. Comply with the following applicable standards and other requirements specified for plumbing fixtures:

1. Slip-Resistant Bathing Surfaces: ASTM F 462.
2. Stainless Steel Residential Sinks: ASME A112.19.3.

F. Comply with the following applicable standards and other requirements specified for lavatory and sink faucets:

1. Faucets: ASME A112.18.1.
2. NSF Potable –Water Materials: NSF 61.
3. Pipe Threads: ASME B1.20.1.
4. Supply Fittings: ASME A112.18.1.
5. Brass Waste Fittings: ASME A112.18.2.

G. Comply with the following applicable standards and other requirements for shower faucets:

1. Faucets: ASME A112.18.1.
2. Hose Coupling Threads: ASME B1.20.7.
3. Pipe Threads: ASME B1.20.1.

H. Comply with the following applicable standards and other requirements specified for Miscellaneous fittings:
   1. Atmospheric Vacuum Breakers: ASSE 1001.
   2. Brass and Copper Supplies: ASME A112.18.1.
   3. Manual Operation Flushometers: ASSE 1037.
   4. Plasitc Tubular Fittings:ASTM F 409.
   5. Brass Waste Fittings: ASME A112.18.2.

I. Comply with the following applicalble standards and other requirements specified for miscellaneous components:
   1. Flexivble Water Connectors: ASME A112.18.6.
   2. Grab Bars: ASTM F 446.
   3 Hose Coupling Threads: ASME B1.20.7.
   4. Pipe Threads: ASME B1.20.1.

PART 2 PRODUCTS

2.01 KITCHEN AND LAVATORY SINKS

A. Kitchen Sinks
   1. Basis-of-Design Product: Subject to compliance with requirements, provide Blanco MicroEdge Single Bowl Model 516193 manufactured by BLANCO AMERICA or a comparable product from one of the following manufacturers:
      a. Kohler Co.
      b. Eljer
      c. Vola
   2. Description: One-bowl, residential, under-counter mounting 18 ga. Stainless steel kitchen sink.
      a. Overall Dimensions: 22 in by 18 in
      b. Metal Thickness: 18 gauge
      c. Bowl: Dimensions: 20 in by 16 in
      d. Depth: 10 in

B. Lavatory Sinks
   1. Basis-of-Design Product: Subject to compliance with requirements, provide Kohler Conical Bell model K-2200-0 or a comparable product from one of the following manufacturers:
      a. Eljer

b. Vola

2. Description: Above-the-counter mounted, vitreous china fixture.

a. Type: Vessel

b. Size: 16-1/4” round

c. Color: White

d. Supplies: NPS 3/8 (DN 10) chrome-plated copper with stops.

2.02 KITCHEN AND LAVATORY FAUCETS AND FIXTURES

A. Kitchen Faucets

1. Basis-of-Design Product: Subject to compliance with requirements, provide Dornbracht Tara Ultra Single Lever Mixer model #303800875 or a comparable product from one of the following manufacturers:

a. Vola

b. Kohler Co.

2. Description: Single-lever mixer with rinsing spray set and strainer waste with control handle.

a. Type: Single lever projection

b. Size: height of fitting 373 mm

c. Material: Brass with Chrome finish

d. Specifications: swivel spout, aerator M 22 x 2 – female thread cartridge with ceramic discs, 2 pressure hoses M10 x 1 x 420 mm.

B. Lavatory Faucets

1. Basis-of-Design Product: Subject to compliance with requirements, provide Kohler Co. Stillness wall-mount lavatory faucet model # K-T944-4 or comparable product from one of the following manufacturers:

a. Vola

2. Description: Wall-mount lavatory faucet trim.

a. Type: Two-handle faucet for wall-mount installations

b. Construction: Solid brass

c. Finish: Polished Chrome

d. Fluid design for ease of cleaning

2.03 SHOWER FIXTURES, DRAINS AND VALVES

A. Showerhead

1. Basis of Design Product: Subject to compliance with requirements, provide Kohler Co. Rain Contemporary Showerhead model # K-10121 or comparable product from one of the following manufacturers:

a. Dornbracht

b. Hansgrohe

2. Description: Single faucet rain simulation showerhead

a. Flow Rate: 2.5 gpm

b. Construction: Solid brass

c. Finish: Polished Chrome

B. Shower Drain

1. Basis of Design Product: Subject to compliance with requirements, provide Quick Drain, USA low profile linear shower drain model # LDBO30SS or comparable product from one of the following manufacturers:

a. Kohler Co.

2. Description: Low profile, liner trench shower drain.

a. Dimensions: 32” length x 1.5” width

b. Finish: Brush stainless steel

C. Shower Valve

1. Basis of Design Product: Subject to compliance with requirements, provide Kohler Co. Taboret Rite-Temp pressure-balancing valve trim model # K-T8228-4 or comparable products from one of the following manufacturers:

a. Dornbracht

b. Hansgrohe

2. Description: Single-function showerhead, arm and flange.

a. Finish: Polished Chrome

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Manufacturer's Instructions: All installation shall follow manufacturer-provided installation guides and approved techniques.

END OF SECTION

http://www.blancoamerica.com/index.html?p=PRODUCT_PORTFOLIO

http://www.us.kohler.com/onlinecatalog/detail.jsp?item=166802&section=2&category=16

http://www.dornbracht.com/en/

http://www.us.kohler.com/onlinecatalog/detail.jsp?item=6124202&section=2&category=8&subcategory=49

http://www.us.kohler.com/onlinecatalog/detail.jsp?item=9910302&section=2&category=8&subcategory=50

http://www.us.kohler.com/onlinecatalog/detail.jsp?item=540602&section=2&category=8&subcategory=50

http://www.quickdrainusa.com/index.html

SECTION 23 07 13

DUCT INSULATION

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for duct lining and insulation.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
2. ASTM C1071, Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material).
3. ASTM G21, Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.
4. ASTM C553, Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications.

B. National Fire Protection Association:

1. NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials.

1.03 ACTION SUBMITTALS

A. Product Data

1. Provide product description, thermal characteristics, list of materials and thickness for each service, and locations.

B. Manufacturer’s Instructions

1. Indicate installation procedures which ensure acceptable workmanship and installation standards will be achieved.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Company specializing in manufacturing products of the type specified in this section with not less than three years of documented experience.
2. Company specializing in performing the type of work specified in this section, with minimum 5 years of experience and approved by manufacturer.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Accept materials on site in original factory packaging, labeled with manufacturer's identification, including product density and thickness.

B. Storage and Handling Requirements
  1. Protect insulation from weather and construction traffic, dirt, water, chemical, and mechanical damage, by storing in original wrapping.

1.06 FIELD OR SITE CONDITIONS

A. Ambient Conditions
  1. Maintain ambient temperatures and conditions required by manufacturers of adhesives, mastics, and insulation cements.
  2. Maintain temperature during and after installation for minimum period of 24 hours.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Duct liner and insulation.

2.02 MANUFACTURERS

A. Owens Corning Corp.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Insulation
  1. Apparent Thermal Conductivity: Maximum of 0.31 at 75 degrees F (0.045 at 24 degrees C).
  2. Service Temperature: Up to 250 degrees F (121 degrees C).
  3. Rated Velocity on Coated Air Side for Air Erosion: 5,000 fpm (25.4 m/s), minimum.

2.04 DESCRIPTION

A. Regulatory Requirements
  1. Surface Burning Characteristics: Flame spread/Smoke developed index of 25/50, maximum, when tested in accordance with ASTM E84, NFPA 255, or UL 723.

2.05 MATERIALS

A. Incombustible glass fiber complying with ASTM C1071; flexible blanket, rigid board, and preformed round liner board; impregnated surface and edges coated with poly vinyl acetate polymer, or acrylic polymer shown to be fungus and bacteria resistant by testing to ASTM G21.

B. Insulation: ASTM C553; flexible, noncombustible blanket.

C. Vapor Barrier Jacket
  1. Kraft paper with glass fiber yarn and bonded to aluminized film.
  2. Secure with pressure sensitive tape.

D. Adhesive: Waterproof, fire-retardant type.

E. Liner Fasteners: Galvanized steel, self-adhesive pad with integral head.

PART 3 EXECUTION

3.01 INSTALLERS

A. A1 Heating & Cooling

3.02 EXAMINATION

A. Verification of Conditions

1. Verify that ducts have been tested before applying insulation materials.
2. Verify that surfaces are clean, foreign material removed, and dry.

3.03 INSTALLATION

A. Special Techniques

1. Install in accordance with manufacturer's instructions.
2. Install in accordance with NAIMA National Insulation Standards.
3. Insulated ducts conveying air below ambient temperature:
   a. Provide insulation with vapor barrier jackets.
   b. Finish with tape and vapor barrier jacket.
   c. Continue insulation through walls, sleeves, hangers, and other duct penetrations.
   d. Insulate entire system including fittings, joints, flanges, fire dampers, flexible connections, and expansion joints.
4. Duct and Plenum Liner Application:
   a. Adhere insulation with adhesive for 90 percent coverage.
   b. Secure insulation with mechanical liner fasteners. Refer to SMACNA HVAC Duct Construction Standards - Metal and Flexible for spacing.
   c. Seal and smooth joints; seal and coat transverse joints.
   d. Seal liner surface penetrations with adhesive.
   e. Duct dimensions indicated are net inside dimensions required for air flow. Increase duct size to allow for insulation thickness.

END OF SECTION

SECTION 23 07 19

HVAC PIPING INSULATION

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Piping insulation, jackets, and accessories.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
2. ASTM C547, Standard Specification for Mineral Fiber Pipe Insulation.
3. ASTM C795, Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel.
4. ASTM E96, Standard Test Methods for Water Vapor Transmission of Materials.

B. National Fire Protection Association:

1. NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials.

1.03 ACTION SUBMITTALS

A. Product Data

1. Provide product description, thermal characteristics, list of materials and thickness for each service, and locations.

B. Manufacturer’s Instructions

1. Indicate installation procedures which ensure acceptable workmanship and installation standards will be achieved.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Company specializing in manufacturing products of the type specified in this section with not less than three years of documented experience.
2. Company specializing in performing the type of work specified in this section, with minimum 5 years of experience and approved by manufacturer.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Accept materials on site in original factory packaging, labeled with manufacturer's identification, including product density and thickness.

1.06 FIELD OR SITE CONDITIONS

A. Ambient Conditions

1. Maintain ambient temperatures and conditions required by manufacturers of adhesives, mastics, and insulation cements.

2. Maintain temperature during and after installation for minimum period of 24 hours.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Glass fiber insulation and vapor barrier jackets.

2.02 MANUFACTURERS

A. Owens Corning Corp.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Insulation

1. Maximum service temperature: 650 degrees F (343 degrees C).

2. Maximum moisture absorption: 0.2 percent by volume.

2.04 DESCRIPTION

A. Regulatory Requirements

1. Surface Burning Characteristics: Flame spread/Smoke developed index of 25/50, maximum, when tested in accordance with ASTM E84, NFPA 255, or UL 723.

2.05 MATERIALS

A. Insulation: ASTM C547 and ASTM C795; semi-rigid, noncombustible, end grain adhered to jacket.

B. Vapor Barrier Jacket

1. White kraft paper with glass fiber yarn, bonded to aluminized film; moisture vapor transmission when tested in accordance with ASTM E96 of 0.02 perm-inches (0.029 ng/Pa s m).

C. Canvas Jacket

1. UL listed 6 oz/sq yd (220 g/sq m) plain weave cotton fabric treated with dilute fire retardant lagging adhesive.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Verification of Conditions

1. Verify that piping has been tested before applying insulation materials.

2. Verify that surfaces are clean, without foreign material, and dry.

END OF SECTION

SECTION 23 09 13.33

CONTROL VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Three-way valve
2. Modulating control valve with magnetic actuator
3. Electronic valve actuator
4. Two-way control valve
5. Electronic damper actuator
6. Three-way ball valve

1.02 REFERENCES

A. American National Standards Institute

1. ANSI Leakage Class IV (0.01% of Cv)
2. ANSI Class 250

B. Underwriters Laboratories, Inc.

1. UL873
2. UL873
3. UL60730 (to replace UL873)

1.03 ACTION SUBMITTALS

A. Product Data

1. The medium to be controlled: water, etc.
2. The maximum inlet temperature and pressure of the medium at the valve.
3. The pressure differential that will exist across the valve under maximum load.
4. The maximum capacity the valve must deliver.
5. The maximum line pressure differential the valve actuator must close against.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Powermite 599 Series MT Series Terminal Unit or similar

B. MXG461…U or similar

C. Powermite 599 MT Series SSC or similar

D. Powermite 599 Series MT Series Terminal Unit or similar

E. OpenAir™ GMA Series Spring Return Rotary or similar

F. 599 Series or similar

2.02 MANUFACTURERS

A. Siemens

B. Siemens

C. Siemens

D. Siemens

E. Siemens

F. Siemens

2.03 PERFORMANCE / DESIGN CRITERIA

A. Powermite 599 Series MT Series Terminal Unit or similar
   1. Valve size 1/2 inch to 1 inch (15 to 25 mm)
   2. Body style: Globe
   3. Seat style Metal-to-metal
   4. Stem travel (Stroke) 7/32-inch (5.5 mm)

B. MXG461…U or similar
   1. Supply voltage 24 Vac, 50/60 Hz
   2. Operating pressure pemax 145 psi (1 Mpa)(10 bar)
   3. Temperature of medium 36°F to 248°F (2°C to 120°C)

C. Powermite 599 MT Series SSC or similar
   1. Operating voltage 24 Vac ±20%
   2. Running time at 50/60 Hz 30 sec ±10%
   3. Nominal force 67 lb (300N)
   4. Nominal stroke 7/32-inch (5.5 mm)

D. Powermite 599 Series MT Series Terminal Unit or similar
   1. Valve size 1/2 inch to 1 inch (15 mm to 25 mm)
   2. Body style Globe
   3. Seat style Metal-to-metal
   4. Stem travel (Stroke) 7/32-inch (5.5 mm)

E. OpenAir™ GMA Series Spring Return Rotary or similar
   1. Operating voltage 24 Vac ±20%; 24 Vdc ±15%
   2. Running/spring return torque 62 lb-in (7 Nm)
   3. Runtime for 90° operating with motor 90 seconds

F. 599 Series or similar
   1. Static pressure 360 psi (2482 kPa)
   2. Media temperature 35°F to 250°F (2°C to 121°C)
   3. Controlled medium Water, glycol solutions to 50%
   4. Ball seals Reinforced PTFE seals with EPDM O-rings

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Manufacturer Installation Instructions

1. Install the valve so that the flow follows the direction of the arrow indicated on the valve body. For best performance, install the valve assembly with the actuator above the valve body. The valve and actuator can be installed in any position between vertical and horizontal. It is not recommended to install the valve assembly so that the actuator is below horizontal or upside down. Allow sufficient space for servicing the valve and actuator.
2. MXG461...U screwed valves are flat-faced to facilitate sealing with the gaskets supplied. Do not use hemp, tape or thread-sealing compound. Do not insulate the actuator.
3. When mounting the actuator in a plenum, the proper cable must be attached to meet local codes. Allow 8 inches (200 mm) above the actuator and 8 inches (200 mm) behind the cable for service.
4. Install the valve so that the flow follows the direction of the arrow indicated on the valve body. For best performance, install the valve assembly with the actuator above the valve body. The valve and actuator can be installed in any position between vertical and horizontal. It is not recommended to install the valve assembly so that the actuator is below horizontal or upside-down.
5. See the detailed mounting instructions included with each actuator.
6. Install the valve so that the flow follows the direction of the arrow cast on the valve body. For best performance, install the valve assembly with the actuator above the valve body. The valve and actuator assembly can be installed in a horizontal pipe in any position between vertical and 45°. Do not install the valve assembly so that the actuator is below horizontal or upside-down.

END OF SECTION

http://www.lutron.com/CMS400/page.aspx?id=25823

SECTION 23 09 23

DIRECT DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 GENERAL

1.01 SCOPE OF WORK

A. The Building Automation System (BAS) manufacturer shall furnish and install a fully integrated building automation system, incorporating direct digital control (DDC) for energy management, as well as equipment monitoring and control.

B. The installation of the control system shall be performed under the direct supervision of the controls manufacturer.

C. BAS manufacturer shall be responsible for all BAS and Temperature Control wiring for a complete and operable system. All wiring shall be done in accordance with all local and national codes.

1. 02 WORK BY OTHERS

A. All wells, valves, taps, dampers, flow stations, etc. furnished by BAS manufacturer shall be installed by others.

B. Electrical (Power) Contractor provides:

1. 120V power to all BAS an/or Temperature control panels
2. Wiring of all power feeds through all disconnect starters to electrical motor.
3. Wiring of any remote start/stop switches and manual or automatic motor speed control devices not furnished by BAS manufacturer
4. Wiring of any electrical sub-metering devices furnished by BAS manufacturer.

C. Products furnished but not installed under this section

1. Section 15xxx - Hydronic Piping:
   a. Control Valves
   b. Temperature Sensor Wells and Sockets
2. Section 15xxx - Refrigerant Piping:
   a. Temperature Sensor Wells and Sockets (water side)
3. Section 15xxx - Duct-work Accessories:
   a. Terminal Unit Controls

D. Products not furnished under this section

1. Section 15xxx - Air Handling Equipment:
   a. Thermostats
   b. Sensors needed for safety circuits and limits
   c. Controllers as provided for local control of equip.

1.03 QUALITY ASSURANCE

A. The BAS system shall be designed and installed, commissioned and serviced by manufacturer employed, factory trained personnel. Distributors or licensed installing contractors are not acceptable. The manufacturer shall provide an experienced project manager for this work, responsible for direct supervision of the design, installation, start up and commissioning of the B.M.S.

B. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.

C. All BAS peer-to-peer network controllers, central system controllers and local user displays shall be UL Listed under Standard UL 916, category PAZX; Standard ULC C100, category UUKL7; and under Standard UL 864, categories UUKL, UDTZ, and QVAX. and be so listed at the time of bid. All floor level controllers shall comply, at a minimum, with UL Standard UL 91 6category PAZX; Standard UL 864, categories UDTZ, and QVAX. and be so listed at the time of Bid.

D. DDC peer-to-peer controllers shall be compliant with the European EMC Directive, Standards EN 50081-2 and EN 50082-2, at the Industrial Levels. Additionally the equipment shall be compliant with the European LVD Directive and bear the CE mark in order to show compliance to both Directives."

E. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference and be so labeled.

1. 04 SUBMITTALS

A. Submit 5 complete sets of documentation in the following phased delivery schedule:

1. Valve and damper schedules (as needed)
2. Equipment data cut sheets
3. System schematics, including:
    a. sequence of operations
    b. point names
    c. point addresses
    d. interface wiring diagrams
    e. panel layouts
    f. system riser diagrams
4. Auto-CAD compatible as-built drawings

B. Upon project completion, submit operation and maintenance manuals, consisting of the following:

a. Manufacturer's equipment parts list of all functional components of the system
b. Auto-CAD disk of system schematics, including wiring diagrams
c. Description of sequence of operations
d. As-Built interconnection wiring diagrams
e. Operator's Manual
f. Trunk cable schematic showing remote electronic panel locations and all trunk data

g. List of connected data points, including panels to which they are connected and input device (ionization detector, sensors, etc.)

1.05 WARRANTY

A. Provide all services, materials and equipment necessary for the successful operation of the entire BAS system for a period of one year after beneficial use.

PART 2 PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Siemens Building Technologies, Inc.

2.02 NETWORKING COMMUNICATIONS

A. The design of the BAS shall network operator workstations and stand-alone DDC Controllers. The network architecture shall consist of multiple levels for communication efficiency, a campus-wide (Management Level Network) Ethernet network based on TCP/IP protocol, high performance peer-to-peer building level network(s) and DDC Controller floor level local area networks with access being totally transparent to the user when accessing data or developing control programs.

B. The design of BAS shall allow the co-existence of new DDC Controllers with existing DDC Controllers in the same network without the use of gateways or protocol converters.

1. System shall have the capability to communicate with a BACnet network over Ethernet or BACnet/IP (according to Annex J). The intent is to use the system provided under this contract to communicate with control systems provided by other vendors. A PICS must be provided describing the BACnet, ANSI/ASHRAE 135-2001 implementation. Minimum system functionality must include monitoring, commanding, and alarming for daily operator functions from a common workstation.

C. Peer-to-Peer Building Level Network:

1. All network resident operator devices or connected via dial-up modems shall have the ability to access all point status and application report data or execute control functions for any and all other devices via the peer-to-peer network. No hardware or software limits shall be imposed on the number of devices with global access to the network data at any time.
2. Field panels must be capable of integration with open standards including Modbus, BACnet, and Lonworks as well as with third party devices via existing vendor protocols.
3. The peer-to-peer Building Level Network shall use the TCP/IP over Ethernet or RS-485 communications.

D. Management Level Network (MLN)

All Ethernet-capable PCs shall simultaneously direct connect to the Ethernet Management Level Network without the use of an interposing device.

1. Operator Workstation shall be capable of simultaneous direct connection and communication with BACnet, OPC, and APOGEE MLN networks.
2. When appropriate, any controller residing on the peer-to-peer building level networks shall connect to Ethernet network without the use of a PC or a gateway with a hard drive.
3. Any PC on the Ethernet Management Level Network shall have transparent communication with controllers on the building level networks connected via Ethernet, as well as, directly connected building level networks.
4. Any break in Ethernet communication from the PC to the controllers on the building level networks shall result in an alarm notification at the PC.
5. The standard client (if used) and server workstations on the Management Level Network shall reside on industry standard Ethernet utilizing standard TCP/IP, IEEE 802.3
6. Any break in Ethernet communication between the standard client and server workstations on the Management Level Network shall result in a notification within the Windows taskbar at each workstation.

2.03 DDC CONTROLLER FLOOR LEVEL NETWORK:

A. This level communication shall support a family of application specific controllers and shall communicate with the peer-to-peer network through DDC Controllers for transmission of global data.

2.04 DDC CONTROLLERS

A. The DDC Controllers shall reside on the Building Level Network.

B. DDC Controllers shall use the same programming language and tools.

2.04.1 DDC CONTROLLER

A. DDC Controllers shall be a 16-bit stand-alone, multi-tasking, multi-user, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size shall be sufficient to fully meet the requirements of this specification and the attached point I/O schedule.

B. Each DDC Controller shall have sufficient memory to support its own operating system and databases, including:

1. Control processes
2. Energy management applications
3. Alarm management applications including custom alarm messages for each level alarm for each point in the system.
4. Historical/trend data for points specified
5. Maintenance support applications
6. Custom processes
7. Password-protected Operator I/O
8. Dial-up communications
9. Manual override monitoring

C. Provide all processors, power supplies and communication controllers so that the implementation of a point only requires the addition of the appropriate point input/output termination module and wiring.

D. DDC Controllers shall provide a RS-232C serial data communication ports for operation of operator I/O devices, such as industry standard printers, operator terminals, modems and portable laptop operator's terminals.

E. The operator shall have the ability to manually override automatic or centrally executed commands at the DDC Controller via local, point discrete, on-board hand/off/auto operator override switches for digital control type points and gradual switches for analog control type points.

1. DDC Controllers shall monitor the status of all overrides and inform the operator that automatic control has been inhibited. DDC Controllers shall also collect override activity information for reports.

F. DDC Controllers shall provide local LED status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device.

G. Each DDC Controller shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components.

H. Isolation shall be provided at all peer-to-peer network terminations, as well as all field point terminations to suppress induced voltage transients consistent with:

1. RF-Conducted Immunity (RFCI) per ENV 50141 (IEC 1000-4-6) at 3 V
2. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact
3. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500 V signal, 1 kV power
4. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max)
5. Isolation shall be provided at all peer-to-peer panel's AC input terminals to suppress induced voltage transients consistent with:
   a. IEEE Standard 587-1980
   b. UL 864 Supply Line Transients
   c. Voltage Sags, Surge, and Dropout per EN 61000-4-11 (EN 1000-4-11)

I. In the event of the loss of normal power, there shall be an orderly shutdown of all DDC Controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 60 days.

1. Upon restoration of normal power, the DDC Controller shall automatically resume full operation without manual intervention.

2. Should DDC Controller memory be lost for any reason, the user shall have the capability of reloading the DDC Controller via the network workstation PC.

2.05 DDC CONTROLLER RESIDENT SOFTWARE FEATURES

A. General:

1. The software programs specified in this Section shall be provided as an integral part of DDC Controllers and shall not be dependent upon any higher level computer for execution.

2. All points shall be identified by up to 30 character point name and 16 character point descriptor. The same names shall be used at the PC workstation.

3. All digital points shall have user defined two-state status indication (descriptors with minimum of 8 characters allowed per state (i.e. summer/winter)).

B. Control Software Description:

1. The DDC Controllers shall have the ability to perform the following pre-tested control algorithms:

a. Two-position control

b. Proportional control

c. Proportional plus integral control

d. Proportional, integral, plus derivative control

e. Automatic tuning of control loops

C. DDC Controllers shall provide the following energy management routines for the purpose of optimizing energy consumption while maintaining occupant comfort.

1. Event Scheduling: Provide a comprehensive menu driven program to automatically start and stop designated points or groups of points according to a stored time.

a) It shall be possible to individually command a point or group of points.

b) For points assigned to one common load group, it shall be possible to assign variable time delays between each successive start or stop within that group.

c) The operator shall be able to define the following information:

1. Time, day

2. Commands such as on, off, auto, and so forth.

3. Time delays between successive commands.

4. There shall be provisions for manual overriding of each schedule by an appropriate operator.

2. Automatic Daylight Savings Time Switchover: The system shall provide automatic time adjustment for switching to/from Daylight Savings Time.

D. DDC Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.

1. A single process shall be able to incorporate measured or calculated data from any and all other DDC Controllers on the network. In addition, a single process shall be able to issue commands to points in any and all other DDC Controllers on the network. Database shall support 30 character, English language point names, structured for searching and logs.

2. Processes shall be able to generate operator messages and advisories to operator I/O devices.
3. DDC Controllers shall provide a HELP function key, providing enhanced context sensitive on-line help with task-orientated information from the user manual.
4. DDC Controllers shall be capable of comment lines for sequence of operation explanation.

E. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each DDC Controller shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic and prevent alarms from being lost. At no time shall the DDC Controllers ability to report alarms be affected by either operator or activity at a PC workstation, local I/O device or communications with other panels on the network.
1. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.
2. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of six priority levels shall be provided for each point. Users shall have the ability to manually inhibit alarm reporting for each point.
3. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 200 character alarm message to more fully describe the alarm condition or direct operator response.

F. A variety of historical data collection utilities shall be provided to manually or automatically sample, store and display system data for points as specified in the I/O summary.
1. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each DDC Controllers point group. Two methods of collection shall be allowed: either by a pre-defined time interval or upon a pre-defined change of value. Sample intervals of 1 minute to 7 days shall be provided. Each DDC Controller shall have a dedicated RAM-based buffer for trend data. All trend data shall be available for transfer to a Workstation without manual intervention.

G. The peer-to-peer network shall allow the DDC Controllers to assign a minimum of 50 passwords access and control priorities to each operator individually. The logon password (at any PC workstation or portable operator terminal) shall enable the operator to monitor, adjust and control the points that the operator is authorized for. All other points shall not be displayed on the PC workstation or portable terminal (e.g. all base building and all tenant points shall be accessible to any base building operators, but only tenant points shall be accessible to tenant building operators). Passwords and priorities for every point shall be fully programmable and adjustable.

2.06 FLOOR LEVEL NETWORK APPLICATION SPECIFIC CONTROLLERS (ASC)

A. Each DDC Controller shall be able to extend its performance and capacity through the use of remote application specific controllers (ASCs) through Floor Level LAN Device Networks.

B. Each ASC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor-based, multi-tasking, real-time digital control processor. Each ASC shall also be capable of providing I/O expansion via a slave mode operation (selectable at start-up).

C. Terminal Equipment Controllers:

1. Provide for control of each piece of equipment, including, but not limited to, the following:
   a. Variable Air Volume (VAV) boxes
   b. Unit Conditioners
   c. Heat Pumps
2. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. Analog outputs shall be industry standard signals such as 24V floating control or 0-10v, allowing for interface to a variety of modulating actuators.
3. All controller sequences and operation shall provide closed loop control of the intended application.

2.07 PORTABLE OPERATOR'S TERMINAL (POT)

A. Provide industry standard, commercially available portable operator terminals with a LCD display and a full-featured keyboard. The POT shall be handheld and plug directly into all DDC Controllers, and Floor Level Network Controllers as described below. Provide a user-friendly, English language-prompted interface for quick access to system information, not codes requiring look-up charts.

2.08 WORKSTATION/SERVER OPERATOR INTERFACE

A. Basic Interface Description

1. Operator workstation interface software shall minimize operator training through the use of user-friendly and interactive graphical applications, 30-character English language point identification, on-line help, and industry standard Windows application software. The software shall provide, as a minimum, the following functionality:
   a. Real-time graphical viewing and control of the BAS environment
   b. Reporting
   c. Scheduling and override of building operations

d. Collection and analysis of historical data
e. Point database editing, storage and downloading of controller databases.
f. Utility for combining points into logical Point Groups.
g. .Alarm reporting, routing, messaging, and acknowledgment
h. "Collapsible tree," dynamic system architecture diagram application:
    1. Showing the real-time status and definition details of all workstations and devices on a management level network
    2. Showing the real-time status and definition details of all DDC Controllers at the building level
    3. Showing the status and definition details of all field-level application controllers
i. Definition and construction of dynamic color graphic displays.
j. Online, context-sensitive help.
k. On-screen access to User Documentation, via online help or PDF-format electronic file.
l. Automatic database backup at the workstation for database changes initiated at DDC Controller operator interface terminals
    1. Backups shall produce a configuration file that contains pertinent details regarding the specific backup. This log file shall be created each time a backup is run and be stored in the backup directory.
    2. Restore dialog box shall list detailed information to facilitate the restore of the correct database.
    3. Ability to restore selected components of a backup.
    4. Delete old backup directories automatically or individually from a detailed list.
m. Display dynamic trend data graphical plot.
    a. Must be able to run multiple plots simultaneously
    b. Each plot must be capable of supporting 10 pts/plot minimum
    c. Must be able to command points directly off dynamic trend plot application.
    d. Must be able to plot both real-time and historical trend data
n. Program editing
o. Transfer trend data to 3rd party spreadsheet software
p. Scheduling reports
q. Operator Activity Log

2. Provide a graphical user interface that shall minimize the use of keyboard through the use of a mouse or similar pointing device, with a "point and click" approach to menu selection and a "drag and drop" approach to inter-application navigation. Selection of applications within the workstation software shall be via a graphical toolbar menu – the application toolbar menu shall have the option to be located in a docked position on any of the four sides of the visible desktop

space on the workstation display monitor, and the option to automatically hide itself from the visible monitor workspace when not being actively manipulated by the user.

3. The software shall provide a multi-tasking type environment that allows the user to run several applications simultaneously. BAS software shall run on a Windows XP, Vista, or Server 2003/2008 operating system. System database parameters shall be stored within an object-oriented database, which is compliant with the Open Database Connectivity (ODBC) or Structured Query Language (SQL) standards. Standard Windows applications shall run simultaneously with the BAS software. The mouse or Alt-Tab keys shall be used to quickly select and switch between multiple applications. The operator shall be able to work in Microsoft Word, Excel, and other Windows based software packages, while concurrently annunciating on-line BAS alarms and monitoring information

a. Provide functionality such that any of the following may be performed simultaneously on-line, and in any combination, via adjustable user-sized windows. Operator shall be able to drag and drop information between the following applications, reducing the number of steps to perform a desired function (e.g., Click on a point on the alarm screen and drag it to the dynamic trend graph application to initiate a dynamic trend on the desired point):

1. Dynamic color graphics application
2. Alarm management application
3. Scheduling application
4. Dynamic trend graph data plotter application
5. Dynamic system architecture diagram application
6. Control Program and Point database editing applications
7. Reporting applications

b. Report and alarm printing shall be accomplished via Windows Print Manager, allowing use of network printers.

4. Operator-specific password access protection shall be provided to allow the administrator/manager to limit users' workstation control, display and data base manipulation capabilities as deemed appropriate for each user, based upon an assigned password. Operator privileges shall "follow" the operator to any workstation logged onto (up to 999 user accounts shall be supported). The administrator/manager shall be able to grant discrete levels of access and privileges, per user, for each point, graphic, report, schedule, and BAS workstation application. And each BAS workstation user account shall use a Windows user account as a foundation.

a. The workstation software shall also include an application to track the actions of each individual operator, such as alarm acknowledgement, point commanding, schedule overriding, database editing, and logon/logoff. The application shall list each of the actions in a tabular format, and shall have sorting capabilities based on parameters such as ascending or descending time of the action, or name of the object on which the action was performed. The application shall also allow querying based on object name, operator, action, or time range.

5. Dynamic Color Graphics application shall include the following:
   a. Must include graphic editing and modifying capabilities
   b. A library of standard control application graphics and symbols must be included
   c. Must be able to command points directly off graphics application
   d. Graphic display shall include the ability to depict real-time point values dynamically with animation, picture/frame control, symbol association, or dynamic informational text-blocks
   e. Animation status indicators shall give you a quick visual indication of a point's value, priority or status in the form of an icon.
   f. Navigation through various graphic screens shall be optionally achieved through a hierarchical "tree" structure or view recently opened graphics through a backward and forward paging.
   g. Graphics viewing shall include zoom capabilities
   h. Graphics shall automatically display the HAND status of points that have been overridden by a field HAND switch, for points that have been designed to provide a field HAND override capability.
   i. Advanced linking within the Graphics application shall provide the ability to navigate to outside documents (e.g., .doc, .pdf, .xls, etc.), internet web addresses, e-mail, external programs, and other workstation applications, directly from the Graphics application window with a mouse-click on a customizable link symbol.
6. Reports shall be generated on demand or via pre-defined schedule, and directed to CRT displays, printers or file. As a minimum, the system shall allow the user to easily obtain the following types of reports:
   a. A general listing of all or selected points in the network
   b. List of all points currently in alarm
   c. List of all points currently in override status
   d. List of all disabled points
   e. List of all points currently locked out
   f. List of user accounts and access levels
   g. List all weekly schedules and events
   h. List of holiday programming
   i. List of control limits and deadbands
   j. Custom reports from 3rd party software

k. System diagnostic reports including, list of DDC panels on line and communicating, status of all DDC terminal unit device points
l. List of programs
m. List of point definitions
n. List of logical point groups
o. List of alarm strategy definitions
p. List of DDC Control panels
q. Point totalization report
r. Point Trend data listings
s. Initial Values report
t. User activity report

7. Scheduling and override

Provide a calendar type format for simplification of time and date scheduling and overrides of building operations. Schedule definitions reside in the PC workstation, DDC Controller, Controller to ensure time equipment scheduling when PC is off-line -- PC is not required to execute time scheduling. Provide override access through menu selection, graphical mouse action or function key. Provide the following capabilities as a minimum:

a. Weekly schedules
b. Zone schedules
c. Event schedules – an event consists of logical combinations of equipment and/or zones
d. Report schedules
e. Ability to schedule for a minimum of up to 365 days in advance

8. Collection and Analysis of Historical Data

a. Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time. Any system point may be trended automatically at time-based intervals (up to four time-based definitions per point) or change of value, both of which shall be user-definable. The system shall have the capability to collect and store trend data on hard disk for future diagnostics and reporting.

b. The entire collection process shall be automated so that the data collection definition, amount of data to be collected, collection report and scheduling take the form a wizard, or online assist utility.

c. Trend data reports shall be provided to allow the user to view all trended point data. Reports may be customized to include individual points or predefined groups of selected points.

d. Provide additional functionality that allows the user to view real-time trend data on trend graphical plot displays. The dynamic graphs shall continuously update point values. At any time the user may redefine sampling times or range scales for any point. In addition, the user may pause the graph and take "snapshots" of plot screens to be stored on the workstation disk for future recall and analysis. Point values may be viewed and the graphs may be printed. Operator shall be able to command points directly on the trend plot by double clicking on the point.

B. Dynamic Color Graphic Displays

1. A color graphic floor plan display and system schematic for each piece of mechanical equipment, including air handling units, chilled water systems and hot water boiler systems, and room level terminal units, shall be provided by the BAS contractor to optimize system performance, analysis and speed alarm recognition.

2. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection, or point alarm association. Graphics software shall permit the importing of Autocad or scanned pictures for use in the system.

3. Dynamic temperature values, humidity values, flow control device values, and status indication shall be shown in their actual respective locations within the system schematics or graphic floor plan displays, and shall automatically update to represent current conditions.

   a. Provide the user the ability to display real-time point values by animated motion or custom picture control visual representation. Animation shall depict movement of mechanical equipment, or air or fluid flow. Animation shall reflect, ON or OFF conditions, and shall also be optionally configurable for up to five rates of animation speed. Animation shall also indicate the priority and alarm status of the point.

   b. Sizable analog bars shall be available for monitor and control of analog values; high and low alarm limit settings shall be displayed on the analog scale.

   c. Provide the user the ability to display blocks of point data by defined point groups; alarm conditions shall be displayed by flashing point blocks.

   d. Equipment state or values can be changed by clicking on the associated point block or graphic symbol and selecting the new state (on/off) or setpoint.

4. Colors shall be used to indicate status and change as the status of the equipment changes. The state colors shall be user definable.

5. Advanced linking within the Graphics application shall provide the ability to navigate to outside documents (e.g., .doc, .pdf, .xls, etc.), internet web addresses, e-mail, external programs, and other workstation applications, directly from the Graphics application window.

6. The windowing environment of the PC operator workstation shall allow the user to simultaneously view several applications at a time to analyze total building operation or to

allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

7. Microgafx Designer, an off the shelf graphic software shall be provided to allow the user to add, modify, or delete system graphic background displays.

4. A clipart library of HVAC application and automation symbols shall be provided including fans, valves, motors, chillers, AHU systems, standard ductwork diagrams and laboratory symbols. The user shall have the ability to add custom symbols to the clipart library.

C. System Configuration & Definition

1. A "Collapsible tree" dynamic system architecture diagram/display application of the site-specific BAS architecture showing status of controllers shall be provided. This application shall include the ability to add and configure workstations, DDC Controllers or HVAC Mechanical Equipment controllers. Symbols/Icons representing the system architecture components shall be user-configurable and customizable.

2. Network wide control strategies shall not be restricted to a single DDC Controller or HVAC Mechanical Equipment controller.

3. Provide automatic backup and restore of all DDC controller controller databases on the workstation hard disk. In addition, all database changes shall be performed while the workstation is on-line without disrupting other system operations. Changes shall be automatically recorded and downloaded to the appropriate DDC Controller or HVAC Mechanical Equipment Controller. Changes made at the user-interface of DDC Controllers or HVAC Mechanical Equipment Controllers shall be automatically uploaded to the workstation, ensuring system continuity.

4. System configuration, programming, editing, graphics generation shall be performed on-line.

5. Point database configuration shall be available to the user within a dedicated point database editor application included in the workstation software. The editor shall allow the user to create, view existing, modify, copy, and delete points from the database. The editor shall provide the option for editing the point database in an online or offline mode with the DDC Controllers.

6. Control program configuration shall be available to the user within a dedicated control program editor application included in the workstation software. The editor shall allow for creation, modification and deletion of control programs. The editor shall provide the option for editing the control programs in an online or offline mode, and also the ability to selectively enable or disable the live program execution within the DDC Controllers.

D. Alarm Management

1. Alarm Notification shall be presented to the workstation in a tabular format, and shall include the following information for each alarm point: name, value, alarm time & date, alarm status, priority, acknowledgement information, and alarm count..

2. Alarm Display shall have the ability to list & sort the alarms based on alarm status, point name, ascending or descending alarm time.
3. Directly from the Alarm Display, the user shall have the ability to acknowledge, silence the alarm sound, print, or erase each alarm. The user shall also have the ability to command, launch an associated graphic or trended graphical plot, or run a report on a selected alarm point directly on the Alarm Display.
4. Each alarm point shall have a direct link from the Alarm Display to further user-defined point informational data.
5. Alarm messages shall be customizable for each point, or each alarm priority level, to display detailed instructions to the user regarding actions to take in the event of an alarm.

2.09 FIELD DEVICES

A. Provide instrumentation as required for monitoring, control, or optimization functions.

B. Room Temperature Sensors

1) Digital room sensors shall be available with multiple options including override button and setpoint slide adjustment.

Temperature monitoring range +55/95F or +20/120°F Output signal
Changing resistance
Accuracy at Calibration point +0.5°F (+/- 0.3°C)

2) Liquid immersion temperature:

Temperature monitoring range +30/250°F (-1°/121°C)
Output signal Changing resistance
Accuracy at Calibration point +0.5°F (+/-0.3°C)

3) Duct (single point) temperature:

Temperature monitoring range +20/120°F (-7°/49°C)
Output signal Changing resistance
Accuracy at Calibration point +0.5°F (+/-0.3°C)

4) Duct Average temperature:

Temperature monitoring range +20° +120°F(-7°/+49°C)
Output signal 4 – 20 mA DC
Accuracy at Calibration point +0.5°F (+03°C)
Sensor Probe Length up to 25’ L (7.3m)

5) Outside air temperature:

Temperature monitoring range -58°+122° F(-50ºC to +50ºC)
Output signal 4 – 20 mA DC
Accuracy at Calibration point +0.5°F (+/-0.3°C)

C. Liquid Differential Pressure Transmitter

Ranges 0-5/30 inches H20
0-25/150 inches H20

	0-125/750 inches H20
	(other ranges as req'd)
Output	4 – 20 mA DC
Calibration Adjustments	Zero and span
Accuracy	+-0.2% of span
Linearity	+-0.1% of span
Hysteresis	+-0.05% of span

F. Static Pressure or Air Pressure Sensor:

Range:	0 to 0.1 in. water (0 to 24.9 Pa)
	0 to 0.25 in. water (0 to 63.2 Pa)
	0 to 0.5 in. water (0 to 124.5 Pa)
	0 to 1.0 in. water (o to 249 Pa)
	0 to 2.0 in water 90 to 498 Pa)
	0 to 5.0 in. water (0 to 1.25 kPa)
	0 to 10.0 in.water (0 to 2.49 kPa)
	(Bidirectional acceptable)
Output signal	4 to 20 mA
Accuracy	0.5% or +1.0% of full scale
Operating Temperature	-40º to 175º F (-40C to 79.5ºC)

G. Humidity Sensors:

Range	0 to 100% RH
Sensing Element	Bulk Polymer
Output Signal	4 – 20 mA DC
Accuracy	At 77°F(25ºC) + 2% RH

H. Control Valves (all control valves shall have electric actuators).

1. Electric Control

Flow Characteristics	Modified. Linear or Equal percentage
Control Action	Normal open or closed as selected
Medium	Steam, water, glycol
Body Type	Screwed ends 2" and smaller
Body Material	Bronze or Cast Iron
Body Trim	Bronze
Stem	Stainless Steel
Actuator	0-10 VDC, 4-20 MA, floating control, or 2 position (24 VAC/120VAC)

Automatic temperature control valves used for modulating service shall be provided with characterized throttling plugs or balls and shall be sized for minimum 25% of the system pressure drop or 5 psi, whichever is less.

K . Damper Actuators

1. Electric control shall be Siemens Building Technologies OpenAir™ direct coupled actuators.

2. Damper actuators shall be Brushless DC Motor Technology with stall protection, bi-directional, fail safe spring return, all metal housing, manual override, independently adjustable dual auxiliary switch.

2.10 MISCELLANEOUS DEVICES

A. Current Sensing Relay:

1. Provide solid-state, adjustable, current operated relay. Provide a relay which changes switch contact state in response to an adjustable set point value of current in the monitored A/C circuit.
2. Adjust the relay switch point so that the relay responds to motor operation under load as an “on” state and so that the relay responds to an unloaded running motor as an “off” state. A motor with a broken belt is considered an unloaded motor.
3. Provide for status device for all fans and pumps.

PART 3 EXECUTION

3.01 POINT SCHEDULE - I/0 SCHEDULE

The contractor shall collaborate with the owner directly to determine the owner's I/O needs and preference for naming conventions, etc. before entering the data in to the system.

3.02 START-UP AND COMMISSIONING

A. When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line.

B. During the course of Start-Up provide any recommendation for system modification to the owner. This includes system modifications, including operating parameters and control settings.

3.03 ELECTRICAL WIRING AND MATERIALS

A. Install, connect, and wire the items included under this Section. This work includes providing required conduit, wire, fittings, and related wiring accessories. In locations that may be subject to physical damage wiring shall be installed in conduit. Plenum rated low voltage control wiring may be run exposed in concealed, accessible locations.

B. Provide low voltage control wiring between thermostats, aquastats and motors.

C. Power wiring of 120VAC and above will be provided by others. This includes 120 volt, single phase, 60 hertz power to every B.M.S. DDC Controller panel, HVAC/Mechanical Equipment Controller, PC console, power supply, transformer, annunciator, modems, printers and to other devices as required. The power supplies are to be extended in conduit and wire from dedicated circuit breakers.

D. Provide status function conduit and wiring for equipment covered under this Section.

E. Provide conduit and/or required wiring between the B.M.S. panels and the temperature, humidity, or pressure sensing elements, including low voltage control wiring in conduit.

F. Provide conduit and/or required wiring between the PC workstation, electrical panels, metering instrumentation, indicating devices, miscellaneous alarm points, remotely operated contactors, and B.M.S. panels, as shown on the drawings or as specified.

G. All wiring to be compliant to local building code and the NEC.

3.04 PERFORMANCE

A. Unless stated otherwise, control temperatures within plus or minus 2^{o}F, humidity within plus or minus 3% of the set point, and static pressure within 10% of set point.

3.05 COMMISSIONING, TESTING AND ACCEPTANCE

A. Perform a commissioning procedure consisting of field I/O calibration and system commissioning. The commissioning must be coordinated with the owner to ensure systems are available when needed. Notify the operating personal of the testing schedule so that authorized personnel from the owner can be present as needed during the commissioning procedure.

1. Prior to system program commissioning, verify that each control panel has been installed according to plans, specifications, and shop drawings. Test, calibrate, and bring on line each control sensor and device.

B. After control devices have been commissioned (i.e. calibrated, tested and signed off), each BMS program shall be put on line and commissioned. Demonstrate each programmed sequence of operation. Test sequence to verify proper response and stable control, within specified accuracies.

C. After all BMS programs have been commissioned, the contractor shall verify the overall system performance as specified. Tests shall include, but not be limited to:

1. Data communication, both normal and failure modes.
2. System response time.
3. System backup and reloading.
4. System status displays.
5. Diagnostic functions.
6. Power failure routines and necessary battery backup.

3.06 TRAINING

A. The manufacturer shall provide factory trained instructor to give full instruction to designated personnel in the operation of the system installed.

B. Provide 8 hours of training for Owner's designated operating personnel. Training shall include:

Explanation of drawings, operations and maintenance manuals
Walk-through of the job to locate control components
Operator workstation and peripherals
DDC controller and ASC operation/function
Operator control functions including graphic generation and field panel programming

Explanation of adjustment, calibration and replacement procedures

ANNEX: INSTRUCTIONS TO OTHER CONTRACTORS

A. Co-ordinate equipment, interface and power requirements with control contractor prior to development of submittals or purchase of equipment

B. Provide complete submittal data to controls system contractor for co-ordination and interface of [equipment] to DDC systems

C. The supplier of the equipment is responsible for the configuration, programming, start-up, and testing of that product to meet the sequence of operation described in this section. The supplier shall also provide any licensing, hardware, and software required for interface to the DDC system.

END OF SECTION

SECTION 23 21 13.33

GROUND-LOOP HEAT PUMP PIPING

PART 1 GENERAL

1.01 SUMMARY

A. This section includes piping for horizontal, direct-buried, ground-loop, heat pump systems that operate between 23 and 104 def F (minus 5 and plus 40 deg C).

1.02 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressure, unless otherwise indicated:

1. Ground-Loop Heat Pump Piping: 160 psig (1100 kPa)

1.03 SUBMITTALS

A. Product data for the following:

1. Pipe and fittings.
2. Joining method and equipment.
3. Propylene glycol solution.

B. Field quality-control test reports.

PART 2 PRODUCTS

2.01 PIPES AND FITTINGS

A. PE Pipe: ASTMD 2239, SIDR Numbers 5.3, 7, 9, or 11.5; with PE compound number required to achieve required system working pressure.

1. Molded PE Fittings: ASTM D 2683 or ASTM D 3261, PE resin, socket- or butt-fusion type, made to match PE pipe dimensions and class.

B. U-Bend Assembly: Factory fabricated with embossed depth stamp every 24 inches (600 mm) unless otherwise noted from U-bend.

2.02 BOREHOLE BACKFILL

A. Surface Seal: Cement with thermal conductivity greater than 1.2 Btu/h x sq. ft. x deg F (0.7 W/sq. m x K).

B. Backfill below Surface Seal: Natural or manufactured and specified in Division 31 Section “Earth Moving”.

2.03 ANTOFREEZE SOLUTION

A. Propylene Glycol: Minimum 99 percent propylene glycol with corrosion inhibitors and environmental stabilizer additives to be mixed with water to protect the piping circuit and connected equipment from physical damage from freezing or corrosion.

B. Quantity: Sufficient solution for initial system start-up and for preventative maintenance for one year from date of Substantial Completion.

C. Dilution Water: Chloride content shall be less than 25 ppm, sulfate less than 25 ppm, and hardness less than 100 ppm.

PART 3 EXECUTION

3.01 EARTHWORK

A. Excavating, trenching, warning tape, and backfilling are specified in Division 31 Section "Earth Moving".

3.02 HORIZONTAL PIPING INSTALLATION

A. Separate trenches by 10 feet (3 m) minimum, unless otherwise indicated. Remove rocks in trenches that could contact pipe.

B. Backfill to 24 inches (600 mm) above pipe with mud developed from excavated rock-free soil or with sand, pea gravel, or fly ash. Backfill from slurry level to grade with excavated soil, compacting as specified for pipe burial in Division 31 Section "Earth Moving".

C. Extend pipe from trench onto the bottom of the body of water at an elevation that is at least 12 inches (300 mm) below frost line. Seal membrane or impervious liner under the body of water after installing piping.

D. Install PE piping in trenches according to ASTM D 2774 or ASTM F 645.

1. Clean PE pipe and fitting and make heat-fusion joints according to ASTM D 2657. Minimize number of joints.

E. Purge, flush, and pressure test piping before backfilling trenches.

F. Install continuous detectable warning tape for underground piping. Locate tape a minimum of 24 inches (600 mm) below finished grade, directly over piping. Underground warning tapes are specified in Division 31 Section "Earth Moving".

G. Common piping installation requirements are specified in Division 23 Section "Common Work Results for HVAC".

3.03 ANTIFREEZE SOLUTION FILL

A. Fill system with required quantity of propylene glycol and water to provide minus 10 deg F (minus 23 deg C) freezing temperature.

3.04 CONNECTIONS

A. Drawings indicate general arrangement of piping, fittings, and specialties.

3.05 FIELD QUALITY CONTROL

A. Piping Tests: Fill piping 24 hours before testing and apply test pressure to stabilize piping. Use potable water only.

B. Hydrostatic Tests: Test at not less than 1-1/2 times the pipe working pressure rating.

1. Increase pressure in 50-psig (345-kPa) increments and inspect each joint between increments. Hold at test pressure for 30 minutes. Slowly increase to next test pressure increment and hold for 30 minutes. After testing at maximum test pressure, reduce pressure to 30 psig (207 kPa). Hold for 90 minutes and measure pressure at 30-minute intervals. Repair leaks and retest until no leaks exist.

C. Prepare reports of testing activity.

END OF SECTION

SECTION 23 21 23.16

BASE-MOUNTED, CENTRIFUGAL HYDRONIC PUMPS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Geothermal loop pump modules, closed loop fittings, hose kits, and accessories.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1.03 QUALITY ASSURANCE

A. Approved Liquid Solutions

1. Methanol
2. Exoendosol
3. Propylene Glycol

1.04 WARRANTY

A. Manufacturer Warranty

1. Parts and labor for five years.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. ARM 29 Geothermal Loop Pump Module

2.02 MANUFACTURERS

A. Flowcenter Products, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. Maximum Operating Pressure of 150 psi.
2. Minimum Operating Temperature of 0°F.
3. Maximum Operating Temperature of 225°F.

2.04 OPERATION

A. The circulator pump in this geothermal loop pump energizes and circulates the liquid through a geothermal heat pump and the earth loop. This results in the transfer of heat.

2.05 MATERIALS

A. Fully insulated cabinet.

B. Full flow 1 ⅛" brass valves.

C. Standard 1" NPT connections.

D. Armstrong E9 cast iron pump.

E. Armstrong E9B bronze pump.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Wall Mounting

1. Designed for quick and easy installation, the ARM series loop pump can be attached to most any wall using the screws and the mounting holes provided on the back of the unit.

B. Filling and Flushing

1. Filling and flushing of the ARM series modules occurs through the connections at front. To direct flow, the module's two brass valves rotate to four positions.

END OF SECTION

http://www.flowcenterproducts.com/
http://www.flowcenterproducts.com/docs/ARM-29.pdf

SECTION 23 31 13.13

RECTANGULAR METAL DUCTS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for metal ductwork.

1.02 REFERENCES

A. National Fire Protection Association:

1. NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems.

B. American Society for Testing and Materials:

1. ASTM A653, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
2. ASTM A666, Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar.
3. ASTM A36, Standard Specification for Carbon Structural Steel.

C. Sheet Metal and Air Conditioning Contractors' National Association:

1. SMACNA (DCS) - HVAC Duct Construction Standards - Metal and Flexible.

1.03 ACTION SUBMITTALS

A. Product Data

B. Shop Drawings

1. Indicate duct fittings, particulars such as gages, sizes, welds, and configuration prior to start of work.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Company specializing in manufacturing the type of products specified in this section should have a minimum of three years of documented experience.
2. Company specializing in performing the type of work specified in this section should have a minimum of five years of documented experience.
3. Ductwork should be constructed to be in regulation with to NFPA 90A standards.
4. Do not install duct sealants when temperatures are less than those recommended by sealant manufacturers. Maintain temperatures within acceptable range during and after installation of duct sealants.

PART 2 PRODUCTS

2.01 MATERIALS

A. Galvanized Steel Ducts: Hot-dipped galvanized steel sheet, ASTM A653/A653M FS Type B, with G60/Z180 coating.

B. Stainless Steel Ducts: ASTM A666, Type 304.

C. Hanger Rod: ASTM A36/A36M; steel, galvanized; threaded both ends, threaded one end, or continuously threaded.

2.02 FABRICATION

A. Fabricate and support in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible, and as indicated. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated.

B. Construct T's, bends, and elbows with radius of not less than 1-1/2 times width of duct on centerline. Where not possible and where rectangular elbows must be used, provide air foil turning vanes. Where acoustical lining is indicated, provide turning vanes of perforated metal with glass fiber insulation.

C. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.

D. Where ducts are connected to exterior wall louvers and duct outlet is smaller than louver frame, provide blank-out panels sealing louver area around duct. Use same material as duct, painted black on exterior side; seal to louver frame and duct.

PART 3 EXECUTION

3.01 INSTALLERS

A. A1 Heating & Cooling

3.02 INSTALLATION

A. Special Techniques

1. Install in accordance with manufacturer's instructions.
2. Duct sizes indicated are inside clear dimensions. For lined ducts, maintain sizes inside lining.
3. Install and seal metal and flexible ducts in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible.
4. Locate ducts with sufficient space around equipment to allow normal operating and maintenance activities.
5. Use crimp joints with or without bead for joining round duct sizes 8 inch (200 mm) and smaller with crimp in direction of air flow.
6. Use double nuts and lock washers on threaded rod supports.
7. Set plenum doors 6 to 12 inches (150 to 300 mm) above floor. Arrange door swings so that fan static pressure holds door in closed position.
8. Provide residue traps in kitchen hood exhaust ducts at base of vertical risers with provisions for clean out.
9. During construction provide temporary closures of metal or taped polyethylene on open ductwork to prevent construction dust from entering ductwork system.
10. At exterior wall louvers, seal duct to louver frame and install blank-out panels.

END OF SECTION

SECTION 23 33 46

Flexible Duct

PART 1 GENERAL

1.01 SUMMARY

A. This section includes specifications for flexible ducting

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Installation

1.03 QUALITY ASSURANCE

A. UL listed

B. Warrenty- 5 years

PART 2 PRODUCTS

2.01 FLEXIBLE DUCT

A. UPC #036

1. Duct meets the following codes

a. UL 181

b. UMC 10-1

c. SBCC

d. BOCA

e. NFPA 90A

f. NFPA 90B

g. HUD 515-2.1

2. Duct holds the following certifications

a. Greenguard Indoor Quality Certification

b. ADC certification

2. Class 1 flexible duct

3. 6 inch diameter

B. Manufacturer

1. ATCO Rubber Products INC.

C. Material

1. Vapor barrier- Tri-directional, scrim reinforced metalized polyester jacket

2. Insulation- Fiberglass wool

3. Core

a. Inner- Steel wire hex

b. Outer- double laminated polyester

D. Performance

1. Maximum positive pressure- 6” w.g.

2. Maximum negative pressure- ¾” w.g.
3. Maximum velocity- 5,000 FPM
4. Vapor Transmission- 0.05 perms
5. R value- 6.0
6. Flame spread- < 25
7. Smoke development- <60

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Tools: To be done with manufacturer recommended tools

B. Instructions: To be done in a manufacture approved and UL approved manner

1. Sharp bends will be avoided
2. Installation will not be near hot equipment

C. Installation is to be done with a NIOSH or MSHA approved disposable dust mask

END OF SECTION

http://www.atcoflex.com/products/insulated/036.html

http://www.atcoflex.com/assets/pdfs/030036031specsheet.pdf

SECTION 23 37 13

DIFFUSERS, REGISTERS, AND GRILLES

PART 1 GENERAL

1.01 SUMMARY

A. This section includes specifications for the diffusers

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Installation

1.03 QUALITY ASSURANCE

A. Diffusers shall meet ANSI/ ASHRAE Standard 70-2006.

PART 2 PRODUCTS

2.01 DIFFUSER

A. DynaFuser TDF-NT or similar
   1. Length- 24 inches
   2. Number of slots- 2

B. Manufacturer
   1. Titus

C. Performance
   1. Heating 20° F difference
      a. Throw- 9 ft
      b. Noise criteria < 10
   2. Cooling 20° F difference
      a. Throw- 13 ft
      b. Noise criteria <10
   3. 100% Horizontal temperature- 62° F
   4. 100% Vertical temperature- 82° F

D. Material
   1. Case- 24 gage steel
   2. Control Blade- extruded aluminum
   3. Actuator- shaped metal alloy wires

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Tools: To be done with manufacturer recommended and provided tools

B. Instructions: To be done in a manufacture approved manner

END OF SECTION

http://www.titus-hvac.com/ecatalog/getfile2.aspx?fileid=7479

http://www.titus-hvac.com/ecatalog/getfile2.aspx?fileid=7478

SECTION 23 57 33

DIRECT GEO-EXCHANGE HEAT EXCHANGERS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for custom designed and fabricated direct geothermal exchanger in the form of a cooling tower and pool.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Custom designed and fabricated cooling tower.

1. Description: Custom fabricated water cistern with integrated evaporative cooling system

B. Metal Wall panels subject to compliances with requirements as indicated; manufacturers offering metal wall panel materials that may be incorporated in the work include: RHINEZINK, America, Inc.

1. Panel Fabrication Select Wall panel Fabricator that has the equipment and personnel capable of providing quality zinc wall panel profiles as indicated on the drawings. Acceptable fabricators:

a. A. Zahner Co.

C. Water-proofing membrane subject to compliance with indicated requirements including the references specified in 33 47 13 – Pond and Reservoir Liner.

D. See specification 22 11 23 – Domestic Water Pump for specific pump used in direct geo-exchange heat exchanger.

2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

B. A. Zahner Co.

C. RHINEZINK, America, Inc.

D. Firestone, BPE

E. Grundfos

2.03 MATERIALS

A. Wood Framing and Structure: See specification 06 10 53 – Miscellaneous Rough Carpentry

B. Zinc Panels See specification 07 42 13 – Metal Wall Panels

C. Cured single-ply synthetic rubber membrane made of ethylene-propylene-diene-terpolymer (EPDM) See specification 33 47 13 – Pond and Reservoir Liner.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Follow manufacturer’s supplied assembly instructions when installing pond liners, pumps, electronics, and landscaping.
2. Insure proper installation of all components prior to filling pond with water.

END OF SECTION

SECTION 23 62 23

WATER-COOLED REFRIGERANT COMPRESSOR AND CONDENSER UNITS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for water-to-air heat pump.
2. Specification for water-to-water

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer’s Instructions

1.03 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. Be certain to inspect all cartons or crates on each unit as received at the job site before signing the freight bill. Verify that all items have been received and that there are no visible damages; note any shortages or damages on all copies of the freight bill. In the event of damage or shortage, remember that the purchaser is responsible for filing the necessary claims with the carrier. Concealed damages not discovered until after removing the units from the packaging must be reported to the carrier within 24 hours of receipt.

B. Storage and Handling Requirements

1. If the equipment is not needed for immediate installation upon its arrival at the job site, it should be left in its shipping carton and stored in a clean, dry area. Units must only be stored or moved in the normal upright position as indicated by the "UP" arrows on each carton at all times. If unit stacking is required, stack units as follows: Vertical units less than 6 tons, no more than two high; horizontal units less than 6 tons, no more than three high. Do not stack units larger than 6 tons.

1.04 WARRANTY

A. Manufacturer Warranty

1. The units shall be warranted by the manufacturer against defects in materials and workmanship for a period of 1) in the case of residentially sold units having the last digit of the serial number as a 'T'; five years on all parts and 10 years on the refrigerant circuit components 2) on all other units; five years on the compressor and one year on all other parts.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Aquarius II (AP025-1VTC)

B. Aquarius II (WT025-1USC)

2.02 MANUFACTURERS

A. FHP Manufacturing Co.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. See the Guide Specifications for the Aquarius II for blower performance data as well as full load and part load heating and cooling capacities.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the Installation Manual for instructions on installing the condensate drain, duct system, piping, electrical and thermostat connections, and safety devices for the Aquarius II.

3.03 MAINTENANCE

A. Filter changes or cleanings are required at regular intervals. The time period between filter changes will depend upon type of environment the equipment is used in. In a single family home, that is not under construction, changing or cleaning the filter every 60 days is sufficient. In other applications such as motels, where daily vacuuming produces a large amount of lint, filter changes may be need to be as frequent as bi-weekly.

B. An annual "check-up" is recommended by a licensed refrigeration mechanic. Recording the performance measurements of volts, amps, and water temperature differences (both heating and cooling) is recommended. This data should be compared to the information on the unit's data plate and the data taken at the original startup of the equipment.

C. Lubrication of the blower motor is not required, however may be performed on some motors to extend motor life. Use SAE-20 non-detergent electric motor oil.

D. The condensate drain should be checked annually by cleaning and flushing to insure proper drainage.

E. Periodic lockouts almost always are caused by air or water flow problems. The lockout (shutdown) of the unit is a normal protective measure in the design of the equipment. If continual lockouts occur call a mechanic immediately and have them check for: water flow problems, water temperature problems, air flow problems or air temperature problems. Use of the pressure and temperature charts for the unit may be required to properly determine the cause.

END OF SECTION

http://www.fhp-mfg.com/newpdfs/AP_Series/AP_Specs.pdf
http://www.fhp-mfg.com/newpdfs/AP_Series/AP_series_installation.pdf

SECTION 23 65 13.16

Closed Circuit, Forced-Draft Cooling Towers

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Geothermal Fluid Cooler

1.02 ACTION SUBMITTALS

A. Product Data

1. Fluid Coolers are designed for use in small commercial building applications and residential housing. Residential Water Source Heat Pumps start off very efficient using the earth's cool subsurface to reject heat. Over time, the ground heats up and becomes thermally saturated, significantly reducing the unit's efficiency and capacity. Installing PowerCold's BreezeMaster® system with the underground heat exchanger can prevent the ground from becoming thermally saturated.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. BreezeMaster

1. Operating Weight: 500 LBS
2. Fan Motor: 1 HP
3. Pump Motor: 1/3 HP
4. Electrical Service: 120/1/60, 20 AMP

2.02 MANUFACTURERS

A. PowerCold

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Manufacturer Installation Instructions

1. Follow each manufacturer's provided installation instruction manual.

B. Special Techniques

1. Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment.

END OF SECTION

SECTION 23 72 23

PACKAGED AIR-TO-AIR ENERGY-RECOVERY UNITS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for central energy recovery ventilator.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1.03 WARRANTY

A. Manufacturer Warranty

1. Trent Metals Limited warrants the entire SummerAire Energy Recovery Ventilator for a period of three (3) years from the date of purchase to be free from defects in material and/or faulty workmanship.
2. Trent Metals Limited warrants the "Core" of the Energy Recovery Ventilator for five (5) years from the date of purchase to be free of material defects and/or faulty workmanship.
3. Trent Metals Limited exclusive obligation under this warranty shall be to supply without charge, a replacement for any part of the SummerAire Energy Recovery Ventilator which is found to be defective within the applicable time period and which is returned prepaid not later than thirty (30) days after the end of the time period by you or your supplier to Trent Metals Limited, 2040 Fisher Drive, Peterborough, Ontario, Canada, K9J 6X6 along with the model number, date code and date of purchase.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. SERV130 Energy Recovery Ventilator

2.02 MANUFACTURERS

A. SummerAire

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. See the manufacturer-supplied specifications for product dimensions as well as performance and efficiency data.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the SummerAire User Manual for a diagram and description of the unit, and instructions for operation.

3.03 MAINTENANCE

A. Every Six Months

1. Disconnect the power supply. Unlatch the door latches at the bottom of the door panel and gently raise the door to a level position while securely holding the door panel in place (apply pressure to the left).
2. Remove filters and vacuum with a hose attachment. Filters must be used to protect the core from dusts and particulate. Filters should be replaced every two years.
3. Clean the ERV core by sliding it out evenly along the channel tracks; then vacuum the exposed faces of the core with a brush attachment. Do not expose the core to fire or water, as they will damage it. DO NOT WASH THE CORE AS IT WILL BE PERMANENTLY DAMAGED.

B. Every Three Years

1. As previously described, unplug the unit and open the access door. Disconnect the fan motor wire leads connector beneath the electrical control box.
2. Slide fan tray assembly forward and remove.
3. Using a small brush (i.e. toothbrush), clean the wheel blades. Caution must be exercised not to disturb the balancing weights on the wheel blades.
4. Vacuum and reassemble, then reconnect the power supply.

END OF SECTION

http://www.summeraire.com/pdfs/ERV/X-SERV130-SP-EN-REV_SCREEN.pdf
http://www.summeraire.com/pdfs/ERV/X-SERV-USMAN-EN-REV1_SCREEN.pdf

SECTION 23 83 16

RADIANT HEATING HYDRONIC PIPING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Radiant heating piping, fittings, and piping specialties.

1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM F876, Standard Specification for Cross-linked Polyethylene (PEX) Tubing.
2. ASTM F1807, Standard Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing.

1.03 ACTION SUBMITTALS

A. Product Data

1. Provide for each type of radiant heating pipe, fitting, manifold, specialty, and control.

B. Shop Drawings

1. Show piping layout and details drawn to scale, including valves, manifolds, controls, and support assemblies, and their attachments to building structure.

1.04 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. RAUPEX O2 Barrier Pipe (3/8”)

B. PRO-BALANCE Distribution Manifold

2.02 MANUFACTURERS

A. REHAU

2.03 DESCRIPTION

A. Regulatory Requirements

1. Limit oxygen diffusion through the tube to maximum 0.10 mg per cu. m/day at 104 deg F (40 deg C) according to DIN 4726.
2. PEX piping must have a minimum Pressure/Temperature Rating of 100 psig (690 kPa) and 180 deg F (82 deg C).
3. Maximum Operating Temperature for manifold is 225 deg F (107 deg C).
4. Thermometer Accuracy: plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

2.04 MATERIALS

A. PEX plastic according to ASTM F876.

B. Fittings according to ASTM F1807, metal insert and copper crimp rings.

C. Manifold

1. Main Shutoff Valves
    a. Factory installed on supply and return connections.
    b. Body: brass or bronze.
    c. Ball: chrome-plated bronze.
    d. Seals: PTFE.
    e. CWP Rating: 150 psig (1035 kPa).
2. Balancing Valves
    a. Body: plastic or bronze, ball or plug, or globe cartridge type.
    b. Ball or Plug: brass or stainless steel.
    c. Globe Cartridge and Washer: brass with EPDM composition washer.
    d. Seat: PTFE.
    e. Visual Flow Indicator: flow-meter with visible indication in a clear plastic cap at top of valve.
    f. Differential Pressure Gage Connections: integral seals for portable meter to measure loss across calibrated orifice.
    g. Handle Style: lever or knob, with memory stop to retain set position if used for shutoff.
3. Thermometers
    a. Mount on supply and return connections.
    b. Element: bourdon tube or other type of pressure element.
    c. Dial: satin-faced, non-reflective aluminum with permanently etched scale markings.
    d. Pointer: black metal.
    e. Window: plastic.
    f. Connector: rigid, back type.
    g. Thermal System: liquid- or mercury-filled bulb in copper-plated steel, aluminum, or brass stem.
4. Mounting Brackets
    a. Copper, or plastic or copper-clad steel, where in contact with manifold.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 APPLICATION

A. PEX piping in interior reinforced-concrete floors.

3.03 INSTALLATION

A. Special Techniques

1. Install piping as indicated in drawings unless deviations to layout are approved.

2. Install radiant heating piping continuous from the manifold through the heated panel and back to the manifold without piping joints in heated panels.
3. Connect radiant piping to manifold in a reverse-return arrangement.
4. Do not bend pipes in radii smaller than manufacturer's minimum bend radius dimensions.
5. Install manifolds in accessible locations, or install access panels to provide maintenance access.
6. Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations.
7. For freeze protection, operate at a maximum of 60 deg F (16 deg C) supply-water temperature.

B. Piping in Interior Reinforced-Concrete Floors
1. Secure piping in concrete floors by attaching pipes to reinforcement using cable ties.
2. Space cable ties a maximum of 18 inches (457 mm) o.c. and at center of turns or bends.
3. Maintain 2-inch (50-mm) minimum cover.
4. Maintain minimum 40-psig (275-kPa) pressure in piping during concrete placement and continue for 24 hours after placement.

C. Perform the following adjustments before operating the system:
1. Open valves to fully open position.
2. Check operation of zone control valves.
3. Set temperature controls so all zones call for full flow.
4. Purge air from piping.

3.04 FIELD QUALITY CONTROL

A. Prepare radiant heating piping for testing as follows:
1. Open all isolation valves and close bypass valves.
2. Open and verify operation of zone control valves.
3. Flush with clean water, and clean strainers.

B. Field Tests and Inspections
1. Leak Test: After installation, charge system and test for leaks. Subject piping to hydrostatic test pressure that is not less than 1.5 times the design pressure but not more than 100 psig (690 kPa). Repair leaks and retest until no leaks exist.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

END OF SECTION

http://na.rehau.com/construction/heating...plumbing/radiant.heating/pex.piping.shtml
http://na.rehau.com/construction/heating...plumbing/radiant.heating/pro-balance.manifolds.shtml

SECTION 23 90 00

RADIANT HEATING HYDRONIC PUMPS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Radiant heating hydronic pumps.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide for each pump and fitting.

B. Shop Drawings

1.04 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data

1.05 WARRANTY

A. Manufacturer Warranty

1. Limited Warranty: 24 months from date of installation but not more than 30 months from date of manufacture.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Comfort System Hot Water Recirculation System

2.02 MANUFACTURERS

A. GRUNDFOS

2.03 DESCRIPTION

A. Wet-rotor, in-line, single stage, maintenance free circulator pump.

2.04 MATERIALS

A. Pump Construction

1. Inlet cone, bearing plate, bearing retainers, rotor can, cladding, shaft retainer, pump housing: 304 Stainless Steel.
2. Volute retainer, stator housing, shaft, upper and lower radial bearings: Aluminum
3. Thrust bearing: Metal Impregnated Carbon
4. O'Ring and gaskets: Ethylene Propylene Rubber

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 APPLICATION

A. Hot water recirculation system pump installed to the radiant floor heating manifold supply.

3.03 INSTALLATION

A. Follow manufacturer's supplied pre-installation checklist and installation guide.

B. Pump Mounting:

1. Close supply water valve.
2. Drain water from the hot water pipe by opening a hot water faucet in the house. Let the water run until it stops flowing and leave the faucet open until pump installation ins complete.
3. Disconnect the hot water heater at the hot water discharge.
4. Install pump onto the water heater discharge, using ¾" female fitting and gasket supplied on the pump ensuring the pump shaft is horizontal. The pump should be installed so the pump is pumping away from the hot water heater, towards the house.
5. Connect the hot water line to the ¾" NPT discharge o the pump. Use pipe dope or Teflon tape to seal threads when connecting to a ¾" female NPT connection.
6. Reopen the supply calve to the hot water heater and allow the water to run until all the air has been purged form the piping.
7. Close faucet inside the house.

END OF SECTION

http://www.grundfos.com/Web/HomeUs.nsf/Webopslag/PAVA-53MKRN

SECTION 25 15 16

Integrated Automation Software for Control and Monitoring Network

PART 1 GENERAL

1.01 SUMMARY

- A. This section includes specifications for Insight-Advanced Workstation

1.02 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Installation

1.03 QUALITY ASSURANCE

- A. Program is to be installed in accordance to manufacturer’s guidelines
- B. Program will be installed on a system the meets the manufacturer’s specifications

PART 2 PRODUCTS

2.01 Insight-Advanced Workstation

- A. Details
    1. Compatible Networks
        - a. Ethernet
        - b. BACnet/IP
        - c. BACnet over Ethernet
        - d. RS-485
    2. Object Oriented Database- Objecivity
    3. Graphics package- Micrografx Designer
- B. Manufacturer
    1. SIEMENS
- C. Capabilities
    1. Operator access and privilege management
    2. Alarm Management
    3. Trending
    4. Scheduler
    5. Graphics creation and editing
    6. Graphic based control operation

PART 3 EXECUTION

3.01 INSTALLERS

- A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

- A. Operating Platform
    1. Windows server 2008

2. Windows server 2003
3. Windows XP Professional
4. Windows Vista Business or Enterprise

B. Insight database server on management level network
1. Any dual-core processor or better
2. 2 GB RAM
3. 7200 RPM hard drive or better
4. USB Port
5. CD-ROM Drive

C. Insight database Client
1. Any single-core processor or better
2. 1 GB RAM
3. 7200 RPM hard drive or better
4. USB Port
5. CD-ROM Drive

END OF SECTION

http://cn.siemens.com/cms/cn/English/SBT/downloading/Building_Automation_Product_Home/Software/Documents/Insight/1en.pdf

SECTION 26 05 11
REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This section applies to all sections of Division 26.

B. Furnish and install electrical wiring, systems, equipment and accessories in accordance with the specifications and drawings. Capacities and ratings of motors, transformers, cable, switchboards, switchgear, panelboards, motor control centers, and other items and arrangements for the specified items are shown on drawings.

C. Electrical service entrance equipment (arrangements for temporary and permanent connections to the utility's system) shall conform to the utility's requirements. Coordinate fuses, circuit breakers and relays with the utility's system, and obtain utility approval for sizes and settings of these devices.

D. Wiring ampacities specified or shown on the drawings are based on copper conductors, with the conduit and raceways accordingly sized. Aluminum conductors are prohibited.

1.02 MINIMUM REQUIREMENTS

A. References to the International Building Code (IBC), National Electrical Code (NEC), Underwriters Laboratories, Inc. (UL) and National Fire Protection Association (NFPA) are minimum installation requirement standards.

B. Drawings and other specification sections shall govern in those instances where requirements are greater than those specified in the above standards.

1.03 TEST STANDARDS

A. All materials and equipment shall be listed, labeled or certified by a nationally recognized testing laboratory to meet Underwriters Laboratories, Inc., standards where test standards have been established. Equipment and materials which are not covered by UL Standards will be accepted provided equipment and material is listed, labeled, certified or otherwise determined to meet safety requirements of a nationally recognized testing laboratory. Equipment of a class which no nationally recognized testing laboratory accepts, certifies, lists, labels, or determines to be safe, will be considered if inspected or tested in accordance with national industrial standards, such as NEMA, or ANSI. Evidence of compliance shall include certified test reports and definitive shop drawings.

B. Definitions:

   1. Listed; Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production or listed equipment or materials or periodic evaluation of services, and whose listing states that the equipment, material, or services either meets appropriate designated standards or has been tested and found suitable for a specified purpose.

2. Labeled; Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.
3. Certified; equipment or product which:
    a. Has been tested and found by a nationally recognized testing laboratory to meet nationally recognized standards or to be safe for use in a specified manner.
    b. Production of equipment or product is periodically inspected by a nationally recognized testing laboratory.
    c. Bears a label, tag, or other record of certification.
4. Nationally recognized testing laboratory; laboratory which is approved, in accordance with OSHA regulations, by the Secretary of Labor.

1.04 QUALIFICATIONS (PRODUCTS AND SERVICES)

A. Manufacturers Qualifications: The manufacturer shall regularly and presently produce, as one of the manufacturer's principal products, the equipment and material specified for this project, and shall have manufactured the item for at least three years.

B. Product Qualification:
1. Manufacturer's product shall have been in satisfactory operation, on three installations of similar size and type as this project, for approximately three years.
2. The Government reserves the right to require the Contractor to submit a list of installations where the products have been in operation before approval.

1.05 APPLICABLE PUBLICATIONS

Applicable publications listed in all Sections of Division are the latest issue, unless otherwise noted.

1.06 MANUFACTURED PRODUCTS

A. Materials and equipment furnished shall be of current production by manufacturers regularly engaged in the manufacture of such items, for which replacement parts shall be available.

B. When more than one unit of the same class or type of equipment is required, such units shall be the product of a single manufacturer.

C. Equipment Assemblies and Components:
1. Components of an assembled unit need not be products of the same manufacturer.
2. Manufacturers of equipment assemblies, which include components made by others, shall assume complete responsibility for the final assembled unit.
3. Components shall be compatible with each other and with the total assembly for the intended service.
4. Constituent parts which are similar shall be the product of a single manufacturer.

D. Factory wiring shall be identified on the equipment being furnished and on all wiring diagrams.

E. When Factory Testing Is Specified:

1. The Government shall have the option of witnessing factory tests. The contractor shall notify the VA through the Resident Engineer a minimum of 15 working days prior to the manufacturers making the factory tests.
2. Four copies of certified test reports containing all test data shall be furnished to the Resident Engineer prior to final inspection and not more than 90 days after completion of the tests.
3. When equipment fails to meet factory test and re-inspection is required, the contractor shall be liable for all additional expenses, including expenses of the Government.

1.07 EQUIPMENT REQUIREMENTS

Where variations from the contract requirements are requested in accordance with Section 00 72 00, GENERAL CONDITIONS and Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES, the connecting work and related components shall include, but not be limited to additions or changes to branch circuits, circuit protective devices, conduits, wire, feeders, controls, panels and installation methods.

1.08 EQUIPMENT PROTECTION

A. Equipment and materials shall be protected during shipment and storage against physical damage, vermin, dirt, corrosive substances, fumes, moisture, cold and rain.
   1. Store equipment indoors in clean dry space with uniform temperature to prevent condensation. Equipment shall include but not be limited to switchgear, switchboards, panelboards, transformers, motor control centers, motor controllers, uninterruptible power systems, enclosures, controllers, circuit protective devices, cables, wire, light fixtures, electronic equipment, and accessories.
   2. During installation, equipment shall be protected against entry of foreign matter; and be vacuum-cleaned both inside and outside before testing and operating. Compressed air shall not be used to clean equipment. Remove loose packing and flammable materials from inside equipment.
   3. Damaged equipment shall be, as determined by the Resident Engineer, placed in first class operating condition or be returned to the source of supply for repair or replacement.
   4. Painted surfaces shall be protected with factory installed removable heavy kraft paper, sheet vinyl or equal.
   5. Damaged paint on equipment and materials shall be refinished with the same quality of paint and workmanship as used by the manufacturer so repaired areas are not obvious.

1.09 WORK PERFORMANCE

A. All electrical work must comply with the requirements of NFPA 70 (NEC), NFPA 70B, NFPA 70E, OSHA Part 1910 subpart J, OSHA Part 1910 subpart S and OSHA Part 1910 subpart K in addition to other references required by contract.
B. Job site safety and worker safety is the responsibility of the contractor.
C. Electrical work shall be accomplished with all affected circuits or equipment de-energized. When an electrical outage cannot be accomplished in this manner for the required work, the following requirements are mandatory:

1. Electricians must use full protective equipment (i.e., certified and tested insulating material to cover exposed energized electrical components, certified and tested insulated tools, etc.) while working on energized systems in accordance with NFPA 70E.
2. Electricians must wear personal protective equipment while working on energized systems in accordance with NFPA 70E.
3. Before initiating any work, a job specific work plan must be developed by the contractor with a peer review conducted and documented by the Resident Engineer and Medical Center staff. The work plan must include procedures to be used on and near the live electrical equipment, barriers to be installed, safety equipment to be used and exit pathways.
4. Work on energized circuits or equipment cannot begin until prior written approval is obtained from the Resident Engineer.

D. For work on existing stations, arrange, phase and perform work to assure electrical service for other buildings at all times. Refer to Article OPERATIONS AND STORAGE AREAS under Section 01 00 00, GENERAL REQUIREMENTS.

E. New work shall be installed and connected to existing work neatly, safely and professionally. Disturbed or damaged work shall be replaced or repaired to its prior conditions, as required by Section 01 00 00, GENERAL REQUIREMENTS.

F. Coordinate location of equipment and conduit with other trades to minimize interferences.

1.10 EQUIPMENT INSTALLATION AND REQUIREMENTS

A. Equipment location shall be as close as practical to locations shown on the drawings.

B. Working spaces shall not be less than specified in the NEC for all voltages specified.

C. Inaccessible Equipment:

1. Where the Government determines that the Contractor has installed equipment not conveniently accessible for operation and maintenance, the equipment shall be removed and reinstalled as directed at no additional cost to the Government.
2. "Conveniently accessible" is defined as being capable of being reached quickly for operation, maintenance, or inspections without the use of ladders, or without climbing or crawling under or over obstacles such as, but not limited to, motors, pumps, belt guards, transformers, piping, ductwork, conduit and raceways.

1.11 EQUIPMENT IDENTIFICATION

A. In addition to the requirements of the NEC, install an identification sign which clearly indicates information required for use and maintenance of items such as panelboards, cabinets, motor controllers (starters), safety switches, separately enclosed circuit breakers, individual breakers and controllers in switchboards, switchgear and motor control assemblies, control devices and other significant equipment.

B. Nameplates for Normal Power System equipment shall be laminated black phenolic resin with a white core with engraved lettering. Nameplates for Essential Electrical System (EES) equipment, as defined in the NEC, shall be laminated red phenolic resin with a white core with engraved lettering. Lettering shall be a minimum of 1/2 inch [12mm] high. Nameplates shall indicate equipment designation, rated bus amperage, voltage, number of phases, number of wires, and type of EES power branch as applicable. Secure nameplates with screws.

1.12 SUBMITTALS

A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.
B. The Government's approval shall be obtained for all equipment and material before delivery to the job site. Delivery, storage or installation of equipment or material which has not had prior approval will not be permitted at the job site.
C. All submittals shall include adequate descriptive literature, catalog cuts, shop drawings and other data necessary for the Government to ascertain that the proposed equipment and materials comply with specification requirements. Catalog cuts submitted for approval shall be legible and clearly identify equipment being submitted.
D. Submittals for individual systems and equipment assemblies which consist of more than one item or component shall be made for the system or assembly as a whole. Partial submittals will not be considered for approval.
    1. Submittals shall be marked to show specification reference including the section and paragraph numbers.
    2. Submit each section separately.
E. The submittals shall include the following:
    1. Information that confirms compliance with contract requirements. Include the manufacturer's name, model or catalog numbers, catalog information, technical data sheets, shop drawings, pictures, nameplate data and test reports as required.
    2. Elementary and interconnection wiring diagrams for communication and signal systems, control systems and equipment assemblies. All terminal points and wiring shall be identified on wiring diagrams.
    3. Parts list which shall include those replacement parts recommended by the equipment manufacturer.

1.13 SINGULAR NUMBER

Where any device or part of equipment is referred to in these specifications in the singular number (e.g., "the switch"), this reference shall be deemed to apply to as many such devices as are required to complete the installation as shown on the drawings.

1.14 ACCEPTANCE CHECKS AND TESTS

The contractor shall furnish the instruments, materials and labor for field tests.

1.15 TRAINING

A. Training shall be provided for the particular equipment or system as required in each associated specification.
B. A training schedule shall be developed and submitted by the contractor and approved by the Resident Engineer at least 30 days prior to the planned training.

END OF SECTION

SECTION 26 05 19

LOW-VOLTAGE ELECTRICAL CONDUCTORS AND CABLES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Wire and cable for 600 volts and less.

B. Wiring connectors and connections.

1.02 RELATED SECTIONS

A. Section 26 05 53 - Electrical Identification.

1.03 REFERENCES

A. NECA 1 - Standard Practices for Good Workmanship in Electrical Contracting; National Electrical Contractors Association; 2000.

B. NETA STD ATS - Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems; International Electrical Testing Association; 2003.

C. NFPA 70 - National Electrical Code; National Fire Protection Association; 1996.

1.04 QUALITY ASSURANCE

A. Conform to requirements of NFPA 70.

B. Products: Furnish products listed and classified by Underwriters Laboratories Inc. or testing firm acceptable to the authority having jurisdiction as suitable for the purpose specified and indicated.

PART 2 PRODUCTS

2.01 WIRING REQUIREMENTS

A. Concealed Dry Interior Locations: Use only building wire in raceway or metal clad cable.

B. Exposed Dry Interior Locations: Use only building wire in raceway.

C. Above Accessible Ceilings: Use only building wire in raceway or metal clad cable.

D. Wet or Damp Interior Locations: Use only building wire with Type THHN/THWN or XHHW insulation in raceway.

E. Exterior Locations: Use only building wire with Type THHN/THWN or XHHW insulation in raceway.

F. Underground Installations: Use only building wire with Type THHN/THWN or insulation in raceway.

G. Use solid conductor for feeders and branch circuits 10 AWG and smaller.

H. Use stranded conductors for control circuits.

I. Use conductor not smaller than 12 AWG for power and lighting circuits.

J. Use conductor not smaller than 16 AWG for control circuits.

K. Use 10 AWG conductors for 20 ampere, 120 volt branch circuits longer than 75 feet.

L. Use 10 AWG conductors for 20 ampere, 277 volt branch circuits longer than 200 feet.

2.02 BUILDING WIRE

A. Description: Single conductor insulated wire.

B. Conductor: Copper.

C. Insulation Voltage Rating: 600 volts.

D. Insulation: NFPA 70, Type THHN/THWN or XHHW.

E. Insulation Color: Conductor sizes 8 AWG and small shall have solid color insulation as required for phasing. Conductors sizes 6 AWG and larger may be black in color.

2.03 METAL CLAD CABLE

A. Description: NFPA 70, Type MC.

B. Conductor: Copper.

C. Insulation Voltage Rating: 600 volts.

D. Insulation Temperature Rating: 60 degrees C.

E. Insulation Material: Thermoplastic.

F. Armor Material: Aluminum or Steel.

G. Armor Design: Interlocked metal tape.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify that interior of building has been protected from weather.

B. Verify that mechanical work likely to damage wire and cable has been completed.

C. Verify that raceway installation is complete and supported.

3.02 INSTALLATION

A. Install wire and cable securely, in a neat and workmanlike manner, as specified in NECA

B. Route wire and cable as required to meet project conditions.

1. Wire and cable routing indicated is approximate unless dimensioned.

2. Where wire and cable destination is indicated and routing is not shown, determine exact routing and lengths required.

C. Use wiring methods indicated.

D. Pull all conductors into raceway at same time.

E. Use suitable wire pulling lubricant for building wire 4 AWG and larger.

F. Support cables above accessible ceiling, using spring metal clips or metal cable ties to support cables from structure. Do not support cables from ceiling suspension system or rest cable on ceiling panels.

G. Use suitable cable fittings and connectors.

H. Neatly train and lace wiring inside boxes, equipment, and panelboards.

I. Clean conductor surfaces before installing lugs and connectors.

J. Make splices, taps, and terminations to carry full ampacity of conductors with no perceptible temperature rise.

K. Use split bolt connectors for copper conductor splices and taps, 6 AWG and larger. Tape uninsulated conductors and connector with electrical tape to 150 percent of insulation rating of conductor.

L. Use solderless pressure connectors with insulating covers for copper conductor splices and taps, 8 AWG and smaller.

M. Use insulated spring wire connectors with plastic caps for copper conductor splices and taps, 10 AWG and smaller.

N. Identify and color code wire and cable under provisions of Section 16075. Identify each conductor with its circuit number or other designation indicated.

3.03 FIELD QUALITY CONTROL

A. Inspect and test in accordance with NETA STD ATS, except Section 4.

B. Perform inspections and tests listed in NETA STD ATS, Section 7.3.2.

END OF SECTION

SECTION 26 05 26

GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 DESCRIPTION

A. This section specifies general grounding and bonding requirements of electrical equipment operations and to provide a low impedance path for possible ground fault currents.

B. “Grounding electrode system” refers to all electrodes required by NEC,as well as including made, supplementary, lightning protection system grounding electrodes.

C. The terms “connect” and “bond” are used interchangeably in this specification and have the same meaning.

1.02 RELATED WORK

A. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements and items that are common to more than one section of Division 26.

B. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW): Low Voltage power and lighting wiring.

C. Section 26 41 00, FACILITY LIGHTNING PROTECTION: Requirements for a lightning protection system.

1.03 SUBMITTALS

A. Submit in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

B. Shop Drawings: Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.

C. Include the location of system grounding electrode connections and the routing of aboveground and underground grounding electrode conductors.

1.04 APPLICABLE PUBLICATIONS

Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by the basic designation only.

A. American Society for Testing and Materials (ASTM):

B1-2001 .... Standard Specification for Hard-Drawn Copper Wire

B8-2004 .... Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard,or Soft

B. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

81-1983.1 .... IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

C. National Fire Protection Association (NFPA):

70-2005 .... National Electrical Code (NEC)

99-2005 .... Health Care Facilities

D. Underwriters Laboratories, Inc. (UL):

44-2005 .... Thermoset-Insulated Wires and Cables

83-2003 .... Thermoplastic-Insulated Wires and Cables

467-2004 .... Grounding and Bonding Equipment

486A-486B-2003 .... Wire Connectors

PART 2 PRODUCTS

2.01 GROUNDING AND BONDING CONDUCTORS

A. Equipment grounding conductors shall be UL 83 insulated stranded copper, except that sizes 6 mm² (10 AWG) and smaller shall be solid copper. Insulation color shall be continuous green for all equipment grounding conductors, except that wire sizes 25 mm² (4 AWG) and larger shall be permitted to be identified per NEC.

B. Bonding conductors shall be ASTM B8 bare stranded copper, except that sizes 6 mm² (10 AWG) and smaller shall be ASTM B1 solid bare copper wire.

C. Isolated Power System: Type XHHW-2 insulation with a dielectric constant of 3.5 or less.

D. Electrical System Grounding: Conductor sizes shall not be less than what is shown on the drawings and not less than required by the NEC, whichever is greater.

2.02 GROUND RODS

A. Copper clad steel, 19 mm (3/4-inch) diameter by 3000 mm (10 feet) long, conforming to UL 467.

B. Quantity of rods shall be as required to obtain the specified ground resistance.

2.03 SPLICES AND TERMINATION COMPONENTS

Components shall meet or exceed UL 467 and be clearly marked with the manufacturer, catalog number, and permitted conductor size(s).

2.04 GROUND CONNECTIONS

A. Below Grade: Exothermic-welded type connectors.

B. Above Grade:

1. Bonding Jumpers: compression type connectors, using zinc-plated fasteners and external tooth lock washers.
2. Ground Busbars: Two-hole compression type lugs using tin-plated copper or copper alloy bolts and nuts.
3. Rack and Cabinet Ground Bars: one-hole compression-type lugs using zinc-plated or copper alloy fasteners.

2.05 EQUIPMENT RACK AND CABINET GROUND BARS

Provide solid copper ground bars designed for mounting on the framework of open or cabinet-enclosed equipment racks with minimum dimensions of 3 mm thick by 19 mm wide (3/8 inch x ¾ inch).

2.06 GROUND TERMINAL BLOCKS

At any equipment mounting location (e.g. backboards and hinged cover enclosures) where rack-type ground bars cannot be mounted, provide screw lug-type terminal blocks.

2.07 SPLICE CASE GROUND ACCESSORIES

Splice case grounding and bonding accessories shall be supplied by the splice case manufacturer when available. Otherwise, use 16 mm² (6 AWG) insulated ground wire with shield bonding connectors.

PART 3 EXECUTION

3.01 GENERAL

A. Ground in accordance with the NEC, as shown on drawings, and as hereinafter specified.

B. System Grounding:

1. Secondary service neutrals: Ground at the supply side of the secondary disconnecting means and at the related transformers.
2. Separately derived systems (transformers downstream from the service entrance): Ground the secondary neutral.
3. Isolation transformers and isolated power systems shall not be system grounded.

C. Equipment Grounding: Metallic structures (including ductwork and building steel), enclosures, raceways, junction boxes, outlet boxes, cabinets, machine frames, and other conductive items in close proximity with electrical circuits shall be bonded and grounded.

D. Special Grounding: For patient care area electrical power system grounding, conform to NFPA 99, and NEC.

3.02 LIGHTNING PROTECTION SYSTEM

Bond the lightning protection system to the electrical grounding electrode system.

3.03 WIREWAY GROUNDING

A. Ground and Bond Metallic Wireway Systems as follows:

1. Bond the metallic structures of wireway to provide 100 percent electrical continuity throughout the wireway system by connecting a 16 mm² (6 AWG) bonding jumper at all intermediate metallic enclosures and across all section junctions.
2. Install insulated 16 mm² (6 AWG) bonding jumpers between the wireway system bonded as required in paragraph 1 above, and the closest building ground at each end and approximately every 16 meters (50 feet).
3. Use insulated 16 mm² (6 AWG) bonding jumpers to ground or bond metallic wireway at each end at all intermediate metallic enclosures and cross all section junctions.
4. Use insulated 16 mm² (6 AWG) bonding jumpers to ground cable tray to column-mounted building ground plates (pads) at each end and approximately every 15 meters.

3.04 GROUND ROD INSTALLATION

A. Drive each rod vertically in the earth, not less than 3000 mm (10 feet)in depth.

B. Where permanently concealed ground connections are required, make the connections by the exothermic process to form solid metal joints. Make accessible ground connections with mechanical pressure type ground connectors.

C. Where rock prevents the driving of vertical ground rods, install angled ground rods or grounding electrodes in horizontal trenches.

END OF SECTION

SECTION 26 05 33

RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Floor outlet boxes.
2. Wall outlet boxes

1.02 REFERENCES

A. NECA 1 - Standard Practices for Good Workmanship in Electrical Contracting; National Electrical Contractors Association; 2000.

B. NEMA FB 1 - Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit and Cable Assemblies; National Electrical Manufacturers Association; 2003.

C. NEMA OS 1 - Sheet Steel Outlet Boxes, Device Boxes, Covers, and Box Supports; National Electrical Manufacturers Association; 2003.

D. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum); National Electrical Manufacturers Association; 2003.

E. NFPA 70 - National Electrical Code; National Fire Protection Association; 1996.

1.03 QUALITY ASSURANCE

A. Conform to requirements of NFPA 70

B. Products: Provide products listed and classified by manufacturer, or testing firm acceptable to the authority having jurisdiction as suitable for the purpose specified and indicated.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Slater Plastic Floor Boxes PS862-TCAL, with Slater Floor Box Cover PS895-TCAL

B. 2 gang non-metallic box

2.02 MANUFACTURERS

A. Pass & Seymour

B. Carlon

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. 2 threaded screw plugs. Includes 3232 15A, 125V duplex receptacle.

2.04 MATERIALS

A. Plastic box, aluminum cover

B. Blue plastic

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Install boxes securely, in a neat and workmanlike manner, as specified in NECA 1.

B. Install in locations as shown on Drawings, and as required for splices, taps, wire pulling, equipment connections, and as required by NFPA 70.

C. Coordinate installation of outlet boxes for equipment connected under Section 16155.

D. Set wall mounted boxes at elevations to accommodate mounting heights indicated.

E. Coordinate locations of boxes with casework, architectural appertenance, plumbing fixtures and other items or fixed equipment that my conflict with the installation or require the outlet in the immediate proximity of the equipment.

F. Coordinate outlet locations with those shown on architectural elevation where applicable.

G. Orient boxes to accommodate wiring devices oriented as specified in Section 16140.

H. Maintain headroom and present neat mechanical appearance.

I. Install pull boxes and junction boxes above accessible ceilings and in unfinished areas only.

J. Install boxes to preserve fire resistance rating of partitions and other elements.

K. Coordinate mounting heights and locations of outlets mounted above counters, benches, and backsplashes.

N. Use flush mounting outlet box in finished areas.

P. Do not install flush mounting box back-to-back in walls; provide minimum 6 inches separation. Provide minimum 24 inches separation in acoustic rated walls.

Q. Secure flush mounting box to interior wall and partition studs. Accurately position to allow for surface finish thickness.

R. Use stamped steel bridges to fasten flush mounting outlet box between studs.

S. Install flush mounting box without damaging wall insulation or reducing its effectiveness.

V. Support boxes independently of conduit.

W. Use gang box where more than one device is mounted together. Do not use sectional box.

X. Use cast outlet box in exterior locations exposed to the weather and wet locations.

Y. Set floor boxes level.

END OF SECTION

http://www.passandseymour.com/

SECTION 26 09 00

INSTRUMENTATION AND CONTROL FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Instrumentation and Control for Electrical Systems
2. Link Power Supply

1.02 REFERENCES

A. American National Standards Institute/Institute of Electrical and Electronic Engineers

1. Instrumentation and Control for Electrical Systems
   a. ANSI/IEEE C62.41-1991 – Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits.

B. Underwriters Laboratories, Inc.

1. Instrumentation and Control for Electrical Systems
   a. UL 489 (2002) - Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures.
   b. UL 508 (1999) - Standard for Industrial Control Equipment
   c. UL 924 (2003) - Emergency Lighting and Power Equipment
   d. UL 1472 (1996) - Solid-State Dimming Controls
2. Link Power Supply
   a. UL (1310 CLASS2)

1.03 ACTION SUBMITTALS

A. Product Data

1. Catalog cut sheets with performance specifications demonstrating compliance with specified requirements.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.04 QUALITY ASSURANCE

A. Manufacturer: Minimum [10] years experience in manufacture of lighting management systems.

B. Manufacturer’s Quality System: Registered to ISO 9001:2000 Quality Standard, including in-house engineering for product design activities.

1.05 WARRANTY

A. Manufacturer Warranty

1. 8-year limited parts warranty for the replacement of defective product from the date of system commissioning.

2. 2-year Support and Maintenance Plan that covers 100% parts and labor from the date of the system commissioning.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Quantum Light Management Hub QP2-1P0CSE-120 or similar

B. QS Link Power Supply (QSPS-P1-1-50/ QSPS-P2-1-50/QSPS-P3-1-50) or similar

2.02 MANUFACTURERS

A. Lutron Electronics Company, Inc.

B. Lutron Electronics Company Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Quantum Light Management Hub

1. Input Voltage: 120V, normal/emergency feeder
2. Output: EcoSystem – 18V 250 mA per loop, Processor – 24V 1 A per link
3. Enclosure: NEMA Type 1, IP-20 protection #16 U.S. gauge steel
4. Surface mount only

B. QS Link Power Supply

1. Input Voltage: Universal (100-240 VAC)
2. Output: 24V
3. Miswire Protection: Electronic Automatic Reset
4. Input Wiring: NEMA 5-15 Plug, CEE 7/7Plug, BS 1363 Plug
5. Weight 0.3 lb

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Manufacturer Installation Instructions

1. Follow manufacturer’s provided installation instruction manual.

B. Special Techniques

1. Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment.

END OF SECTION

http://www.lutron.com/CMS400/page.aspx?id=25823

SECTION 26 09 23

LIGHTING CONTROL DEVICES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for lighting control device
2. Specification for LED controller

1.02 REFERENCES

A. American National Standards Institute/Institute of Electrical and Electronic Engineers

1. ANSI/IEEE C62.41-1991 – Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits.

B. American Society for Testing and Materials

1. ASTM D4674 -02a Standard Test Method for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Fluorescent Lighting and Window-Filtered Daylight.

1.03 QUALITY ASSURANCE

1. Lighting control device
   a. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
   b. Comply with NFPA 70.
2. LED Controller
   a. Dimming Range: 100% to 1% measured Meets FCC Part 15 Non-Consumer requirements for EMI/RFI emissions in a typical grounded fixture.
   b. Class P thermally protected.

1.04 WARRANTY

A. For a period of one year from the date of purchase, and subject to the exclusions and restrictions, the manufacturer warrants each new unit to be free from manufacturing defects. The manufacturer will, at its option, either repair the defective unit or issue a credit equal to the purchase price of the defective unit to the Customer against the purchase price of comparable replacement part purchased from the manufacturer. Replacements for the unit provided by the manufacturer or, at its sole discretion, an approved vendor may be new, used, repaired, reconditioned, and/or made by a different manufacturer.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Lighting Control Device

1. Maestro Wireless Dimmer MRF2-600M-XX or similar
   Maestro Wireless Controller MRF2-3BRL-L-XX or similar

B. LED Controller

1. Hi-lume LED Driver

2.02 MANUFACTURERS

A. Lutron Electronics Company, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Lighting Control Device

1. Capacity

   a. 600 W

   b. 30 foot communication radius

2. 120V single pole/multi-location smart dimmer with RF receiver for control of halogen/incandescent lighting loads.

3. Rated to handle any type of lighting up to 8A at 120V or up to 6A at 277V

4. Directly control up to 1000W of incandescent or 1000VA of magnetic low-voltage (MLV)

5. 3-button, raise/lower wireless controller with car visor clip and wall-mounting clip.

B. LED Controller

1. Operating Voltage: 120/277 V at 50/60 Hz

2. Dimming Range: 100% to 1%

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Furnish all devices (dimmers, accessories, & wallplate kits), labor and other services necessary for the proper installation of the devices as indicated on the drawings and specified herein.

2. Be responsible for derating dimmer capacity if side sections are removed.

3. Run separate neutral wires in 120/208 VAC installations.

4. Install all back boxes with a minimum wallbox depth of 2.5 inches.

5. Devices shall be installed utilizing manufacturer's recommended application, wiring and installation instructions.

6. Provide seamless wall plate covers per specification 2.02 for all devices ganged in a common box. Provide barriers within the box where required by code.

<u>END OF SECTION</u>

SECTION 26 09 33

CENTRAL DIMMING CONTROLS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for occupant sensors.
2. Specification for daylight sensors.

1.02 REFERENCES

A. American National Standards Institute/Institute of Electrical and Electronic Engineers (ANSI/IEEE)

1. C62.41-1991 – Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits.

B. ASTM International (ASTM)

1. D4674 -02a Standard Test Method for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Fluorescent Lighting and Window-Filtered Daylight.

C. Canadian Standards Association (CSA) .

1. CSA C22.2 # 14 Industrial Control Equipment
2. CSA C22.2 # 184 Solid-State Lighting Controls
3. CSA C22.2 # 156 Solid-State Speed Controls

D. International Electrotechnical Commission .

1. (IEC) 801-2 Electrostatic Discharge Testing Standard.
2. IEC/EN 60669-2-1 Switches for household and similar fixed electrical installations - electronic switches.

E. International Organization for Standardization (ISO)

1. 9001:2000 – Quality Management Systems.

F. National Electrical Manufacturers Association (NEMA)

1. WD1 (R2005) - General Color Requirements for Wiring Devices.

G. Norma Official Mexicana (NOM).

1. NOM-003-SCFI Productos eléctricos - Especificaciones de seguridad (Electrical products - Safety Specifications)

H. Underwriters Laboratories, Inc. (UL):

1. 94 – Flammability Rating
2. 916 – Energy Management Equipment.
3. 508 (2005) - Standard for Industrial Control Equipment.
4. 244A – Appliance Controls
5. 935 (2005) - Fluorescent Ballasts

1.03 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Manufacturer: Minimum [10] years experience in manufacture of architectural lighting controls.

C. Manufacturer's Quality System: Registered to ISO 9001:2000 Quality Standard, including in-house engineering for product design activities.

1.04 WARRANTY

A. For a period of one year from the date of purchase, and subject to the exclusions and restrictions, the manufacturer warrants each new unit to be free from manufacturing defects. The manufacturer will, at its option, either repair the defective unit or issue a credit equal to the purchase price of the defective unit to the Customer against the purchase price of comparable replacement part purchased from the manufacturer. Replacements for the unit provided by the manufacturer or, at its sole discretion, an approved vendor may be new, used, repaired, reconditioned, and/or made by a different manufacturer.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. LOS-CDT-500R-WH Ceiling Mount Sensor or similar

1. Description: Ceiling-mount dual-technology sensors, eliminates manual sensitivity and timer adjustments during installation and over the life of the product.

B. C-SR-M1-WH EcoSystem Daylight Sensor or similar

1. Description: Designed specifically to implement daylight harvesting, allowing the system to automatically dim the lights when the available daylight is high and brighten the lights when the available daylight is low in order to maintain a specific light level in the space.

2.02 MANUFACTURERS

A. Lutron Electronics Company, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Occupant Sensors

1. 500 sq.ft. (46 m^2) coverage
2. Operating voltage: 20 – 24V, PELV (Class 2: USA) low-voltage
3. Control Output: 20 – 24V active high logic control signal with short-circuit protection, open collector when unoccupied

B. Daylight Sensors

1. Designed for Class 2 operation only. Voltages do not exceed 35VDC.
2. Operating voltage: Low-voltage Class 2, 20V
3. Analog Signal: 0 – 2 mA
4. IR Output: 0 – 20V

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the General Installation Manual for Lutron Occupant Sensor LOS-C Series and C-SR-M1 EcoSystem Daylight Sensor. A link is provided at the end of this section.

END OF SECTION

http://www.lutron.com/products/pdf/LOS-CDT%20Series.pdf
http://www.lutron.com/products/pdf/031260a.pdf
http://www.lutron.com/CMS400/WorkArea/downloadasset.aspx?id=10365

SECTION 26 24 16

PANELBOARDS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Power distribution panelboards.

1.02 REFERENCES

A. NECA 1 - Standard Practices for Good Workmanship in Electrical Contracting; National Electrical Contractors Association; 2000.

B. NEMA PB 1 - Panelboards; National Electrical Manufacturers Association; 2000.

C. NEMA PB 1.1 - General Instructions for Proper Installation, Operation and Maintenance of Panelboards Rated 600 Volts or Less; National Electrical Manufacturers Association; 2002.

D. NETA STD ATS - Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems; International Electrical Testing Association; 2003.

E. NFPA 70 - National Electrical Code; National Fire Protection Association; 1996.

1.03 SUBMITTALS

A. Shop Drawings: Indicate outline and support point dimensions, voltage, main bus ampacity, integrated short circuit ampere rating, circuit breaker and fusible switch arrangement and sizes.

B. Manufacturer's Installation Instructions: Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, and installation of product.

C. Project Record Documents: Record actual locations of panelboards and record actual circuiting arrangements.

D. Maintenance Data: Include spare parts listing; source and current prices of replacement parts and supplies; and recommended maintenance procedures and intervals.

1.04 QUALITY ASSURANCE

A. Conform to requirements of NFPA 70.

B. Products: Listed and classified by Underwriters Laboratories, Inc. or testing firm acceptable to the authority having jurisdiction as suitable for the purpose specified and indicated.

1.05 MAINTENANCE MATERIALS

A. Furnish one of each panelboard key.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Square D

B. Cutler-Hammer

2.02 POWER DISTRIBUTION PANELBOARDS

A. Description: NEMA PB 1, circuit breaker type.

B. Panelboard Bus: Copper, ratings as indicated. Provide copper ground bus in each panelboard.

C. Minimum integrated short circuit rating: As indicated.

D. Molded Case Circuit Breakers: With integral thermal and instantaneous magnetic trip in each pole; UL listed. For air conditioning equipment branch circuits provide circuit breakers UL listed as Type HACR.

E. Circuit Breaker Accessories: Trip units and auxiliary switches as indicated.

F. Enclosure: NEMA PB 1, Type 1, 3.75 inches deep, 14.25 inches wide, cabinet box.

G. Cabinet Front: Surface type, fastened with screws, hinged door with flush lock, metal directory frame, finished in manufacturer's standard gray enamel.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install panelboards in accordance with NEMA PB 1.1 and NECA 1.

B. Install panelboards plumb. Install recessed panelboards flush with wall finishes.

C. Height: 6 feet to top of panelboard; install panelboards taller than 6 feet with bottom no more than 4 inches above floor.

D. Provide filler plates for unused spaces in panelboards.

E. Provide typed circuit directory for each branch circuit panelboard. Revise directory to reflect circuiting changes required to balance phase loads.

3.02 FIELD QUALITY CONTROL

A. Inspect and test in accordance with NETA STD ATS, except Section 4.

B. Perform inspections and tests listed in NETA STD ATS, Section 7.5 for switches, Section 7.6 for circuit breakers.

END OF SECTION

http://www.schneider-electric.us/products-services/product-detail/?event=datasheet&partnumber=HOM42M225C&countrycode=us

SECTION 26 24 19

MOTOR CONTROL CENTERS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Motor control centers.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide for each brushless servomotor.

1.04 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data

1.05 WARRANTY

A. Manufacturer Warranty

1. 12 Month Standard Manufacturer Warranty.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. AKM Series Brushless Servomotor: AKM42G-ANCNR-01

2.02 MANUFACTURERS

A. Danaher Motion

2.03 DESCRIPTION

A. Brushless Servomotor.

2.04 MATERIALS

A. Motor Construction.

1. Die-cast Aluminum Housing.
2. Stator Class F High Density Windings.
3. Neodymium-Iron-Boron magnets

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 APPLICATION

A. Driving the track system in order to move the Aluminum Screen Doors.

3.03 INSTALLATION

A. Install per Manufacturer Instructions within applicable NEC regulations.

END OF SECTION

www.danahermotion.com/website/common/download/document/200608011600510.AKM_Selection_Guide.pdf

SECTION 26 27 13

ELECTRICAL METERING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Electrical Metering Enclosure

1.02 REFERENCES

A. NECA 1 - Standard Practices for Good Workmanship in Electrical Contracting; National Electrical Contractors Association; 2000.

B. NEMA PB 1 - Panelboards; National Electrical Manufacturers Association; 2000.

C. NEMA PB 1.1 - General Instructions for Proper Installation, Operation and Maintenance of Panelboards Rated 600 Volts or Less; National Electrical Manufacturers Association; 2002.

D. NETA STD ATS - Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems; International Electrical Testing Association; 2003.

E. NFPA 70 - National Electrical Code; National Fire Protection Association; 1996.

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide for each enclosure

B. Shop Drawings

1.04 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data

1.05 WARRANTY

A. Manufacturer Warranty

1. Limited Warranty: 24 months from date of installation but not more than 30 months from date of manufacture.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Electrical System: Metering

2.02 MANUFACTURERS

A. Cutler-Hammer

2.03 DESCRIPTION

A. 200 Amp meter socket, Bottom feed, ringless, surface mounted, NEMA 3R rated.

2.04 MATERIALS

A. Enclosure Construction

1. Surface type, fastened with screws, hinged door with flush lock, metal directory frame, finished in manufacturer's standard gray enamel

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 APPLICATION

A. Electrical metering of the Solar house

3.03 INSTALLATION

A. Follow manufacturer's supplied pre-installation checklist and installation guide.

B. Install enclosure in accordance with NEMA PB 1.1 and NECA 1.

C. Install enclosure plumb. Install recessed enclosure flush with wall finishes.

D. Height: 6 feet to top of enclosure; install enclosure taller than 6 feet with bottom no more than 4 inches above floor.

E. Provide filler plates for unused spaces in enclosure.

3.04 FIELD QUALITY CONTROL

A. Inspect and test in accordance with NETA STD ATS, except Section 4.
B. Perform inspections and tests listed in NETA STD ATS.

END OF SECTION

http://www.eaton.com/EatonCom/Markets/Electrical/Products/ResidentialProducts/MeteringProducts/MeterSockets/index.htm?ssSourceNodeId=4254&ssSourceSiteId=EatonCom

SECTION 26 27 26
WIRING DEVICES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Wall switches.

B. Wall dimmers.

C. Receptacles.

D. Device plates and decorative box covers.

E. Floor box service fittings.

F. Poke-through service fittings.

1.02 RELATED SECTIONS

A. Section 26 05 33 – Raceways and Boxes for Electrical Systme

1.03 REFERENCES

A. NECA 1 - Standard Practices for Good Workmanship in Electrical Contracting; National Electrical Contractors Association; 2000.

B. NEMA WD 1 - General Color Requirements for Wiring Devices; National Electrical Manufacturers Association; 1999.

C. NEMA WD 6 - Wiring Device -- Dimensional Requirements; National Electrical Manufacturers Association; 2002.

D. NFPA 70 - National Electrical Code; National Fire Protection Association; 1996.

1.04 SUBMITTALS

A. Shop Drawings: Indicate outline and support point dimensions,

B. Manufacturer's Installation Instructions: Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, and installation of product.

1.05 QUALITY ASSURANCE

A. Conform to requirements of NFPA 70.

B. Products: Provide products listed and classified by Underwriters Laboratories, Inc. or testing firm acceptable to the authority having jurisdiction as suitable for the purpose specified and indicated.

PART 2 PRODUCTS

2.01 WALL SWITCHES

A. Wall Switches: Heavy Duty, AC only general-use snap switch, complying with NEMA WD 6 and WD 1.

1. Body and Handle: Plastic body with nylon toggle handle of color selected by the Architect from manufacturer's standard colors.

2. Ratings:

a. Voltage: 120 - 277 volts, AC.

b. Current: 20 amperes.

B. Switch Types: Single pole, double pole, and 3-way.

2.02 WALL DIMMERS

A. Wall Dimmers: Semiconductor dimmer for incandescent lamps, Type as indicated on drawings, complying with NEMA WD 6 and WD 1.

1. Body and Handle: Plastic with linear slide of color selected by the Architect from manufacturer's standard colors.

2. Voltage: 120 volts.

3. Power Rating: Match load shown on drawings; 600 watts minimum.

B. Accessory Wall Switches: Match dimmer appearance.

2.03 RECEPTACLES

A. Receptacles: Heavy duty, complying with NEMA WD 6 and WD 1.

1. Device Body: Nylon body of color selected by the Architect from manufacturer's standard colors.

2. Configuration: NEMA WD 6, type as specified and indicated.

B. Convenience Receptacles: Type 5 - 20.

C. Duplex Convenience Receptacles.

D. GFCI Receptacles: Convenience receptacle with integral ground fault circuit interrupter to meet regulatory requirements.

2.04 WALL PLATES

A. Decorative Cover Plates: White, nylon.

B. Weatherproof Cover Plates: Gasketed plastic with hinged gasketed device cover. Device shall remain weatherproof with standard plug inserted in the receptacle.

2.05 FLOOR MOUNTED SERVICE FITTINGS

A. Flush Cover Convenience Receptacles:

1. Material: Nickel.

2. Configuration: Duplex flap opening.

B. Protective Ring: Nickel finish.

2.06 POKE-THROUGH FITTINGS

A. Pole-Through Fittings: Assembly comprising service fitting, poke-through component, fire stops and smoke barriers, and junction box for conduit termination.

1. Fire Rating: 3 hours.

2. Type: Flush.

3. Housing: Round Brass.

4. Device Plate: Brass.

5. Configuration: Two duplex and Two Communcication Outlets of types as indicated.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify that outlet boxes are installed at proper height.

B. Verify that wall openings are neatly cut and will be completely covered by wall plates.

C. Verify that branch circuit wiring installation is completed, tested, and ready for connection to wiring devices.

3.02 PREPARATION

A. Provide extension rings to bring outlet boxes flush with finished surface.

B. Clean debris from outlet boxes.

3.03 INSTALLATION

A. Install securely, in a neat and workmanlike manner, as specified in NECA 1.

B. Install devices plumb and level.

C. Install switches with OFF position down.

D. Install wall dimmers to achieve full rating specified and indicated after derating for ganging as instructed by manufacturer.

E. Do not share neutral conductor on load side of dimmers.

F. Install receptacles with grounding pole on top.

G. Connect wiring device grounding terminal to outlet box with bonding jumper.

H. Install decorative plates on switch, receptacle, and blank outlets in finished areas.

I. Connect wiring devices by wrapping conductor around screw terminal. Stab connections at back of wiring devices shall not be utilized.

J. Install galvanized steel plates on outlet boxes and junction boxes in unfinished areas, above accessible ceilings, and on surface mounted outlets.

3.04 FIELD QUALITY CONTROL

A. Inspect each wiring device for defects.

B. Operate each wall switch with circuit energized and verify proper operation.

C. Verify that each receptacle device is energized.

D. Test each receptacle device for proper polarity.

E. Test each GFCI receptacle device for proper operation.

3.05 ADJUSTING

A. Adjust devices and wall plates to be flush and level.

3.06 CLEANING

A. Clean exposed surfaces to remove splatters and restore finish.

END OF SECTION

http://www.lutron.com/products/dimmers/wallplate.asp?s=17000&t=17200

SECTION 26 27 73

DOOR CHIMES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:

1. Door Chime
2. Doorbell Button

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer’s product and complete installation data for products in this specification.

B. Manufacturer’s Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

A. Qualifications

1. An employer of workers trained and approved by manufacturer for installation and maintenance of units is required for this project.

1.04 WARRANTY

A. Manufacturer Warranty

1. One year for parts and labor, backed by manufacturer’s toll-free support.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. SpOre Inc. Ring Doorbell Model # CHR

1. Size: 4.25” wide x 1.5” deep
2. Finish: Deep silver luster and satin finish anodized aluminum

B. SpOre, Inc. Round Illuminated doorbell button Model # DBR-Blue

1. Colored Lights: Blue
2. Size: 2.64” wide x .68” deep
3. Finish/Materials: Colored translucent elastomeric resin with UV inhibitors, satin finish anodized aluminum.
4. Hardware included.

2.02 MANUFACTURERS

A. SpOre, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. True “ding dong” sound
2. 11 years/100,000 of illumination provided by LEDs
3. Less than 1 Watt of power use

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. Place units in final locations after finishes have been completed in each area. Follow provided manufacturer’s installation guide.

END OF SECTION

http://www.sporeinc.com/products.html

SECTION 26 31 00
PHOTOVOLTAIC COLLECTORS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for bifacial photovoltaic collectors.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1.03 WARRANTY

A. Manufacturer Warranty

1. Sanyo warrants the product to be free from defects in materials and workmanship under normal application, installation, use, and service conditions. If the product fails to conform to this warranty, Sanyo will, at its sole option, either repair or replace the product. This warranty shall extend for a period ending twenty-four (24) months from date of purchase by the customer. This repair or replacement remedy shall be the sole and exclusive remedy provided under this warranty and the original product warranty period remains in effect and will not be extended, nor will a new warranty period begin, upon repair or replacement of defective product.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. HIT Double 190 Bifacial Photovoltaic Module

2.02 MANUFACTURERS

A. Sanyo Energy Corp. (USA)

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. Rated electrical characteristics are within –5% to +10% of the values measured at STC. STC Conditions are; irradiance of 1000W/m2, 25oC cell temperature, and solar spectral irradiance per IEC 60904-3.

2. Under normal conditions, a photovoltaic module may experience conditions that produce more current and/or voltage than reported at Standard Test Conditions. Accordingly, the values of Isc and Voc marked on modules should be multiplied by a factor of 1.25 when determining voltage ratings, conductor capacities, fuse sizes, and size of controls connected to the module output. Refer to Section 690 of the National Electrical Code (NEC) for an additional multiplying factor of 1.25, which may be applicable.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the General Installation Manual for Sanyo HIT Double Photovoltaic Modules. A link is provided at the end of this section.

3.03 PROTECTION

A. For information regarding the protection of the photovoltaic collectors, see the General Installation Manual for Sanyo HIT Double Photovoltaic Modules.

3.04 MAINTENANCE

A. Some maintenance is recommended to maintain optimal output performance of the solar modules.

B. When a module's front or back surface becomes dirty, power output is reduced.

C. It is recommended to clean the front surface of the module with water and a soft cloth or sponge, twice or more per year. It is recommended to clean the back surface as needed.

D. A mild, non-abrasive detergent may be applied for persistent dirt.

E. It is also recommended to inspect the mechanical and electrical connections annually.

END OF SECTION

http://us.sanyo.com/dynamic/product/Downloads/HIT%20Double%20190%20Data%20Shet-49567522.pdf
http://us.sanyo.com/dynamic/product/Downloads/HIT%20Double%20Installation%20Manual%20(DA3)%2020090101-26232870.pdf
http://us.sanyo.com/dynamic/product/Downloads/Solar%20Warranty%20All%20HIP-xxxDA3%20Modules%201%20April%202007-2936494.pdf

SECTION 26 32 13

ENGINE GENERATORS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for engine generators to be used during initial construction of site.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

C. Shop drawings.

1.03 WARRANTY

A. Manufacturer Warranty

1. Honda GX Commercial grade general purpose engines are covered by this warranty for a period of 24 months for noncommercial/non-rental use and 24 months for commercial/rental use from the date of original retail purchase.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. GX390 Commercial Grade

2.02 MANUFACTURERS

A. HONDA Engines

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. EPA/CARB Compliant
2. Air cooled, 4-stroke, OHV, single cylinder engine type
3. 11.0 max HP output
4. Dimensions: 16" L x 17.7" W x 17.4" H

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the General Installation Manual and Use and Care Guide.

3.03 PROTECTION

A. For information regarding the protection of the photovoltaic collectors, see the General Installation Manual for Sanyo HIT Double Photovoltaic Modules.

3.04 MAINTENANCE

A. Some maintenance is recommended to maintain optimal output performance .

B. Keep engine clean and well oiled to maintain power output levels.

C. It is recommended to change the oil in the engine twice or more per year, depending on frequency of use. It is recommended to clean as needed. A mild, non-abrasive detergent may be applied for persistent dirt.

E. It is also recommended to inspect the mechanical and electrical connections annually.

<u>END OF SECTION</u>

http://www.honda-engines.com/engines/gx390.htm#spe

SECTION 26 51 13

INTERIOR LIGHTING FIXTURES, LAMPS, AND BALLASTS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Ceiling light fixtures
2. Fluorescent bulbs
3. Fluorescent Electronic dimming ballasts
4. LED floor lamp
5. LED desk lamp
6. Linear LED fixtures
7. LED downlights
8. RGB LED strips
9. LED transformer
10. LED pendant lamp

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

1.03 QUALITY ASSURANCE

A. Testing

1. Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.03 WARRANTY

A. Manufacturer Warranty

1. Ceiling light fixture: For one year from the invoice date, that all units purchased will be free of defective materials (except lamps, ballasts and transformers) and workmanship when shipped. Should any defects in materials or workmanship appear within the period of the guarantee, the manufacturer will repair or replace, at our sole option, without charge, those items found to be defective (other than ballasts, lamps and/or transformers).
2. Fluorescent light: For one year from the invoice date, that all units purchased will be free of defective materials (except lamps, ballasts and transformers) and workmanship when

shipped. Should any defects in materials or workmanship appear within the period of the guarantee, the manufacturer will repair or replace, at our sole option, without charge, those items found to be defective (other than ballasts, lamps and/or transformers).

3. Fluorescent Electronic dimming ballast: Manufacturer’s warranty covering 3 years, 5 years with factory commissioning on ballasts from date of purchase.
4. LED floor lamp: One year manufacturer warranty.
5. LED floor lamp: One year manufacturer warranty.
6. Linear LED fixtures: Manufacturer warrants to the purchaser that each product manufactured and sold by it will be free from defects in material and workmanship in its intended use (normal wear and tear excepted) for the period of two years from date of purchaser's purchase (the invoice date) from manufacturer.
7. LED downlights: Manufacturer warrants to the purchaser that each product manufactured and sold by it will be free from defects in material and workmanship in its intended use (normal wear and tear excepted) for the period of two years from date of purchaser's purchase (the invoice date) from manufacturer
8. Except as otherwise provided, Seller warrants for a period of one (1) year from the date of shipment that the goods supplied to Buyer shall be of good materials and workmanship. Seller further warrants for a period of one (1) year that the goods supplied by Buyer, when properly installed and used, are fit for the ordinary purpose or purposes indicated in the catalog and will conform to the catalog or to any other specifications supplied by Seller.
9. Except as otherwise provided, Seller warrants for a period of one (1) year from the date of shipment that the goods supplied to Buyer shall be of good materials and workmanship. Seller further warrants for a period of one (1) year that the goods supplied by Buyer, when properly installed and used, are fit for the ordinary purpose or purposes indicated in the catalog and will conform to the catalog or to any other specifications supplied by Seller.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Ceiling light fixture
   1. Basis of Design Product: Cove Style F301
   2. Description: Large concealed, remote ballast
      a. Up to eight 55W lamps per reflector
      b. Adjustable aiming – tailor performance to the application
      c. Electronic ballasts – instant on, quiet, dimming optional
      d. Glare is minimized and asymmetry of the beam is maximized resulting in high beam efficiency and superior surface uniformity

B. Fluorescent light

1. Basis of Design Product: T5 Linear Fluorescent or similar
2. Description: Linear fluorescent light
    a. Base: Miniature Bipin
    b. Color Temperature: 3,000K
    c. Color Rendering Index: 82
    d. Rated Lifespan: 20,000 hours

C. Fluorescent Electronic dimming ballast
1. Basis of Design Product: Hi-lume 3D
2. Description: Electronic dimming ballast, performance of 100% at full-range to less than 1% fluorescent dimming.
    a. Standard 3-wire line-voltage phase-control technology for consistent fixture-to-fixture dimming performance.
    b. Dimming Range: 100% to 1% measured relative light output for T5
    c. Lamp Current Crest Factor: less than 1.7
    d. Power Factor: greater than .95
    e. Maximum Ballast Case Temperature: 75 ºC (167 ºF)

D. LED floor lamp
1. Basis of Design Product: i-Tower High Power HL5000W-MBK or similar
2. Description: High power energy efficient LED lamp with a built-in dimmer
    a. Energy consumption: 9.3W
    b. Bulbs: 6 High power LEDs
    c. Rated Lifespan: 40,000 hours to 70% brightness
    d. Color Temperature (Warm): 3,200K – 3,700K
    e. Color Temperature (Daylight): 4,600K – 5,600K
    f. Brightness Adjustability: 4-steps dimming

E. LED desk lamp
1. Basis of Design Product: i-Bar Mini LED Desk Lamp HL1100
    a. Energy consumption: 7.4W
    b. Bulbs: 4 High power LEDs
    c. Rated Lifespan: 40,000 hours to 70% brightness
    d. Color Temperature (Warm): 3500K
    e. Color Temperature (Daylight): 5500K
    f. Brightness Adjustability: 4-steps dimming

F. Linear LED fixtures
1. Description – eW Cove Powercore: Dimmable, light for interior alcoves and niches
    a. Energy Consumption: 4.5W max at full output, steady state
    b. Beam angle: 110º x 110º
    c. Lumens: 177

d. Efficacy: 39.3 Lm/W

e. Color Rendering Index: 77

2. Description – eW Profile Powercore: Ultra-low profile, under cabinet fixture

a. Energy Consumption: 5.5W max at full output, steady state

b. Beam angle: 110º x 110º

c. Lumens: 50

d. Efficacy: 25.0 Lm/W

e. Color Rendering Index: 71

3. Description – eW Downlight Powercore: Energy efficient LED downlight

a. Energy Consumption: 15W max at full output, steady state

b. Beam angle: 65º or 30º full-width at half-maximum

c. Lumens: 406 (30º beam angle) 414 (65º beam angle)

d. Efficacy: 28 Lm/W (30º beam angle) 28 Lm/W (65º beam angle)

e. Color Rendering Index: 84

5. Description – eW Graze Powercore: LED surface light for wall washing

a. Energy Consumption: 14.5W max at full output, steady state

b. Beam angle: 10º x 60º

c. Lumens: 404

d. Efficacy: 27.9

e. Color Temperature: 2700k

G. LED downlights

1. Description – eW Downlight Powercore 2700k

a. Energy Consumption: 15W max at full output, steady state

b. Beam angle: 65° or 30°

c. Lumens: 406

d. Efficacy: 28

e. Color Temperature: 2700k

2. Description – Calculite® LED Downlight C410LEDDL30K

a. Energy Consumption: 10W

b. Lumens: 485

c. Efficacy: 56.4

d. Color Temperature: 3000k

H. RGB LED strips

1. Description - LED – RGB Strip 833.05.100

a. Energy Consumption: .7W per 250mm strip

b. Power: DC12V

c. Color Temperature: Variable

I. LED transformer

1. Description - Transformer distributor block 833.06.102
   a. Energy Consumption: 30W max at full output, steady state
   b. Power: 120V 60Hz 12DC
   c. Dimensions Item No. 137mm x 38mm x 32mm

J. LED pendant lamp
1. Description – Tubular (Custom)
   a. Energy Consumption: 25w
   b. Power: 120 VAC
   c. Dimensions: 4’L x 6”W

2.02 MANUFACTURERS

A. Elliptipar
B. Elliptipar
C. Lutron Electronics Company, Inc.
D. Koncept Technologies Inc.
E. Koncept Technologies Inc.
F. Philips Color Kinetics
G. Philips Color Kinetics/Lightoiler
H. Hafele
I. Hafele
J. Focal Point

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Manufacturer Installation Instructions
1. Follow each manufacturer’s provided installation instruction manual.

B. Special Techniques
1. Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment.

END OF SECTION

http://www.elliptipar.com/Brochures/Cove_Broch.pdf
http://www.elliptipar.com/ceiling/Clngpdf/C45.pdf
http://www.konceptech.com/highpoweritower.html
http://colorkinetics.com/support/datasheets/eW_Cove_Powercore_4200K_SpecSheet.pdf
http://colorkinetics.com/support/datasheets/eW_Profile_Powercore_2700KW_SpecSheet.pdf
http://colorkinetics.com/support/datasheets/eW_Downlight_Powercore_2700K_SpecSheet.pdf
http://www.elliptipar.com/performance/IAL.pdf
http://www.lutron.com/CMS400/page.aspx?id=10089

SECTION 27 21 00

DATA COMMUNICATIONS NETWORK EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Wireless ID tag
2. Wireless Router
3. Ethernet Switch
4. Cable Modem

1.02 ACTION SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for products in this specification.

B. Manufacturer's Instructions

1. The product manufacturer shall provide a written installation guide along with maintenance data.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

1. BlipNet Beacon (or comparable product)
   a. Description: BlipNet Beacon is a new concept for Real Time Location Systems (RTLS). Unlike other RTLS systems, BlipNet Beacon is based on tagging the location and not on tracking the mobile device itself. A BlipNet Beacon network is a RTLS network for tracking Bluetooth enabled phones. The system is very easy to deploy since no broadband connection are required. Only power is required at the site. The system can be applied to locate mobile phones. The phone must be able to run the BlipBeacon Tracker application.
   b. Input voltage: 100-240 AC
   c. Power consumption: <0,5W
   d. Frequency band: 2.4-2.483 GHz
   e. Range adjustable from approx. 10 cm to 30 m.
2. Simultaneous Dual-band Wireless WRT400N (or comparable product)
   a. Description: Experience faster wireless connectivity with fewer interruptions with two bands of Wireless-N, today's most advanced wireless technology. The 5 GHz and 2.4 GHz bands are designed to work separately yet simultaneously, so you can easily customize your ideal configuration.
   b. Receive Sensitivity: 5 GHz: 54Mbps: -72 dBm @ Typical
   c. Antenna Gain in dBi: 5GHZ: RIFA 1 <= 3.85 dBi (Typical)

d. Standards: Draft 802.11n, 802.11a, 802.11g, 802.11b, 802.3, 802.3u

3. EtherFast 4124 24-Port 10/100 (EF4124) (or comparable product)

a. Description: Ethernet connectivity for up to 24 devices. Created connection between media, file-sharing, printing, Internet, etc.

b. Standards: IEEE 802.3, IEEE 802.3u, IEEE 802.3x

c. Ports: 24 10/100 Auto-Negotiation RJ-45 Ports

d. Cabling: Type UTP/STP Category 5 or Better

4. Surfboard SB5101 (or comparable product)

a. Description: With the next-generation SURFboard SB5101 cable modem, you're compatible with today's broadband Internet--and ready for the future, too. When your cable service provider upgrades to a DOCSIS 2.0 network system, you'll surf the Internet at as much as 30 Mbps--3 times faster than earlier modems.

b. CableLabs DOCSIS 1.1 and 2.0 Certified

c. Capable of up to 30 Mbps upstream capacity when connected to a DOCSIS 2.0 cable network

d. Supports up to 63 users

2.02 MANUFACTURERS

A. Blip Systems

B. Linksys

C. Linksys

D. Motorola

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Manufacturer Installation Instructions

1. Follow each manufacturer’s provided installation instruction manual.

B. Special Techniques

1. Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment.

END OF SECTION

http://www.blipsystems.com/Default.aspx?ID=684

SECTION 31 66 00

SPECIAL FOUNDATIONS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for special foundations.

1.02 REFERENCES

A. American National Standards Institute/American Society of Mechanical Engineers:

1. ANSI/ASME PALD 1993, Portable Automotive Lifting Devices

B. European Norm

1. EN1494, Moveable jacks and associated lifting equipment

1.03 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1.04 WARRANTY

A. Manufacturer Warranty

1. Enerpac warrants the product to be free of defects in materials and workmanship under normal use for as long as they are owned by the original purchaser, subject to the exclusions and limitations described below. This warranty does not cover ordinary wear and tear, overloading, alterations, (including repairs or attempted repairs by parties other than the manufacturer or its Authorized service representatives), improper fluid, use in a manner for which they are not intended or use which is contrary to instructions for the products.
2. If the product is defective, the product must be delivered, or shipped freight prepaid, to the nearest manufacturer's Authorized Service Center. The customer should contact the manufacturer to locate an Authorized Service Center in the customer's area. Products that do not conform to this warranty will be repaired or replaced at the manufacturer's expense and returned by ground transportation, freight prepaid.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Hydraulic Bottle Jack – EBJ-30GC

2.02 MANUFACTURERS

A. Enerpac U.S.A.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. Product max lifting load of 30 tons.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the General Installation Manual for Enerpac Hydraulic Bottle Jacks Models EBJL1.5GC – EBJ100GC. A link is provided at the end of this section.

3.04 MAINTENANCE

A. Some maintenance is recommended to maintain optimal output performance of the hydraulic jack.

B. Use only Enerpac hydraulic oil.

C. Thoroughly lubricate after every 10 cycles. Lubricate all pivot pins (3) and other moving parts.

D. Periodically, check ram for signs of corrosion and lubricate all moving parts.

END OF SECTION

http://www.enerpac.com/files/catalogues/EBJ_325US_0.pdf
http://www.enerpac.com/files/im/hydraulic_equipment/cylinders/L2322_c.PDF

SECTION 33 47 13

POND AND RESERVOIR LINERS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Rubber liners for on-site rainwater collection ponds, landscaping ponds, and direct geo-exchange heat exchanger ponds.
2. Adhesives and pressure sensitive tape

1.02 REFERENCES

A. American Society for Test and Materials

1. ASTM D2240 – Standard Test Method for Rubber Property

B. WRc-NSF's Aquatic Life Compatibility Certification

1.03 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions for installation

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Geomembrane PondGardTM for Decorative Pond applications

B. Splice Adhesive Model # SA-1065

2.02 MANUFACTURERS

A. Firestone, BPE

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. Because of its specific formulation and production process, only the Firestone Pond LinerTM membrane is guaranteed to be compatible with aquatic life in accordance with testing reports published by the Water Research Centre in the UK.
2. Thickness: 0.45"

2.04 MATERIALS

A. Geomembrane: Cured single-ply synthetic rubber membrane made of ethylene-propylene-diene-terpolymer (EPDM)

B. Adhesive: Butyl-based contact adhesive.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Preparation:

1. Allow the membrane to relax for approximately 30 minutes before splicing. The substrate needs to be smooth, dry and free of sharp objects, oil, grease, and other materials that may damage the Geomembrane.

2. Stir Adhesive before and during use. Keep adhesive at approximately room temperature prior to application. Apply in thick, even, smooth coat on both surfaces with a 75 to 100 mm wide solvent resistant paintbrush. Do not use circular motions.

B. Install the Firestone Geomembrane in accordance with current specifications.

END OF SECTION

http://www.firestonebpe.com/lining/syst_comp/epdm_geomembrane/_en/index.shtm

SECTION 34 43 23

WEATHER OBSERVATION EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for weather observation equipment.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions for installation

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. WeatherHawk 520 Wireless Solid State Weather Station

2.02 MANUFACTURERS

A. Scientific Sales, Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. The WeatherHawk 521 weather station measures wind speed & direction, barometric pressure, solar radiation, rainfall, air temperature & relative humidity. This rugged sensor system has no moving parts and includes an integral thermostatically controlled sensor head heater, data logger, 3 AHr battery pack & wireless 916 MHz spread spectrum radio.

2. Dimensions: 20" L x 12" W x 16" H

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Preparation:

1. Allow the membrane to relax for approximately 30 minutes before splicing. The substrate needs to be smooth, dry and free of sharp objects, oil, grease, and other materials that may damage the Geomembrane.

2. Stir Adhesive before and during use. Keep adhesive at approximately room temperature prior to application. Apply in thick, even, smooth coat on both surfaces with a 75 to 100 mm wide solvent resistant paintbrush. Do not use circular motions.

B. Install the Firestone Geomembrane in accordance with current specifications.

END OF SECTION

http://www.weatherhawk.com/store/show.cfm

SECTION 48 19 16

ELECTRICAL POWER GENERATION INVERTERS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for grid-tied, electrical power generation inverters.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1.03 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. All Sunny Boy inverters are thoroughly tested and inspected before they are packed and shipped. Although they are shipped in sturdy, recyclable packaging; damage can still occur during shipping. It is important to carefully inspect the shipping container prior to beginning the installation. If any external damage to the packaging makes you suspect the inverter itself could be damaged, or if you find that the inverter is damaged after unpacking it, report the damage immediately to your SMA dealer and to the shipping company that delivered the Sunny Boy. If it becomes necessary to return the Sunny Boy, use the original packaging in which it was delivered.

1.04 WARRANTY

A. Manufacturer Warranty

1. A ten year warranty applies to the following products: Sunny Boy SB700US, SB3000US, SB4000US, SB5000US, SB6000US, and SB7000US. The SMA factory warranty covers any repair or replacement part costs incurred during the agreed period, beginning on the device's purchase date, subject to the conditions listed below. This is not associated with the durability warranty.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Sunny Boy 5000US Grid-Tied Inverter

2.02 MANUFACTURERS

A. SMA Solar Technology

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. See the Sunny Boy Data Sheet for input and output data as well as product efficiencies, weights, and dimensions.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the Sunny Boy Solar Inverter Installation guide for instructions on unpacking, mounting, and wiring the inverters.

3.03 MAINTENANCE

A. See the Sunny Boy Solar Inverter Installation Guide for instructions on cleaning the fans and handle covers, testing the fans, and exchanging the fuses.

END OF SECTION

http://download.sma.de/smaprosa/dateien/4752/SUNNYBOY567-DUS091314W.pdf
http://download.sma.de/smaprosa/dateien/4752/SB50US-70US-IUS090523.pdf

SECTION 48 19 19

ELECTRICAL POWER GENERATION SOLAR TRACKING EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Specification for solar tracking equipment for electrical power generation.

1.02 ACTION SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

1.03 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. All Electrak PPA-M Actuators are thoroughly tested and inspected before they are packed and shipped.

1.04 WARRANTY

A. Manufacturer Warranty

1. A two-year from date of substantial completion manufacturer's warranty applies to all Electrak PPA-M Actuators.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Electrak PPA-M Linear Actuators

2.02 MANUFACTURERS

A. Thomson Linear Motion by Danaher Motion Co.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

1. See the Electrak PPA-M Actuator Data Sheet for maximum and minimum stroke length, speed, torque, and load data as well as product efficiencies, weights, and dimensions.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. Special Techniques

1. See the Electrak PPA-M Actuator Installation guide for instructions on unpacking, mounting, and wiring the inverters provided by the manufacturer.

3.03 MAINTENANCE

A. See the Electrak PPA-M Actuator Installation Guide for instructions on cleaning the fans and handle covers, testing the fans, and exchanging the fuses.

END OF SECTION

http://www.danahermotion.com/website/com/eng/products/actuators/linear_actuators/electrak_non-driven/electrak_ppa-m.php
http://www.danahermotion.com/website/com/eng/products/actuators/linear_actuators/electrak_non-driven/electrak_ppa-m_literature.php

Solar Decathlon 2009 – Structural Calculations

Virginia Tech College of Architecture & Urban Studies

Table of Contents

STATE OF NEW YORK
PETER G. TILLSON
LICENSED PROFESSIONAL ENGINEER

ARUP	Job No. 75948-74	Sheet No. S-1	Rev.
	Member-Location		
Job Title Solar Decathlon	Drg. Ref.		
Virginia Tech Entry	Made by PGT	Date Dec 08	AO7 Chd.

1.0 Structure, Materials, Loading & Codes

1.1 Codes & Standards

- 2009 Solar Decathlon - Building Code September 29, 2008
- 2006 International Residential Code
- 2006 International Building Code
- 2005 ASCE/SEI 7 Minimum Design Loads for Buildings & other Structures

1.2 Material Properties

- Structural Steel

	Grade	F_y [ksi]	
Rolled sections	ASTM A572-Gr 50	50	
HSS square & rectangular	ASTM A500-Gr B	46	
HSS round	" "	42	
Pipe	ASTM A53-Gr B	35	
Plate	ASTM A572-Gr 50	50	$t \leq 2''$

- Welding Electrodes E7018 — F_u [ksi] 70
- Normal weight concrete
  - f'_c 3,000 psi
  - γ_c 150 pcf

- Allowable bearing pressures
  - Temporary Installation 1500 psf
  - Permanent 2000 psf

ARUP

Job No.	Sheet No.	Rev.
75948-74	S-2	

Member-Location

Drg. Ref.

Job Title Solar Decathlon VT

Made by PST Date Dec '08 Chd. [illegible]

1·3 Structure

See attached sheets S-3, S-4, S-5.

1·4 Loading

1·4·1 Temporary Installation - The Mall, Washington D.C.

Live Load	[psf]
Egress	100
Floor	50
Roof (covers snow also)	20
†Equipment	50

Dead Load		
Floor	2½" NWC on 1½"-20ga Lok-Floor	41
Roof	10 ¼" SIPS panels (R-Control)	4
	Services + lightweight ceiling	5
Solar Panels	Photovoltaics (<3500 lbs) 13 ft × 36 ft	7.5
Sliding Panels	2 layers 16ga stainless + frame	5
Walls	1" insulated glass	15
Plywood pallet foundations		15

Wind Load	
Basic wind speed (3-second gust)	60 mph
Exposure Category	C
Factor of safety against overturning & uplift	2

†Equipment

Mechanical Room [> 20 sq ft]	[lbs]
Heat pumps (2)	410
Inverters	286
Water tank	134
Washer/dryer	176
TOTAL	1006 ⇒ 50 psf

1.4.2 Permanent Installation (Category II Occupancy)

Live Load

		[psf]
Floor		40
Roof		20

Dead Load

See 1.4.1

Snow Load

		[psf]
Ground snow load	p_g	30
Flat roof " "	$p_f = 0.7 C_e C_t I p_g$	21
	I	1.0
	C_e	1.0
	C_t	1.0

Wind Load

Basic wind speed	V	100 mph
Exposure category		B
Height	h	≤ 15 ft
Importance	I	1.0

ASCE 7 simplified method

net horizontal $p_s = \lambda K_{zt} I p_{s30}$

$= 1.0 \times 1.0 \times 1.0 \times 15.9 = 15.9$ psf Zone A

" " $10.5 = 10.5$ psf Zone C

net vertical $p_s =$ $= -19.1$ E

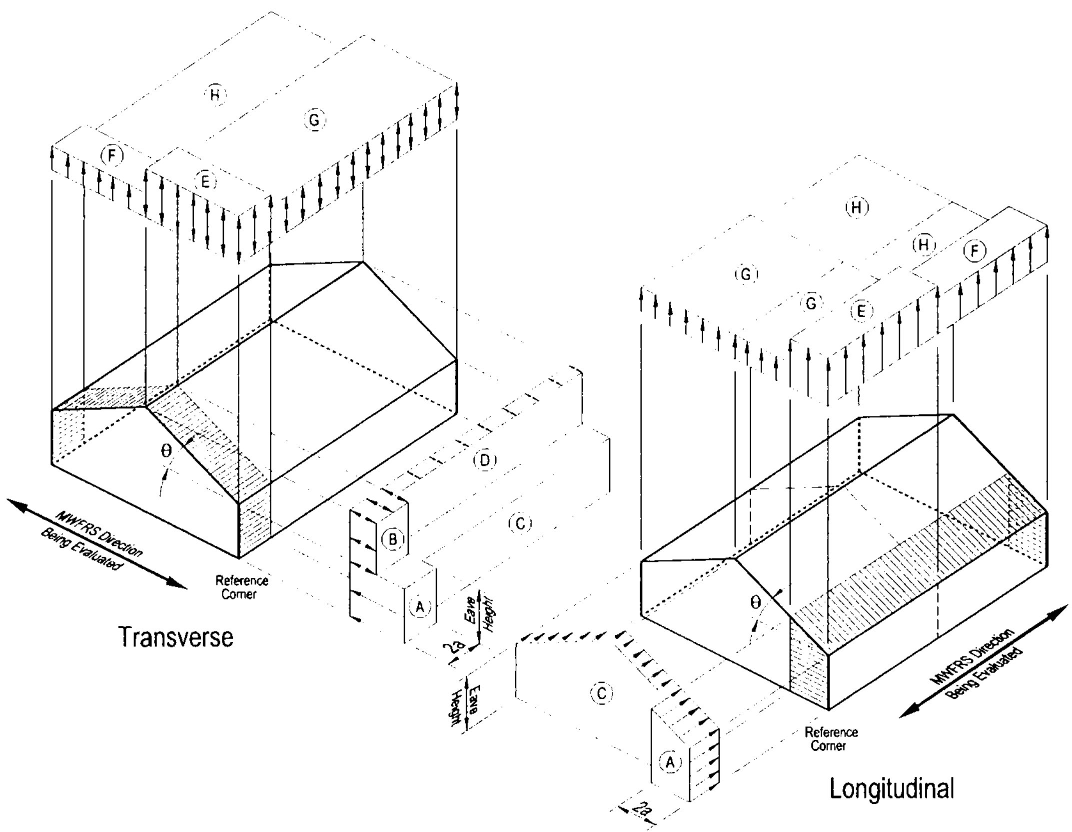
$= -10.8$ F

$= -13.3$ G

$= -8.4$ H

see S-2.2 for code diagram

Main Wind Force Resisting System – Method 1		h ≤ 60 ft.
Figure 6-2	Design Wind Pressures	Walls & Roofs
Enclosed Buildings		



Notes:

1. Pressures shown are applied to the horizontal and vertical projections, for exposure B, at h=30 ft (9.1m), I=1.0, and K_{zt} = 1.0. Adjust to other conditions using Equation 6-1.
2. The load patterns shown shall be applied to each corner of the building in turn as the reference corner. (See Figure 6-10)
3. For the design of the longitudinal MWFRS use $\theta = 0°$, and locate the zone E/F, G/H boundary at the mid-length of the building.
4. Load cases 1 and 2 must be checked for $25° < \theta \leq 45°$. Load case 2 at 25° is provided only for interpolation between 25° to 30°.
5. Plus and minus signs signify pressures acting toward and away from the projected surfaces, respectively.
6. For roof slopes other than those shown, linear interpolation is permitted.
7. The total horizontal load shall not be less than that determined by assuming $p_S = 0$ in zones B & D.
8. The zone pressures represent the following:
   Horizontal pressure zones – Sum of the windward and leeward net (sum of internal and external) pressures on vertical projection of:
   - A - End zone of wall — C - Interior zone of wall
   - B - End zone of roof — D - Interior zone of roof

   Vertical pressure zones – Net (sum of internal and external) pressures on horizontal projection of:
   - E - End zone of windward roof — G - Interior zone of windward roof
   - F - End zone of leeward roof — H - Interior zone of leeward roof
9. Where zone E or G falls on a roof overhang on the windward side of the building, use E_{OH} and G_{OH} for the pressure on the horizontal projection of the overhang. Overhangs on the leeward and side edges shall have the basic zone pressure applied.
10. Notation:
    a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).
    h: Mean roof height, in feet (meters), except that eave height shall be used for roof angles <10°.
    θ: Angle of plane of roof from horizontal, in degrees.

ARUP

Job No.	Sheet No.	Rev.
75948-74	S2.3	

Member-Location

Job Title Solar Decathlon

VT

Drg. Ref.

Made by PGT Date Dec '08 Chd.

Earthquake Load (Representative of Eastern US Site)

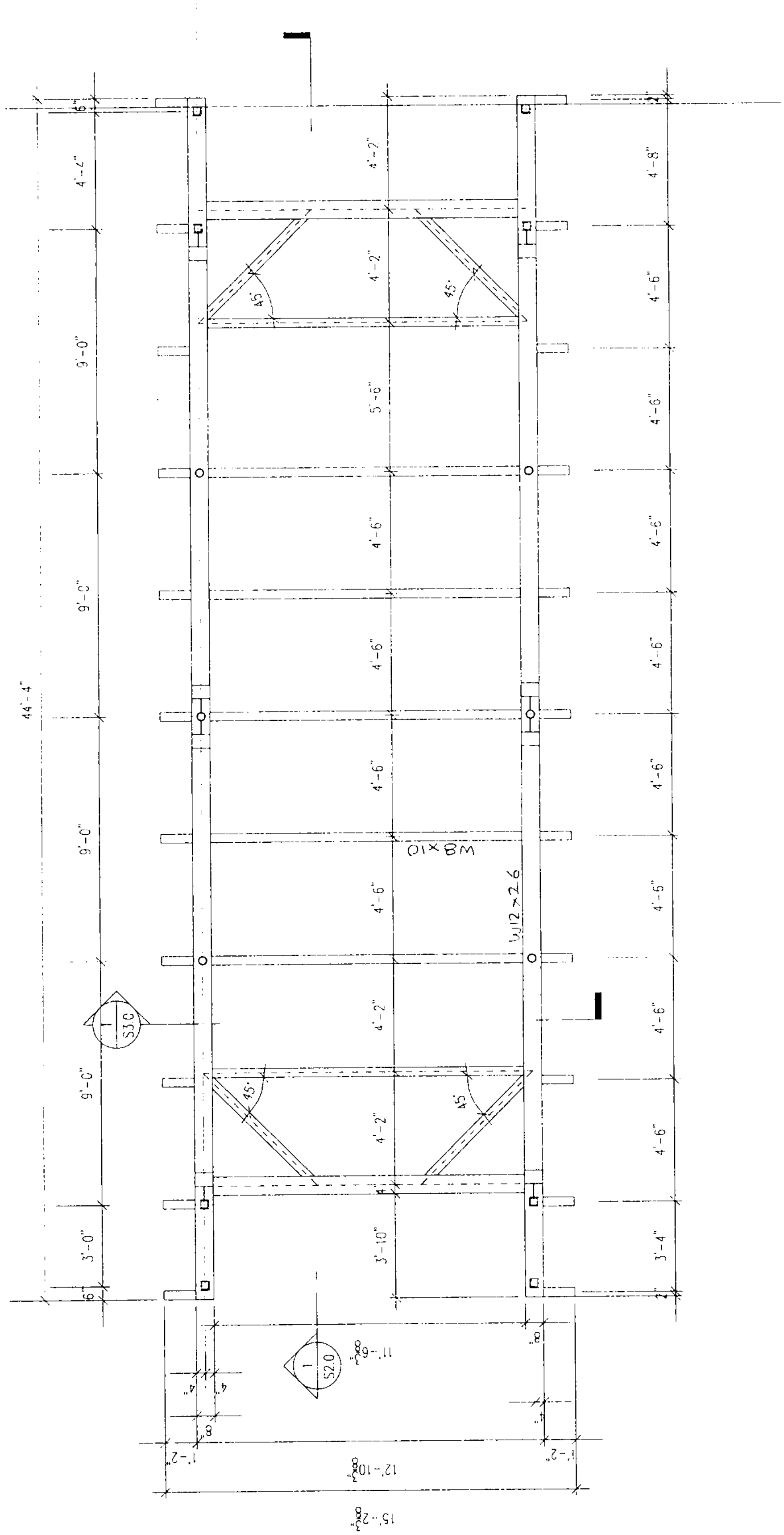
Site Class		C
Spectral accelerations	S_s	25% g
	S_1	8% g
Site coefficients	F_a	1.2
	F_v	1.7
Adjusted MCE accel.	S_{MS}	30% g
	S_{M1}	13.6% g
Design spectral accel.	S_{DS}	20% g
	S_{D1}	9% g
Seismic design category		
for S_{DS}		B
for S_{D1}		B

Design Category B.

Period	T	≤ 0.1 sec
Importance	I	1.0

Seismic Force Resisting System
- SIPS panel across building $R = 2.0$
- Concentrically braced frame along building, $R = 3.25$

S-3

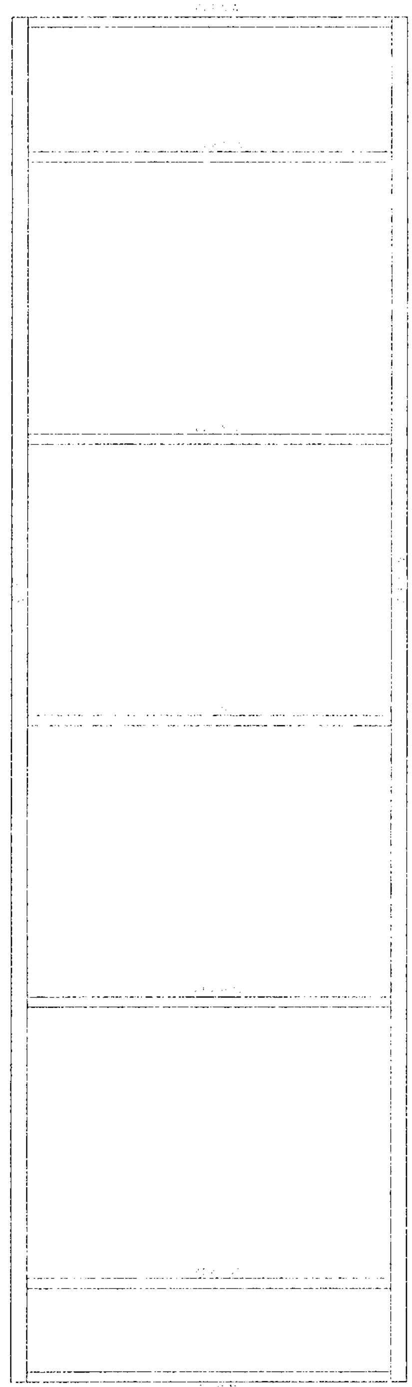


Floor Framing Plan
SCALE 1/4"=1'-0"

1
S1.0

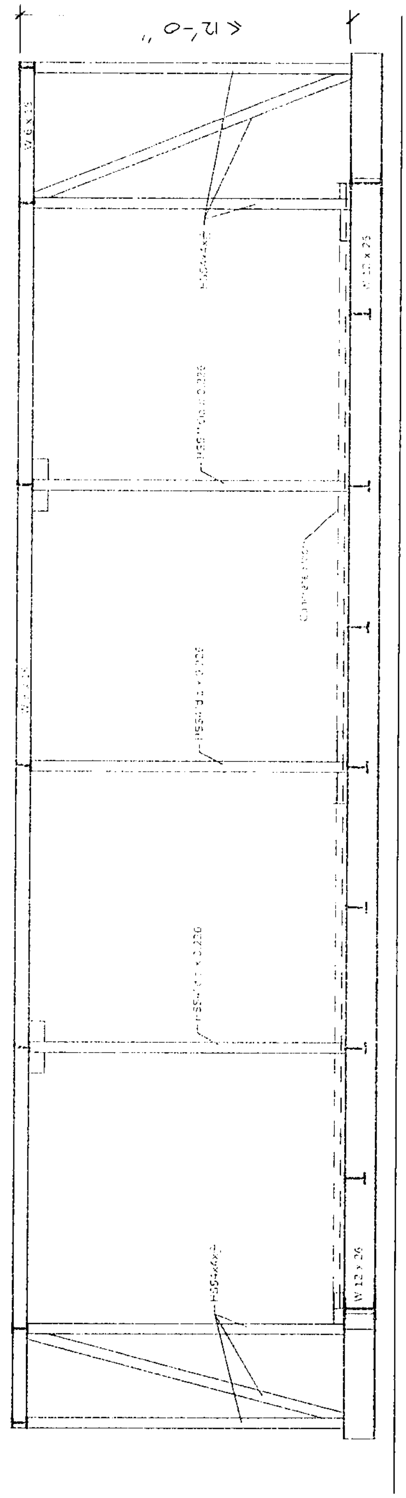
S-4

S-4



Roof Framing Plan

S-5



Typical Elevation

ARUP

Job No.	Sheet No.	Rev.
75948-74	S-6	
Member-Location		
Job Title: Solar Decathlon VT	Drg. Ref.	
	Made by PGT Date Dec'08	Chd.

2.0 Floor Framing

Design all beams to be non-composite, although studs may be provided.

2.1 Typical Beam

Span, L = 12'-2" (treat as simply supported)
Spacing, b_t = 4'-6"

Loading $\omega_D = 10 + 4.5'(41 + 10)$ = 240 lb/ft
miscellaneous

$\omega_L = 4.5' \times 100$ = 450 " "

ASD $\omega_a = \omega_D + \omega_L$ = 690 " "

$V_a = \omega_a L/2 = .69 \times 12.2/2$ = 4.2 kip
$M_a = \omega_a L^2/8 = (.69 \times 12.2^2/8)$ = 12.8 kip-ft
$2V_a$ = 8.2 kip

from AISC Manual 13th Edition
w/ flange fully restrained $\Omega_b = 1.67$

for L=12' W_a = 14.6 kip OK

Typical Beam
W8×10

2.2 Typical Stub Cantilever

Span, L = 1'-6"
Spacing, b_t = 4'-6'
Loading $\omega_D = 10 + 4.5'(41+10)$ = 240 lb/ft

$\omega_L = 4.5' \times 100$ = 450 lb/ft

$P_D = 4.5' \times 12'(5 + 15)$ = 1.1 kip

$V_a = 0.69 \times 1.5' + 1.1$ = 2.1 kip

$M_a = \frac{1}{2} \times .69 \times 1.5^2 + 1.5 \times 1.1$ = 2.43 kip-ft

from AISC Manual
M_n/Ω_b = 22 kip-ft OK

Typical Stub
W8×10

ARUP

Job No.	Sheet No.	Rev.
75948-74	S-7	

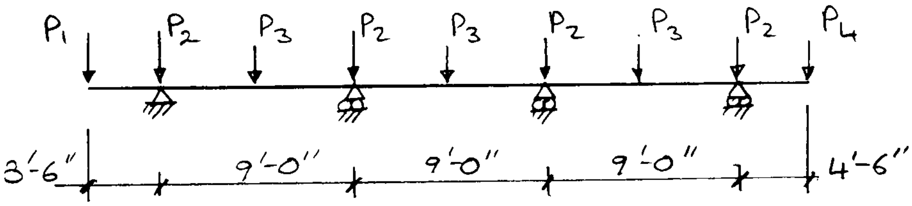
Member-Location

Job Title: Solar Decathlon VT

Drg. Ref.

Made by PGT Date Dec '08 Chd.

2.3 Edge Beam



Load P_1, P_2 from roof & floor

P_3 from floor only

Load P_2 transfers directly to foundation

Pt Load	Atrib [ft²]	P_D [kip]	P_L [kip]	P_L^r [kip]	P_S [kip]
P1	13.0	0.9	1.3	0.3	0.3
P3	34.0	2.9	3.4	0.7	0.7
P4	17.0	1.2	1.7	0.4	0.4

$P_{1a} = 2.2^k$

$P_{3a} = 6.3^k$

$P_{4a} = 2.9^k$

Cantilever moment $M_a^{max} = 2.9 \times 4.5 = 13.1$ k-ft

Span moment $M_a^o = P_{3a} L/4 + \omega_{self} L^2/8$

$\simeq 6.3 \times 9/4 + .026 \times 9^2/8$

$= 14.4$ k-ft (if simply supported)

with bracing 4.5' oc W12×26 capacity

$M_n/\Omega = 93$ k-ft $\gg M_a^o, M_a^{cant}$

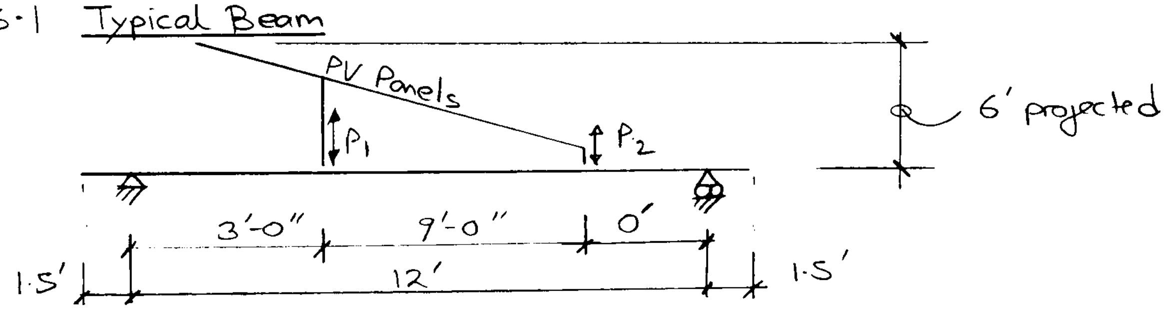
shear OK by inspection

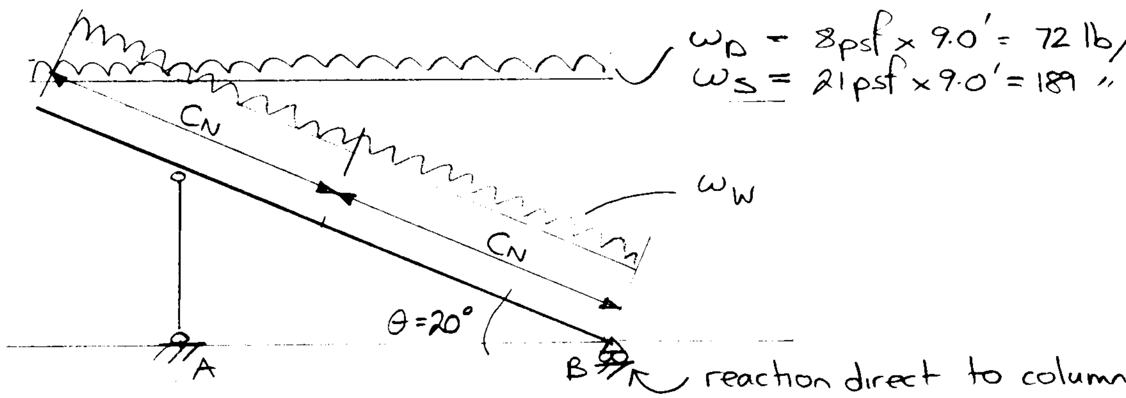
$\boxed{\text{Edge Beam: W12×26}}$

3.0 Roof Framing

SIPS panels provide lateral restraint to top flange of beams. Panels span parallel to typical beam

3.1 Typical Beam





$\omega_D = 8 psf \times 9.0' = 72\ lb/ft$
$\omega_S = 21 psf \times 9.0' = 189$ " "

Wind Load (permant installation)

Consider wind on monoslope roof over open building to estimate loads Figure 6-18A $\gamma = 0°, 180°$
6-18D $\gamma = 90°$

maximum reaction @ A

$\gamma = 0°$, clear wind flow $C_{NW} = \boxed{-2.4}$ or -1.5
$C_{NL} = \boxed{-0.3}$ or -1.6

$\gamma = 90°$, clear wind flow $C_N = -0.8$ or $+0.8$

$\gamma = 180°$, obstructed wind flow $C_{NW} = +0.5$ or $\boxed{+1.3}$
$C_{NL} = -1.0$ $\boxed{0}$

not critical

Reaction @ A:

$p = C_N G q_h$

$q_h = 0.00256 K_z K_{zt} K_d V^2 I$ ASCE 7 Eq 6-15

$= 0.00256 \times 0.57 \times 1.0 \times 0.85 \times 100^2 \times 1.0$

$= 12.4$ psf

$p = C_N \times 0.85 \times 12.4 = 10.5 C_N$ psf

GSA analysis file "PV_Panel".

Roof beams supporting PV panels are 9' o.c (ie every other beam)

from analysis (see sheets S-10 to S-14)

A_1 : 0.6D + W $M_a = -2.87$ k-ft (bottom flange in compression)

$\equiv 34.4$ k-in

A_2 : D + S $M_a = +5.24 = 63$ k-in

for uplift beam is braced at ends only

$L_b = 12' > L_r = 1.95 r_{ts} \left(\frac{E}{.7F_y}\right)\sqrt{\frac{J_c}{S_x h_o}}\left[1+\left(1+6.76\left(\frac{.7F_y}{E}\cdot\frac{S_x h_o}{J_c}\right)^2\right)^{1/2}\right]^{1/2}$

$\simeq \pi r_{ts}\left(\frac{E}{.7F_y}\right)^{1/2} = 98''$

$\Rightarrow M_n = F_{cr} S_x \leq M_p$

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_{ts}}\right)^2}\left(1 + 0.078 \frac{J_c}{S_x h_o}\left(\frac{L_b}{r_{ts}}\right)^2\right)^{1/2}, \quad C_b = 3.0$$

for W6 x12 :

$r_{ts} = 1.08''$

$J_c = 0.0903$ in^4

$h_o = 5.75''$

$S_x = 7.31$ in^3

$F_{cr} = 96.3$ ksi $> F_y$

$\Rightarrow M_n = F_y Z_x = 50 \times 8.3 = 415$ k-in

$M_n/\Omega_b = 415/1.67 = 248$ k-in $\gg M_a$ OK

Typical Beam
W6 x12

ARUP

Soalr Decathlon
Structural Frame
PV Panel Supports

Job No.	Sheet No.	Rev.
75948-74	S-10	
Drg. Ref.		
Made by PGT	Date 12-Dec-2008	Checked

Titles and Model Statistics

```
Job number:              75948-74
Job title:               Soalr Decathlon
Subtitle:                Structural Frame
Calc. heading:           PV Panel Supports
File:                    X:\Project\Possible Jobs\75948-74
                         Virginia Tech Solar Decathlon\4 Internal
                         Project Data\4-04
                         Calculations\PGT\PV_Panel.gwb
Notes:                   (none)
Structure Type:          Plane
Invalid Directions:      Y XX ZZ
Global Directions:       (none)

Number of nodes:             6
Highest node:                6
Number of elements:          6
Highest element:             7
Number of members:           0
Highest member:              0
Number of load cases:        3
Highest load case:           3
```

Load Case Titles

Case	Name	Type
L1	Dead	Dead
L2	Snow	Snow
L3	Wind	Wind

Combination Case and Envelope Details

Cases for which results are not available are displayed in red

Combination Cases

Case	Name	Permutation	Description
C1	C1 0.6D+W		0.6A1 + A3
C2	C2 D+S		A1 + A2

Analysis Envelope Tasks

This table is empty.

Titles and Model Statistics

```
Job number:              75948-74
Job title:               Soalr Decathlon
Subtitle:                Structural Frame
Calc. heading:           PV Panel Supports
File:                    X:\Project\Possible Jobs\75948-74
                         Virginia Tech Solar Decathlon\4 Internal
                         Project Data\4-04
                         Calculations\PGT\PV_Panel.gwb
Notes:                   (none)
Structure Type:          Plane
Invalid Directions:      Y XX ZZ
Global Directions:       (none)

Number of nodes:             6
Highest node:                6
Number of elements:          6
Highest element:             7
Number of members:           0
Highest member:              0
Number of load cases:        3
Highest load case:           3
```

Load Case Titles

Case	Name	Type
L1	Dead	Dead
L2	Snow	Snow
L3	Wind	Wind

Analysis Details

Analysis Task 1

```
Name:        Task 1
Solver:      GSS 10.28.1.18 Static
Status:      post-analysis (Analysed: Friday, December 12, 2008)
```

Analysis Cases

Case	Name	Description	Error norm
A1	Dead	L1	not calculated
A2	Snow	L2	not calculated
A3	Wind	L3	not calculated

Combination Case and Envelope Details

Cases for which results are not available are displayed in red

Combination Cases

Case	Name	Permutation	Description
C1	C1 0.6D+W		0.6A1 + A3
C2	C2 D+S		A1 + A2

Analysis Envelope Tasks

This table is empty.

Case Permutation Factors

Case	Name	Permutation	Description	Case	Factor	Name
C1	C1 0.6D+W	p1	0.6A1 + 1A3	A1	0.6000	Dead
				A3	1.000	Wind
C2	C2 D+S	p1	1A1 + 1A2	A1	1.000	Dead
				A2	1.000	Snow

Nodes

Output axes: global

Node	x	y	z	Constraint Axis	Restr.	Gen. Restr.	Spring Support
	[ft]	[ft]	[ft]				
1	0.0	0.0	0.0	Global	Pin		
2	3.000	0.0	0.0	Global			
3	12.00	0.0	0.0	Global	7		
4	-0.2160	0.0	4.446	Global			
5	4.053	0.0	2.892	Global			
6	5.892	0.0	2.223	Global			

Maxima

1 W6x12	Steel	W6x12	3.550	22.10	2.979	0.09034	0.5278	***0.3470*** N/A	0.0
1 W6x12	Steel	W6x12	3.550	22.10	2.979	0.09034	0.5278	0.3470 N/A	***0.0***

Beam Section Summary

Values of Length, Mass, Surface Area and Cost are totals for all the elements / members that reference the property and are based on unmodified properties.

Description	No. of Elements	Elements: Length [ft]	Elements: Mass [lb]	Elements: Surface Area [ft²]	Elements: Cost [USD]	No. of Members	Members: Length [ft]	Members: Mass [lb]	Members: Surface Area [ft²]	Members: Cost [USD]
1 W6x12	6	28.08	339.2	64.70	0.0	0	0.0	0.0	0.0	0.0
Maxima										
1 W6x12	6	***28.08***	339.2	64.70	0.0	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	***339.2***	64.70	0.0	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	***64.70***	0.0	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	***0.0***	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	***0.0***	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	0.0	***0.0***	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	0.0	0.0	***0.0***	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	0.0	0.0	0.0	***0.0***
Minima										
1 W6x12	6	***28.08***	339.2	64.70	0.0	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	***339.2***	64.70	0.0	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	***64.70***	0.0	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	***0.0***	0	0.0	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	***0.0***	0.0	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	0.0	***0.0***	0.0	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	0.0	0.0	***0.0***	0.0
1 W6x12	6	28.08	339.2	64.70	0.0	0	0.0	0.0	0.0	***0.0***
Totals										
		28.08	339.2	64.70	0.0		0.0	0.0	0.0	0.0

Beam Loads

This table is empty.

Beam Loads

This table is empty.

Reactions

Reactions due to restraints, spring supports, applied displacements and grounded springs
Output axes: global
Refer to Combination Case and Envelope Details for details of enveloping permutations

Node	Case	Fx [kip]	Fy [kip]	Fz [kip]	|F| [kip]	Mxx [kip-ft]	Myy [kip-ft]	Mzz [kip-ft]	|M| [kip-ft]
1	A1	0.0	0.0	0.4963	0.4963	0.0	0.0	0.0	0.0
	A2	0.0	0.0	1.251	1.251	0.0	0.0	0.0	0.0
	A3	-0.5702	0.0	-1.254	1.378	0.0	0.0	0.0	0.0
	C1	-0.5702	0.0	-0.9565	1.114	0.0	0.0	0.0	0.0
	C2	0.0	0.0	1.747	1.747	0.0	0.0	0.0	0.0
2	A1	0.0	0.0	0.4787	0.4787	0.0	0.0	0.0	0.0
	A2	0.0	0.0	1.206	1.206	0.0	0.0	0.0	0.0
	A3	0.0	0.0	-0.3124	0.3124	0.0	0.0	0.0	0.0
	C1	0.0	0.0	-0.02519	0.02519	0.0	0.0	0.0	0.0
	C2	0.0	0.0	1.685	1.685	0.0	0.0	0.0	0.0
Maxima									
2	A1	***0.0***	0.0	0.4787	0.4787	0.0	0.0	0.0	0.0
1	A1	0.0	***0.0***	0.4963	0.4963	0.0	0.0	0.0	0.0
1	C2	0.0	0.0	***1.747***	1.747	0.0	0.0	0.0	0.0
1	C2	0.0	0.0	1.747	***1.747***	0.0	0.0	0.0	0.0
1	A1	0.0	0.0	0.4963	0.4963	***0.0***	0.0	0.0	0.0
1	A1	0.0	0.0	0.4963	0.4963	0.0	***0.0***	0.0	0.0
1	A1	0.0	0.0	0.4963	0.4963	0.0	0.0	***0.0***	0.0
1	A1	0.0	0.0	0.4963	0.4963	0.0	0.0	0.0	***0.0***
Minima									
1	C1	***-0.5702***	0.0	-0.9565	1.114	0.0	0.0	0.0	0.0
1	A1	0.0	***0.0***	0.4963	0.4963	0.0	0.0	0.0	0.0
1	A3	-0.5702	0.0	***-1.254***	1.378	0.0	0.0	0.0	0.0
2	C1	0.0	0.0	-0.02519	***0.02519***	0.0	0.0	0.0	0.0
1	A1	0.0	0.0	0.4963	0.4963	***0.0***	0.0	0.0	0.0
1	A1	0.0	0.0	0.4963	0.4963	0.0	***0.0***	0.0	0.0
1	A1	0.0	0.0	0.4963	0.4963	0.0	0.0	***0.0***	0.0
1	A1	0.0	0.0	0.4963	0.4963	0.0	0.0	0.0	***0.0***

Beam and Spring Forces and Moments

The force in an element at any point is the force required to maintain equilibrium if the element is cut at that point and the end 2 part of the element is discarded. Thus +ve axial forces are tensile
Forces and moments are output in element axis directions
i.e. Fx: axial force; Fy & Fz: shear forces, Mxx: torsion; Myy & Mzz: moments
Element axes for springs are as defined by the spring property axis no
Element list: 1 2
Refer to Combination Case and Envelope Details for details of enveloping permutations.

Elem	Case	Pos	Fx [kip]	Fy [kip]	Fz [kip]	Mxx [kip-ft]	Myy [kip-ft]	Mzz [kip-ft]
1	A1	1	0.0	0.0	-0.4963	0.0	-344.9E-9	0.0
		2	0.0	0.0	-0.4963	0.0	-1.489	0.0
	A2	1	0.0	0.0	-1.251	0.0	411.1E-9	0.0
		2	0.0	0.0	-1.251	0.0	-3.752	0.0
	A3	1	0.5702	0.0	1.254	0.0	-712.5E-9	0.0
		2	0.5702	0.0	1.254	0.0	3.763	0.0
	C1	1	0.5702	0.0	0.9565	0.0	-919.5E-9	0.0
		2	0.5702	0.0	0.9565	0.0	2.870	0.0
	C2	1	0.0	0.0	-1.747	0.0	66.15E-9	0.0
		2	0.0	0.0	-1.747	0.0	-5.241	0.0
2	A1	2	0.2409	0.0	0.1654	0.0	-1.489	0.0
		3	0.2409	0.0	0.1654	0.0	-8.058E-9	0.0
	A2	2	0.6070	0.0	0.4169	0.0	3.752	0.0
		3	0.6070	0.0	0.4169	0.0	62.41E-9	0.0
	A3	2	-0.03862	0.0	-0.4181	0.0	3.763	0.0
		3	-0.03862	0.0	0.4181	0.0	42.03E-9	0.0
	C1	2	0.1059	0.0	-0.3188	0.0	2.870	0.0
		3	0.1059	0.0	-0.3188	0.0	37.19E-9	0.0
	C2	2	0.8479	0.0	0.5823	0.0	-5.241	0.0
		3	0.8479	0.0	0.5823	0.0	54.36E-9	0.0
Maxima								
2	C2	2	***0.8479***	0.0	0.5823	0.0	-5.241	0.0
1	A1	1	0.0	***0.0***	-0.4963	0.0	-344.9E-9	0.0
1	A3	1	0.5702	0.0	***1.254***	0.0	712.5E-9	0.0
1	A1	1	0.0	0.0	-0.4963	***0.0***	-344.9E-9	0.0
1	A3	2	0.5702	0.0	1.254	0.0	***3.763***	0.0
1	A1	1	0.0	0.0	-0.4963	0.0	-344.9E-9	***0.0***

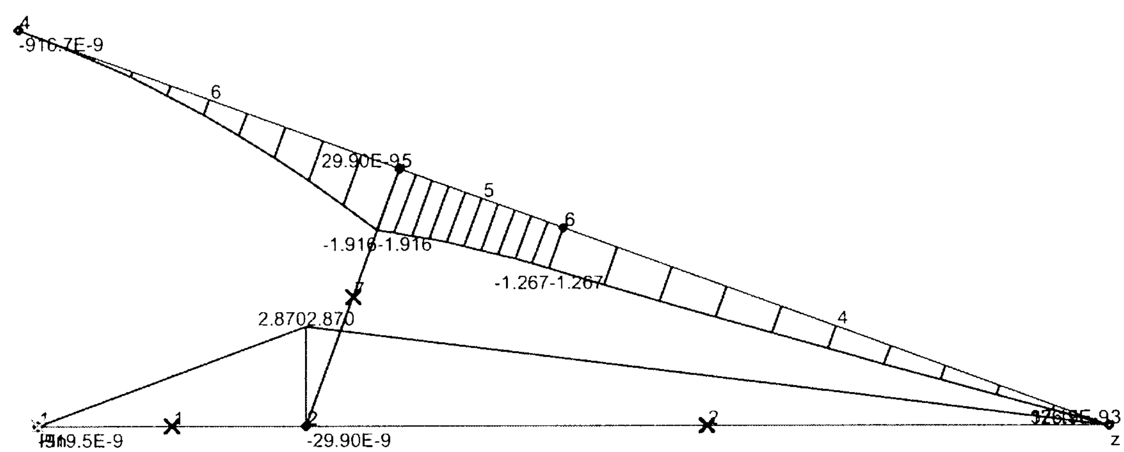
Minima

ARUP

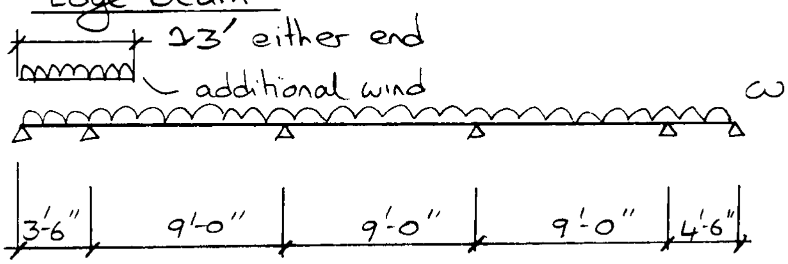
Soalr Decathlon
Structural Frame
PV Panel Supports

Job No.	Sheet No.	Rev.
75948-74	S-14	
Drg. Ref.		
Made by PGT	Date 12-Dec-2008	Checked

Scale: 1:23.58
Labels:
Node No.s
Elem. No.s
Moment, Myy: 2.000 kip-ft/pic.cm
Case: C1 : C1 0.6D+W



3.2 Edge Beam



$b_t = 7.5$ ft

PV loads go directly to columns

Allow for possible removal of PV panels in the future

$\Rightarrow \quad \omega_D = (7.5' \times 9) + 7.5\,(12/4.5) + 15 = 103$ lb/ft
(SIPS etc, beams, selfweight)

sliding panel $\omega_D' = 12' \times 5 = 60$ lb/ft

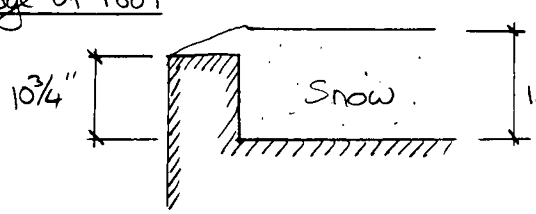
$\omega_S: = 7.5' \times 21 = 158$ lb/ft

$p_f = 21$ psf

snow depth: $\gamma = 0.13 p_g + 14 \leq 30$ pcf
$= 0.13 \times 30 + 14$
$= 17.9$ pcf

$h_s = \frac{21}{17.9} = 14''$

edge of roof



$h_c/h_b < 0.2 \Rightarrow$ do not consider drifting

ω_W

Zone	p_W [psf]	ω_W' [lb/ft]	ω_W'' [lb/ft]	
E	-19.1	-143	-57	-117
F	-10.8	-81	-32	
G	-13.3	-	-60	
H	-8.4	-	-38	-70

Governs

ARUP

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75948-74	S-16	
Member-Location		
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Made by PGT	Date Dec '08	Chd.

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VT

treating beam as simply supported over 9'0" (conservative)

$\omega_a^{max} = \omega_D + \omega_S \quad = 103 + 60 + 158 \quad = 321$ lb/ft

$M_a^{max} = 1/8\, \omega_a L^2 \quad = 39$ k-in (3.25 k-ft)

$V_a^{max} = 1/2\, \omega_a L \quad = 1.44$ k

$\omega_a^{min} = .6\omega_D + \omega_W \quad = (.6 \times 103) + (-143) = -81$ lb/ft

$M_a^{min} = \quad = 9.8$ k-in (0.82 k-ft)

$V_a^{min} = \quad = 0.365$ k

for uplift $L_b = 4.5$ ft $= 54"$

top flange is braced by SIPS panels.

capacities of W6 x 15

positive moment $M_n/\Omega = 224$ k-in OK

$L_p = 1.76 r_y \sqrt{\frac{E}{F_y}} = 1.76 \times 1.45 \left(\frac{29000}{50}\right)^{1/2} = 61"$

$\Rightarrow L_b < L_p$

$M_n \triangleq S_x F_y = 486$ k-in

$M_n/\Omega = 291$ " " OK

Edge Beam
W6 x 15

ARUP

Job No.	Sheet No.	Rev.
75948-74	S-17	
Member-Location		
Drg. Ref.		
Made by P6T	Date Dec '08	Chd.

Job Title: Solar Decathlon

VT

4.0 Columns

Columns are braced against sidesway, $K = 1.0$

$l. = 10\text{ ft}$

Maximum load on column:

$A_{trib} = 9 \times 7.5 = 67.5\text{ ft}^2$

$P_{D+S} = \underset{PV}{0.48^k} + \underset{Snow}{1.21^k} + \underset{Roof}{(13.7 \times 67.5)} + \underset{Self\ weight}{(15 \times 10')} + \underset{Panel}{(60 \times 9')}$

$= 3.30^k$ (compression

for architectural reasons columns are either

⌀ HSS 4.0 × .226

⌗ HSS 4.0 × 4.0 × 5/16

$P_{.6D+W} = .6(13.7 \times 67.5) + (67.5' \times -19.1)$ [no PV, no panel

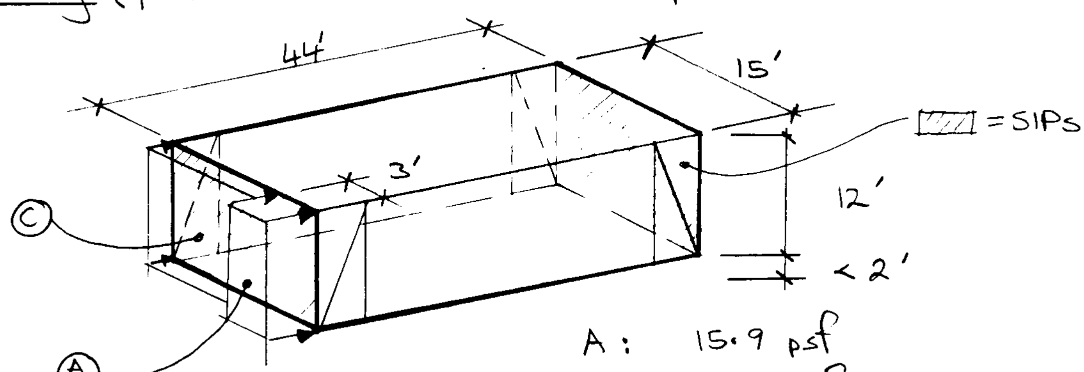
$= -0.73^k$ (ie tension)

Axial compression capacities

$$\left.\begin{array}{lll} \text{HSS } 4.0 \times 0.226 & P_n/\Omega_c & = 38.5^k \\ \text{HSS } 4.0 \times 4.0 \times 5/16 & P_n/\Omega_c & = 73.1^k \end{array}\right\} \text{Both OK}$$

Columns
HSS 4.0 × 0.226
or HSS 4.0 × 4.0 × 5/16

5.0 Bracing (permanent installation V = 100 mph)



A : 15.9 psf

C · 10 5 psf

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Job Title Solar Decathlon	Drg. Ref.		
VT	Made by PGT	Date Dec '08	Chd.

Maximum wind force at corner of roof

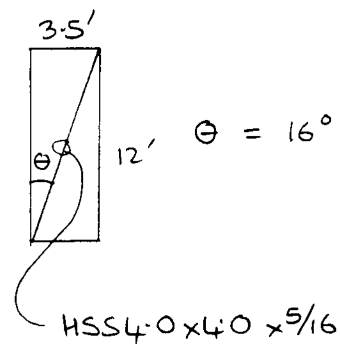
$$P_W = (3' \times 12/2)\,15.9 + (7.5' - 3')\,\frac{12'}{2} \times 10.5$$

$$= 570 \text{ lbs}$$

⇒ Sharing force between 2 brace elements

$$C_{brace} = \frac{\frac{1}{2} P_W}{\sin\theta} = 1.0 \text{ kip}$$

OK by inspection



$\theta = 16°$

Braces
HSS4.0x4.0x5/16

6.0 SIPS Panel Bracing Panels & Roof Panels

6.1 Roof Panels

Panel : R-Control 10¼" SIP spanning 12 ft

$\omega_D + \omega_S = (9 + 21) = 30$ psf

Allowable load w/ factor of safety 3.0 $\quad P_{all} = 51$ psf w/ $\Delta \leq L/360$

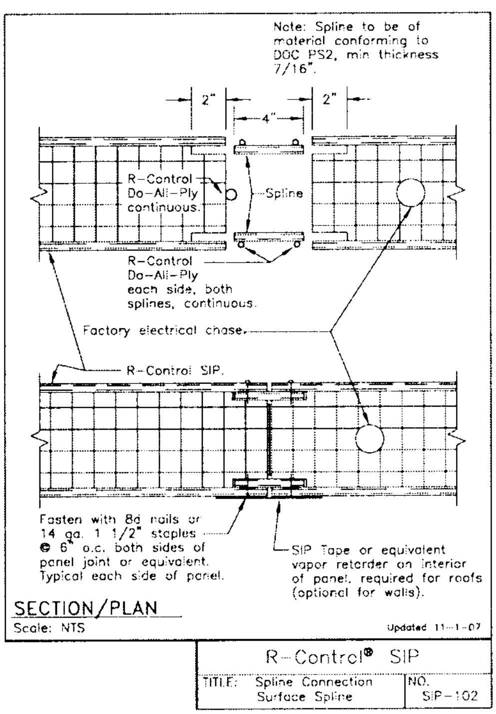
See sheet S-19 for product data

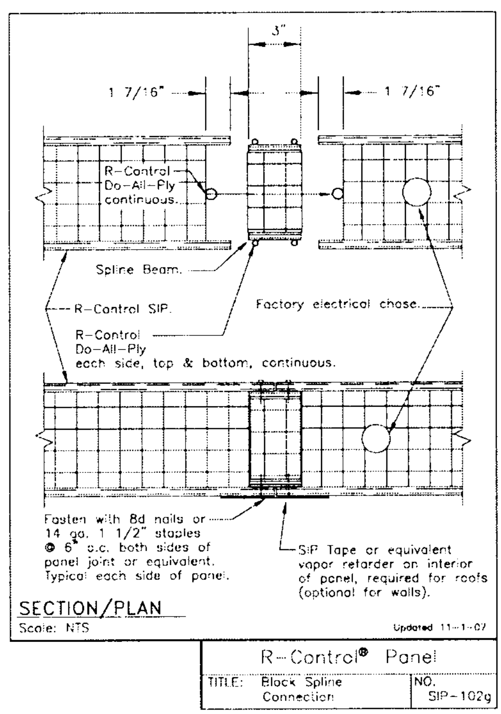
Roof/Floor - Transverse Loading
LOAD DESIGN CHART #1
(SEE SPLINE DETAILS SIP-102 or SIP-102g)

R-CONTROL® SIPs																
PANEL SPAN		SIP THICKNESS														
		4 1/2"			6 1/2"			8 1/4"			10 1/4"			12 1/4"		
DEFLECTION		L/360	L/240	L/180	L/360	L/240	L/180	L/360	L/240	L/180	L/360	L/240	L/180	L/360	L/240	L/180
TRANSVERSE LOAD (PSF)	4'- 0"	65	80[1]	80[1]	89	122[1]	122[1]	92	136[1]	136[1]	107	136[1]	136[1]	104	136[1]	136[1]
	6'- 0"	40	53[1]	53[1]	58	81[1]	81[1]	64	96[1]	96[1]	75	96[1]	96[1]	73	96[1]	96[1]
	8'- 0"	28	40[1]	40[1]	42	61[1]	61[1]	51	76[1]	76[1]	61	76[1]	76[1]	60	76[1]	76[1]
	10'- 0"	20	30	32[1]	32	48	49[1]	44	64[1]	64[1]	54	64[1]	64[1]	55	64[1]	64[1]
	12'- 0"							40	56[1]	56[1]	51	56[1]	56[1]	55	56[1]	56[1]

[1] LIMITED TO ULTIMATE FAILURE LOAD DIVIDED BY A FACTOR OF SAFETY OF THREE.

[2] PLEASE REVIEW NOTES ON PAGE 3.





ARUP	Job No. 75948-74	Sheet No. S-20	Rev.
Job Title: Solar Decathlon VT	Member-Location		
	Drg. Ref.		
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6.2 Wall Panels (End Walls)

- Transverse Loads

ASCE 7 (6-2) $P_{net} = \lambda K_{zt} I p_{net30}$

$= 1.0 \times 1.0 \times 1.0 \times -27.0$

corner zone $a = 3ft$

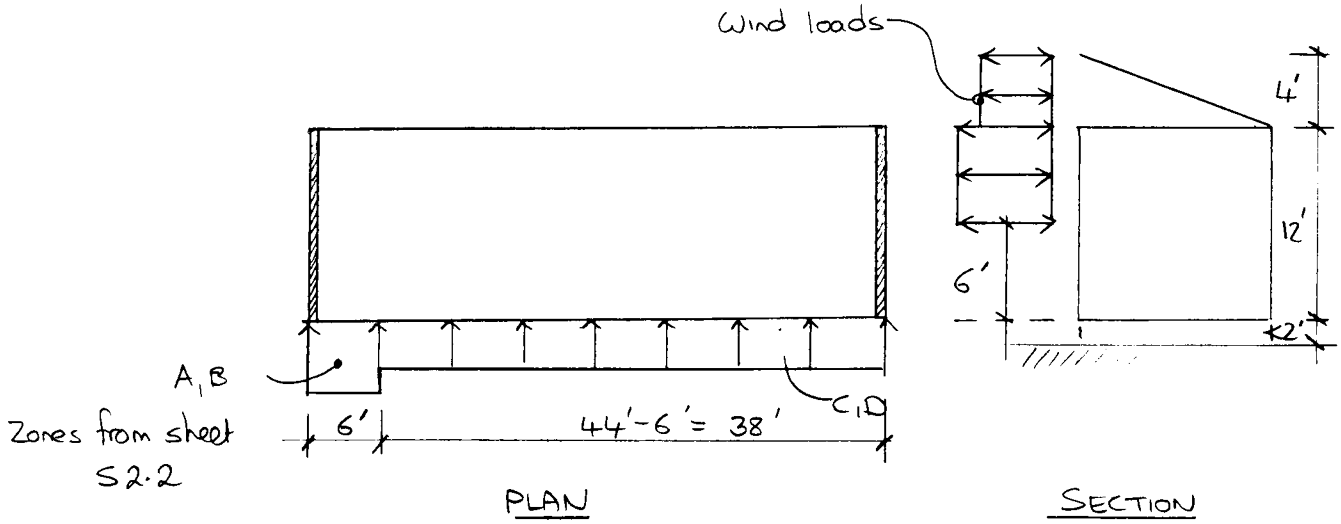
$= -27$ psf

$h = 12ft$ 6 ½" SIP

$P_{all} = 38$ psf w/ $\Delta \leq L/240$ OK

- In-Plane (Racking) Loads

If end walls resist all lateral loads & PV panels are in place



Zone	Pressure
A	15.9
B	-8.2
C	10.5
D	-4.9

← neglect (conservative

Maximum shear on end wall $V_w = (22-6)6 \times 10.5 + 6 \cdot 6 \times 15.9$

$= 1.58^k$

With SIP-140 Panel $\sigma_{allow} = 335$ lb/ft

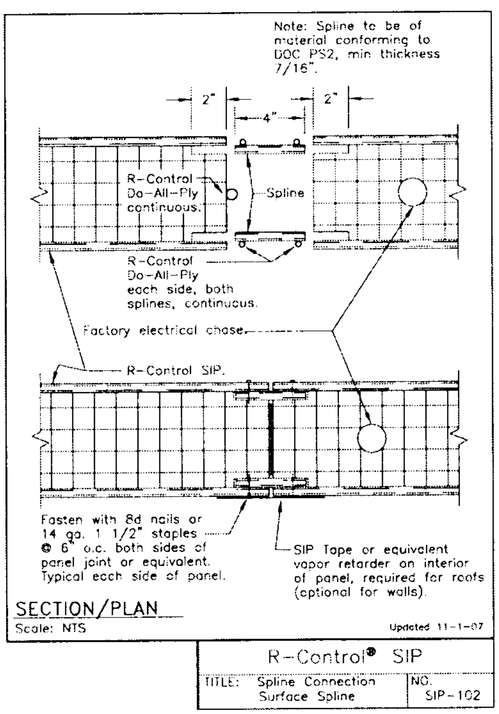
$L_w \geq 4.7$ ft OK

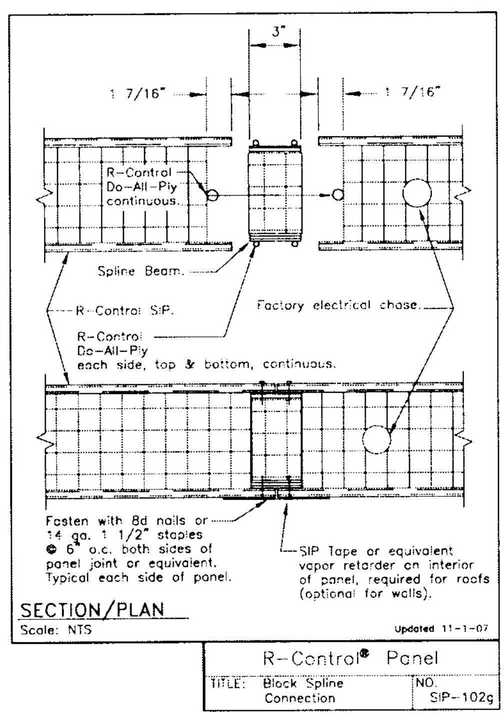
Wall - Transverse Loading
LOAD DESIGN CHART #4
(SEE SPLINE DETAILS SIP-102 or SIP-102g)

R-CONTROL® SIPs							
	PANEL HEIGHT	SIP THICKNESS					
		4 1/2"			6 1/2"		
	DEFLECTION	L/360	L/240	L/180	L/360	L/240	L/180
TRANSVERSE LOAD (PSF)	8' - 0"	28	40[1]	40[1]	42	61[1]	61[1]
	10' - 0"	20	30	32[1]	32	48	49[1]
	12' - 0"	15	22	27[1]	26	38	41[1]
	14' - 0"				21	31	35[1]
	16' - 0"				17	26	31[1]

[1] LIMITED TO ULTIMATE FAILURE LOAD DIVIDED BY A FACTOR OF SAFETY OF THREE.

[2] PLEASE REVIEW NOTES ON PAGE 3.





ARUP

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75948-74	S-22	
Member-Location		
Drg. Ref.		
Made by PGT	Date Dec '08	Chd.

Job Title Solar Decathlon VT

7.0 Overall Stability & Foundations (Temporary Installation)

7.1 Overturning & Sliding Due To Wind

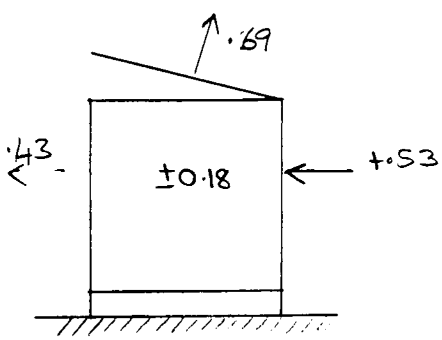
Total Wind Loads ($V = 60$ mph)

$h = 15$ ft

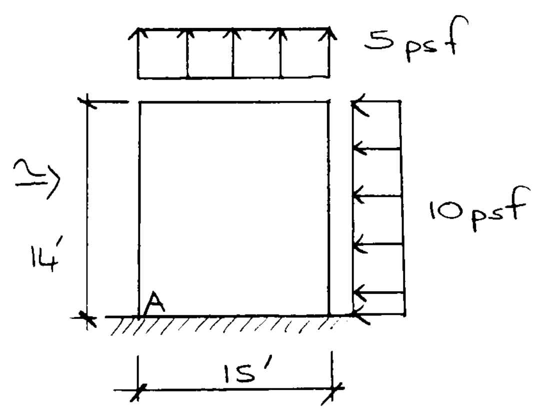
Exposure C:

$$q_h = 0.00256 \times 0.85 \times 1.0 \times 0.85 \times 60^2 \times 1.0$$
$$= 6.66 \text{ psf}$$

$$p = q\,GC_p - q_i\,(GC_{pi})$$
$$\equiv q_h\,(GC_{pf} - GC_{pi})$$
$$= 6.66 \times (.53 - (-.43))$$
$$= 6.4 \text{ psf} \quad < p_{min} = 10 \text{ psf} \quad \text{ASCE 7 6.1.4.1}$$



GC_f



Base shear $\quad V_w = 10 \times 14' \times 44' = 6.2^{kip}$

Overturning about A $\quad M_w = V_w h/2 + P_w b/2 = (10 \times 14 \times 44) \times \frac{14}{2} + (5 \times 15 \times 44) \times \frac{15}{2}$
$= 66.2$ kip-ft

Uplift $\quad P_w = 5 \times 15 \times 44 = 3.3^{kip}$

Resisting Moments & forces due to 0.6 D

Dead load			
	- Roof (w/o PV panels)	$9 \times (15 \times 44) =$	5.94^k
	- Walls	$15 \times 12 \times (44+15)2 =$	21.24^k
	- Floor	$47 \times (15 \times 44) =$	31.0^k

Restoring moment: $M_R = \cdot6(5\cdot9 + 21\cdot2 + 31) \times \frac{15}{2} = 262$ k-ft

$FoS = \frac{M_R}{M_W} = 3\cdot95 > 2\cdot0$ OK

Uplift $\cdot6P_D = 34\cdot5^k$

$FoS \quad \frac{\cdot6P_D}{P_W} = \frac{34\cdot5}{3\cdot3} = 10\cdot6 > 2\cdot0$

Sliding: Coefficient of friction (static)

$\mu_s \geq \frac{V_W \, FoS^{MIN}}{\cdot6P_D} = \frac{6\cdot2 \times 2\cdot0}{34\cdot5}$

$= 0\cdot36$

This should be achievable with plywood on grade/concrete

$\mu_s^{\text{concrete - soil}} = 0\cdot30 - 0\cdot75$

$\mu_s^{\text{steel - steel}} = 0\cdot30$

$\mu_s^{\text{wood - wood}} = 0\cdot48$

7.2 Temporary Foundation Bearing Pressure

Consider load combinations

$A_1 = 0\cdot6D + W$

$A_2 = 1\cdot0D + W$

$A_3 = D + L \qquad A_4 = D + \cdot75(L + S)$ ← not critical

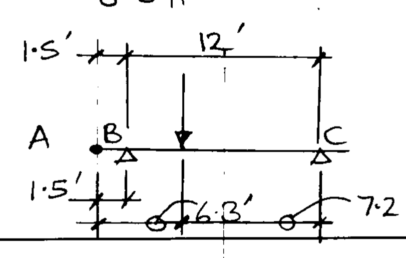
(1) $0\cdot6D + W$

Lever arm between foundations = 12'

about A $\quad M_W + 0\cdot6M_D = -66\cdot2 + 262 = +196$ kft

$P_W + 0\cdot6P_D = -3\cdot3 + 34\cdot5 = 31\cdot2^k$

$e = M_a/P_a = \frac{196}{31\cdot2} = 6\cdot3$ ft



$\Rightarrow$ Reaction @ B $\Sigma R_a = 31.2 \times \frac{7.2}{12} = 18.7^k$

with 5 foundations

$$R_{a_i} = \frac{18.7}{5} = 3.74^k$$

allowable bearing pressure:

$$P_b = 1.5\ k/ft^2$$

$$A_{footing} \geq \frac{3.74}{1.5} = 2.5\ ft^2$$

(2) D + W

$$e = \frac{370}{54.2} = 6.8'$$

$$e' = 6.7'$$

$$R_{a_i} = \frac{54.2}{5} \times \frac{6.7}{12} = 6.0^k$$

$$\Rightarrow A_{footing} \geq 4.0\ ft^2$$

(3) D + L (L = 50 psf not reduced)

$$P = 57.5 + 50 \times 10^{-3} (14' \times 43') = 87.6^k$$

$$R_{a_i} = \frac{87.6}{2 \times 5} = 8.76\ k$$

$$\Rightarrow A_{footing} \geq 5.8\ ft^2$$

$$\Rightarrow 2.5' \times 2.5'$$

Temporary Footing
10 №
2'-6" × 2'-6"

ARUP

Job No.	Sheet No.	Rev.
75948 - 74	S-25	
Member-Location		
Drg. Ref.		
Made by P6T	Date Dec '08	Chd.

Job Title Solar Decathlon
VT

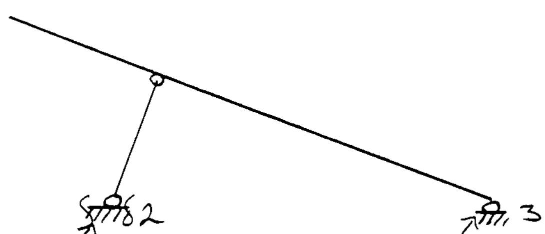
7.3 Check Localized Uplift

from sheet S-23

$$R_{ac}^{min} = \frac{31.2}{5} \cdot \frac{12-7.2}{12} = 4.2^k \text{ compression}$$

⇒ no uplift
⇒ no tie-downs required

8.0 Connection of PV Panel Frame To Roof Beam



$V_D = 0.7^k$
$V_S = 1.7^k$ } 2.4^k
$V_W = -1.8^k$

$V_{D+S} = 1.7^k$
$V_{.6D+W} = 0.03^k$

Capacity of A307 Bolts in single shear, threads included in shear plane:

½"ø $F_{nv}/\Omega = 2.35^k$
5/8"ø $= 3.68^k$ ← selection

Provide
1-5/8ø A307 bolt in single or double shear

DETAILED WATER BUDGET

300 gallon potable water tank

100 gallon reservoir for charging the system

2000 gallon geothermal pool

300 gallon rainwater harvesting tanks

2700 gallons

SUMMARY OF UNLISTED ELECTRICAL COMPONENTS

All electrical components are UL listed and comply with all applicable codes.

RETAIL PV PRICE QUOTE

The photovoltaic panels chosen by Virginia Tech were purchased from Sanyo for $3/watt. The retail price that would be charged by a local dealer is $4/watt, in addition to the dealer's mark-up amount.

SUMMARY OF RECONFIGURABLE FEATURES

The Virginia Tech Solar Decathlon house is equipped with a series of large, operable insulation panels and sun screens. If the panels and screens are open to their maximum positions, they will infringe upon the site boundaries/solar envelope established in the SD rules. An example of this can be found in drawing A-113 of the construction documents. However, we do intend to limit the operation of these features to remain within the site boundaries. The rule-compliant positioning of these operable features is shown in drawing A-101.

VT Solar - 115

team name and lot number

PV SYSTEMS

Module Manufacturer	Short Description of Array	DC Rating of Array (sum of the DC ratings)
Sanyo	HIT 195 watt bifacial panels	556 V, 486.5 V

Total DC power of all arrays is 11.5 kW (in tenths).

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

INVERTERS

Inverter Manufacturer	Model Number	Voltage	Rating (kVA or kW)	Quantity
SMA Sunny Boy	7000 US	600 (max)	8.75(DC), 7(AC)	2

Total AC power of all inverters is 14 kVA or kW (in whole numbers).

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Please include the following in the Project Manual:

1) One-line electrical schematic – the loads do not have to be detailed.
2) Calculations of service/feeder net computed load and neutral load (NEC 220)
3) Plan view of the lot showing the house, decks, ramps, tour paths and the service point.
4) Elevation view(s) showing the terminal box (contains the service point), meter, and other service equipment (such as the distribution panel or load center).

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Provide the Team's "Electrical Engineer" contact info in the "Team Officer Contact Info" database on the Yahoo Group. See Rule 3-2.

Please see the "Grid Interconnection Process for Teams" file on the Yahoo Group for more details on the interconnection process and the Terminal Box Mounting Panel.

ENERGY ANALYSIS RESULTS AND DISCUSSION

Table of Contents

Introduction

An exponential increase in population with a parallel rise in energy demand has produced a newfound need for sustainable energy solutions. The Virginia Tech Solar Decathlon Team has dedicated two years to develop a new architectural design platform. The 2009 Virginia Tech Solar Decathlon submission, the LUMENHAUS, merges aesthetics and functionality while integrating the most efficient mechanical systems, electrical systems, and passive energy collection components (figure 1). The house features such as a forty-two panel solar array, solar radiation heating, and automated shading and insulation increase building's carbon neutrality and functionality. Automated controls with user overrides permit the house to adapt the house to the user's desired comfort level while minimizing the energy usage. The adaptability allows the user to customize the house and allows the house to optimize itself for the most efficient operation.

Figure 1- The Virginia Tech 2009 Solar Decathlon entry

The energy design of the house was comprised of two sections: the mechanical and electrical system and the energy simulation. The first component of the energy design was to create the mechanical and electrical systems. The system designs focused on the usage of the most efficient equipment and system that can maintain a comfortable living environment. The energy simulation was created after the mechanical and electrical systems design to project energy savings and create data for house automation optimization.

Mechanical/ Electrical Overview

The competition strategy for energy performance used a combination of efficient and adaptable design. The house can withstand a variety of living conditions and adapt to a variety of weather patterns. All of the mechanical and electrical components are designed to operate in a variety of climates. The engineered mechanical and electrical system components include a water-to-air heat pump, a reheat appliance, energy recovery ventilator, a water-to-water heat pump, a geothermal source/sink emulation, a hot water tank, a radiant floor heating system, shading screen, a lighting system, and a photovoltaic panel system.

Terminal Air Unit

The air heating and conditioning dominates energy usage in the average houses, so proper equipment size is important to reduce energy cost. The team used equipment energy usage and CFM (Cubic feet per minute) of air flow to size the equipment. The team decided that a water to air heat pump is the most efficient air conditioning unit. ASHRAE Standard 62 dictates that a residence must have 8.4 air-exchanges in a 24 hour period (0.35 air-exchanges an hour). The interior volume of the house is approximately 5600 ft^3 (158 m^3), so the equipment needed to produce 32.7 CFM. The smallest available model, the Aquarius II AP025, will to air condition the house. The Aquarius II AP025 features a two stage cycle; the smallest setting is 750 CFM.

The first stage cycle provides a total capacity of 18.54 kBtu/hr (5.43 kW) for a required power requirement of 1.06 kW (3.62 kBtu/hr) for an entering fluid temperature of 85°F (29.4^{o}C) and an entering air temperature of 75°F (23.89^{o}C) dry bulb or 63°F (17.2^{o}C) wet bulb. The second stage of the heat pump, which provides 950 CFM for 1.73 kW under similar conditions, will be locked out during the competition due its large comparative consumption of power.

Terminal Air Unit Control

A Siemens controller provided the central point for automatic control in the house. The controller assessed the hot tank water temperature to determine the need for the desuperheater, a device that uses excess heat from air cooling to heat water. This can allow for some or all of the hot water to be heated using the exhaust heat from the water-to-air heat pump, possibly eliminating the need to run both the water to air heat pump and water to water heat pump. The desuperheater has the possibility of heating the water for only the water pump energy usage, reducing power usage from 2.71 KW to .23 KW. Days when running a short heating cycles are ran, using the desuperheater is an option. If the desuperheater is not sufficient to extract the excess energy, the heat can also be dissipated to a geothermal loop (figure 2).

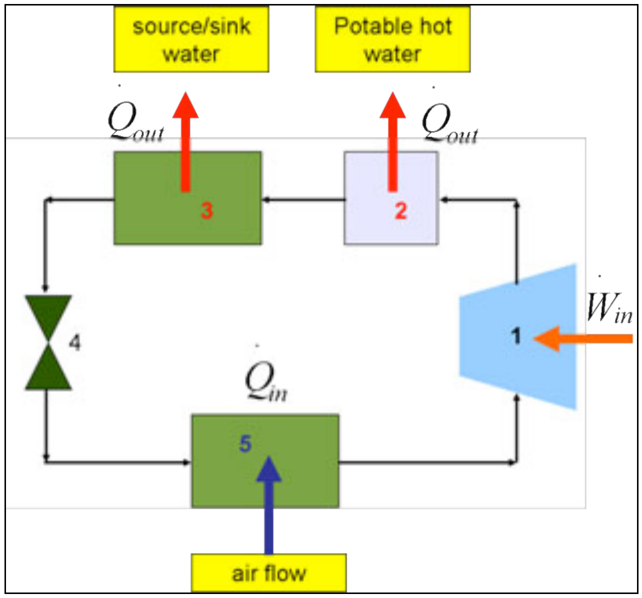
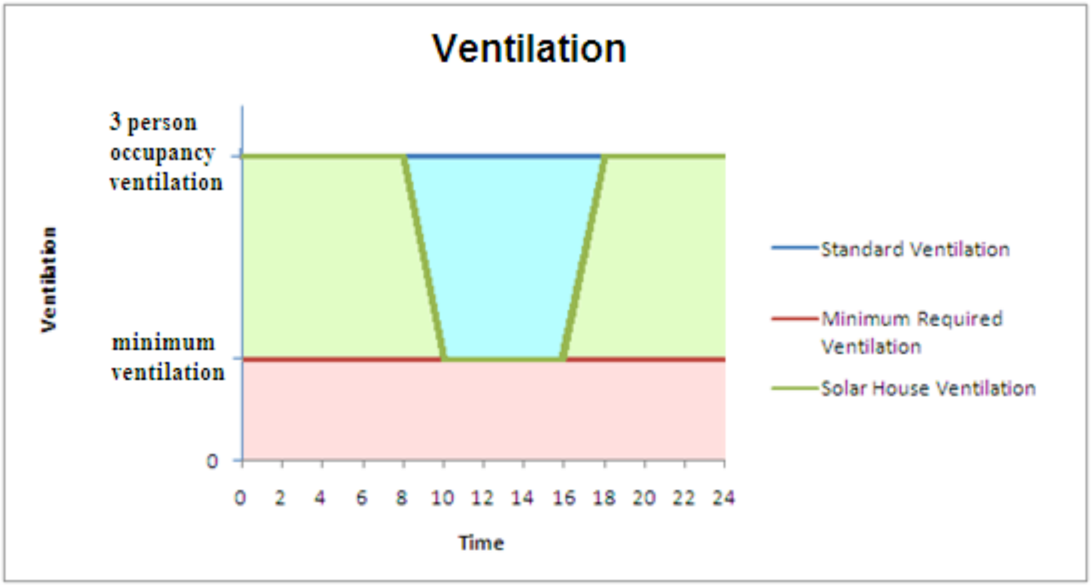


Figure 2- Water-to-air heat pump cooling cycle. Components: 1-compressor, 2-desuperheater, 3-evaporator, 4-throttling valve, 5-condensor

For the heating months, the desuperheater was not used and instead the WAHP is placed into reverse mode for heating (figure 3); the heat-exchanger heated the air by rejecting energy to the air. Thus, the compressor's superheated vapor (1) passed through the desuperheater (2) but without any hot-water flow so almost no energy is lost. Instead, the reversing valve routed the vapor through the condenser (5), through the throttling valve (4), and finally though the evaporator (3) before the cycle repeated.



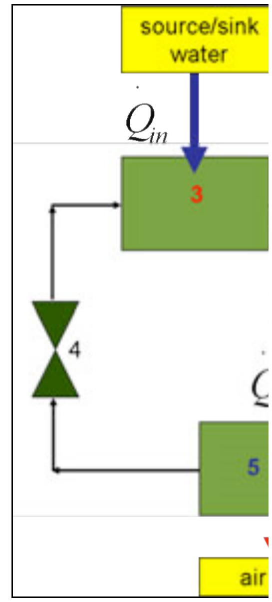


Figure 3- Water-to-air heat pump heating cycle. Components: 1-compressor, 2-desuperheater, 3-evaporator, 4-throttling valve, 5-condensor

Air Volume Control

The required air ventilation of a house varies upon house occupancy; however, most houses cannot determine the level of occupancy. House ventilation rates are typically set to the worst case scenario, a constant three person occupancy. The solar house is designed to determine the number of occupants using a combination of infrared and sonar sensors, so the house can determine the minimum required ventilation at any time (figure 4). Typically during the day, the house occupancy is zero, so minimum ventilation can be used during the day, and the house can adjust ventilation to higher occupancy standards if the number of occupants increases. An approximately eight hour period of ventilation can be reduced using the occupancy sensors.

Figure 4- Ventilation. The blue area is the potential energy savings

Reheat Appliance

During the cooling cycle, the WAHP removed water from the air before it enters the conditioned spaces, thus, dehumidifying the air. Contest rules and general comfort dictate relative humidifies between 40% and 55%. In hot weather in a sealed house, the WAHP will naturally reduce humidity within the prescribed range. In the spring and fall months, short cooling cycles and high outside humidity can raise indoor humidity if the house in not closed. Washington, D.C. climate averages reinforced the need for a reheater (figure 5).

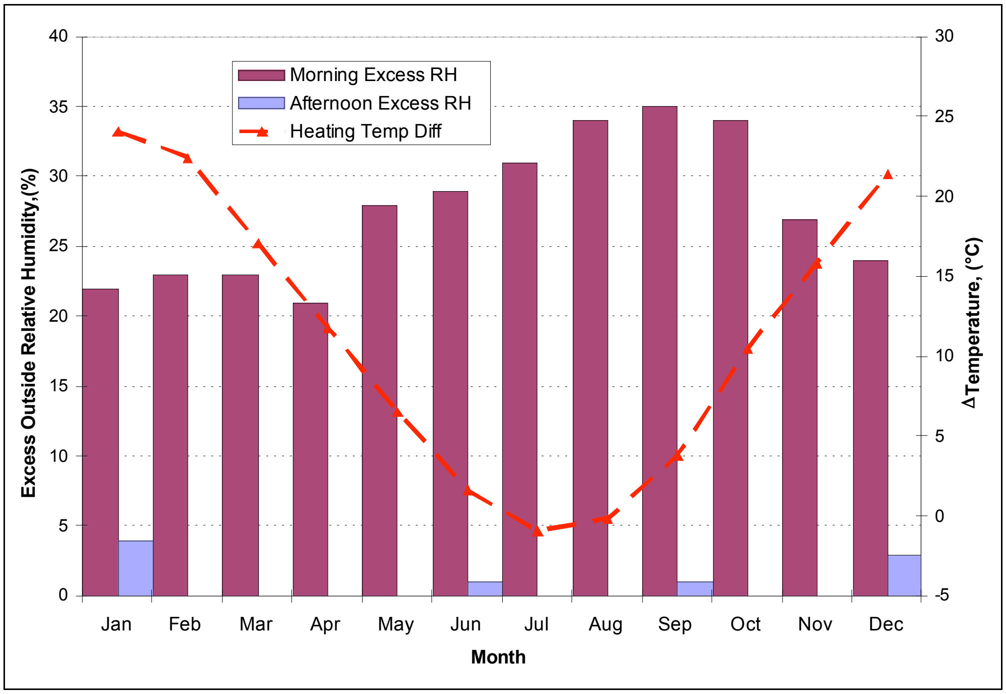


Figure 5- Differences between contest acceptable relative humidity and temperature and the outside relative humidity and temperature. The climate never has a humidity beneath the acceptable range

Reheat is the process of using energy either from the desuperheater or from the warm exiting WAHP and routing to a heat exchanger in the WAHP supply duct. The heat exchanger rewarms the cooled dehumidified. Because the air is rewarmed, the WAHP runs longer and removes more water from the air. Once the humidity reaches the targeted range, the reheat can be turned off, and the condenser water is sent directly to the geothermal source/sink.

Energy Recovery Ventilator

Because the house is tightly sealed, fresh air needs to be forced in the house. The house must exchange the air, so the house can have an Energy Recovery Ventilator (ERV) installed. The ERV will exchange some of the heat from the exhaust air and have it exchanged with the fresh air and reduce heating and air conditioning energy usage. The heat differences between the outgoing and incoming air are exchanged to reduce the difference between the uptake air and house air. The energy exchange reduces the amount of energy needed to condition new air.

Water to Water Heat Pump

The water-to-water heat pump (WWHP) was an efficient method to provide hot water for the hot water tank and the radiant floor heating. The heat pump required water from the geothermal heat exchanger. The heat pump varied its power input and load capacity under different conditions, but under the condition of source water entering at 85°F (29.4°C) and load water leaving at 44°F (6.7°C) , it would have a capacity of 24 kBtu/hr (7.03 kW). It would also have a power input is 1.72 kW (5.69 kBtu/hr) under a water flow rate is 5.0 GPM (18.92 LPM) for the load and 6.2 GPM for the source water.

Water to Water Heat Pump Control

The water to water heat pump runs to provide heated water to the hot water tank (figure 6). The central controller of the heat pumps will choose a plan where one device will be running at a time, unless hot water demand requires WWHP operation. The time that operation of both heat-pumps is beneficial is during a WAHP cooling cycle because the WWHP source-out flow can be routed to the WAHP.

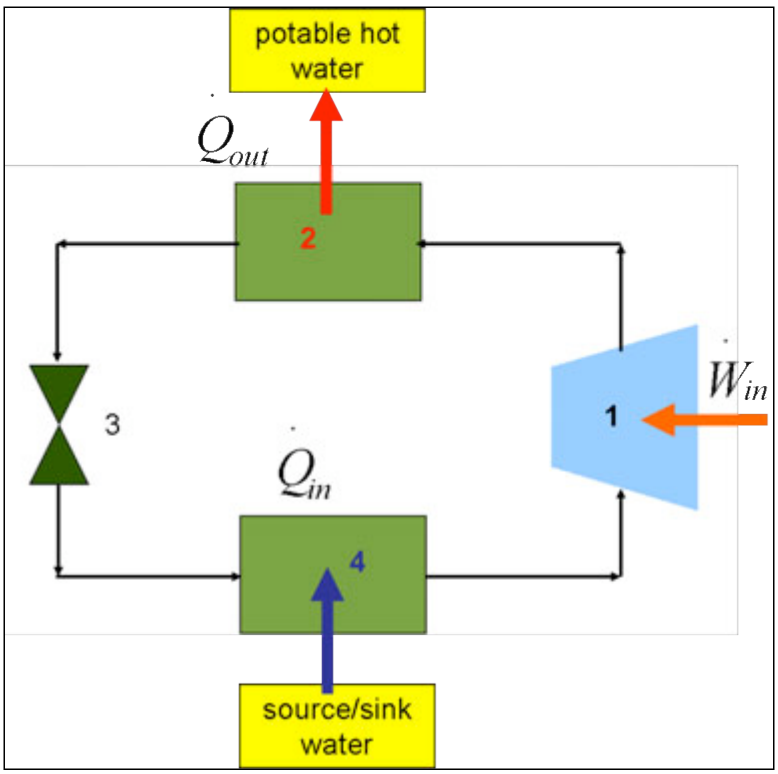


Figure 6- Water-to-water heat pump heating cycle. Component: 1-compressor, 2-condensor, 3-throttling valve, and 4-evaporator

The need for the WWHP will depend on the temperature in the hot-water tank and whether the desuperheater. A weekly schedule will be used to select the most efficient choice of threshold temperatures. A sensed occupancy increase may be programmed to adjust the hot water temperature for higher hot water demand.

Geothermal Exchange Simulation Tank

The geothermal exchange tank is a large tank of water located on the north-west side of the building. This 8' wide by 17' long by 2' deep tank provides approximately 2,000 gallons of water to act as either a sink or source for the two heat pumps depending on what mode they are in. This tank is fabricated from reinforced plywood and waterproofed with a custom fabricated EDPM liner. A closed-loop heat exchanger is located in the tank and is interconnected to both the water-to-air and the water-to-water heat pump. The surface of the tank is shaded by a vertical wall, 5-ft. in height measured from the ground. Shading is provided to be in compliance with competition guidelines so the tank will not become an additional source of energy as a result of solar gain.

To ensure the tank does not become saturated during the cooling mode of the heat pumps operation, an evaporative cooler is being incorporated to dissipate heat from the tank. This amounts to pumping water at approximately 10gpm across a corrugated slate surface. The slate panel runs the 17 ft. length of the tank and the broad-side faces north and slopes at a 30 degree angle. A header configuration runs along the top to encourage laminar water flow across the corrugated slate surface.

Water Heater

The hot water tank was a 77-gallon tank that possesses internal heat exchangers (figure 7). Standby heat loss is rated at 7200 BTU/day (2.1 kWh/day). The large tank volume should make the water draw challenge an easy accomplishment but at increased energy draw. Because it uses a heat exchanger and no pump, it uses no energy to store and heat water. The tank supplies the house's potable hot water and the radiant floor heating system.

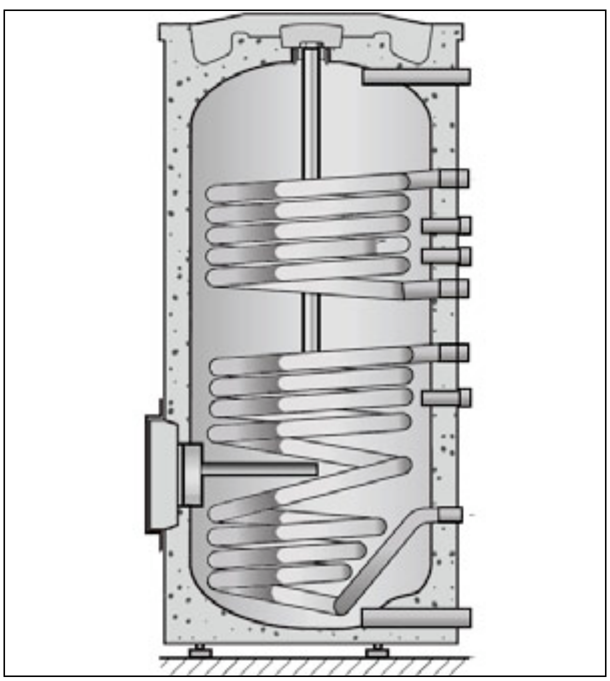


Figure 7- Domestic hot water tank

Radiant Floor Heating and Temperature Sensing

8The Solar Decathlon House used a radiant floor heating system to heat the house. The radiant floor heating is energy efficient, clean, economical, and quiet system. The hot water tank supplies the PEX pipe with heated water. The hot water circulated in the pipes and warmed the concrete slab (figure 8). As a result, heat energy radiated from the floor directly to the air and warmed the room air.

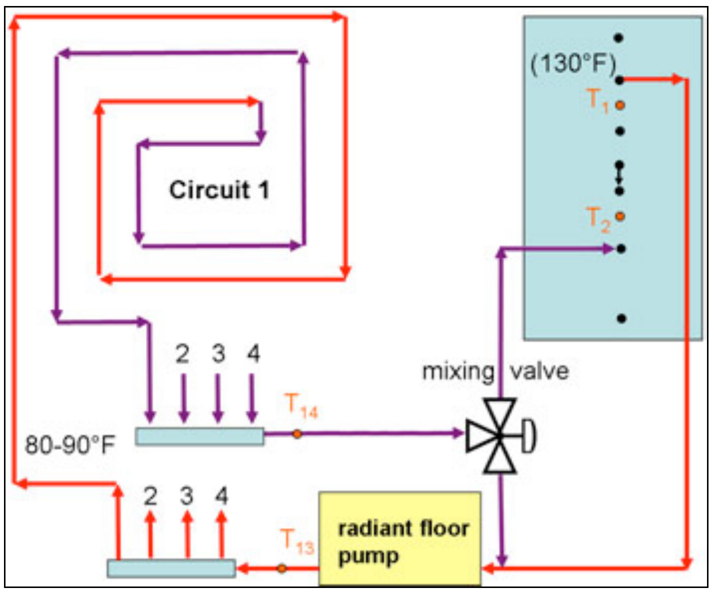


Figure 8- Radiant floor heat loop

Temperature measured at the return and the hot water tank provides control inputs to mix cooled return flow with the hot outgoing fluid flow, thereby regulating the temperature difference across the circuit (figure 9).

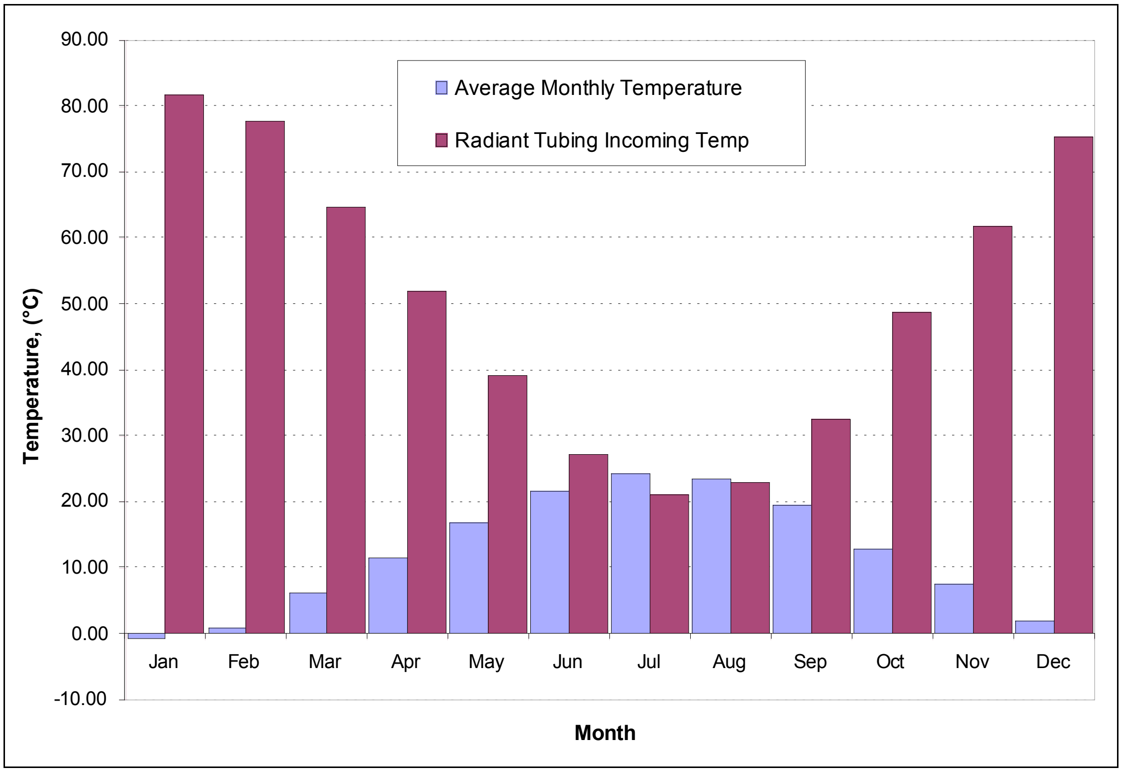


Figure 9- Proposed radiant heating temperature setting

The radiant floor heating runs inside all of the floors and provides heating to the four different zones of the house: the bedroom, the living room (includes 2 independent zones), and the bathroom. A mixing valve will be installed to mix the outgoing water with the incoming fluid so the radiant floor temperature is around 90°F. The activation of the pump is initiated by the controls algorithm when the thermostatic measurement devices detect a temperature out of the required range.

Sunscreen Characterization Study

The exterior most layer of the multi-layer dynamic enclosure system is a moveable sunscreen. These sunscreen/privacy panels are 11 ft (3.35 m) high, covering the façade from the floor to the top of the parapet, and 18 ft (4.49 m) wide spanning half of the house. The purpose of these panels is to provide control over solar exposure plus provides privacy. These perforated, powder coated, stainless steel screens, allow partial light and ventilation to filter through. These panels consist of various size holes ranging in size from two-inch to one-inch in diameter. The perforations are produced by laser-cutting, 16 gauge stainless steel sheet. The laser cutting process does not cut a complete circle but stops to leave tabs so the disks are retained in the sheet. The disks can then be bent to various angles providing a flexible method to produce a high-customizable shading strategy. The plane of the disk can also be adjusted by where the tabs are placed. The tabs are always 180 degrees opposite one-another but can be rotated 360 degrees, providing a highly-flexible positioning strategy.

The overall panel can be configured to optimize shading, ventilation, or privacy, or a combination of the three. Through computer controlled manufacturing techniques, these panels represent a highly-customizable strategy, adaptable to many different conditions. From the proposed location of a house, an outward-looking, large-field laser scan could be done to characterize what objects are on the horizon. This information, in combination with sun-path, wind vector data, and occupant preference, could produce a highly tailored solution, satisfying operating efficiencies, human thermal comfort and privacy.

For purposes of doing a computer thermal simulation, the physical characteristics of the panel had to be determined. A representative panel, 40-inch by 27-inch was fabricated and placed in an opaque box with the interior painted flat-black (figure 10 figure 11). This box was placed outside and oriented facing due-south.

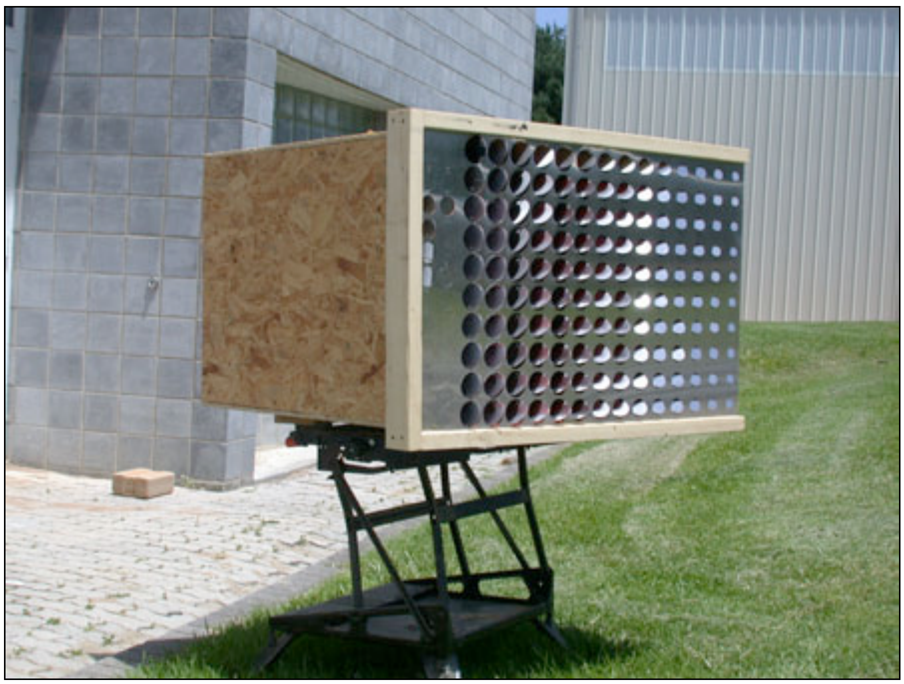


Figure 10- sun screen test box

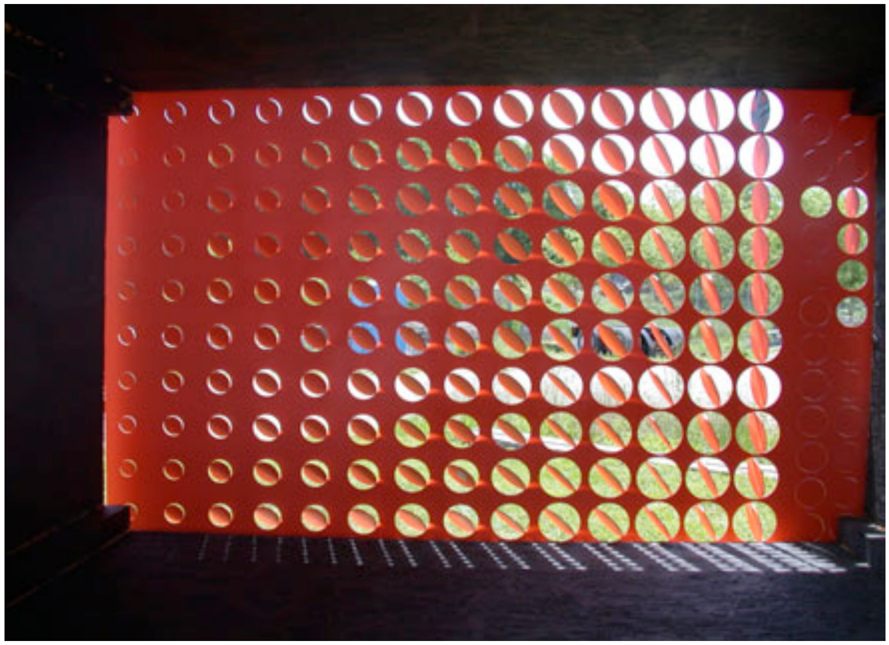


Figure 11- sun screen test sample

In order to determine the characteristics of the perforated screen, visible transmittance of the screen measurements were made using a combination of a light meter and a camera. These measurements were performed every hour from 7:30 AM to 06:30 PM on May 30, 2009. A series of illuminance readings (figure 12 and 13) were taken during this twelve hour period. One reading was taken in front of the box in a vertical position and in the other taken in front of the camera lens located in the box. Spurious light was masked with black polyethylene plastic so the measurements taken, only represented the influence of the perforated sunscreen. These values were calculated as the ratio of two positions. Accompanied with these measurements, interior photographic images of the perforated screen was taken by a camera equipped with an intervalometer so an image was recorded every 10 minutes.

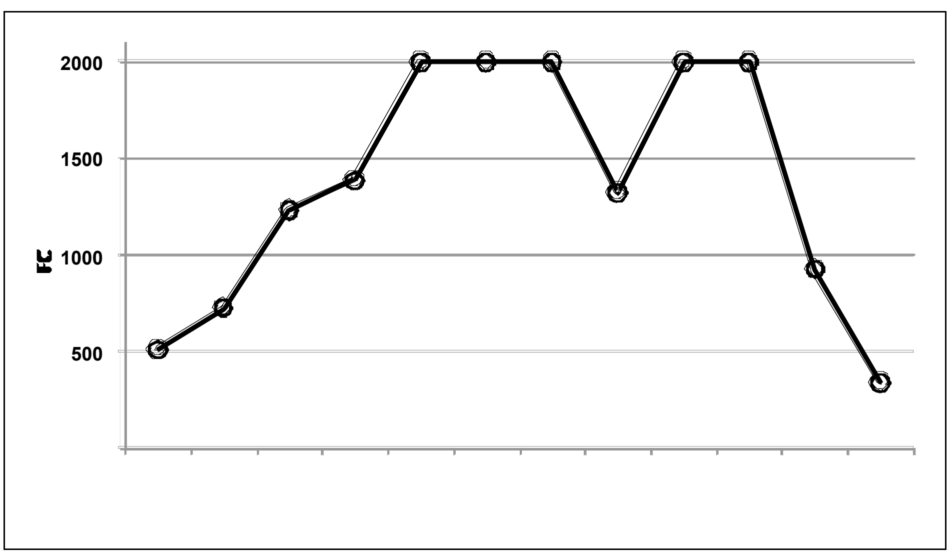


Figure 12- Illuminance in front of the box in a vertical position

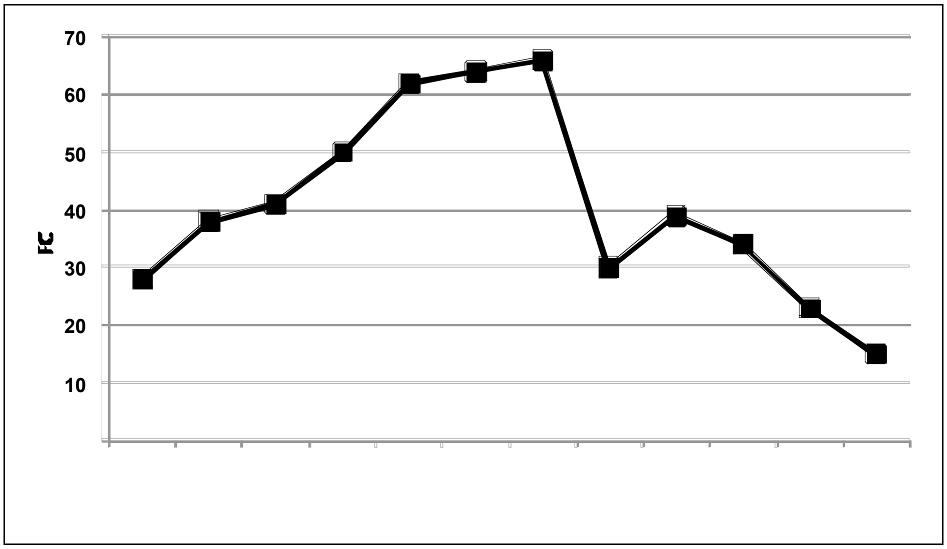


Figure 13- Illuminance on the floor located in the center of the box

These images were analyzed using the open source software program ImageJ. ImageJ was used to determine pixel value statistics of the photographic images of the perforated screen. The program was also used to create density histograms and line profile plots. Figure 14 shows a representative 3D plot of the pixel density histogram.

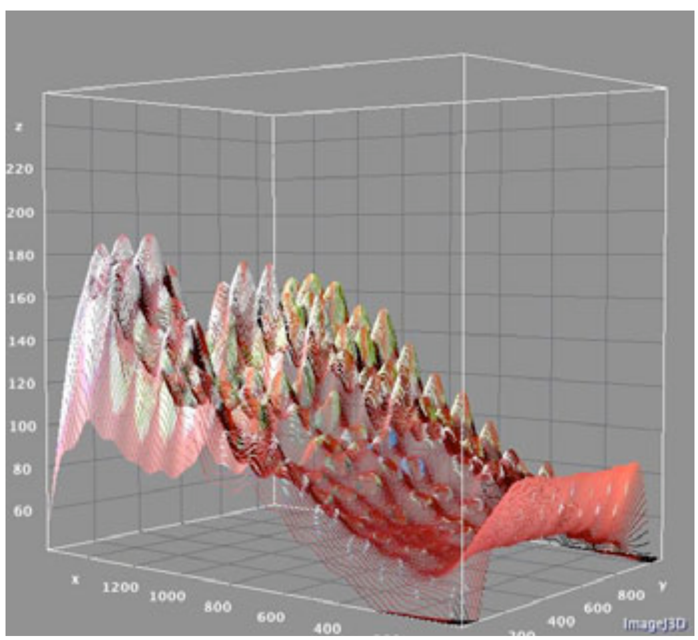


Figure 14- light intensity

Lighting

The lighting design of the LUMENHAUS uses 93 lights total to ensure adequate lighting. The lighting uses a combination of high efficiency lights: phosphorus tape, florescent lights, and LEDs. The lights are connected to occupancy and light sensors to prevent wasted light usage. The lights can be overrided manually, but are preprogrammed to provide the most efficient lighting solution (figure 15).

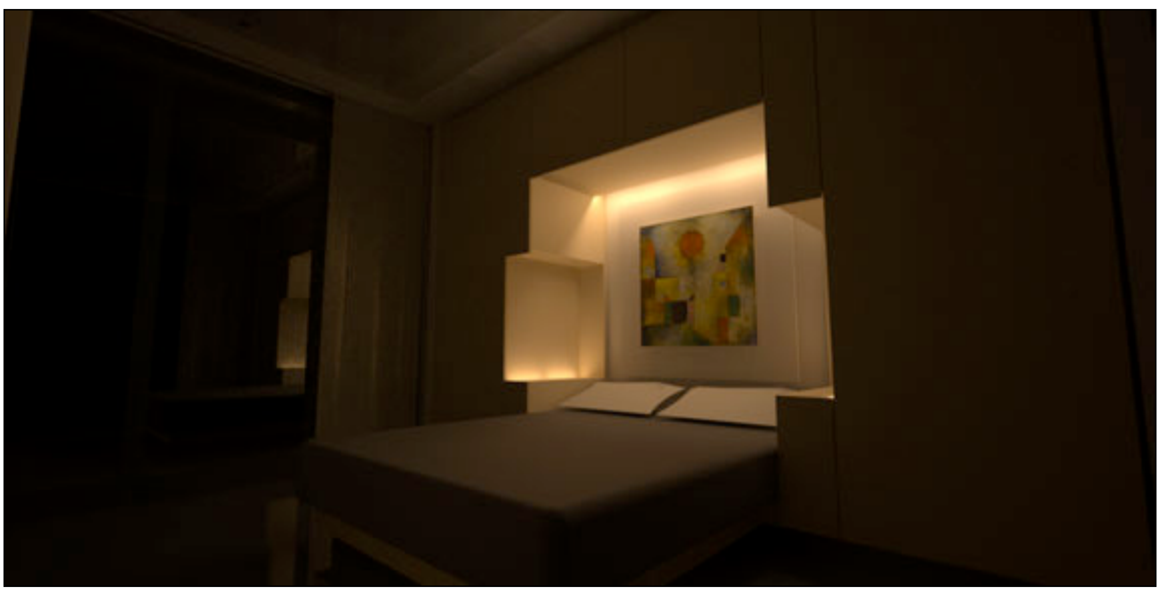


Figure 15- building light rendering

The house is designed to have two walls to be covered almost entirely by windows. During the day, the house will almost never need artificial lighting because the house can use sunlight for lighting (figure 16).

Figure 16- building sunlight rendering

Solar Panel

The panels require no energy to collect sunlight, and do not release any green house gases or harmful substances during their use. The solar panel only need the occasional washing of the top glass sheet for maintenance, because natural cleaning occurs from rainwater. The panels are built to withstand average wind velocities and small object impacts, so repair needs are minimal.

Because of the relatively high efficiency of the hybrid panels and their ability to collect sunlight on the back side of the panels when inclined, the energy payback time is lower than that of panels consisting of only one side and panels that are made solely of thin-film or crystalline silica. Silicon solar technologies are usually single crystalline, poly-crystalline, and amorphous silicon. Individually, these technologies are 15%, 14% and 7% efficient, respectively. By combining single crystalline and amorphous silicon in one solar cell, Sanyo is able to achieve 17.8% to 20.2% efficiency for a single HIT panel.

For the Virginia Tech photovoltaic panels, we selected the Sanyo HIT Double 195. They are bifacial panels which can generate power from the direct sunlight on one side as well as from the ambient light reflected onto the back-side of the panel. Each panel can produce 195 watts of power, not including the power generated from the ambient reflected light on the backside of the panel. According to manufacture's information, the back face of the panel has the potential to increase its power output up to 30%. With a lower temperature coefficient, the Sanyo panels can offer better output performance at higher temperatures than conventional panels. Because of increased module efficiency, there is less module area needed to create the same amount of electricity. In normal cases, this conserves space on the roof. On average, the increased efficiency provides 25% space savings. The location of the study alters energy produced due to different sunlight intensities in different parts of the country (figure 17).

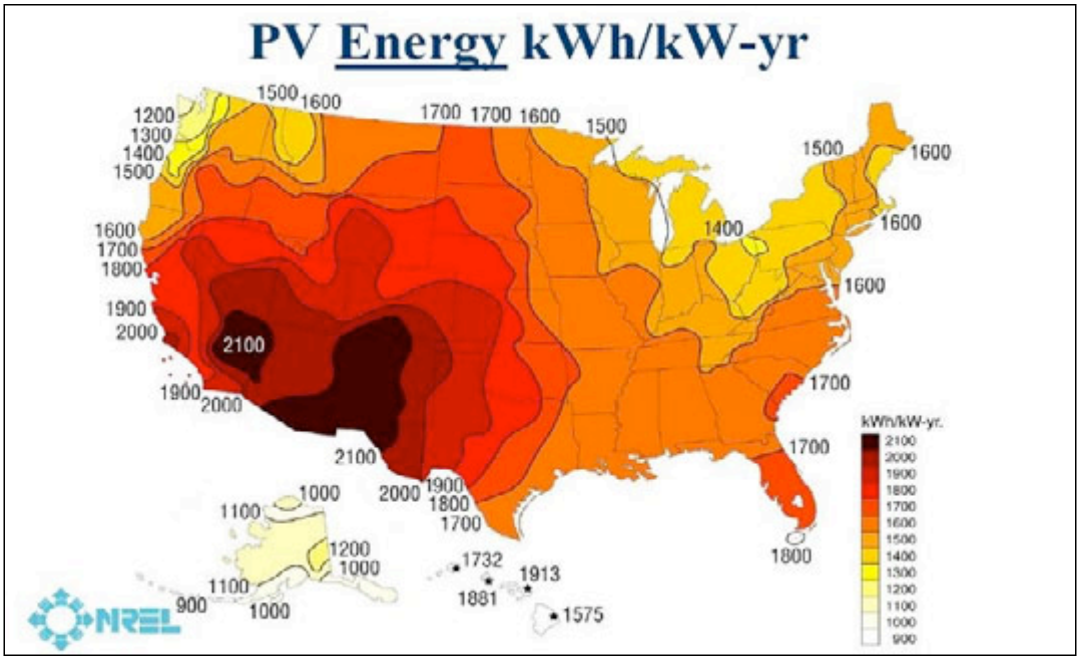


Figure 17- Map of how many kWh are generated per kW of solar panels according to geographic location within the U.S.

Two inverters will be used, one handling four of the sets while the other handles three of the sets. SMA Sunny Boy 5000 inverters will be used to convert the DC power from the panels into AC power and are equipped to accommodate grid-tie operation. These highly efficient inverters are ideal for the amount of power that we can expect to generate from our PV panel array.

Energy Analysis and Simulation

Goals of the Energy Study

The energy model will be a helpful tool in analyzing energy efficiency. Upon completing the energy model, the mechanical design team will be able to:

- Determine which times of the year each sliding panel configuration is optimal;
- Run a simulation of a house where the R-values change reflecting the R-values of the different configurations during optimal times (when weather is such that the solar decathlon house uses the least HVAC energy);
- Compare energy use over an entire year using weather data for Washington, D.C.

- Determine the optimal configuration of the shading and insulation panels for the heating and cooling seasons.

Creating an Energy Model with Trane® Trace 700™ and eQuest®

In parallel with the eQuest® DOE-2™ modeling and analysis, a similar set of calculations were made using Trace 700™. The latter is an energy modeling software developed by software manufacturer CDS® and sold by the HVAC systems, controls, and services company Trane. The software conducts load, system, energy, and economic analyses accounting for weather variations. It uses the same simulation engine as DOE-2™. Trace 700™ was used as an independent check on the DOE-2™ results.

The data produced by the Trace™ model was analyzed and used to start new models with eQuest®. A thermal energy load analysis of the house was performed using eQuest®, an energy simulation program developed by James J. Hirsch & Associates and Lawrence Berkeley National Laboratory and written by the U.S. Department of Energy. It allows the user to simulate architectural and building science technology innovations. For instance, the sliding panels can be put on schedules which effectively change the U-value of the envelope based on incident irradiation or light intensity. This type of capability cannot be produced in Trace™ yet is applicable to the controls algorithm for the house. eQuest® augmented the analysis completed with Trace™ and provide more data for house controls and automation; thus, accomplish the goals set forth for the energy analysis.

Modeling Approach

To obtain at the peak heating and cooling loads, a materials list was compiled with their R-values and thicknesses. Next, these materials were entered into DOE-2™ and were grouped into “constructions” (walls, floors, roof, windows, sliding shading, and insulation panels that are composed of multiple layers). These constructions are only generic templates; they are just a collection of layers without defined dimensions besides thicknesses.

The next step was to specify where the actual walls, windows, roof, and floor were. The surfaces were named, constructions were selected, and dimensions were specified. Once these are all entered, the program simulated the heating and cooling requirements.

Space Conditioning

The analysis uses ASHRAE values for typical building materials and product specifications provided by manufacturers (table 1 and 2).

NAME	CONDUCTIVITY (Btu/hr-ft-°F)	DENSITY (lb/ft^3)	SPECIFIC HEAT (btu/lb-°F)
4.5” SIPS	0.0287	2	0.2
6.5” SIPS	0.0233	2	0.2
10.5” SIPS	0.023	2	0.2
18 GA. METAL	24	1684	0.1
MECH. ROOM DOOR	0.016	1	0.2
BATHROOM WALL	0.0227	1	0.2
4” CONCRETE	2.27	153	0.18

Table 1- Conductivity, density, and specific heat values of the building materials

NAME	SUMMER U-FACTOR ($Btu/h\text{-}ft^2\text{-}°F$)	SHADING COEFFICIENT	VISIBLE TRANMISSIVITY	INSIDE VISIBLE REFLECTIVITY	SOLAR TRANSMISSIVITY	INSIDE SOLAR REFLECTIVITY
NORTH GLASS	0.39	0.49	0.7	0.11	0.29	0.25
SOUH GLASS	0.53	0.72	0.75	0.15	0.5	0.35
WEST GLASS	0.52	0.87	0.81	0.33	0.2	0.35
NORTH INSULATION PANEL	0.0207	0.383	0.449	0.33	0.35	0.22
SOUTH INSULATION PANEL	0.021	0.563	0.5025	0.33	0.1	0.44
NORTH SHADING PANEL	0.387	0.2	0.1	0.4	0.25	0.15
SOUTH SHADING PANEL	0.524	0.22	0.1	0.4	0.3	0.15

Table 2- Optical properties of glass panes and sliding panels

In the Trace 700™ and eQuest® models, the house was divided into 4 zones. A zone consists of all the area controlled by one thermostat. Since the living space in the house must fall within 72°-75°F during the competition, the main room and the bedroom were included in the same zone; open-plan layout of the house makes it impossible to condition the living room space independently of the bedroom space (figure 18).

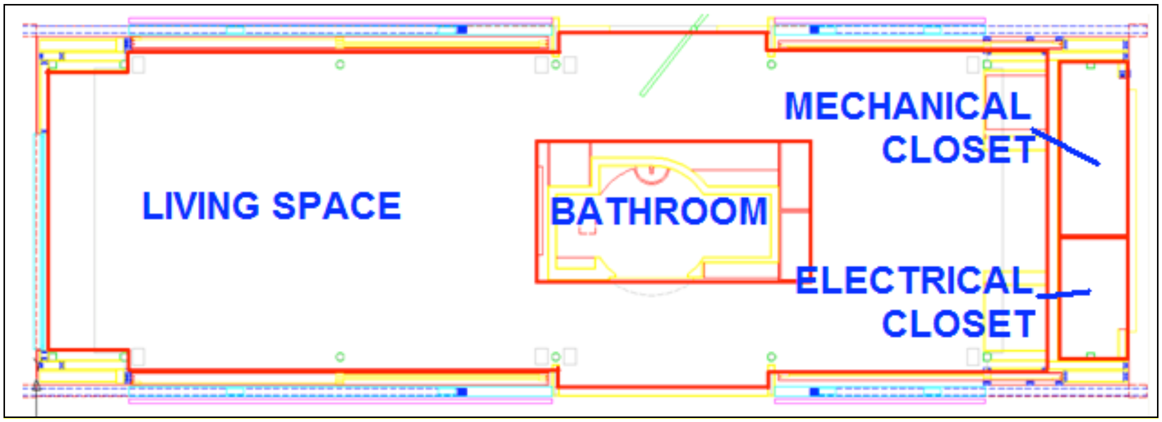


Figure 18- Room allocation scheme for the energy model

The bathroom, mechanical closet, and electrical closets were placed in their own zones to account for the fact that they are not exposed to direct sunlight. The closets are ventilated but not conditioned. The mechanical and electrical closets are separated by a partition and are expected to generate different internal loads; they were each given their own zone.

When all rooms had been created, the rooms were assigned to zones and the zones were assigned to “system”. The “system” is basically comprised of the airside portion of our HVAC (i.e., the ductwork, water-to-air heat pump, ventilation system, and energy recovery ventilator). The zone containing the living space and bathroom was assigned to a “Water Source Heat Pump”-type system. The radiant floor heating gets its own system, a “Radiant – Heating only”-type system. Since the mechanical and electrical closets use fans for cooling, these zones were assigned to separate systems. The mechanical and electrical closets were assigned to systems of type “Unit Ventilator.”

After the systems were assigned simulation was run. The house is subject to typical weather conditions over the span of a year, and the energy required to keep the house at its specified temperature range is determined. The programs can use a variety of weather data sources. This energy study will be using Washington, D.C. TMY2 8760, which is hourly data (8760 hours per year) for Washington, D.C. over the course of a year based on a typical meteorological year (TMY) established from data collected during 1961-1990.

Trace™ is unable to model the sliding panels directly. It is able to model external and internal shading devices, but these devices have fixed U-values that cannot be changed. Because the changing U-value of the insulation panel is one of the critical properties of the house, these shading devices will not suffice in the energy model. To work around this, the panels are implemented as glass with new values for U-values and light transmission properties. The total U-values for each configuration are shown in figure 19. Listed are the U-values for the four panel configurations on the north and south sides of the house.

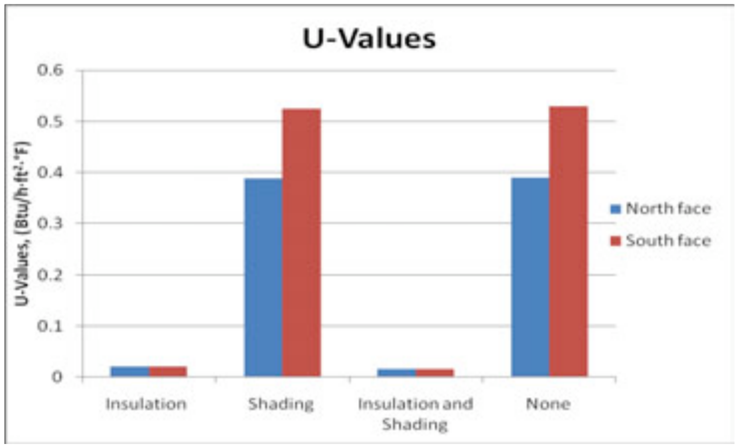


Figure 19- U-Value of North and South face

Trace™ requires the glass's U-value, shading coefficient, visible and solar transmissivity, and inside solar and visible reflectivity. While these values are known for the glass, it is not known for the insulation and shading panels. Data is available for the shading coefficient and visible transmissivity for the insulation panel, but these data are for a polycarbonate panel without Nanogel™ (figure 20). The transmissivity and reflectivity values are approximately 60% opaque as an average across the face of the panel. About 40% of direct (beam) solar radiation will fall on the windows.

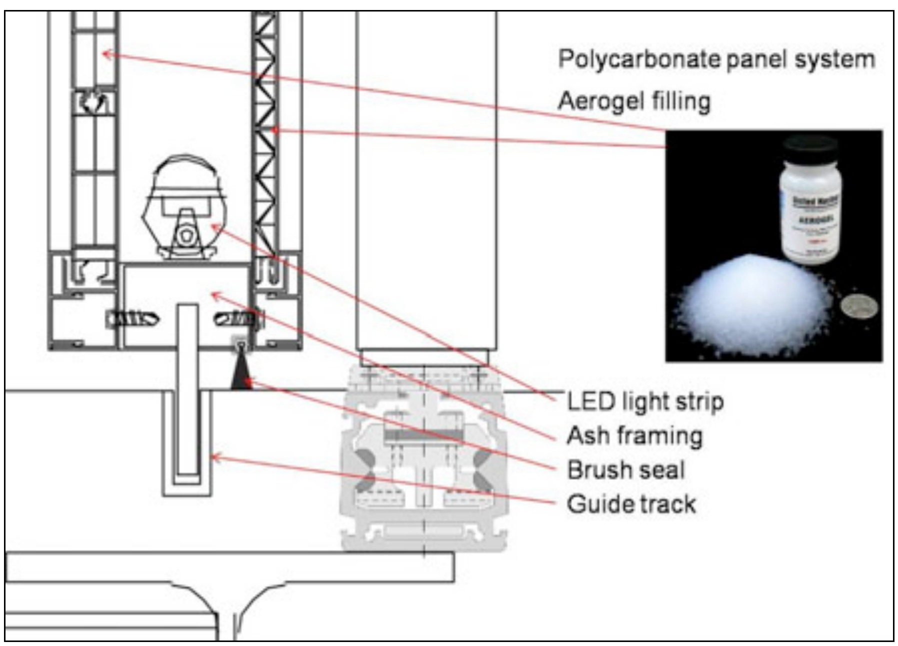


Figure 20- Nanogel filled insulation panels

Case Descriptions

This analysis focused on the three architectural strategies utilized as part of the envelope to control solar radiation. These strategies include:

1. Exterior shading panels
2. Aerogel insulation panels
3. Interior blinds

1. Exterior shading panels

The exterior shading panels (figure 21) were used on the solar house north and south faces. It provides partial shading and extra privacy, while allowing light and air in the house. The partial shading serves to influence the solar gain on the concrete floor. The shading screens are composed of panelized segments which are cut out of pieces of sheet metal. Each panel is composed of two layers separated by two inches providing a louver effect. There are two screens on each of the house (four screens total) that open and close either via user demand or pre-engineered settings.

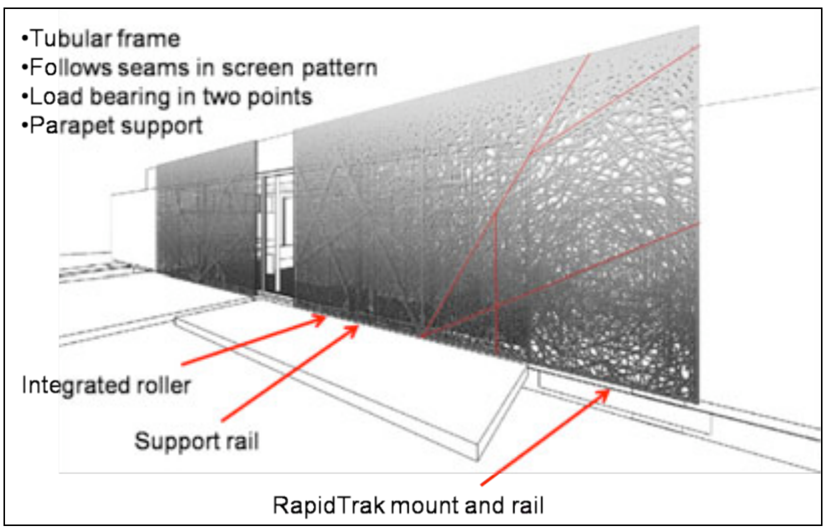


Figure 21- Shading Panel Concept

For the energy simulation, the exterior shading panels are employed based on a seasonal schedule. The schedule is divided into two seasons: representing the summer and winter. The shading panels are placed in front of the windows from 6 a.m. to 6 p.m. during the summer. The panels permit 40% of direct (beam) solar radiation to fall on the windows. During winter, the panels remain retracted from the windows, allowing maximum direct (beam) solar radiation to fall on the windows.

To model these panels in eQuest®, the panels are assigned two values: The value of 1 (full transmittance) is used to indicate the retracted state of the panels in winter. The value of 0.4 is used to represent the presence of the panels in front of the windows during the summer.

2. Aerogel insulation panel

The insulation panels are composed of a double layer translucent polycarbonate panel system filled with Aerogel, creating an insulating “sandwich”. When the panels are open, they split and nest beside the house (figure 22).

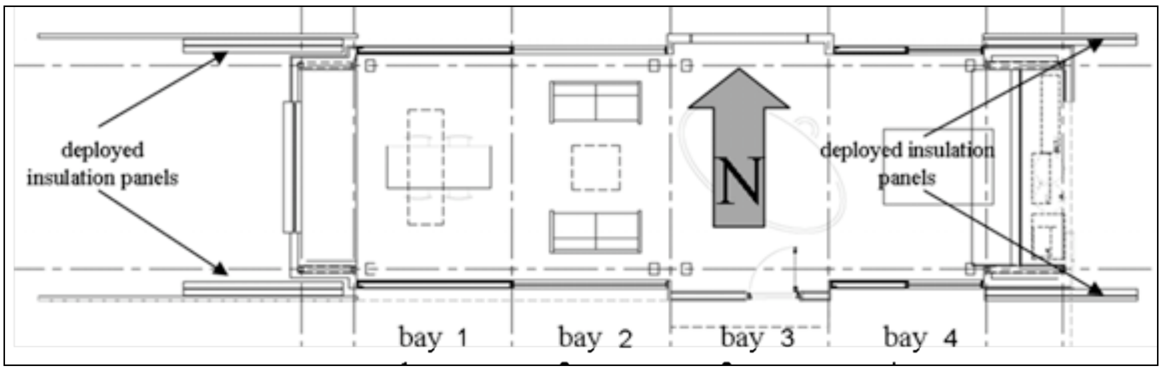


Figure22- Insulation panel retraction

The operation of the insulation panels is activated by a set temperature of 65°F and will close under this condition. Using a solar gain factor of 0.36, the panels reduce 64% of the solar gain through the windows. A conductance factor of 0.532 reduces the conductance of double-glazed windows from 0.39 Btu/h-ft^2-°F to 0.0207 Btu/h-ft^2-°F.

3. Interior blind

There are two different simulations used for modeling the interior blind.

The first approach modeled each interior blind as a movable interior blind, conventional modeling method. In the energy analysis, the blinds’ operation is controlled by the level of solar radiation (direct plus diffuse) transmitted through the window surface. A schedule for solar radiation was divided into two seasons: the summer and winter. The threshold solar radiation level for the cooling season is 40 Btu/hr-ft^2, so the blinds will close if the outside solar radiation exceeds 40 Btu/h-ft2. This threshold takes advantage of solar gain for space heating. In winter, the threshold solar radiation level is 20 Btu/hr-ft^2 to reduce solar gain.

The second approach was used to confirm the findings from the first approach. A switchable glazing function was used in the model can to simulate interior blind. The switchable glazing function allows the windows open only in the day time. The blinds will shutdown if the radiation level exceeds the control limit which will not occur during the night time. Therefore, the switch glazing method can be applied. An alternative window assembly was selected from the window library that matched the window and blinds. In this case, four layers of glass filled with argon is defined. This method does not allow two season scheduling like the first approach. Therefore, a minimum of 0 Btu/hr-ft^2 and a maximum of 20 Btu/hr-ft^2 solar radiation level were defined threshold for the switched glazing.

The results of two models were almost identical. The switch glazing was used in the full integrated strategy model to allow for the interior blind layer along with the shading from the exterior insulation panels to create the most accurate model.

The energy analysis tool also leads to one of the main goals of the energy study: creating a basis for the controls algorithm that controls the movement of the shading and insulating panels. The results produced from eQuest® are detailed enough to show data for cooling and heating energy over the span of a year. In that way, it is possible to determine which panel configuration is most efficient at different times during the year.

Results and Conclusions of the Energy Model

Five simulations were created to analyze the envelope components. A control model using none of the strategies was created to provide a performance baseline, and then the three strategies were analyzed in separate simulations to gauge their individual effectiveness. Finally, a model was developed using the three strategies in their most efficient mode of operation.

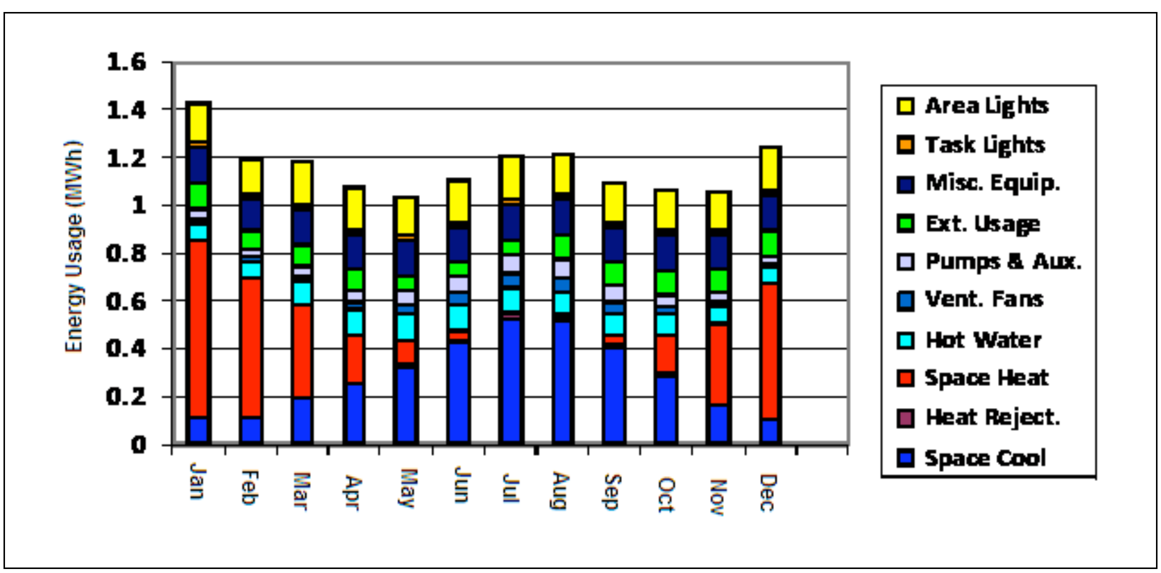


Figure 23- Energy usage with no shades or insulation

Exterior Shading Strategy

Shading devices are closed during the summer cooling months and opened during the heating months from 6 a.m. to 6.00 p.m.

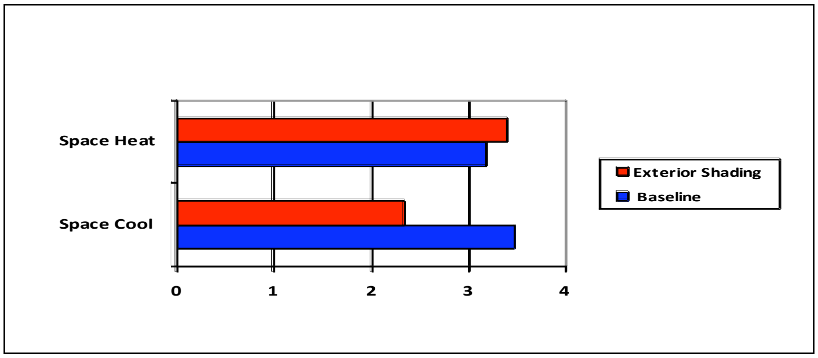


Figure 24- annual energy usage with just an exterior shading strategy in MWh

Results - The exterior shading panels reduced space cooling requirements by approximately 32%. A slight increase in space heating requirements denotes that further refinement is needed for the shading threshold. This will be accomplished using data gathered from the house the once construction is complete.

Insulation Panel Strategy

Insulation panels will close over the windows whenever the ambient dry-bulb temperature is lower than 65 °F.

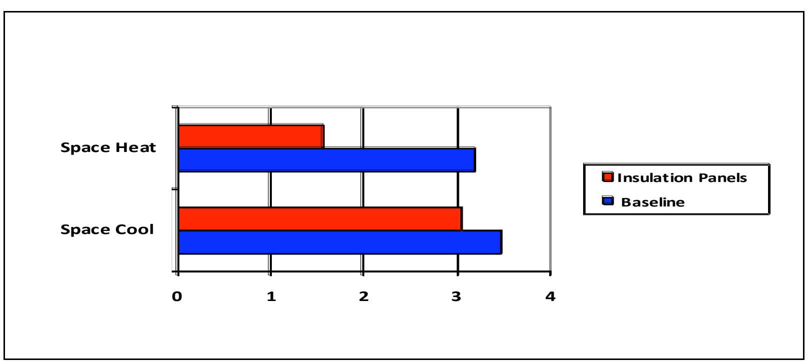


Figure 25- annual energy consumption with an insulation panel strategy in MWh

Results - The exterior insulation panels reduced space heating requirements by approximately 51% and space cooling requirements by 12%. This strategy provides a clear benefit in all scenarios.

Interior Blind Strategy

Blinds will close whenever the solar radiation is higher than 20 Btu/h-ft^2 in summer and 40 Btu/h-ft^2 in winter.

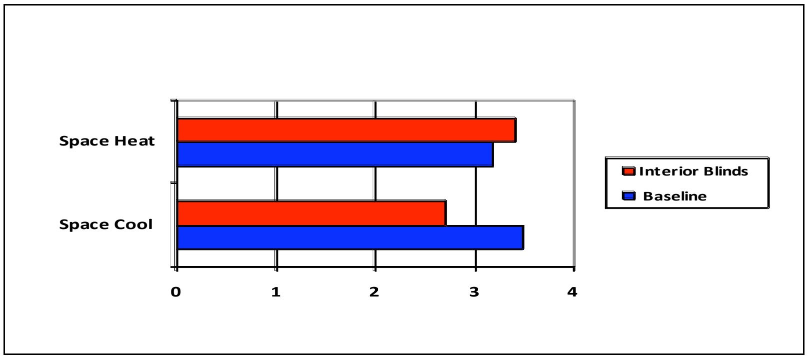


Figure 26- annual energy consumption with a interior blind strategy in MWh

Results - The interior blinds reduced space heating requirements by approximately 22%. A slight increase in space heating requirements denotes that further refinement is needed of the interior blind threshold. This will also be accomplished using data gathered from the house the once construction is complete.

Energy Consumption and Demand Relative Comparison

The most efficient design combines all of the design strategies to optimize the results (figure 22). The final model mixed all of the design strategies for efficiency. From the simulations, we calculated the annual energy consumption and peak kW consumption.

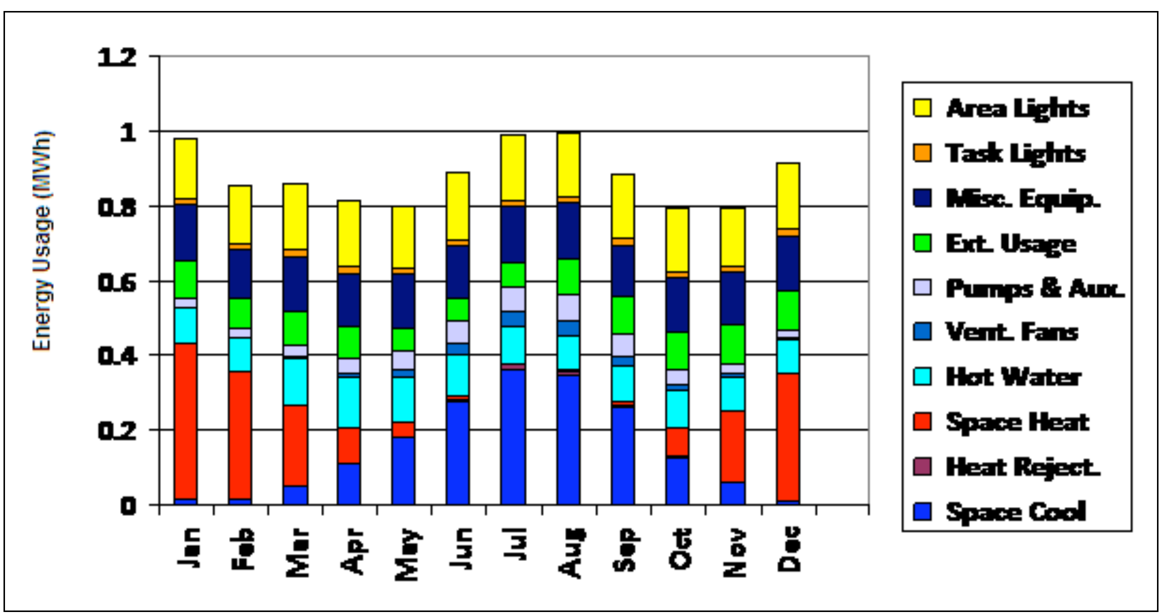


Figure 27- annual energy usage with all control strategies

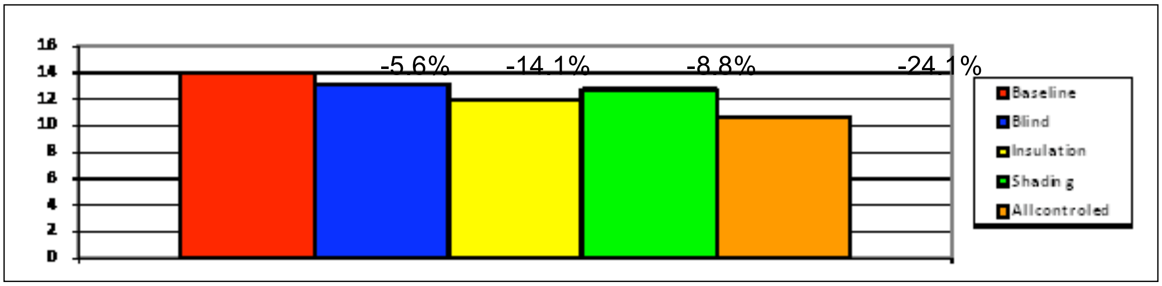


Table 3- annual energy consumption

	Baseline	Blind	Insulation	Shading	All controlled
Energy Total	13.94	13.16	11.97	12.71	10.58

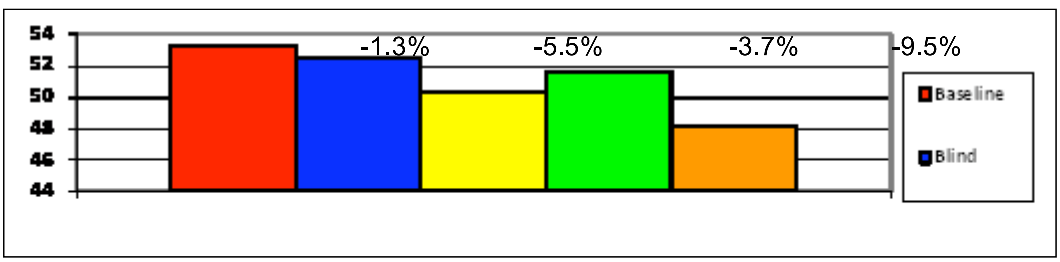


Table 4- Peak energy demand (kW)

	Baseline	Blind	Insulation	Shading	All controlled
Peak Demand	53.27	52.56	50.32	51.58	48.2

Photovoltaic Energy Analysis

To predict how much energy would be delivered by the photovoltaic array, PV – Design Pro from Maui Solar Energy Software Corporation was used. Since the building will be operated as a grid-tied system, PV Design Pro-G was used within the software suite which is specifically designed to analyze grid-tied systems. An advantage of using this program is that it comes with weather information for 239 cities. The program also characterizes more than 400 PV panels including the Sanyo HIT Double 195 double solar panel which we will be using. With options on how solar tracking is done, analysis on typical loads, and easy to read outputs, this software was ideal for our PV energy analysis.

Using the weather information for Sterling, Virginia, the closest data to that of the actual competition site, we were able to produce valuable information about the energy we could produce. Though there is an option to input the load characteristics of our house, we decided to leave the load characteristics blank to see how much power could be generated over the course of a typical meteorological year (TMY) for Sterling, Virginia. Figure ___ illustrates the power production of the PV without a building load. The month-by-month consumption bar was determined by performing a heating and cooling load calculations utilizing eQuest,® a front-end to DOE-2™. DOE-2™ is a building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, constructions, operating schedules, conditioning systems (lighting, HVAC, etc.) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills.

Because of the buildings dynamic enclosure system, a methodology was developed to account for the thermal variability of the different physical states of the panel systems. Five simulations were created to analyze the envelope components. A control model using no panel movement was created to provide a performance baseline, and then three strategies were analyzed in separate simulations to gauge their individual effectiveness. Finally, a model was developed using the three strategies in their most efficient mode of operation. The "Consumption" bar in Figure __ reflects this optimized mode of the panel operation.

Using the same weather data as in DOE-2™, for the location Sterling, Virginia, we were able to produce information on how our solar array would perform at the competition location. We found that we could produce 12,840 kilowatt-hours of energy over the course of a year. Even though this more than satisfies our energy demand, this estimate does not account for the bifacial nature of the solar panel; according to manufacture's literature, we can expect up to 30% extra production from the back-plane of the panel,. This means we could produce up to 16,700 kilowatt-hours of energy annually. A conservative estimate that we could expect half of this potential from the back plane, producing 15% extra, would yield 14,770 kilowatt-hours annually.

With the PV energy analysis, a comparison of the power production and consumption was done (figure 28). The house shows a clear net gain in electrical production for eleven out of twelve months. The solar energy gain is potentially greater than the simulated valves, because the simulation cannot account for the back face solar energy collection, which would produce additional energy.

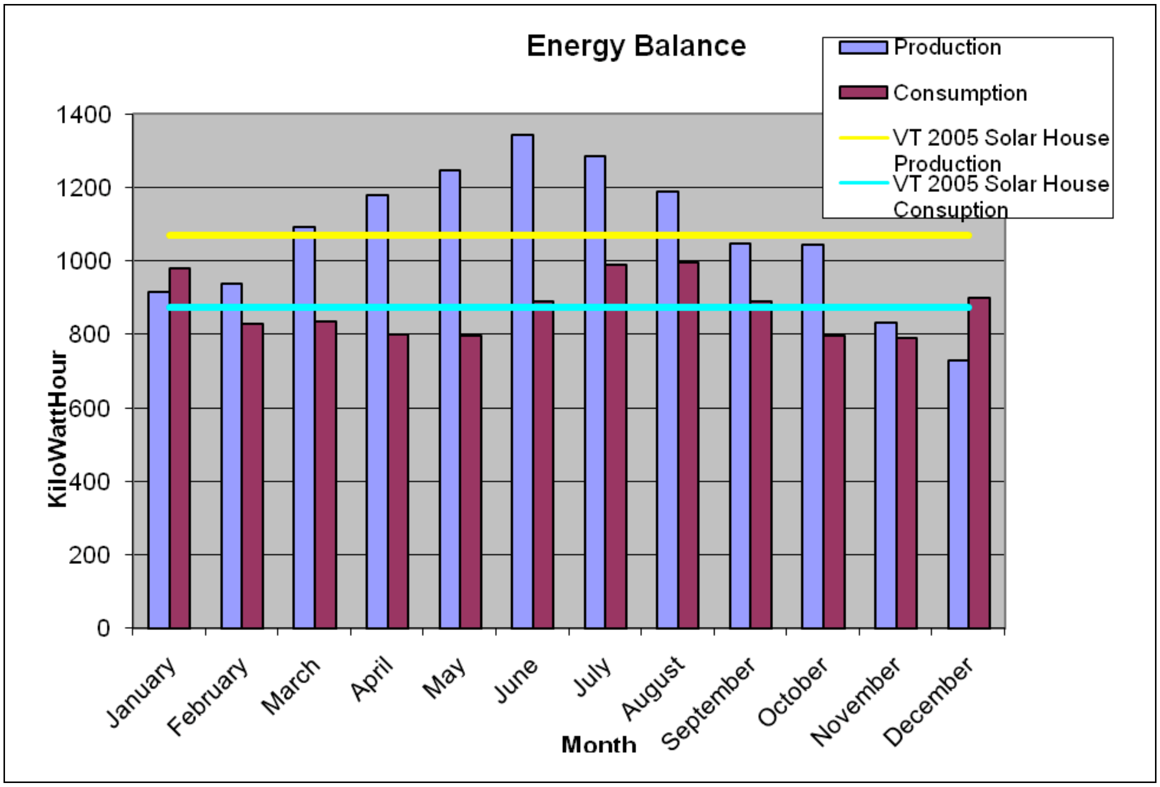


Figure 28- Energy Production and Consumption Comparison

Summary

The simulations of the house load and of the PV energy production display a net energy gain for the yearly operation. The simulations demonstrate a success of the team's energy goals. Actual efficiencies may vary from the model, but the simulations provide a firm ground to enter the competition with the possibility of winning and to potentially market the house to interested consumers.

ARCHITECTURE DESIGN NARRATIVE

Introduction

The Virginia Tech Solar Decathlon Team is working to provide a model for an energy independent architecture that accommodates active lifestyles of a changing society in a spatially rich environment. A collaborative of students, faculty, and staff from the departments of architecture, industrial design, building construction, landscape architecture, interior design, mechanical, structural, and electrical engineering, green engineering, materials science, power electronics, computer science, and marketing have come together to design, build and operate a unique solar house that demonstrates a comfortable living and working environment, excellence in sustainable construction, and strong architectonic expression. As a pilot fish in design research we are pushing the envelope to crack open new ideas regarding residential construction and the use of energy in buildings. We are harnessing technology in *a brighter way*, to build *a brighter day*. Our elements are bold, our thoughts tempered, our decisions reasoned, and our work is with passion. This may seem a provocative house for a conservative market, but aspirations are set to Daniel Burnham's polemic, "Make no small plans, they fail to stir the hearts of men." (and women)

Mission

The mission of the Virginia Tech Solar Decathlon Team is to inform and educate the public about issues regarding energy (particularly solar) and sustainability while enhancing student education through a design-build process of innovative research, testing and application.

Our multidisciplinary team strives to achieve the following goals:

- Illustrating how solar energy can improve the quality of life through increased energy and access to natural light in residential building
- Increasing public awareness of energy use in daily life, and to illustrate the energy consumption of daily activities
- Demonstrating that market-ready technologies exist that can meet the energy requirements of our daily activities by tapping into the sun's power
- Providing an awareness of electrical use thereby promoting a mandate for conservation
- Demonstrating that sustainable materials and technologies can comprise a beautiful structure in which to live, work, and play
- Establishing a home that is responsive to its environment and integrates passive heating, cooling and day-lighting
- Examining a project in a prototypical manner to develop solutions that can be reproduced and realized through manufacturing techniques with economic benefit
- Challenging conventional architectural practice through interdisciplinary collaboration and corporate partnerships

A Brief History

With the design of a third solar house our goal is to continue to re-establish the ideals of solar energy by further exploring the relation of architecture and technology and disseminating this information to the public. The 2005 Virginia Tech Solar House now resides in front of the State Science Museum of Virginia in Richmond. As a premier exhibit of the institution, it serves as an educational/research facility for the public school system and the general public. Our intention is to continue this pattern of outreach and media coverage through established programs at the local, regional and national levels. The primary deliverable of the competition is a house that harvests the sun's energy. However, the larger goal of the DOE is to raise awareness among the general public about renewable energy and energy efficiency, and what technologies are available today to reduce energy usage in daily life. We pursue both goals with equal veracity.

Though our teams have changed over the years, the research has continued with continuity. One of the unique strengths of the School of Architecture + Design at Virginia Tech is the integration of teaching, research and outreach, and the inculcation of collaboration within the undergraduate curriculum. The Solar Decathlon has brought us to an educational watershed challenging the relation between academia and practice and between research and its corresponding contribution to society. The first two teams have graduated, yet the knowledge derived from these initial endeavors has been transferred to and is being transformed by our 2009 team. The increase in complexity between our 02 and 05 projects is evident, and we are aware that to effectively compete we must develop a commensurate increase in sophistication for the next Solar Decathlon.

In the summer of 2007, an interdisciplinary team of Virginia Tech students was formed to begin conceptualizing the house design for the 2009 competition. Students considered innovations, research, and lessons learned from the design construction and operation of the 2002 and 2005 Solar Decathlon houses. The efforts of the summer program yielded a house concept entitled *Responsive Architecture*. In Fall 2007, a school-wide design competition was held to enrich the project concept and introduce new members to the team. In Spring 2008, a design studio was formed to further develop the project. Work continued through the Summer 2008 with design development and the initiation of construction drawings.

Fall semester brought the coalescence of team diversity. Students in electrical engineering, mechanical engineering and computer science began work on specific components and systems. Design of the structural frame advanced with specific consultation and calculation from the office of Ove Arup. Shop drawings were produced and sent to Kullman Building Industries in New Jersey. The frame assembly was fabricated and transported to Blacksburg, Virginia using a similar transport method of the 2005 house. (The concept of the detachable bogey and gooseneck in conjunction with a lowboy double-drop trailer was pioneered in the 05 house.) Construction is now fully underway at the research facilities of the School of Architecture + Design.

Design Concept and Philosophy

The Virginia Tech Solar House is driven by a multidisciplinary approach that challenges research through application. It harnesses the tension created by the dualities of calculation and intuition; technological innovation and architectural expression; optimized performance and sensible materials; and between physical fact and psychic effect. Simultaneous consideration of technology and architectural content has guided the identity of the house. *Every decision involving quantitative criteria was measured in terms of its contribution to spatial quality*. New forms have been derived from technical considerations, and enriched patterns of daily life find expression in a celebration of energy awareness and resource conservation.

This project pushes existing paradigms by proposing an architectural form that celebrates solar energy while obtaining a high level of system integration. Issues of energy are often interpreted as primarily technical, comprising data and enhanced by equipment. We subscribe to this mandate and affirm that the calculative world of science and engineering are indispensable. Yet, we also believe that these efforts in themselves are not sufficient - it ultimately must be beautiful as well as functional.

Architectural concepts that inform the design:

- A house larger than itself – plan and section orchestrated by light and material to enhance spatial perception of a small footprint and volume
- A house that responds to changing environmental conditions and user requirements
- Every technical decision is measured in terms of its contribution to spatial effect
- Material considered for its technical capacity and architectonic expression
- The landscape and architecture are one
- Enriched patterns of daily life find expression in a celebration of energy awareness and resource conservation.
- Energy efficient and sustainable living is offered in a rich and sensuous environment
- Marketability and innovation – simultaneous awareness of public taste and the need for something meaningfully different and exciting

LUMENHAUS

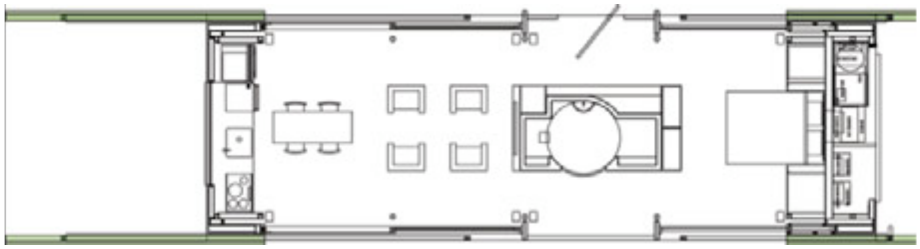
The name LUMENHAUS and the notion of *living a brighter day*, *everyday* finds expression in a specific architectural type. The house takes the provocative position of a pavilion - an architectural space of distinction unlike most solar powered houses. Where most energy conscious houses are closed with strategic openings to resist heat transfer, this house has flowing spaces linking inside and outside. Open on the north and south facades, the house seems much larger than its small footprint. Decks, water features and landscape mesh with the architecture to create a seamless environment of sun and space. Rich and divergent qualities of light fill the house from sunrise to sunset, and sliding panel systems (see *Eclipsis© System.* below) respond to climactic conditions, providing a full range of protection from the elements and a rich architectural experience. The duality of open and closed is possible through a sophisticated integration of the architecture and the technology.

A narrative describing *Responsive Architecture* is as follows: *Consider this* - You are sitting in your living room around 10:00 a.m. on a cold, cloudy winter day. Dispersing clouds allow sunlight to strike the south facing window wall. As heat builds, sensors indicate the passive solar gain to be a positive contribution to the indoor thermal climate. Automatically, insulation panels slide open and admit the sunlight. *Later that day* - you sense the direct sunlight is too strong for reading but the solar warmth feels good. You reach for your i-phone, select the MY HOUSE icon, and signal the shutters to close. Soft, natural light spills through the delicate shutter screens offering a subtle degree of privacy. This is a grid-tied solar house on the cutting edge of *Responsive Architecture*. It adjusts to climactic changes and user requirements through systems that optimize energy use and offer an architecture of delight. *While your away* - the house responds on its own, adapting to changing conditions sensed by the weather station mounted on the roof. From your i-phone, commands can be issued so that appropriate temperature, mood lighting and desired music are orchestrated as you enter the house after a hard day at the office.

The Plan

The house is comprised of a rectangular plan of open and flowing space. Mechanical and electrical equipment anchor the west façade; the kitchen is embedded in the east wall. These elements serve as bookends to the plan inflecting the space to the north and south decks. A ribbon window contiguous with the kitchen counter admits afternoon light. Bouncing off the west water pond, the yellow glow of dappled sunlight splashes on the ceiling. The kitchen is designed to support the active life style of a young professional couple and empty nesters desiring smaller but generous living. It is a center of activity supporting informal social gatherings and a transformable workspace. Of particular note is a table that nests with the counter. This element can be slid to make second work surface as a galley kitchen, or it can move over the dining table to create a side table, separating the dining from the living room. The kitchen table can be rolled in the opposite direction supporting activities on the north or south decks. Cabinets are designed with intricate “fold down – slide out” elements that make a small space efficient.

A central core accommodates storage, bathroom and office areas, playing an important functional and spatial role. As an object in the space rather than an assembly of walls, it separates the living area from the bedroom allowing a full reading of the volume. It also yields alternate paths on which one can walk through the dwelling. The core is “cave-like” and introverted reinforced by vertical light. Its wall treatment is dark in relation to the brightness of the rest of the house. This contrast sets a rhythm of expansion and contraction, giving a perception of destination and a larger space.



Plan showing Shutter Screens and Insulation Panels open

The north and south walls are comprised of sliding layers of curtains, glazing, insulating panels, and metal shutters. The characteristics of each layer of the changing wall system create a diversity of spatial readings. The space resonates as experienced in varying natural and electric light, mediated in different ways by each layer of the outside wall. In good weather, the wall panels can be opened, creating both a physical and psychological connection with the outdoors. Sensors and servo-motors control these sliding components and enhance energy performance while delivering a generosity and transparency of space.

An aspect of research taken from the Virginia Tech 2005 house is the transportation strategy. Here it is developed further with a design for a carriage that is the integral structure of the house. The structure of the house is a rigid steel frame factory assembled to close tolerances. Structural insulated panels (SIPs) comprise the roof and end walls. With high insulation values, these panels also serve as the sheer bracing for the structural frame. Removeable diagonal bracing allows for the frame to resist deflection and carry heavy loads. Thus, the house can be transported intact with little site assembly. The detachable gooseneck (connection to cab) and bogey (rear wheel assembly) are prototypes for a distribution strategy for mass produced units.

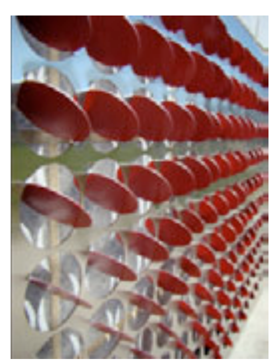
Structural frame in transport


Torque box assembly (connection to bogey)

Eclipsis© System

The house adapts to optimize energy efficiency, and articulates the architectural space differently though combinations of sliding panels. It is designed to be flexible and fluid to a wide range of climactic conditions while accommodating various modes of living. The north and south walls are comprised of sliding layers of curtains, glazing, insulating panels, and metal shutters. The two outer layers are part of the *Eclipsis© System.* The outermost layer is a stainless steel sheet metal assembly with a circular geometry of laser-cut holes and folded tabs. It functions as a shutter with a four-fold role: to keep the summer sun off the façade; to offer degrees of privacy while maintaining contact to the outside; to break sunlight into fractals that intensify and enrich the space, and to permit cross ventilation. The folded tabs have three variables – the diameter of the circular cut; the orientation of the tab and the degree of tab fold. These variables are articulated to block and bounce sunlight and block or create views. For example, in the bedroom the tabs are folded on a vertical axis favoring south-east/north west orientation. This causes the rising sun to strike the backside of the tabs and bounce into the bedroom while blocking direct views into the space. In the dining room, strategic tabs are fully folded (90°) on a horizontal axis to create a direct view outside from dining height while blocking direct sunlight.


Shutter Screen development


Shutter prototype

The second layer is an assembly of polycarbonate panels filled with Nanogel (Cabot Chemical's trade name for aerogel). An innovative wall assembly contains light literally and phenomenally. This double wall section gives an R-24 insulation value while transmitting a beautiful translucent light. This highly insulated wall acts as a dematerialized surface, holding light similar to that of a Japanese pagoda. Increasing natural daylight in building has long been a goal in architectural design. Studies have shown that people thrive in natural lighting: they are healthier, happier and more productive. In this house, there is no need for electric light from sunrise to sunset and the energy collected during the day is symbolically radiated back out at night through the lantern glow of the house. Between the layers of the polycarbonate panels is a three-inch airspace containing banks of LED (light emitting diode) fixtures. The glow of these lights through the polycarbonate reflecting off the water will give the house a unique night-time identity.

Night view with Shutter Screens and insulation panels open

Architecture and Technology

Though the concept of *Responsive Architecture* and the innovative use of computer monitoring and controls, the 2009 Virginia Tech solar house has the ability to operate at an optimal energy efficiency 24 hours a day without compromising the comfort and beauty of a modern architectural home. Through sensors and servomotors linked to centralized computer controls, moveable building components such as shutters, and insulating panels of the *Eclipsis© System* are adjusted on an hourly, daily, or seasonal basis to maximize building performance. Linkage to current and forecast weather data from the house weather station is incorporated into system control strategies for solar collection and storage, as well as utilization of thermal storage. These controls will also be used to position photovoltaic cells on daily and seasonal tracking.

Virginia Tech's computer science department is developing an application for the i-Phone that will enable the manual control of all house systems remotely. This will include access to power management displays that will tell how much energy the house is producing and consuming, including detailed information regarding energy consumption of each appliance. This is a valuable tool for active public engagement in reducing energy use on a daily basis. When the house is initially occupied, it goes through a training mode asking the user a set of questions regarding daily routines and schedules, comfort levels, and personal choices such as lighting levels at different times of day and background music for dinnertime atmosphere. This information is integrated into the programming of the house controls to make it operate at the most energy efficient level.

The i-Phone is intended to render the sophisticated technology transparent and give the user a greater understanding of energy and their home. The technology plays numerous roles in creating the architecture. The *Art of Integration*, the conceptual position of a previous project, has evolved to *Responsive Architecture* in a manner that makes the technology and architecture synonymous. For example, the stainless steel shutters of the *Eclipsis© System* are designed to protect from the summer sun, create privacy, permit cross ventilation, and deliver a soft glowing sunlight to the space. The panel composition – laser cut circles with folded tabs and painted one side – is the primary façade element. During the day the color of the backside of the rotated tabs gives a dynamic and lively play against the stainless steel surface depending on one's position and direction of movement. At night, the panels deliver a strong nighttime identity with LED lights reflecting through the pattern and onto the water. As they slide responding to climactic changes or user preferences, the house takes on a sculptural, magical quality.

General concepts for sustainable architecture – compact volume, little air infiltration, strategic insulation, natural/cross ventilation, integrated geothermal energy sink and passive heating are articulated with appropriate technologies. The 8.7 KW array is reasonably sized to the scale of installation. It will meet the highest demands of the house while generating additional energy to power an electric vehicle or return to the grid. Other features difficult to demonstrate in renderings but critical to the architecture include:

- The concrete floor aids in passive heating also provides a sense of dwelling through its massive presence; the extra weight is balanced by a spatial condition of permanence and security.


Installation of Radiant Floor


Concrete Floor Polishing

- Radiant heating is the highest quality heat, particularly for the elderly and highly sensitive individuals - there is no moving air, it is quiet, the heat is in the best location at one's feet and the ambient temperature can be kept lower saving energy.
- Translucent polycarbonate panels filled with Nanogel offer high insulating values (R-24) while delivering a beautiful translucent natural light from sunrise to sunset.
- Shutters provide a simultaneous sense of protection and openness.
- The transforming features of the wall system give the presence of a large house though the volume is small.
- The pavilion characteristics of the house allows for less mechanical heating and cooling throughout the year.
- The iconic image of the shutter screens is derived from an historical archetype - similar to the mashrabiya (a highly crafted, delicate screen found in Middle Eastern countries) – it integrates technical function and cultural implications.

Landscape

The landscape is built to demonstrate water conservation techniques through development of a system that integrates the exterior and interior environments inclusive of rainwater harvesting system, constructed wetlands, and hydroponic planting schemes. The goals of the landscape plan are:

- Demonstrate and promote water and energy conservation within the interior and exterior environments while making a visual and spatial contribution to the whole environment
- Develop a system to treat the grey-water from the home by independent natural vegetative means for reuse within the house and to supplement irrigation of the exterior landscape

- Demonstrate systems that enable this home to be completely independent, through rainwater collection, grey-water purification and reuse, using plants through design to affect the functional and aesthetic qualities of the dwelling.
- Create an innovative landscape system support complete independence of the home while exploring the aesthetic and functional qualities of the system and the place

Features of the landscape include rainwater harvesting that will become a primary source of water for the home. A grey water treatment system will take water from sinks, showers and washing machines and use a two-stage system for cleaning. The first treatment involves anaerobic and aerobic digestion that leads to a secondary system of hydroponic plants. Black water is treated in the same manner giving way to a drain field built over the geo-thermal heat pumps ground based heat exchanger systems to support the sustainability of the ground temperature.

The constructed (hydroponic) wetlands are organized through a modular grid system. A variation of a green roof modular system is utilized as the base for our wetland cells due to the ease in moving and constructing the system. These elements are placed in the three reflective water basins around the house. The grey-water from primary treatment passes through modular wetland units to naturally remove the nutrients from the water. Floating plants in the reflective ponds further cleanse the grey-water. Three small pumps aerate and agitate the water to accelerate the movement of water in the basin. The ponds are interconnected with back flow prevention and when the water reaches the last pond, it is thoroughly treated and passes through a final UV filter for distribution with the water closet in the house with the remainder for use in irrigation. The water is passed through the living system. The hydroponic wetland provides high performance levels for Biological Oxygen demand (BOD), and Total Suspended Solids (TSS). (Reed, 1993). The surface flow wetland is the second stage of this system, which contains a final anaerobic and aerobic environments to promote the removal of nitrogen and dissolved solids. Clean water is collected from these areas and diverted back to the home for second use options.

The surface landscape ground cover system is designed to absorb Co_2 emissions from the surrounding environment and its inhabitants, therefore reducing the carbon footprint of the residents and the home. The material used from the ground cover is different from a typical lawn in that it is a dense and course texture thereby increasing the leaf surface area for the absorption of CO_2. For the demonstration on the Mall this system will be set up, managed and controlled in green-roof planting trays.

What Makes this Solar House Different and Better

Ever since the 1970's, solar technology has been burdened with a stigma of ugly and unreliable equipment that destroyed any sense of proportion and beauty in building. Arbitrarily attached to new or existing construction, the product became associated with a small clique of individuals disenfranchised from mainstream public taste. This project is designed to challenge those perceptions and reestablish the ideals of solar energy by integrating architecture and technology. It pushes existing paradigms by proposing an architectural form that celebrates solar energy while obtaining a high level of system integration.

This building is designed for spatial clarity, integrity of material, quality of light, and energy performance. The United States Green Building Council's (USGBC) LEED Residential program provides us with an outline on which to layer additional architectural meaning by designing with environmental sustainability and human health in mind. Design decisions and material selection aim to reduce indoor pollutants, minimize global warming, reduce waste, include recycled content, represent low embodied energy in manufacture and harvest, limit destruction to habitat, and rapidly renew resources.

Though the focus of the competition is solar, no effort would be coherent without an awareness and consideration of this larger picture. At the same time, we are concerned about manufacturers' tendency to call everything green. We realize there are trade-offs and compromises one makes to realize a greater good. We have tried to balance design quality, resource conservation and energy efficiency.

Visual Timeline

The architecture project narrative ends with the beginning - a brief snapshot of the evolution of the project from its initial phases. The following pages document the process as a visual timeline showing various modes of engagement. The educational experience is enriched with a research effort that includes, reviews from practitioners, meetings with consultants, visits to manufacturers, direct work with fabricators, collaboration with industry leaders, attendance at international expositions, prototype development, and many forms of cross disciplinary collaborations.

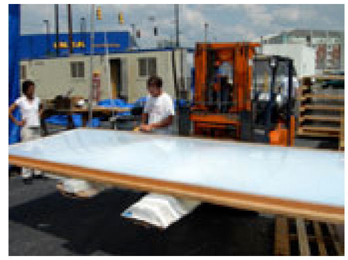
VIRGINIA TECH SOLAR HOUSE

Design and Construction Process

Visual Time Line

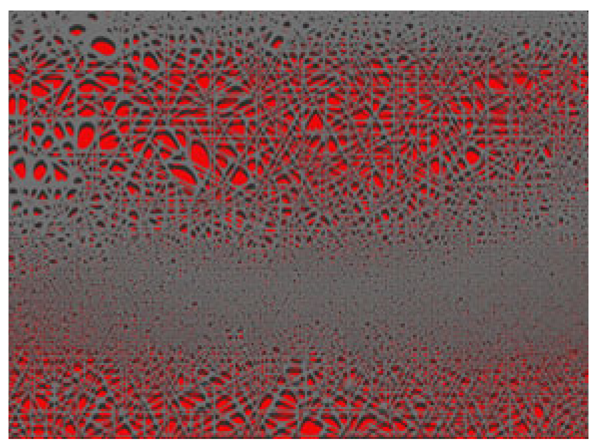
October 2007

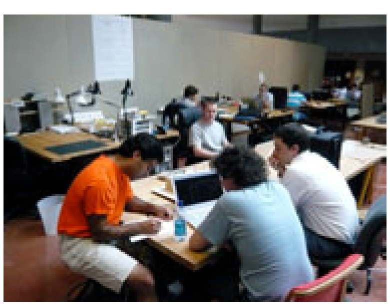
- After success in the 2005 Solar Decathlon, the Virginia Tech team sits out the 07 competition and begins working tor the 2009 event.
- Virginia Tech faculty serve as consultants for the Georgia Tech 07 Solar Decathlon project. Virginia Tech team travels to Atlanta to advise on several issues.
- The Virginia Tech team helps set up the Georgia Tech house on the Mall. Students study, first hand, entries from the 19 other research institutions and gain valuable insights regarding design and construction for the 09 project.

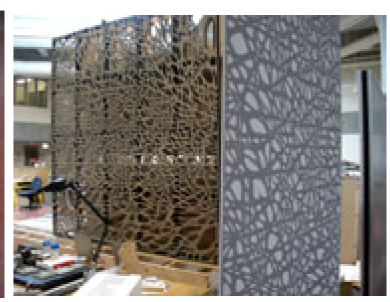


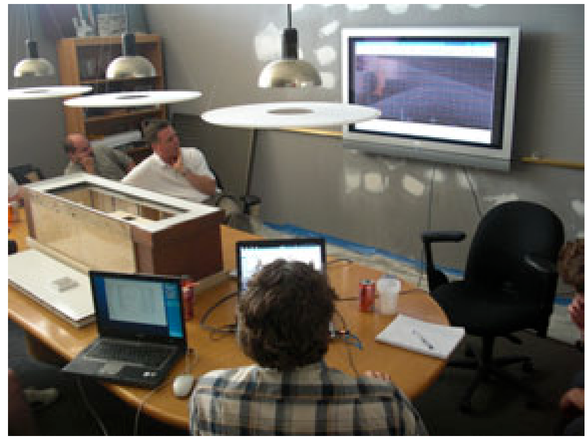

Summer 2008

- Ten students awarded academic fellowships to participate in solar decathlon summer studio. Architecture, industrial design and building construction students advance the preliminary design and develop the concept of *Responsive Architecture.*
- Summer studio office established.
- Initial full-scale mock-ups of sliding shutter screens
- Polycarbonate panels with aerogel prototyped
- Initial presentation in Houston to ConocoPhillips



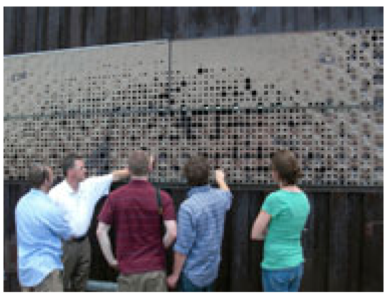


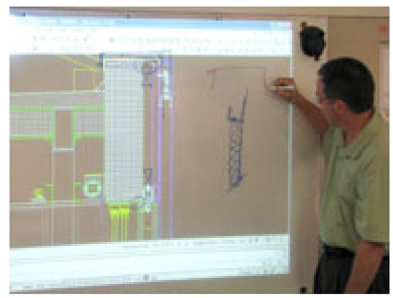




June 2008

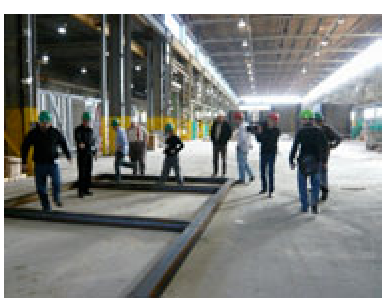
- Solar team travels to the A. Zahner Company in Kansas City. Zahner is a specialized sheet metal fabricator who produces most of the cladding for high profile architecture (Frank Gehry. L. A. Concert Hall). The company agrees to produce the sliding screen/shutter panels (Eclypsis System).
- Robert Zahner consults with the solar team at Zahner fabrication facilities in Kansas City.

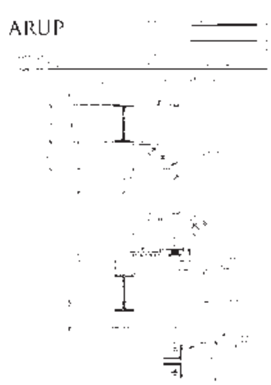




October 2008

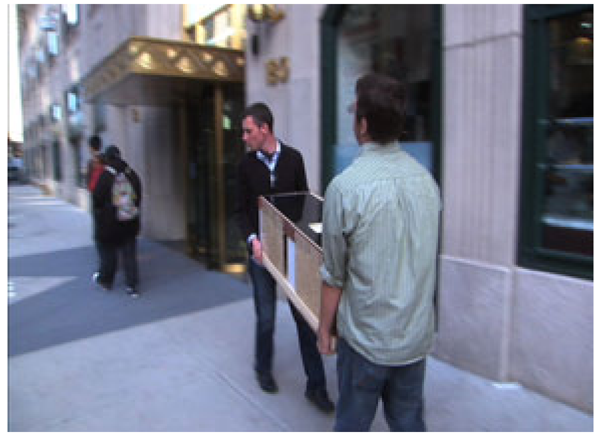
- Solar team visits Kullman Building Industries, Lebanon, New Jersey - Kullman is the leading worldwide off site builder of permanent steel and concrete multi-story buildings.
- Ove Arup serves as consultant and executes engineering calculations.
- Digital drawings sent to the factory; material take-offs made, steel ordered and cut. Team observes fabrication of frame.
- Adjustments and corrections to steel assembly made on site.





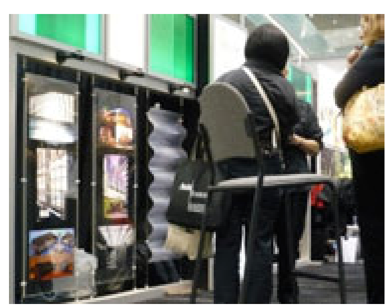
October 2008

- Team travels to New York - presents preliminary project to design offices - RDS 4, Ove Arup and Shop Architects
- Team visits Fabrication exhibit at the Museum of Modern Art
- Film crew accompanies team for initial filming of video that documents design and construction processes.
- RFP for Solar Decathlon Europe is successful. Virginia Tech Solar House is one of 20 (two from the U.S.) scheduled to compete in Madrid, Spain in June of 2010.



November 2008

- Team members attend GreenBuild Convention in Boston; solicit and meet with corporate sponsors; two manufacturers (Cabot Chemical and DuoGard) have displays showing 05 solar house as examples of excellence regarding their products
- Exhibition at Architecture Exchange East, AIA State convention; solar house and Advanced Personal Transport (APT) are presented as research projects regarding energy use in the home and automobile
- Exhibition, Society of International Journalists, emphasis on issues of sustainability

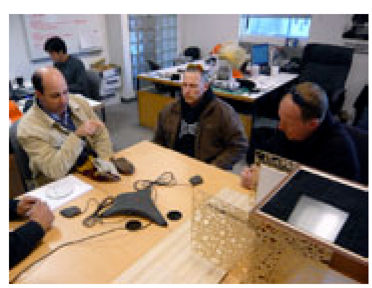


December 2008

- Torque boxes fabricated by Fontaigne Specialized in Birmingham, Alabama and transported to Kullman for installation in the frame.
- The bogey (wheel system from the 2005 project) utilized to bring the frame from New Jersey to campus in Virginia.

January 2009

- Solar panels arrive - Sanyo Double Hit, 45 panels. 9 kilowatt array
- Testing to determine panel efficiency under different conditions
- Meetings and conference calls with supplies and installers begin to ramp up
- Solar house featured in *Inform Magazine*
- *MODEA* agrees to produce web page
- *Spine 3D* to create graphic animation of house



February 2009

- Plumbing and wiring chases placed
- Floor heat sensors installed
- Radiant floor system installed
- Agreement with National Building Museum, Virginia Tech Solar house to be part of a sustainability exhibition, to be located on the lawn in front of the institution during the month of Sept

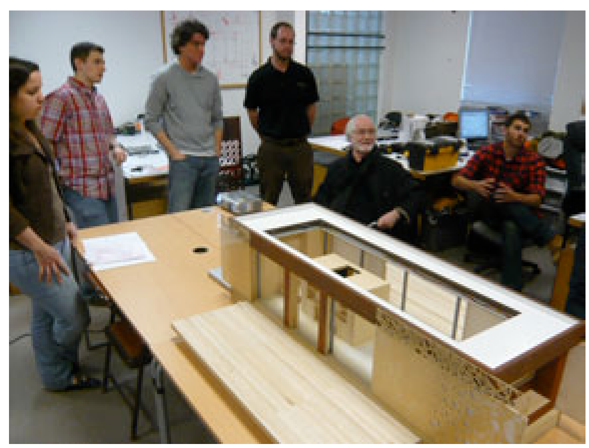
March 2009

- Pouring of the slab
- Next days temperature in the teens, structural insulated panels used as thermal blankets
- Slab has a technical and spatial function - passive heating and radiant floor yield high quality and efficient heat; the materiality of the slab lends a sense of permanence and dignity to dwelling.
- Installation of roof Structural Insulated Panels (SIPs)

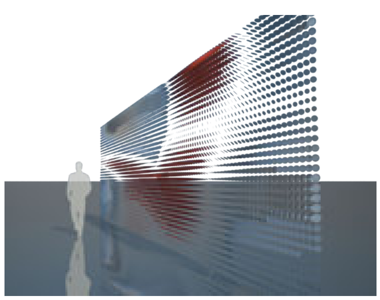
March 2009

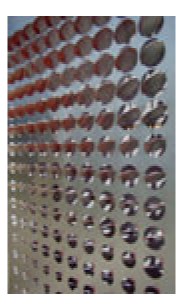
- Specialty concrete finishers from Alabama and Tennessee bring equipment and expertise to grind and polish the concrete to a granite like finish
- Mechanical/electrical closet completed - serves as sheer wall for east end of the frame
- Roof Structural Insulated Panels (SIPs) installed
- Outriggers that carry beam for sliding panels (Eclipsis System) installed

April 2009



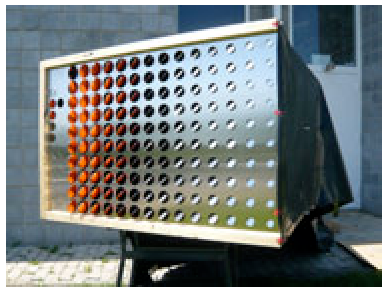
- Juhani Pallasmaa visits the solar studio to discuss issues of prefabrication and industrialized processes
- Mechanical Closet equipment installation begun
- Continued development of the shutter screen





May 2009

- Structural Insulated Panels serve as sheer wall at Kitchen
- Further development of Shutter Screens with prototype development
- Shutter Screen Characterization studies to determine light transmission
- Mechanical and electrical equipment installation initiated
- Steel beams for sliding panel (*Eclipsis System*) fabricated


Market Viability Narrative

Introduction

In today's economic environment the Architecture, Engineering and Construction (AEC) industry is under pressure to improve productivity, reduce cost and improve quality of work. With the growing demand for affordable housing, increasing construction costs, and increasing concern for energy-efficiency, designers and builders across America have recently begun to re-examine their options for the delivery of housing. This trend has resulted in a growing interest in prefabricated (prefab) building systems.

As a result, the Virginia Tech Solar Team (VTST) places major emphasis on the **duality** of prefabricated building systems through an architectural context; meaning, many structures sacrifice **quality** of architecture for **affordability** or **sustainability**. Homebuyers should not have to make this sacrifice. Our home of the future responds to these challenges of the built environment, termed "responsive architecture."

Responsive architecture *enables a structure to take advantage of its environment*. Responsive architectural objectives can be achieved through thoughtful, innovative design[1]. The Virginia Tech house, named LUMENHAUS, proposes solutions in this architectural context through prefabrication success that responds to the following current, critical market parameters: affordability of total product, reduction of on-site costs, and concern for energy-efficiency. Further, prefabrication success requires appropriate solutions to these market parameters through: innovative transportation techniques, flexible designs, multiple design models, intelligent facilities and building assemblies' automation. Our solutions through prefab are designed to increase access to broad markets and demographics, while also promoting solar power as a viable option for today's home. We establish viability of LUMENHAUS through: 1) case-based analysis that compares current prefab solutions with LUMENHAUS, including livability considerations; 2) designing for build-ability (reduction of on-site costs) and 3) understanding needs for the product to be marketable (implementable in various markets). We conclude with our strategy for establishing cost issues surrounding current prefab systems and our response through the architectural context.

Definitions of Marketability

In an effort to be accurate with this study, the VT Solar Decathletes have defined the following terms for use in our work:

- *Affordability* – the necessity of surrendering an acceptable cost for a product or service and price commensurate with the financial capability of the target market.
- *Sustainability* – adding longevity to the life of a product through the use of low resource consuming inputs; a product that efficiently consumes resources
- *Architectural quality* – competent aesthetically and functionally in design; a design that exceeds the required minimums through innovative components
- *Marketability* - A measure of the ability of a security to be bought and sold. If there is an active marketplace for a security, it has good marketability. Marketability is similar to liquidity, except that liquidity implies that the value of the security is preserved, whereas marketability simply indicates that the security can be bought and sold easily.

[1] Building Futures Council (2006). White Paper: Measuring Productivity and evaluating Innovation in the US Construction Industry. Industry innovation has made significant advances in safety, productivity and product durability, while little has been done to understand these advances in light of architectural integrity.

1) Livability and Case Study Analysis

The VTST bases much of its marketability analysis of previous housing and supporting structure examples that were designed to increase access to broad markets and demographics, while also promoting innovative design and technologies as a viable option for today's home. The point of these case studies is to find current problems or solutions to issues of affordability, sustainability and architectural quality through the utilization of our proposed prefabrication methodologies: innovative transportation techniques, flexible designs, multiple design models, responsive architecture and building assemblies' automation as some examples. This work defines these methodologies for housing as follows: Innovative Transportation Techniques is *a means of utilizing common transportation to relocate a home*; Flexible Designs is *the compatibility of multiple design modules within the design of a home;* Multiple Design configurations are *the components that complete a design and must all be compatible and interoperable;* Intelligent Facilities are *building systems that are user friendly and adaptable to human and environmental necessities* and Building Assemblies' Automation is the *ability of building systems to move for maximum function .* These examples are listed below, in Table 1:

Case	Designer	Location	Size (SF)	Cost ($/SF)	Market	Successful Features
Glidehouse	Michelle Kaufmann	Oakland, CA	2210 sf	$163.00	Single Family	1. Multiple Configurations 2. Flexible Designs
Flatpack	Lazor	Minneapolis, MN	Varies	$300.00	Varies	1. Flexible Designs 2. Multiple Configurations
Quik House	Kalkin	Bernardsville, NJ	2000 sf	$92.00	Single Family	1. Flexible Designs
LV House	Romero	Perryville, MD	1150 sf	$32.00	Single Family	1. Flexible Designs 2. Multiple Configurations
Micro Compact Home	m-ch Ltd.	UK, Germany & Australia	76 sf	$422.00	One or Two People	1. Responsive Architecture
SideBreeze	Kaufmann	Oakland, CA	2380 sf	$155.00	Single Family	1. Flexible Designs 2. Multiple Configurations
P.L.U.G.	Lutz & VT Students	Maha Mountains	N/A	N/A	Research/Single Family	1. Transportation 2. Responsive Architecture
Supporting Structures						
kitHAUS: K1	Sancerato & Wehman	Los Angeles, CA	289 sf/ Module	$400.00	Supporting Structure/ Varies	1. Flexible Designs
kitHAUS: K3	Sancerato & Wehman	Los Angeles, CA	114 sf/ Module	$260	Supporting Structure/ Varies	1. Flexible Designs
Global Village Shelter	D. & M. Ferrara	Grenada	67 sf	$9.00	Temporary Homes/Family of 4	1. Transportation 2. Flexible Designs
Studio Shed	Grey Designs	Seattle, WA	216 sf	$140	Supporting Structure/ Varies	1. Flexible Designs
Magic Box	Jun Ueno	Palos Verdes, CA	121 sf	$769	Supporting Structure/ Varies	1. Flexible Designs 2. Transportation

Table 1: Case Study Analysis

Each of these structures introduces housing qualities that have been either accepted or rejected by the single family housing market. VTST implemented the successful features in the design of their home, LUMENHAUS, to ensure the house would be marketable. The following section compares successful features of the houses and supporting structures in Table 1: how they are implemented in our house and how problems associated with these features were addressed.

Both the Glidehouse and Sidebreeze utilize large spans of glazing to maximize exposure to the environment. In both instances these glazings provided exceptional daylighting and passive ventilation during the day; however, at night these expansive glazings proved to be energy inefficient. VTST Decathletes decided that daylighting and passive ventilation were necessary in LUMENHAUS; so they included approximately 80% of the façade as glazing. The team also designed a series of automated panels to limit the inefficiencies experienced in the two case studies. A solar shade is used to limit overexposure to the sun during the torrid summer months without eliminating passive ventilation; and Aerogel insulated panels were included to seal the house at night and during cold weather to limit heat loss.

Energy efficiency throughout the house was another top priority of VTST. The Glidehouse and Quik House created energy efficiency very effectively through ensuring high insulation ratings in the roof, walls and floor. Our house consists of a radiant concrete floor slab, R-40 Roof and Wall SIPs, and Aerogel-filled insulation panels, and systems that are cutting edge technologies for increasing home energy efficiencies.

Since the competition rules strictly limit the square footage of the home, space efficiency was an obvious requirement of our design. Multiple ideas were provided through the case study. The Micro Compact House led VTST to implement dual function spaces. kitHAUS, Global Village Shelter, Studio Shed and Magic Box addressed addressed good examples to implementing design flexibility through providing open space. Our home's living room also acts as a dining room and workstation, when required. If guests visit, the living room can be cleared out to allow for additional seating.

Prefabrication was identified as a necessary means of keeping construction costs low on LUMENHAUS. Instances of successful prefabrication of building components were evident in each of the nine homes studied. The two that were deemed to be most applicable to our home were the Flatpack's prefabricated wall panels and the Quik House's recycled steel structure. VTST adapted the Flatpack's wall panels to design the system of roof and wall SIPs built and stored for efficient buildability. A steel truss-like structure was designed and engineered to provide a portable chassis to build upon.

The Portable Laboratory on Uncommon Ground introduced innovative transportation techniques to VTST. Able to travel by ship, train and foot the P.L.U.G. gave evidence that a design can accommodate any means of transportation necessary. The team took this idea and developed a transportation scheme that turns LUMENHAUS into a chassis that supports itself during travel. This idea makes the home more mobile and allows more construction to be completed off-site than if it was carried traditionally on a truck bed.

These case studies provide examples of successful features that will improve the affordability, sustainability and architectural quality in Virginia Tech's LUMENHAUS. Still, none of the cases implements all features, as LUMENHAUS does, nor do any of the structures utilize automation techniques as a market solution. With solutions to these issues identified, VTST focused on how to implement these solutions to best address livability needs of the homeowner.

Livability
LUMENHAUS has been designed to provide a client (Family, couple or individual) with a beautiful, resourceful, responsive and enjoyable place to live. It is understood that the issues of livability will determine whether a homeowner can envision themselves living in LUMENHAUS, and actually enjoy themselves. Table 2 (below) identifies livability issues addressed and the solutions implemented in the design of the home.

The most important livability consideration our home was an architecture that evokes a sense of place, a commitment to quality and a spirit of innovation regarding awareness of environmental issues. The exterior, consisting mainly of glazing and sunshades, gives stakeholders an open and modern vision. Inside the house, the occupant is comforted by exterior views and considered finishes. The transformability of the space (kitchen sliding counter and table, furniture, work table, bedroom closets, Eclipsis© system layers) and the pavilion atmosphere, of a seamless flow from inside to outside, accommodates the active lifestyle of our younger and older target markets.

LUMENHAUS has also addressed livability considerations of the future through its innovative function and controllability. All of the automated panels and mechanical systems are controlled from an application on the homeowner's iPhone.

The DOE, except for the row category "Prefabrication" at the bottom, specified all of the "Livability Considerations" addressed in Table 2. VTST included prefabrication because it is a crucial consideration in making our home affordable, sustainable and architecturally sound. Prefabrication reduces uncertainty through control of process and material risks and costs, while improving the quality of the product. For instance, the steel frame of the home was required to be exact for the Structural Insulated Panels (SIPs) and glazing to fit properly. Since the steel frame was built strictly to pre-determined plan dimensions, SIPs and glazing (as well as other home components) fit properly, limiting air infiltration, thermal conduction, material waste, and labor scope creep.

Table 2: Livability Considerations

Livability Considerations	DOE Livability Considerations	SD VT 2009 Livability Considerations
Aesthetics	1) Responds to aesthetic tastes of entire range of people?	The LUMENHAUS home provides a modern design for an affordable price that maximizes environment awareness.
	2) How are views to the outside?	The house is enclosed with 80% exterior glazing that is sealed at night for thermal enclosure.
	3) Is the home appealing to someone who is passing by?	The steel shade screen is not only attention-grabbing but it is also very attractive.
Maintenance	1) Will snow or other condensation obstruct PVs and how will owner remove obstruction?	A hydraulic lifting device allows the PV array to tilt to maximize solar exposure and limit the collection of leaves and snow.
	2) How do exterior surfaces hold up to environment?	Metal claddings, glazing, roof membrane and soffit products were selected specifically due to their durability and life cycle analysis data. Sustainability and longevity drove decisions regarding materials.
	3) How will water and dirt affect floors and countertops and how are they cleaned?	Charcoal concrete floors will limit affect of dirt and paperstone countertops will negate any weathering due to water.
	4) Are there interior surfaces that are difficult to clean?	All interior surfaces are within reach of any person and a step stool. There are no hard to reach nooks.

Livability Considerations	DOE Livability Considerations	SD VT 2009 Livability Considerations
	5) How is oven cleaned and how is the freezer defrosted?	The stovetop can be cleaned with windex and water while the freezer will have a defrost setting.
	6) How often must vegetation be watered and is watering convenient?	The house provides multiple water hook-ups for exterior vegetation.
	7) Is the car protected in inclement weather?	The competition does not currently allow for a car.
	8) Can appliances and furniture be easily moved for cleaning and maintenance?	Yes.
	9) Is mold or rust likely to form anywhere on or in the house?	Exterior materials were selected based on durability and beauty of weathering.
	10) Is replacement of broken components or finishes easy?	The home consists of multiple pre-manufactured components that are easy to remove with the proper service manual.
Comfort	1) Is the bathroom floor comfortable on a cold winter morning?	The entire concrete floor slab is controlled through radiant heating.
	2) How does the house keep exterior noises out?	Aerogel Insulation panels double as an excellent acoustical barrier.
	3) Are there any uncomfortable drafts?	None, the exterior of the house is air tight and the radiant flooring system contains no air movement.
	4) Is there any uniform temperature differentiation throughout house?	No.
	5) Is the house comfortable for peope of all shapes, sizes and special conditions?	The bathroom accommodates the handicapped with the ADA required five-foot turn around circle. The house is also ADA accessible. Further, radiant heating systems are best suited for highly sensitive individuals.
	6) Are there any annoying sounds or smells emitted from any building components?	Low emitting products were used throughout the home to limit off-gassing and absorptive materials were limited to prevent mold build-up.
	7) Is the furniture and workstation comfortable?	All furniture is built to accommodate both large and small size people and both workstation and furniture is within site of the exterior glazing for daylight/views.
	8) Does the floor plan allow for different furniture arrangements if the occupants host company?	The open floor plan allows for flexible furniture arrangements and even space to add more furniture for additional guests.
Privacy	1) Do the bedroom and bathroom offer visual and auditory privacy from other rooms and outside?	The living room and bedrooms are located on opposite ends of the house and are divided by the kitchen/bathroom unit. When the bedroom closet doors are opened, they close off the bedroom from the rest of the house and reveal the bedroom TV.
	2) Is it necessary to travel through public areas when walking from the bathroom to the closet?	The closet is located within the bedroom, which is connected to the bathroom.
	3) Can all windows in the house be covered to provide occupants with total privacy?	Yes, sliding panels can be closed at the occupant's discretion for ultimate privacy.
	4) Do the outdoor living spaces offer sufficient privacy?	When the exterior panels open they provide side barriers to outdoor patio.
Convenience	1) Are appliances appropriately sized?	Kitchen and countertop space was designed to situate specific appliances.
	2) Is the toilet dispenser easy to operate and conveniently located?	The toilet paper dispenser is conveniently located beside the toilet for a comfortable reach.
	3) In inclement weather is it necessary to put on boots or rain garments to retrieve mail or take-out trash?	The modern design of the home will allow occupants to access email from the comfort of his/her living room or bedroom. This will limit the waste created by the house and allow for recycling of paper products that do not have an alternate options.
	4) Number of remotes required to operate Home Entertainment Equipment?	The entire home will be capable of being controlled by an iPhone and the appropriate application.
	5) Are electric, network, phone, and other outlets conveniently located?	Yes.

Livability Considerations	DOE Livability Considerations	SD VT 2009 Livability Considerations
	6) Are wastebaskets and recycling bins conveniently located?	All areas requiring wastebaskets are accommodated and there is a Hafele recycling receptacle located in the center of the house.
Functionality	1) Is the bathroom mirror foggy after a shower?	No, the exhaust fan in the bathroom prevents fogging through direct air return.
	2) Where does one air-dry a towel in the bathroom or bedroom?	The radiant flooring system will reduce ambient moisture throughout the bathroom space to facilitate drying for items on hooks.
	3) Is there an effective means for people to clean and dry shoes immediately upon entrance?	Built-in grate is provided at the front entranceway on the deck and the heated floors will evaporate any condensation brought in by visitors.
	4) Do the windows block UV rays that could damage interior finishes or furnishings?	All products are sun-stain proof and the soffit will prevent unwanted overexposure to the sun.
	5) Does the smoke alarm sound when stir-frying is happening in the kitchen?	No, the proper exhaust fan is installed above the stovetop to prevent similar situations.
	6) How is moisture managed in the bathroom and kitchen?	All countertops are waterproof. Water that lands on the floor will be evaporated and returned to the outside or will drain appropriately.
	7) Do the high-tech or ultra-efficient devices perform as well as advertised?	All Photovoltaic and MEP systems have been tested prior to the houses relocation to the competition site. They all passed the specified commissioning specs.
	8) Is there sufficient storage space for clothes, food, etc.?	Pantry space is provided in the kitchen and his and hers closets are located in the bedroom.
	9) How fast and consistently do the various water fixtures respond to different temperature settings?	Water temperature responds immediately to settings and a 77-gallon hot water tank provides sufficient tempered water to meet demand.
	10) Does the workstation contain equipment and features sufficient for a home office?	All necessary outlets and feeds are located in the workstation and storage for books and equipment is provided in the unit.
	11) Do low flow showerheads, sink faucets and toilets perform their respective functions satisfactorily?	Yes.
	12) How accessible are house controls for the occupant?	Thermal controls, positioning of the sunshades and positioning of the thermal panels are all controlled from the occupant's iPhone. While the occupant is away on business or vacation, he/she can adjust the temperature settings of the home according to weather reports before returning.
Special Features	1) Is the house fully accessible to someone with physical disabilities?	The exterior deck has ramp access adhering to ADA standards and the bathroom provides the ADA approved turn-around area.
	2) Can the house accommodate a baby?	The bedroom can accommodate a crib; however it is recommended that throw rugs be placed to protect baby from falls.
	3) How well does the house accommodate its niche market, if there is one?	Each specific area of the house can adapt to accommodate a young professional or a retiring couple in multiple geographic locations in the U.S.
Flexibility	1) How difficult would it be to redecorate or rearrange the interior and exterior?	Wall units are built-in and permanent; however, the furniture arrangement is flexible for the occupant to rearrange according to immediate needs.
	2) To reduce cost, would less-expensive appliances and furnishings detract from the house's appeal?	No, less-expensive appliances and furnishings would not diminish the house's appeal as long as the new appliances and furnishings were capable of the same tasks as the older, more expensive ones.
	3) Is the house wired to accommodate future breakthroughs in consumer electronics and/or home controls?	All conduit is run beneath the home and up through the floor slab; so it is possible to remove and run new conduit at the occupants request.
	4) If the homeowner's needs change, as they grow older will the house adapt to the homeowner's requirements?	The house has been designed to adjust according the occupants needs. Furniture and appliances can be replaced or more added.

Livability Considerations	DOE Livability Considerations	SD VT 2009 Livability Considerations
Safety	1) Is it difficult for a potential thief to break in?	Security system is tied into the building control system and security hardware has been placed at all entrances.
	2) Do daily or seasonal maintenance tasks present any hazards?	Replacing PV's would be dangerous without the appropriate scaffolding in place.
	3) Do appliances pose any hazard to children?	No, all appliances are located out of the reach of children.
	4) Is the workstation ergonomically comfortable?	The workstation is conveniently located in the living room with all desk space within arms reach. Desk height is at a comfortable level for both short and tall individuals.
Prefabrication	1) How does the design minimize waste of materials used?	The frame was built from steel that is recyclable and reusable at the end of its life cycle in the Lumenhaus. Mass production and the economy of scale will limit the waste of materials through efficient reproduction.
	2) Does the construction of the house put workers in dangerous settings and how were they protected?	All factory manufacturing is completed according to OSHA standards. On-site construction is limited to securing the house to the foundation, which will also be completed using OSHA specifications.
	3) Is the production of the house able to be manufactured in a non-linear process?	The steel frame was being constructed simultaneously with the Wall and Roof SIPs and the Window Walls. This limits construction time lost to material lead-time delays.
	4) Were off-site pre-manufactured components built and stored for easy and safe installation?	Roof and Wall SIPs were kept in adjacent storage room and were appropriately tagged according to sequence of installation. The Window Walls were stored the same.

Build-ability

It is commonly believed that the prefabrication of housing holds many advantages over conventional stick built construction. Despite its advantages, prefabricated construction has been slow in gaining acceptance. The reasons for lack of commercialization of prefabricated construction are the misconceptions people have about the prefabricated homes and also the nature of the current prefabricated construction industry. According to literature on the subject, the following items limit the construction, and therefore commercialization, of prefab housing:

- High transportation costs because of the need of module shipment to the project site for permanent installation (House-Building 2004): VTST has therefore created an innovative transportation system that keeps this limitation as minimal as possible for our home's delivery. The transportation system has also been designed in a way to minimize issues of construction as well. For building the home in the factory, the wheels allow the building to move along a production line or fit into any warehouse setting.
- High transportation costs as a requirement of double handling as equipment and materials are shipped to the plant and to the site (Bodke 2004): Again, VTST has created an innovative transportation system, while minimizing double handling is difficult in prefabrication. VTST decided that the quality and performance controls inherent in the prefabrication process (control of moisture and damage on-site) were more important than reduction of double handling in this case.
- Module size limitation as different restrictions for each mode of transport, trucks, trains etc. (Bodke 2004): While LUMENHAUS does require "oversize" shipping (via truck) labels, it is self-contained in its parts and delivery pieces. VTST learned form previous competitions that the home, as multiple parts, was unsustainable for moving to multiple site settings.
- Designer needs to consider dividing modules according to transportation constraints (Bodke 2004): as above, LUMENHAUS is self-contained and responds well to transportation

constraints.
- The modules need to be shipped to the site (Bodke 2004): Again LUMENHAUS contains no separate modules for shipping to the site.
- Access site constraints need to be carefully considered, especially in dense urban areas. (Bodke 2004): The LUMENHAUS transportation system allows for tight site conditions: either pulling up to the foundation and setting down onto it or stacked against other units, based on the Luminocity community development system.
- Requires more intense engineering effort (Bodke 2004): The prototype for the home requires additional engineering upfront, while the production version of the home would require a minimal amount. Compared with other residential systems, the need for additional engineering, based on new home iterations, is eliminated with LUMENHAUS.
- Zoning and regulatory restrictions (Bodke 2004): LUMENHAUS is fully code-compliant and incorporates technology that is applicable to any regulatory environment in the country.
- Low quality (Noguchi 2005b): As is evident by the design and construction plans, LUMENHAUS is a top-quality, luxury home.
- Limited life (Noguchi 2005b): The cladding system for this home is both stainless steel and zinc, materials that have extended lives. The main framing system is constructed of structural steel and cast-in-place concrete, tough enough for road travel, making it among the strongest examples of residential construction in the market. These elements are built through a manufacturing environment that facilitates re-creation for future models.
- “Cookie cutter” Architecture (Noguchi 2008): Again, LUMENHAUS is a highly designed home that is unique in the market.

Marketability

Identifying the Target Markets

Marketing is made most efficient through identifying a product’s target markets. VTST previously submitted the following target market parameters as a basis for our work:

- Location: Washington D. C. metropolitan area
- Housing type: Single family detached house
- # of occupants: Two adults
- Occupant demographic: Generation Y (25 -30 year olds)
Baby Boomers (55 – 70 year olds)
- Homeowner annual income: 150K (double income couple)
- # of bedrooms: one

LUMENHAUS, as a prototype, is admittedly expensive for the prefabricated home market. While a custom residential home market would be most appropriate, VTST nevertheless has considered, in addition to our previous parameters, multiple markets for a diversity of prefabricated structures’ market viability. Our goal is to ensure that these parameters, as multiple targets of the home, identify likely purchasers of the house that would be satisfied with its amenities. Again, we did not intend to simply limit our target market to our pre-conceived targets, but to also see possibilities within the range.

Therefore, table 3 identifies a range of possible target markets for LUMENHAUS, similar to the examples provided by the competition requirements. Tables 4 and 5 further apply affordability constraints to our home through income level and geographic location likely for our market’s homeowner.

Table 3: Target Markets

Market I.D. Parameter	1	2	3
Location of Permanent Site	Southwest U.S.	Northeast U.S.	Coastal Areas
Housing Type	Single Family	Single Family	Single Family
# of Occupants	2 Adults	2 Adults	2 Adults
Occupant Demographic	Young Professionals	Baby boomer/ retired person(s)	Baby boomer/ retired person(s)
Average Homeowner Annual Income	$65,000	$70,000	$45,000
# of Bedrooms	One	One	One

Market 1

Contrary to Washington D.C., land plots are cheaper in the Southwest, including the Northeast. The Southwest also provides maximum solar exposure to best utilize the PV array and a large number of young professionals are locating themselves in the Southwest U.S. Further, the average homeowner annual income compares favorably in the Southwest U.S. to the cost of LUMENHAUS.

Market 2

While pre-manufactured homes are most prevalent in the Northeast, housing is most expensive in the Northeast. With LUMENHAUS, couples that no longer have children residing within their home have the opportunity to downsize to prepare for retirement. An investment in our home offers couples, of retirement age, with a home of minimal operation and maintenance costs. The home allows for relocation to a more tempered climate if desired. As above, the average homeowner annual income compares favorably to the cost of LUMENHAUS.

Market 3

Retired persons are the most likely to purchase a pre-manufactured home in coastal areas. Coastal areas would provide high solar exposure to produce PV converted energy. The Eclipses home may be purchased and easily relocated to any location along the continental or coastal U.S. due to its innovative transportation system. Unlike above, the average homeowner annual income compares unfavorably to the cost of LUMENHAUS.

Table 4: Affordability: Qualifying Income Approach

Year	Cost of Single Family Home	Qualifying Income	Home Affordability Ratio (Cost/Income)
2007	$217,900	$52,992	4.11
2008	$197,100	$46,125	4.27
2009	$430,000 (VT Lumenhaus)	**$102,625**	4.19 (Average of 2007 & 2008)

Qualifying Income to purchase the VT Lumenhaus = $102,625

Source: Data provided by the Housing Affordability Index

The Qualifying Income Approach was developed to identify a family's necessary income to purchase LUMENHAUS. Data from the Housing Affordability Index was taken to establish the average price of single family homes in the U.S. and the average incomes of those that own a house of similar value. These averages were noted for 2007 and 2008 and then the cost of LUMENHAUS was divided by the Affordability Ratio to determine the qualifying income, based on an averaged 2009 Home Affordability Ratio. These figures fit well our target market of two-person income, originally set at $150,000. Current 2009 housing affordability trends suggest that housing will only become more affordable in the near future. VTST therefore sees the market for this home, based on tables 3 & 4, as a home for a retirement-age couple or young couple with two incomes. This type of single family is the most common in today's market.

Table 5: Geographic Costs of Housing

Location	$/Sq. Ft.	Sq. Ft. of Single Family Home	Cost of Single Family Home
U.S.	$92.51	2479	$229,332
Southeast	$109.72	2479	$271,996
Northeast	$116.98	2479	$289,993
Southwest	$121.78	2479	$301,893
VT Lumenhaus	$510	810	$430,000

Cost of Housing in NE and SW are most comparable
Data provided by HousingEconomics.com

The Cost of Housing Approach was developed to identify where in the U.S. LUMENHAUS would be most cost comparable. All geographic locations were considered; however, the high cost of our home narrowed the pool to only the most expensive locations per square foot in the US. The cost per square foot of homebuilding in each location and the average square footage of a single family home were taken from HousingEconomics.com. These two numbers were then multiplied to establish an estimated cost of a single family home for each location. The Southwest again proved to be the most comparable in price and the Northeast was second closest. Again, not included in this approach were increases in pricing, due to housing density, and the reduced pricing, around 15 percent, of LUMENHAUS when in mass production. Based on tables 3, 4 and 5, We see the target market for our home as young or retirement-age couples with two incomes in the Southwest, optimally, but also in the Northeast and Southeast. LUMENHAUS remains affordable in almost all markets, according to these parameters.

Marketability Analysis Conclusions

Prefabrication:

As a research project, LUMENHAUS proposes to concentrate on issues of affordability in sustainable home construction through the use of prefabrication. Table 6 shows a preliminary comparison between the average costs of a typical, traditionally stick-built home versus a typical, factory-built wooden home in Blacksburg, Virginia. Our comparison shows that the factory built home costs about $94,123, while the same sized stick built home costs about $98,178. Prefabrication, based on typical construction processes, results in a $4,055 or $5/ per square foot savings. For a stick-built structure, these numbers equate to a 4.3% reduction in cost and high, risk reduction unable to be quantified here. Thus, prefabricated homes are generally less expensive than their traditionally stick-built counterparts. This comparison nevertheless omits the reduced costs from materials and labor if the house is eventually mass-produced at a large scale, as our plan requires. Prefabricated homes' overall project cost will dramatically decrease as the number of units in production increases. In applying the Virginia Tech Solar House to both urban and suburban contexts, multiple models would allow for a larger consumer range, facilitating large-scale production. Most importantly, prefabrication greatly increases the quality of the product, allowing for a more precise and valuable building.

Table 6: Prefabrication Cost Comparison

Type	Total Cost	Cost/ SF
Stick-built Home: 850 SF	$98,178	$116
Factory-built Home: 850 SF	$94,123	$111

LUMENHAUS is an entirely pre-fabricated home. This allows the house to be mass-produced at a very rapid and affordable scale. VTST has constructed the frame and floor at Kullman Buildings Corporation (Kullman) in Lebanon, New Jersey. Kullman is a plant that specializes in prefabricated, modular steel structures. Prefabrication plants like Kullman allow a safe building environment for both workers and the public. Working in an enclosed, controlled environment prevents weather-related scheduling delays as well as higher worker productivity. The organization of a prefabrication plant also allows better precision and facilitates a reduction in construction waste, significantly reducing the cost of a project. Our team then relocated the house to the Virginia Tech Research and Development Facility in Blacksburg, VA. VTST will now work in an enclosed facility, similar to Kullman, with access to the rest of the school resources, including: wood and metal shops, laser-cutter, CNC milling machine, and plasma cutting machine. The Home will require very little preparation on site making for simpler building construction for both the competition and beyond. The benefits of prefabrication increase the speed and quality of a product, while significantly reducing the cost.

Innovative Transportation Techniques:
The house incorporates an innovative transportation system, built into its structure, which allows for a quick, affordable, and efficient transition from production plant to site. Torque boxes, installed in structure below the house, contain a removable gooseneck and bogey (typically fixed components for trucking trailers). Due to the integration of the transportation system into the house, it rides lower to the ground during transport, as opposed to the traditional flatbed truck. This design allows for larger, more elegant ceiling heights in the home. When placed on the site, the gooseneck and bogey are removed and reused for the next delivery- dramatically reducing transportation costs.

Flexible Designs and Multiple Design Models:
Our solar house will be available in different models, with varying materials and sizes, appealing to a broad market. The house present on the Capital lawn will represent the highest level of our modeling efforts with the highest quality materials. Because this house is a prototype, the increase in research, material, and redesign increases the cost. However, costs will greatly reduce when the house is mass produced and placed in the market. Our approach also provides less expensive models which have been designed to show that the Virginia Tech house might also be afforded by a large demographic. Our designs accomplish this affordability without sacrificing energy efficiency or architectural quality. The house can also be applied to urban scales, significantly decreasing the building footprint of a neighborhood. Thus, the Virginia Tech solar house proves highly affordable, versatile and adaptable.

Responsive Architecture and Building Automation
Our team will be working with Virginia Tech's Computer Science and Engineering Departments. The Virginia Tech house will be designed to fully respond and adapt to its environment through innovative building automation techniques. All of these automated systems will be controlled with an Apple iPhone. The Apple iPhone has a proven market and reliable consumer product history, costing approximately $300. The iPhone is much smaller and less expensive than most home operating devices, and would still be able to perform its primary functions: phone, MP3 player, Internet etc. The photovoltaic system will be a single-axis tracking array- this provides a significant increase in efficiency and a resulting decrease in non-renewable energy use. This increase in energy allows the house to fully function off the grid. However, if this home were installed in a grid-tied location, it would have the ability to produce extra energy. This additional energy being produced can be sold back to a power source, saving money and creating a source of income for the homeowner. Also, the exterior screens will be designed to

automatically open and close depending on the weather conditions outside. The automation not only decreases the energy costs, it creates a connection between the occupant and the environment. The house's panels, rain screens, and photovoltaics will always be adjusting according to the weather, making the occupant aware of the weather outdoors. The home's automation makes daily living functions much easier for the elderly and disabled. Our building automation makes the home, as a functioning object, easier and more efficient for the homeowner through entering and exiting systems, thermal settings, and lighting controls.

Our data show that the cost of the house on the Capital lawn will be roughly $430,000 including labor. This house is a prototype that is provided with the highest quality materials and designer appliances. Extra costs include: researching innovative technologies, redesign/build increases and up front engineering for the costs of the prototype, an initially costly transportation system, an innovative photovoltaic system and start-of-the-art systems throughout. The cost of our prototype home must be considered in regard to the affordable case-based examples provided above, as they have a lower price due to a standardization of product. Our more marketable model, a production prototype version, is predicted to cost approximately 20% less, $344,000 or $424/sf, and be able to house a single family. Regardless, these findings show that not only are the initial construction costs decreased, the efficiency and energy conservation of the house is increased. Because of the responsiveness and adaptability of the house, the amount of energy required to power the house will greatly reduce. Therefore, the life cycle and maintenance of the Virginia Tech Solar House will be very cost effective and affordable to the public. The home is ideal for coastal living, as it is transportable, and the affordability would currently match closest based on local income.

We at Virginia Tech view this competition as a great forum for demonstrating the progress of affordable solar power for the general public. However, these homes cannot sacrifice architecture or sustainability for affordability: all of these must be achieved. LUMENHAUS is a thoughtful, innovative design that shows how quality architecture can make a building a lasting home, rather than a temporary residence. A building that is preserved and maintained due to its architecture is far more sustainable than a typical home with a short lifespan. Further, LUMENHAUS is appropriate and affordable in multiple markets. The Virginia Tech solar house therefore advocates sustainability and quality architecture as something not only available or valuable to the wealthy. Through innovative construction practices and sensitive design, the Virginia Tech Solar Team hopes to make this assumption a thing of the past.

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ENGINEERING DESIGN NARRATIVE

Solar Tracking System

1.1 Introduction to the Methods Used to Select the Solar Tracking Scheme

The first part of the Solar Decathlon Engineering concept design document is focused on a determination of the mathematics used to optimize the solar light collection and on the general design of the solar panel system. The mathematics are then used to simulate the effectiveness of various solar radiation collection design concepts. As part of the simulation, losses from light scatter, light absorption, angle of incidence, and reflective surfaces losses are tracked for each concept's accumulated score. To improve the model realism, estimations of how many photovoltaic panels (PV) and at what angle they can be positioned in relation to the sun are additional factors in the model.

Once the general type of solar collection is determined, concepts for the PV panel support structure are developed. Concept selection factors for the support structure include weight, appearance, and the amount of work required to elevate the array. After selection of a support structure, concept generation and selection is done for the array's lift mechanism. The choice of a lift mechanism includes how much additional design is required to interface it to the Siemens controller. The Siemens controller is the central point for automating house functions, and providing the user with indirect control of all house functions. Changing the PV panel angles as the seasons change is just a small portion of its duties.

As noted in section 2.9, concept generation and selection occurred while the architects were developing the final house plans. This disconnect caused the PV team to completely discard the concepts developed thus far, update the constraints, and adopt a concept discarded earlier as infeasible as the final design concept. However, in spite of the difficulties encountered, major portions of the detail design for the PV support structure are presented in the final sections. A number of the smaller but important details, like the size of pins to use at the pivot points, are undeveloped as yet. Also the choice of panel cooling methods under consideration is changing to just air cooling because the double-side PV panels chosen require light reflected light for maximum efficiency. Chapter 1 then finishes with some conclusions.

1.2 Solar and Panel Angle of Incidence

After traveling 1.495 x 10^{11} meters, the light striking the Earth can be modeled as parallel light rays. However, because of the Earth's tilt of 23.45 degrees and the effects of latitude, the angle the Sun makes at any location varies with time of day, day of the year, latitude and longitude. Figure 1 shows one accepted means of determining the angles with the Sun. Besides the three angles depicted in Figure 1, the solar hour, latitude, longitude, and Julian day are needed. The solar hour in degrees is the difference in longitude between the current longitude and the longitude where the Sun is directly overhead. If the solar hour is provided in hours, then for each hour there is 15 degrees of longitude.

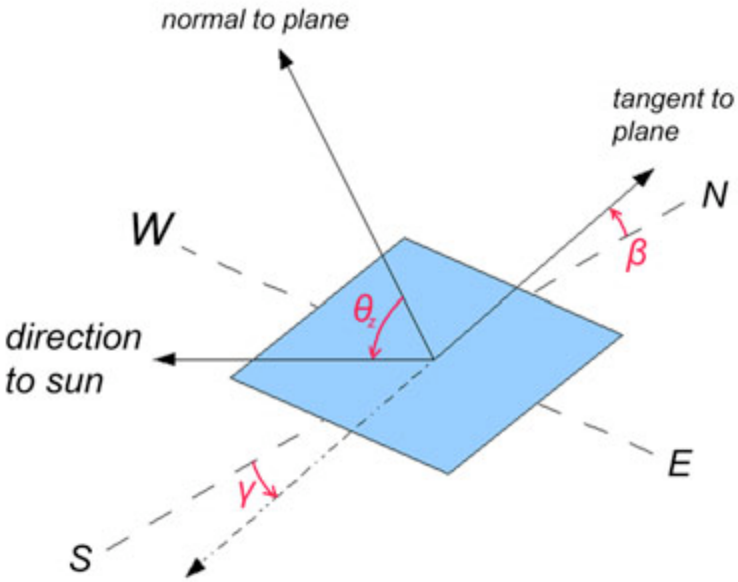

Figure 1. Solar angle of incidence with a plane where θ_z is the angle of incidence with the sun, γ is the angle the plane makes with the southern meridian, and β is the angle of the plane with the surface of the Earth at that location.

Using the Julian day it is possible to calculate the declination angle, δ, which is the angle, plus or minus the 23.45 degrees, that the Earth's North-South polar axis is tilted in relation to the plane of the ecliptic. The plane of the ecliptic is the plane described by the Earth's rotation about the Sun. The following relation determines the angle of declination (Duffie, 1980):

(1)

where J_{day} is the Julian day and is in degrees. Once the declination is known, the angle of incidence is given by (Duffie, 1980)

(2)

where is the latitude, the angle the plane makes with a surface tangent to the Earth's surface, the departure from due south that the plane is facing, and the solar hour in degrees.

Tracking the Sun to optimize solar radiation collection can be accomplished with four basic methods: *i*) lay the panels horizontally packed as close as possible to minimize the foot print, *ii*) pivot the panels on an axis running east and west and change the inclination based on the season or time of day, *iii*) pivot the panels on an axis running north and south and change the inclination based on the solar hour, and *iv*) pivot on a single-axis east and west plus pivot about the surface normal. The latter of these is potentially the most effective method for tracking the sun. For the Solar Decathlon, the rules prevented the use of tall roof top structures or using any panel arrays with a horizontal cross section greater than 800 ft^2 (74.32 m^2).

Figure 2 presents a side view of a single plane of panels limited to elevation angles from 14.5, which is a good summer angle for Washington, D.C., to 20 degrees, which is consistent with the limit on height based on the rules and the planned height of the house. This is design concept one. The major reason for the envelope is to prevent large arrays from shading contestant opponents. In the winter time, the best angle to catch the most sun light is 62 degrees, which amounts to a 42 degree difference in angle or a 26 percent loss in area for light collection. Pending clarification of the rules, modeling for year round condition may allow for greater angles. One advantage to the single plane is that the number of panels, 61 to 63, is significantly greater than for the other tracking methods.

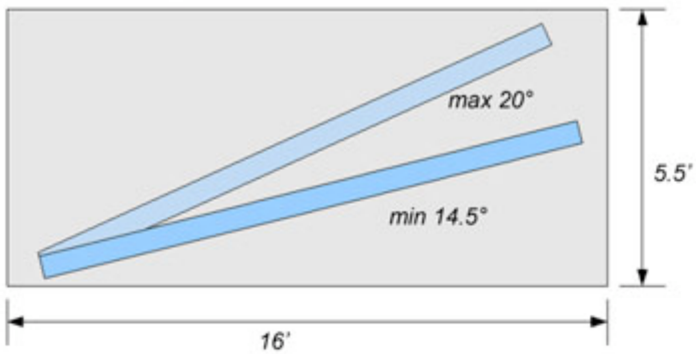

Figure 2. Single plane fixed or with partial tracking.

Figure 3 presents a side view of a dual-plane of panels that reach the optimal winter angle of 62 degrees in Washington, D.C. This is design concept two. Other than the rule's envelope, the largest constraint on this design is possible shading of the back plane of panels. Any shade cast on a panel reduces the power output of the entire set of panels connected in series. This configuration also requires that the rear set of panels translate as well as rotate to prevent shading. To prevent shading, the maximum number of panels that can be placed on the roof for such a dual-plane configuration is 34 to 36. The advantage is that in winter and fall conditions, it can achieve the optimal angle in Washington, D.C. of up 62 degrees.

One additional concept tested is a variation of concept two. Concepts one and two make at most one daily elevation angle adjustment for power savings. Concept three is the same physical configuration as concept two only that the elevation angle is adjusted for the optimum solar angle in one minute intervals. This concept will be tested to see if the energy generated with continuous tracking exceeds the power required.

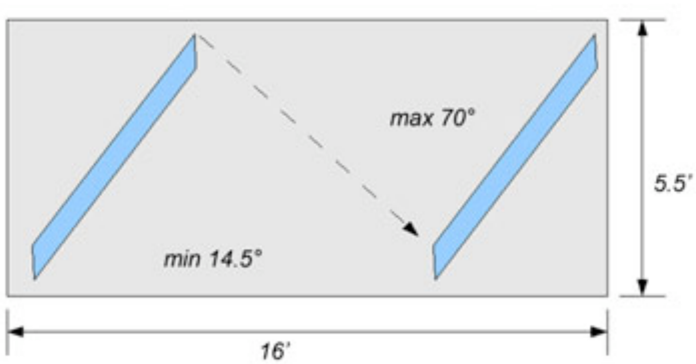

Figure 3. Dual plane single-axis tracking.

In Figure 4, another specialized version of single-axis tracking is presented. This is concept four. In an attempt to put more panels on the roof, the maximum tracking angle has been limited to 40 degrees. The total number of panels is 43 to 45. The choice of 40 degrees means that the three rows can be positioned closer to one another without shading. Like the dual-row tracking system, two of the rows will have to translate as well as rotate to eliminate the shading problem.

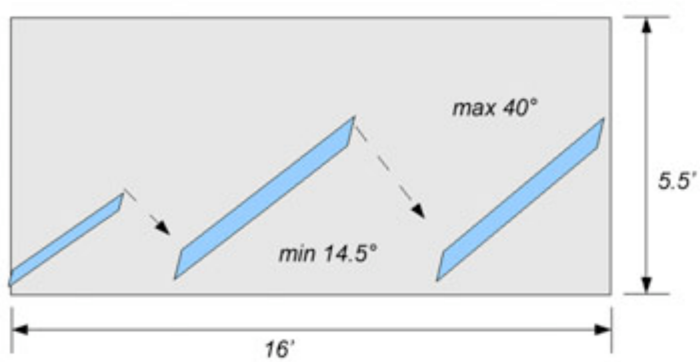

Figure 4. A specialized version of the single-axis tracking with limited elevation angle to put more panels on the roof to fit in the extra short row.

Concept five, dual-axes tracking, requires that a single-axis tracking system rotate about a pivot running normal to the Earth's surface. When this is done without shading and without exceeding the height limits and the tracking is continuous, 100 percent of the available light reaches the solar panels at the best angle possible. The downside is the continuous need for power and the number of panels that can be mounted on the roof. Generous but rough estimates place the maximum number of panels for the dual-axis tracking at 16.

An additional specialized version of the single-axis tracking is to fix the angle of the plane in the east-west direction and then pivot about an axis running north-to-south. This concept is eliminated out of hand, since the house would need to be oriented with its length running north-to-south to have any chance of getting more than 5 degrees of elevation towards the sun.

Concepts one and four are simulated using equation (2) with sums based on calculations of the angle of incidence, $\square_z$, on an hourly basis, and using the assumption that only a single adjustment for the best angle of incidence is made in the morning. Concept five assumes continuous tracking, so it receives the best available solar radiation computed for that time period. Because concept three assumes a continuous elevation adjustment and an analytical equation is available, namely (Duffie, 1980),

(3)

equation (3) is used to model the performance of concept two. A similar analytical equation for a one time panel adjustment is (Duffie, 1980)

(4)

and equation (4) is used to model concept two. Because concepts two and three are based on the same physical design, this provides a means to compare how much energy is saved with continuous angle adjustments to the PV panels. Both equations (3) and (4) are variants of equation (2), although Duffie does not go into great depth on their derivation.

The task of selecting the designs that are competitive given the contest limitations require that the relative year-round performance be included in the model. To refine the model, other factors such as incident radiation losses due to the solar radiation passing through the atmosphere and losses from reflection need to be included. Reflective losses are discussed next.

1.3 Solar Light Reflective Losses

Figure 5 shows the two paths a beam of light may take on contacting a transparent medium with a given index of refraction. The reflected light leaves the surface at the same angle from the vertical as the incident light. The angle of transmitted light, θ_2, depends on the ratio of the coefficients of refraction and the angle of the incident light, θ_1, such that

(5)

where n_1 is the *index* of refraction for the medium of the incoming incident light and n_2 is the index of refraction for the medium contacted (Duffie, 1980).

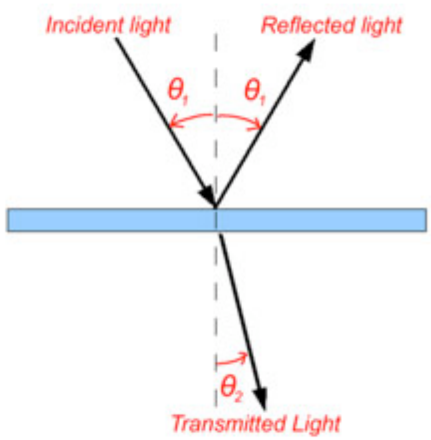

Figure 5. Reflection and transmission angles for the incident light.

Once the angles are known, the following relationship can be used to find how much light is reflected, which is a loss for a PV application. Thus the ratios of the reflected light is

(6)

where θ_1 and θ_2 are not equal. For the special case where they are equal, the ratio of reflected light is

. (7)

Solar panels use either PMMA (Poly(methylmetacrylate)) or glass to cover the solar cells. Both materials have a similar index of refraction, i.e., 1.526 (PMMA has a slightly lower value), while air has an index of refraction of essentially 1. Thus for direct sunlight, 4.34 percent is lost due to reflection; and at incident angles of 60 degrees, there is only a loss of 9.3 percent.

1.4 Solar Constant, Air Mass, and Available Solar Energy

Prior to striking the Earth's outer atmosphere, the light spectrum is termed AM0 and is equivalent to the spectrum produced by a black body at 5762 K with an energy flux, G_{sc} (the so-called solar constant), of 1367 W/m^2 (DOE, 2008a). The energy flux varies plus or minus 3 percent based on the time of year (Duffie, 1980). After entering the atmosphere and striking the ground perpendicularly at sea level, the light spectrum is termed AM1.0. The standard for the continental United States uses averages for radiation at 48.2 degrees latitude and is termed AM1.5g with an energy flux of 970 W/m^2, which for PV panel applications is approximated as 1000 W/m^2. The component of AM1.5g composed of direct light is called AM1.5d[1], and the remainder is scattered light. The difference between AM1.5d and AM0 is due to the fact that 28 percent of the AM0 energy is lost to absorption and 10 percent to scattering (DOE, 2008a). Figure 6 shows the energy flux versus wavelength for AM0, AM1.5g and AM1.5d.

Figure 6. ASTM G173-03 Reference Spectra for AM0, AM1.5g (direct and diffuse), and AM1.5d (direct). (US DOE, 2008a).

In modeling the solar radiation losses due to passage though the atmosphere, clear skies are assumed the normal condition and air mass related losses are assumed to be linear with a rate of loss, L_{am}, of 28 percent per 1.5 air masses or 18.7 percent per air mass. The value for the air mass, *AM*, is calculated from the following function without corrections for angles greater than 60 degrees (Duffie, 1980):

(8)

where $\square_{el}$ is the solar angle of elevation. Based on a figure found to late to incorporate into the model, the linear relationship used in the model is only an approximation. One figure in *An Atmospheric Solar Irradiance Model* (Farrell, 2002) shows radiation levels for air masses up to 11.47 (an angle of incidence of 85 degrees), while using the 18.7 percent value as a linear proportionality constant, the air mass with zero available radiation would be 5.3.

[1] A 28 percent reduction from AM0 is 991 W/m^2 or AM1.5d, but AM1.5g is 1000 W/m^2 a difference of 1 percent, so there is no apparent difference between AM1.5g and AM1.5d.

The final value of solar radiation per unit area striking the panels or the insolation, *I*, is the product of the air mass, the proportionality constant for losses per air-mass, and the solar constant, i.e.,

$$I = AM\, L_{am}\, G_{sc} \qquad (9)$$

1.5 Design Performance for the Solar Radiation Model

Figure 7 shows the results obtained when using the solar angle of incidence computed for each hour of daylight, losses due to light passing though the atmosphere, and reflection losses for each of the five designs under consideration. The clear winner is the single plane of 60 plus PV panels angled from 0 to 20 degrees (design concept one). The panel angle is based on computing the best possible angle for solar noon every day and making a single panel elevation adjustment. From the model simulation, 162 MW-yr of solar energy can be collected on a yearly basis. The next best concept is the triple-row design (design concept four) at 131 MW-yr of energy. This is the energy available to the PV panels before electrical conversion losses are factored in. More details about the photovoltaic panels given next.

Figure 7. Comparison of available solar power and energy for each design concept.

1.6 Photovoltaic Performance for the Concept Selected

The original concept developed for the mid-term report was based on an 800 ft^2 (74.32 m^2) house footprint and the use of SunPower 230 W panels with nominal dimensions of 30 in x 60 in (76.2 cm x 152.4 cm). However, Sanyo HIT double-sided photovoltaic panels are going to be used to generate power for the Solar Decathlon house. They not only have different dimensions, but portions of the 800 ft^2 (74.32 m^2) house footprint had to be utilized for other house features such as the sliding doors so that the final number of PV panels is 46.

The Sanyo panels selected are double-sided so that they are can outperform the SunPower panels under the right conditions. The panel efficiency and maximum output power has a range from 16.8 percent and 205 W to 20.5 percent and 249 W. The efficiency and power achieved is based on how effective the reflective surface behind the panels is. With the single plane concept selected as the design to develop, the house has the potential before wiring and electrical conversion losses of 9.4 kW-hr to 11.5 kW-hr. The above specifications are all assuming standard test conditions (STC), which are that the panels receive of 1000 W/m^2 solar radiation at 25°C.

Figure 8 graphically shows the current-voltage characteristics of the Sanyo panel for a range of temperatures. Furthermore since the Sanyo specifications (Sanyo, 2008) provides a power loss constant of -0.29%/°C, it is possible to calculate the potential power losses. If the panels are not cooled to 25°C, then a temperature increase to 50°C results in a 7.25% power loss. Once the temperature reaches 75°C, losses are double at 14.5%.

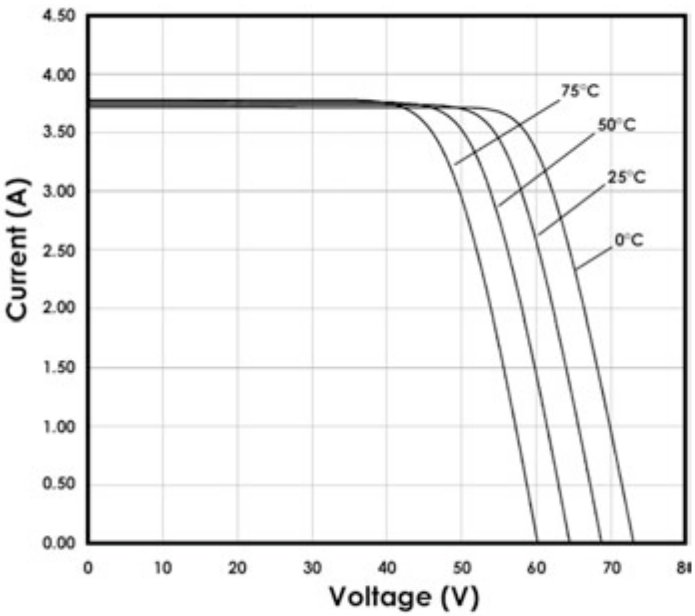

Figure 8. Sanyo double-sided current-voltage characteristics for different temperatures (Sanyo, 2008).

In the mid-term report, both air and water were considered for cooling; but the double-sided Sanyo panels preclude the use of water as a cooling agent, since heat-sinks or misting of a panel's backside reduces its overall efficiency. One concept under development that will improve both cooling and efficiency is the use of Mylar®. Once deployed under the panels, light that would otherwise reflect off of the roof and not strike any panels could be directed back toward the panels. The added light collection from reflection would potentially make the morning and evening hours productive for a longer time. In addition as an aid to cooling, the Mylar® channels the blown air, thereby increasing the velocity and the heat transfer coefficient.

1.7 Mid-term Sturctual Design Constraints

The physical contraints listed below are based on dimensions discussed in early meetings with the architectural group. Figure 9 shows the points where support beams are located on an early non-dimensioned diagram of the house. The length and depth dimensions in red are based on early concepts for the house. Out of meetings just prior to Thanksgiving, the constraints, as the M.E. team understand to be, were:

1. There is up to 42 in (106.7 cm) of bridge clearance while stowed during transportation to the site.
2. The structure is 50 ft (15.24 m) wide.
3. The structure is 16 ft (4.88 m) deep.
4. The weight of the PV support structure must be distributed among the house's fourteen support columns.

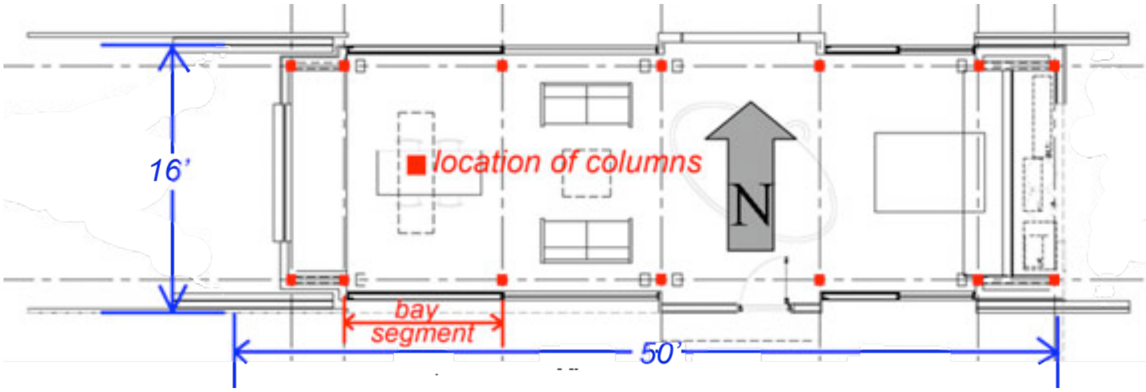

Figure 9. Top view of house with constraints indicated.

1.8 Concepts for the PV Panel Elevation Support Structure

1.8.1 Concept 1

With the general panel configuration defined as a single plane with limited single axis tracking, the method of changing the angle of elevation is the next concept to develop. One promising concept is shown in Figure 10. In the stowed position, the highest point is the plane of PV panels 42 in (106.7 cm) above the roof.

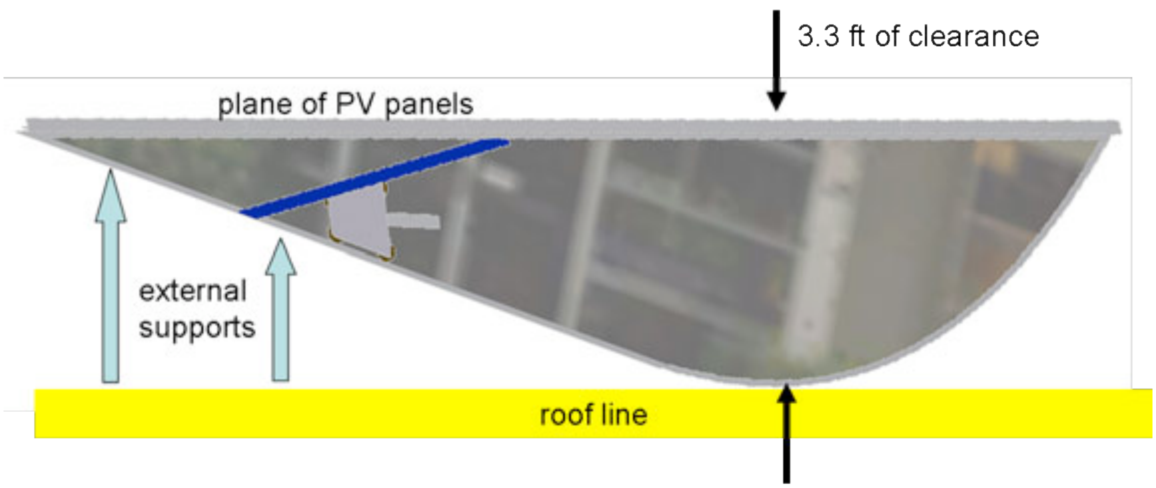

Figure 10. Side-view of concept 1 in the stowed position and ready for transport position.

Once in the deployed position at the contest site, elevation is adjusted by pushing a wedge or equivalent mechanism to get the 16 in (40.64 cm) of vertical lift necessary to change the angle of elevation from 20 degrees to 14.5 degrees (Figure 11). Some concepts to push the wedge include a WZ60 linear rod drive from Danaher Motion; and a representative for Siemens suggests instead using multiple torque motors ganged together into a single unit.

The curved profile in this concept allows the required work to lift the leading edge to be a function of choosing a pivot point as close to the center of gravity as practical. The less work required places a smaller demand on the house's energy consumption; but if the pivot point is chosen too close to the center of gravity, wind forces could cause the structure to rock back and forth without control.

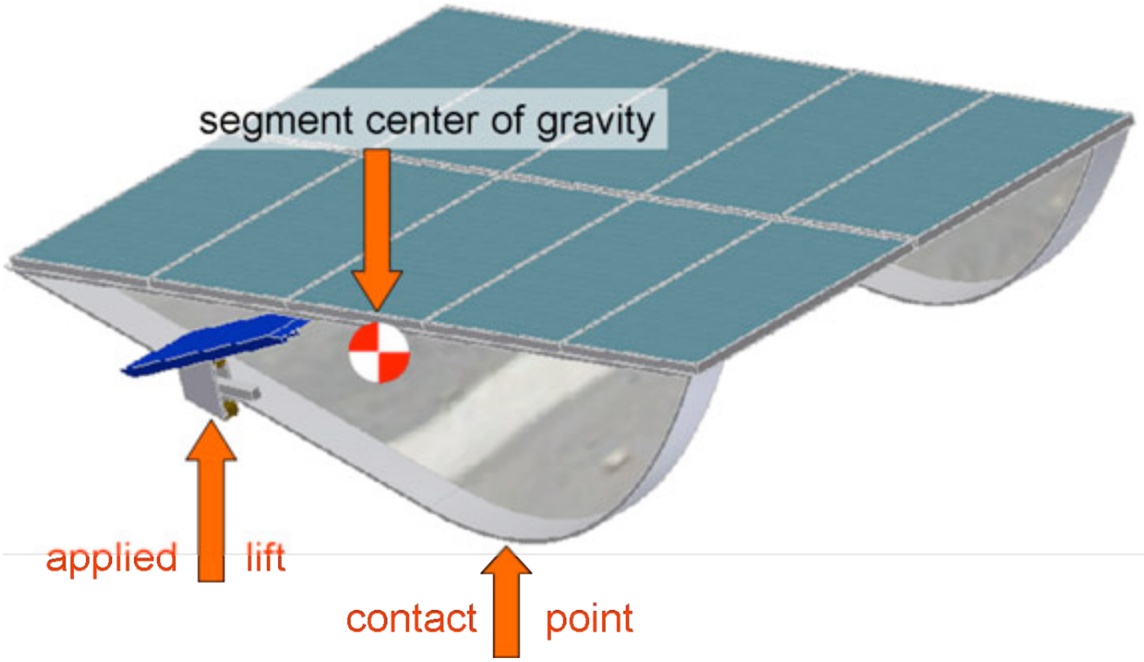

Figure 11. Orthographic-view of concept 1 in the deployed position.

1.8.2 Concept 2

Concept 2, as seen in Figure 12, is a trimmer version of concept 1, requiring 24 in (60.96 cm) above the roof line for bridge clearance, once the support and pivot column in magenta is removed for transport. Its biggest disadvantage is the requirement that the main structural supports and the weight of all the PV panels have to be jacked-up before the vertical support and pivot is installed and this must be done once the house is on the contest site. In addition to the support column, some kind of truss section must be installed for lateral stability after arrival at the contest site. In the prior concept, the necessary lateral support already exists prior to transportation.

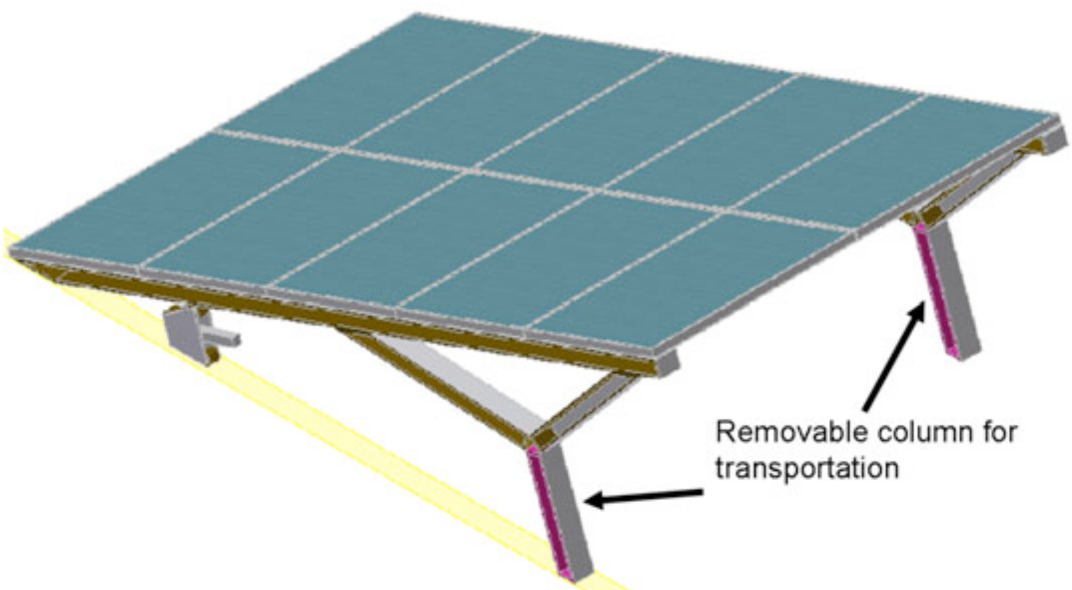

Figure 12. Orthographic-view of concept 2, the magenta support is removeable for transport.

1.9 Elevation-Control Lift Concept Selection

Five different concepts are considered for lifting the front edge of the panel support structure. Table 1 summarizes the results of the concept selection process. The first concept and the datum against which the performance of the other four are measured is the Siemens torque motor mounted at the pivot point of the array. The major advantage of the Siemens motor is the simplicity of interfacing to the Siemens controller and the lack of auxiliary parts. However, the amount of torque required to position the entire array means a great deal of energy would be needed. The second concept, B, considered is a scissors lift (similar to a car jack). A big challenge with this concept is the need to turn the power screw through multiple revolutions and track how high the mechanism is. The third concept, C, is a hydraulic cylinder, which with no known devices compatible with the Siemens controller, may require additional control devices. The forth concept, D, which is a roller mounted to a wedge, requires very little force to elevate the array structure, but every main component, except the motor and small parts, would require manufacture. The final concept, E, uses a cam and the Siemens torque motor. Interfacing just requires wiring the motor to the Siemens controller, but the cam requires manufacture.

Scoring is accomplished by multiplying the weight (the column “Wt”) by the score (the first column under each concept) giving the decimal value in the adjacent column. Total scores for each concept are shown in the “weighted total” row. The value given for each weights is based the subjective evaluation of a criteria’s rank. The score assigned is a bit more objective and its values ranged from -1 (did not meet the criteria), 0 (not-applicable), and 1 (met the criteria).

Table 1 . Concept selection table for the lift mechanism.

		Siemens Torque Motor		***Scissor Lift***		***Hydraulic Lift***		***Roller + Wedge***		***Cam + torque motor***	
Criteria	**Wt**	**Datum**		**B**		**C**		**D**		**E**	
Minimal electrical power required to move panels	1	1	0.071	1	0.071	1	0.071	1	0.071	1	0.071
No additional power needed to keep position	2	0	0.000	1	0.143	1	0.143	1	0.143	1	0.143
Low to no noise	2	1	0.143	1	0.143	-1	-0.143	1	0.143	1	0.143
Low cost	3	1	0.214	0	0.000	0	0.000	1	0.214	1	0.214
No additional development	1	1	0.071	-1	-0.071	-1	-0.071	-1	-0.071	-1	-0.071
Interfaces to Siemens Apogee as-is	2	1	0.143	-1	-0.143	-1	-0.143	-1	-0.143	1	0.143
Wind Resistant	2	-1	-0.143	1	0.143	1	0.143	1	0.143	-1	-0.143
Support is not near center of gravity of panels	1	-1	-0.071	1	0.071	1	0.071	1	0.071	1	0.071
Weighted Total		**0.429**		**0.357**		**0.071**		**0.571**		**0.571**	
Winner total	0.571							**Roller + Wedge**		**Cam + torque motor**	

The two concepts selected are concepts D and E. The first preference, E, is to use the cam in conjunction with the Siemens toque motor. However, the size of the cam for 16 in (40.64 cm) of vertical lift requires too large a torque for just one torque motor. For example, cams with 30 degree contact surfaces are smaller but generate larger normal forces and still require a large amount of torque near the end of their rotation, while cams with a 10 degree contact surfaces grow so large that once again very large torques are generated. Thus, the large cams require too many torque motors to justify the power consumption.

A simplified diagram of the roller and wedge design is shown in Figure 13. The blue text block shows where the motor and power screw used to push and pull the mechanism for elevation control is mounted. A linear resister in the form of a piston-cylinder is mounted between a fixed point on the roof and the main support beam. The model chosen is compatible with the Siemens controller to simplify interfacing. However, these concepts and the PV support structure concepts can not in the end be used as explained in the next section.

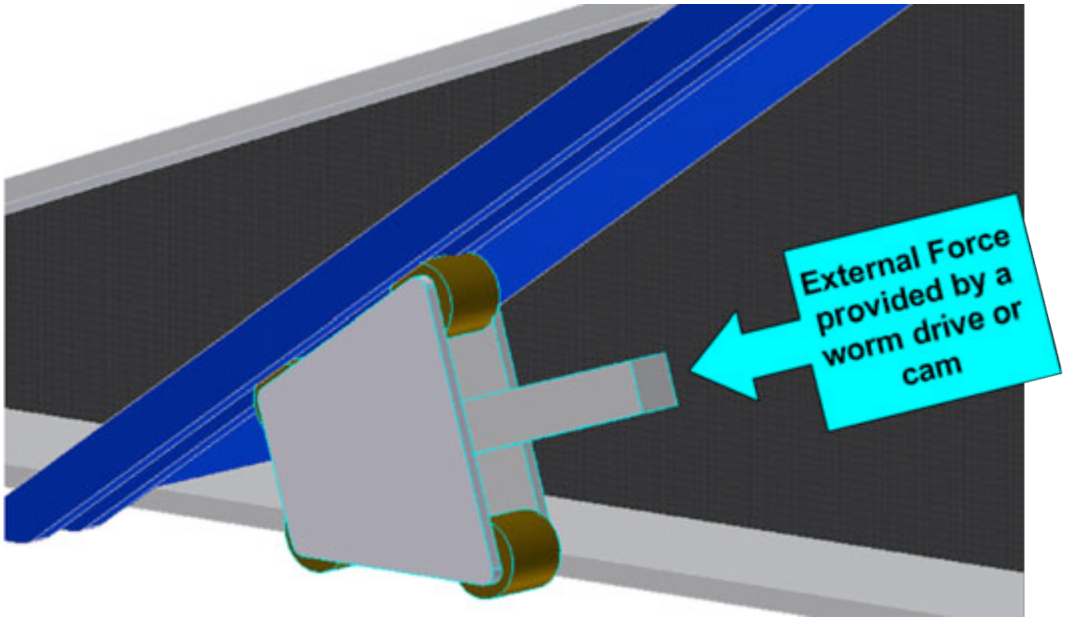

Figure 13. The final concept selected for either support concept described earlier.

1.10 Updated Structual Contraints

Just prior to Thanksgiving an undimensioned drawing of the house frame in Inventer™ DWG format was distributed by the architechtural group. After using Inventor™ to compute the distance from the gound to the very top of the house, the bridge clearance changed from 42 in (106.7 cm) to 12.5 in (31.75 cm). Even earlier in the semester, the cross-sectional area for the panels had changed from 60 ft x 16 ft (18.29 m x 4.88 m) to 44 ft x 15 ft (13.41 m x 4.57 m), which further constrained the number of panels that could be placed on the roof. Figure 14 shows the points where support beams and column access is provided. The dimensions in red are based on known dimensions of the Sanyo panels. The current house constraints are

1. There is 12.5 in (31.75 cm) of height to mount the lift and support system in its stowed position for travel to the contest site.
2. The structure is 44 ft 2 in wide (13.46 m).
3. The structure is 15 ft deep (4.57 m).
4. The weight of the PV support structure must be distributed among the house's fourteen support columns.
5. There is access to support beams and columns to mount the PV supports.
6. The PV panel support structure is a monolitic plane.

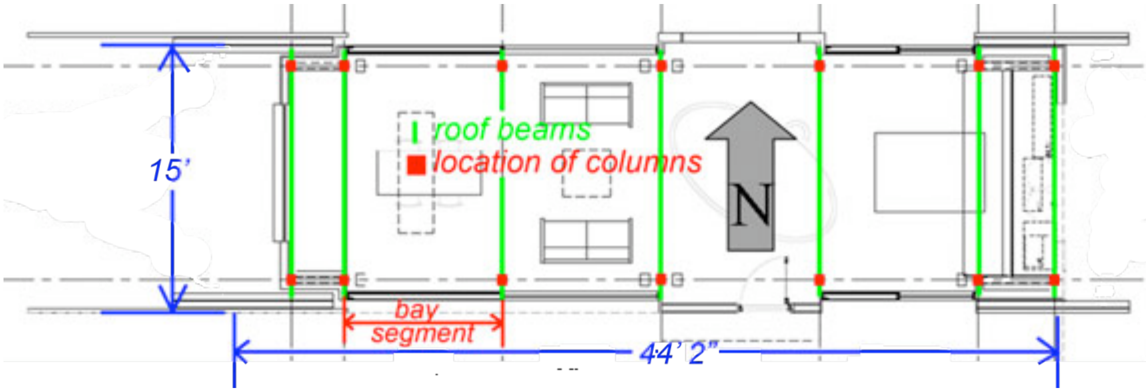

Figure 14. Updated design constraints for the PV structural support.

1.11 Elevation-Control Lift Design Concept Selected

With the constraints well defined and after a meeting with the architects, Figure 15 shows an orthographic view of one section of the PV support structure out of four in the fully elevated position at 20 degrees. Each section supports 10 panels with a combined weight of 507 lb. Six spanning beams (3.5 in (8.89 cm) angle iron) mounted perpendicular to the main beams support the panels. On Figure 15, the spanning beams provide support and attachment points where the PV panels (blue-green) meet at the gray seam. The total weight of the six spanning beams is 438 lb. An individual main support beam is about 300 lb including weldments (welded joints). Besides the four main segments, there are two wings using six spanning beams and two main beams. The weight of the entire support structure is estimated at 9,000 lb.

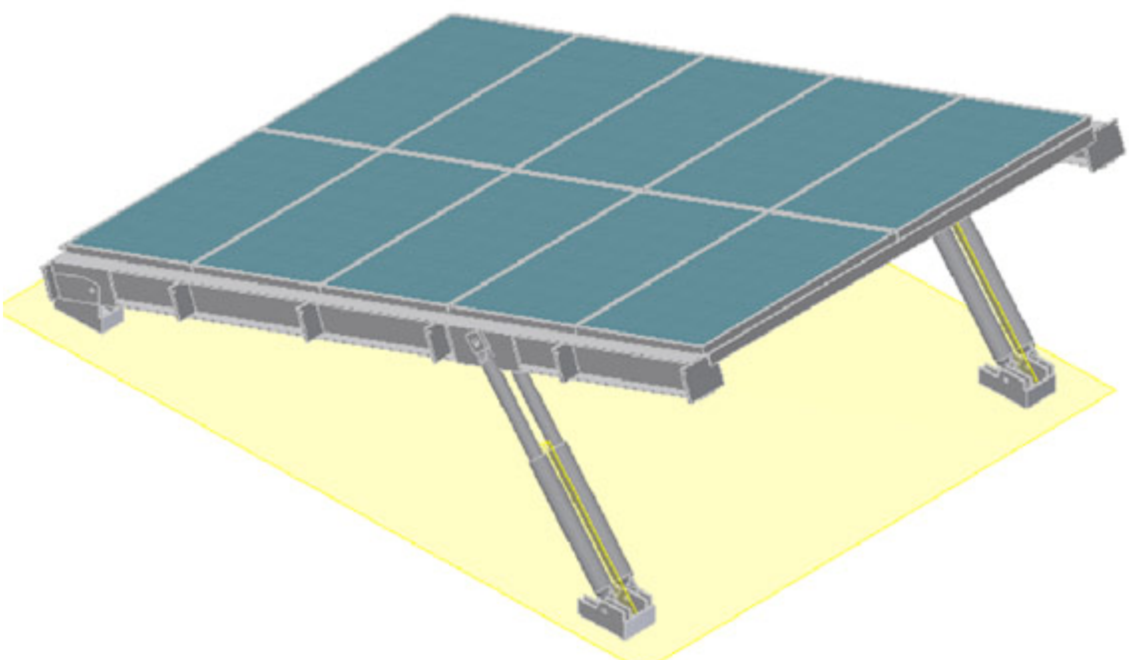

Figure 15. Orthographic view of one segment (house bay) of the final PV support structure concept.

Figure 16 is a top view of one support segment. The main beam (balloon 3) is built around a standard S8x18.4 I-beam. To attach the spanning beams (balloon 5), plates designed to fit inside the web and welded in place provide a means to either bolt or weld the spanning beams to the main beam. The front of the house and location of the front bracket is on the far left of the figure. At this location, two plates are welded to the main beam across the web to provide additional support against shear forces from the pivot pins. Approximately two-thirds of the way to the right are similar plates to protect against shear stress from the hydraulic cylinders.

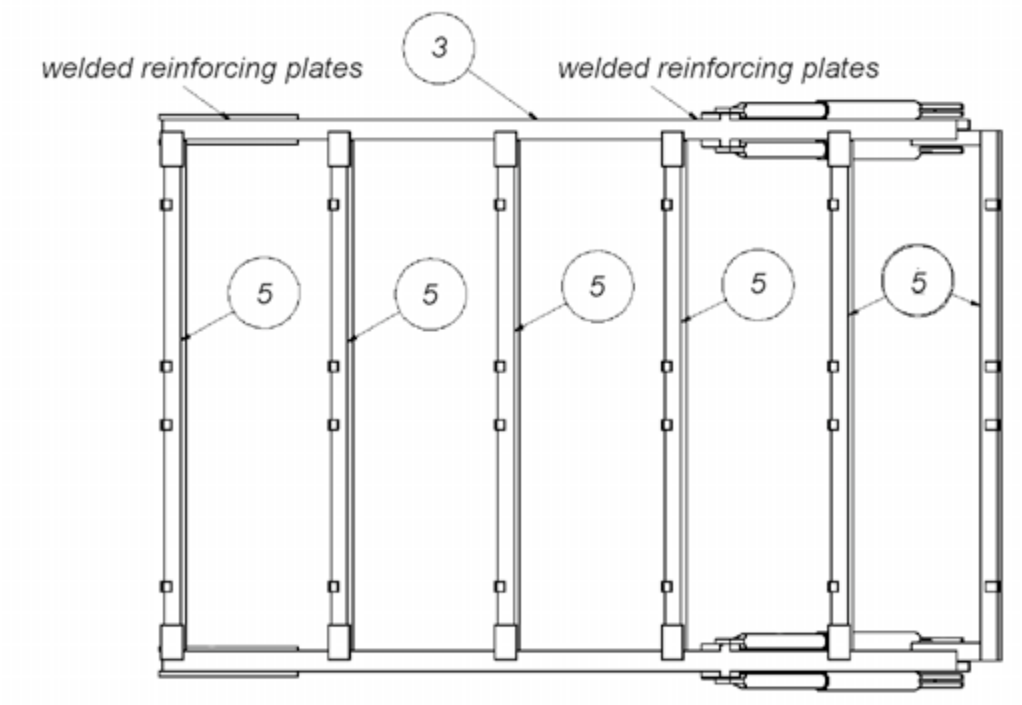

Figure 16. Top-view of PV support structure. Items labeled 3 are the main beams (S8-18.4 I-beams with weldments) and items labeled 5 are the spanning beams (L3.5x3.5x3/8 with weldments)**.**

Figure 17 is a side-view that provides a better perspective on where the web plates are welded inside the main beam (balloon 3) web. Balloon 1 locates the front bracket, which has a pivot point 4.75 in (12.07 cm) off of the main roof beams (preliminary), and it is built from welded pieces of ½ in (1.27 cm) angle iron and ½ (1.27 cm) plate. The choice of thickness is preliminary, since the specifics for the hydraulics is unknown at this time. Balloon 2 points to the location of the rear bracket and like the front bracket is built from the same kind of materials. The pivot point for the hydraulic cylinder is best placed as close to the roof as possible for leverage; therefore if a 3 in (7.62 cm) hydraulic cylinder is used, then an educated guess is that 4 in (10.16 cm) above the roof is the best place for the pivot point.

Balloon 4 is the hydraulic cylinder and the current estimate is that two 3 in (7.62 cm) cylinders are needed per main beam to lift the entire structure. Using the pivot height on the main beam and the rear pivot height on the rear bracket and assuming a 32 in (81.28 cm) cylinder length, the angle of the applied force is about 10.6 degrees. With this information, each cylinder needs to supply up to 4000 pounds of force for the initial lift. To prevent twisting, there are two cylinders for each main beam for a total of fourteen cylinders. An additional requirement of the hydraulics is that the cylinders stay synchronized, for which the architectural group is going to supply a vendor.

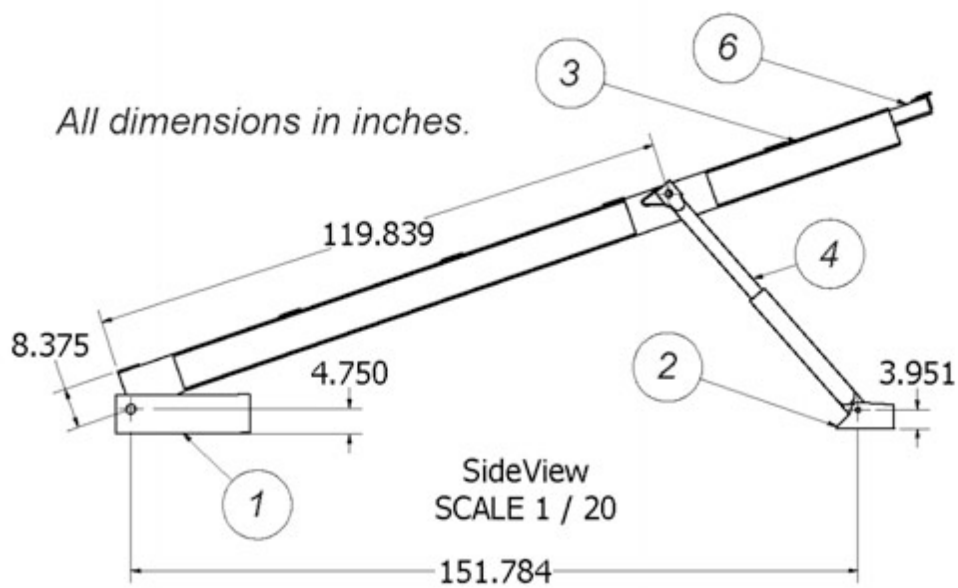

Figure 17. Side-view of the PV support structure. Items labeled 1 are the front brackets, 2 the rear brackets, 3 the main beams, 4 the hydraulic cylinders. The spanning beams are not visible.

1.12 PV Support Structure and Current and Future Work

1.12.1 Measurements and Control

It is not known if the hydraulic system chosen can interface with the Siemens controller system. If it does provide robust feedback on position, then the design for the measurement and control is complete. Otherwise, installation variable sliding resistors in the form of a piston, cylinder between the main beams and a fixed position on the roof is how position feedback can be accomplished. In this case, development would include an Siemens Apogee™ program which converts a desired angle into an output voltage or current to control the hydraulics. The program then follows up with a voltage or current measurement of the roof sensor with a conversion from of the electrical signal to an actual angle. Either proportional control or the Apogees™ control logic built into the software could be used.

1.12.2 Testing and Validation Plan

For the detailed design, the support beams and angle iron selected are based upon meeting a safety factor of at least 2. A consultation with the firm stamping the plans is in order to make sure this choice is prudent. In addition, calculated deflections can not exceed ¼ in (0.635 cm). The spanning beam safety factors against yield are 2.3. The main beam's safety factor against yield is 3.2 during the lift. All member deflections are under ¼ in (0.635 cm).

Work in progress is a computation for stress concentrations around holes and adjustments for safety factors. Also, no work has been done to assess the adequacy of the front and rear brackets, since the final design is waiting on the selection of the hydraulic cylinders. The minimum analysis is the stress concentration calculations. If safety factors are greater than 3 or 4 after stress concentration calculation, then Finite Element Analysis (FEA) should be redundant. However, a few FEA runs with a coarse mesh is still the best means to double check the hand calculations. The choice of 3 or 4 for the bracket safety factors could change based on the consultation with a professional engineer.

Validation requires that a professional engineer sign the plans for the PV support structure.

1.13 Photovoltaic Panels

The single plane of PV panels with a variable degree of inclination is the design concept to develop, since it out performs its closest competitor by 19 percent Photovoltaic (PV) panels are the core power supply of the 2009 Virginia Tech Solar House. The array consists of 46, Sanyo HIT 195 Bifacial solar panels. These double panels have cells on both faces, which allows for a maximum efficiency of up to 20.5%, or 240W/panel. Any power requirements above the output of the solar array will be supplied by a grid-intertie to the DC power system. Conversely, any surplus power produced by the 2009 house will be relayed to the power grid and recorded.

Due to the new methodology of selling excess power, the array design criterion has shifted from neutral energy balance to net energy production. Recent calculations have demonstrated that the 2009 array will be capable of generating twice as much power as necessary for house functions, at optimum efficiency and light availability. A major effort is also placed in minimizing losses in the electrical system and energy transfer due to heating and cooling. Despite increased energy collection, reducing the amount of energy used to run appliances and systems within the house has become a priority; this includes recovering energy whenever possible. In order to achieve these goals, placing an array which covers the entire roof footprint is necessary. The array is also inclined at an angle of 21° for maximum light absorption on average for all seasons. Also, due to the bifacial nature of the Sanyo HIT Double panels, reflective material will be placed underneath the array to capture ambient light on the ventral surface.

Sanyo HIT Double solar panels were selected over other products due to their compact footprint with high power density. The dimensions of Sanyo panels allow for an array of 46 to be placed on the roof of the house, producing an estimated 11.5kW of electrical power. The panels are capable of such generation due to their bifacial nature. HIT Doubles have two faces, allowing for collection of ambient light from the underside. This yields up to 30% more power generation compared to the nominal value. Other panels that were considered, such as the Sun Power 230, had higher power generation capabilities, but were larger than Sanyo products. Therefore, fewer could be fit into the dimensions of the roof. Thus, Sanyo HIT Double panels are an excellent candidate in all criteria, as listed below.

Maximizing square footage of the overall array:
46 panels will cover the entire roof, except for a small area used for the skylight.

Optimizing the angle of the array in relation to the sun:
The array will be angled at 21° for the competition but the moveable array can be optimize when not lighting conditions in an adjustable static configuration.

Minimizing cost while maximizing efficiency:
Sanyo has agreed to sponsor the Virginia Tech Solar Decathlon Team, bringing the cost of the array to $3/Watt. Sanyo Double Sided panels have efficiency between 16.8 to 20.5%, making them the best fit in both regards. Based on potential electrical losses of 7 to 15 percent from the panels reaching temperatures above 50°C, exploration of some kind of air cooling will be part of the new development this spring.

Moving Sun-shading Panel

1.14 Introduction

The purpose of the shading panels, used on the solar house facades, is for extra privacy as well as a source of partial shading, while still allowing light and air to pass through. The light screens are composed of smaller panelized segments, which are cutouts of pieces of steel sheet metal two inches apart from each other. There are two screens on either side of the house (four screens total) that open and close via a user interface or via what the outside conditions and the energy requirements of the house are. Because of this, the screen must be both mobile and move with the least power expenditure. In the sections that follow, the steps taken to choose an appropriate solution for screen mobility and power consumption are presented.

1.15 Mission and Objectives

The mechanical engineering team in charge of this must design a shading panel frame and support structure as well as the accompanying system for the panels to roll or glide on. The frame must be aesthetically sound and easy to construct, while providing adequate support for the panel. In other words, the support structure must be strong enough yet hidden from view so that it does not draw attention away from the screen itself. Furthermore, the mobility system must have minimal friction, noise, cost, and power consumption, while maintaining its ability to adapt to changing conditions in a timely manner.

1.16 Scope and Assumptions of the Solution Procedure

The shading panel system is designed for use in a single bedroom, power efficient house that requires all utilities to be extremely power efficient. For this reason, power efficiency is given priority. A limitation on the system is that it must have minimal noise, since it will be sliding back and forth all day and must not be bothersome for the homeowner. The amount of power it uses is a further limitation and because of its priority cancels out some of the ideas proposed in later sections. The panels are 11 ft (3.35 m) high, covering the façade from the floor to the top of the parapet, and 18 ft (4.49 m) wide spanning half of the house. The weight of the shading panels is another limiting factor as they are made of steel and weigh around 2000 lbs (907.2 kg) total for the four panels. For this reason, they must be structurally rigid with an appropriately sized frame to hold the structure. The system must also be compact and clean so that it does not draw attention away from the door.

1.17 Approach and Methods Used in the Design Process

1.17.1 Shading Panel Structure

Progress on the design of the structure and mobility system has been delayed due to the architecture department's design of the shading panels constantly changing, and as a result the needs of the system change as well. The final design of the shading panel has now been set so that the design concept generation phase of the structure and mobility system can proceed. Given below is a description of ideas for the different aspects of the shading panels that are needed in order for them to function effectively and efficiently.

The shading panels will be constructed, in part, by the Zahner Company, an architectural metal façade design and construction firm. Their team of engineers has developed a series of systems in order to clad the surface of any building with metal. They are capable of cutting sheet metal and forming operations in three dimensions. One of the core competencies of the company is to create shading systems composed of custom patterns, which is precisely the needs that must be fulfilled for this portion of the project. The main difference between the typical work of the Zahner company and the needs for the Solar Decathlon house is that the house, requires moveable panels, which is an added element to Zahner paneling systems. Matching the paneling system of the Zahner Company to the rolling frame of the shading panels is important to ensure that the aesthetic, performance, and structural requirements are met.

The shading panel concept developed by the architecture department uses a fractal pattern to define perforations in the panel that control the amount of light entering the interior spaces. The fractal's design also incorporates the seams between panels that make up the entire shading screen. Consequently, the support frame giving structure to the whole façade also follows the fractal lines. The idea is simple. However adapting these ideas to the structure is somewhat harder. Each segment of the screen is cut out individually and needs to be placed together. These intersections of the segments form the frame of the door. How these segments go together is an open question. Several ideas have been proposed, each with their own set of problems to overcome.

There are two main fastening/construction systems that could potentially be used as construction methods. One is a skinned frame system, whereby a tubular metal frame, that follows the panel seams, serves as an attachment point to any of the various Zahner panel systems. Here, the frame serves as the main structural component. The second system uses flanges that are folded into the panelized segments of the screen as the structure and attachment points. Various options exist with this solution also. The design is dependent upon how strong the individual segments of the screen are and how capable this construction is able to support its own weight as well as any other loads and stresses put on the system.

The best way to incorporate the components of the panel, from the sheets that make up the screen to the hardware that will allow the panel to move to its various position, is to have more detailed discussions with engineers at Zahner. These are planned for early spring.

1.17.2 Shading Panel Mobility System

Since the one- to two-person solar house is highly advanced, it is targeted at people that have the money to afford it. Therefore the cost of the shading panels was not a large concern. As it turns out though, generally as the price of the panels increases, so does the power required to run it. Furthermore, the system must be clean and compact, so that it does not take up much space and is easy to install as well as service.

The system that supports the doors is derived from a preexisting design typically found in sliding entrance gates for driveways. The gates are massive metal constructions that roll along a track on the ground with a secondary upper support that keeps the door upright and minimizes swaying. On the solar house, the track system is bolted directly to the frame of the house. The track on the bottom of the door supports the entire load of the door and guides it into position. Another track, mounted to the top of the parapet supports the panel to avoid any side-to-side movement.

Since these panels are operable and automatic, a drive mechanism needs to be implemented so that active control is possible. A few options exist. A magnetic linear actuator would move the door much the same way a maglev train works, whereby the changing polarity in magnets and coils would propel the panel sideways. All other systems require direct contact. The best solution for these is a rack and pinion mechanism. The doors construction would incorporate a rack gear along its entire length. A motor mounted to the house would engage the rack and move the panel sideways. The current location for this system is in the parapet, as there is a usable void within the cladding of the house to store components. Another option would be to build the motor into the deck area and drive the door from the bottom.

1.18 Results and Discussion

The problem of the shading panel internal structure is still up for debate. The architects are weighing the pros and cons of each possible solution. Analysis is still being performed to determine final product design specifications as well as 3D models and cost.

Insulation Panel Design

1.19 History

The 2009 Solar Decathlon house is a descendant of the 2005 competition entry. As such, ideas that were fundamental to the function and ultimate accomplishments of the 2005 house have been transposed and updated in the 2009 solar house. One of the returning elements that was and is again vital to the success of the house is the translucent insulation panels. The panels are composed of a composite of materials and products that work together to produce an efficient and operable insulation wall solution.

1.20 Mobility

A principal difference, to be noted between the insulation panels of the two houses is that in the updated version, the requirement of mobility is imposed. Despite the added complexity of implementing such a system, one of the main criticisms of the 2005 house was its overall lack of operable windows. One of the driving factors in the architectural contest is that of maintaining the concept of the “all glass house.” When the weather allows, the house should be able to be opened to a pavilion state at the push of a button. As such, the insulating panels, while maintaining primarily the same composition as in the 2005 house, must be mobile. Some manufacturers and suppliers have already been chosen to supply certain products for the construction of the panels. These products begin to indicate parameters of what other design aspects of the insulation panels still need to be designed.

1.21 Main Dimensional Criteria

The entire length of the glazed façade is approximately 38 ft long. Currently this length is divided into four equal width “bays” (approximately 9 ft per bay).

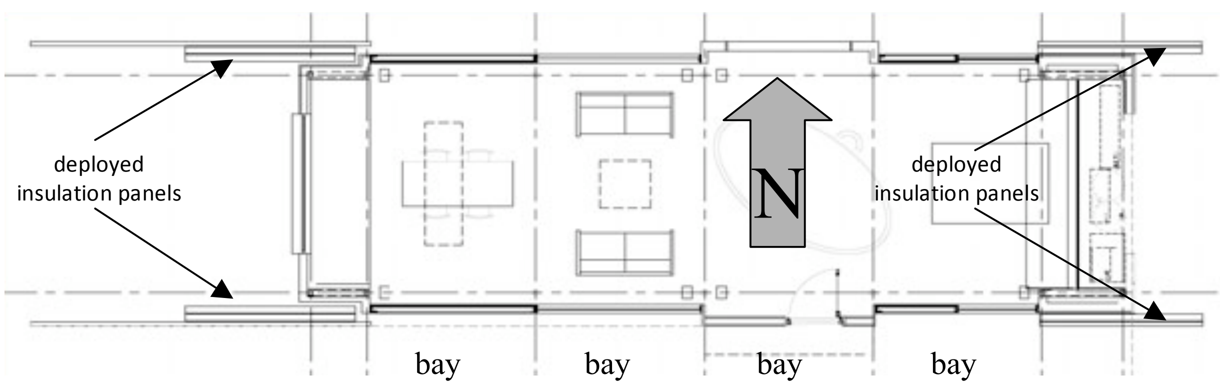

Figure 18: The overall layout of the house, indicating the positions of the deployed insulation panels.

Separating the east (bay 1 and 2) and west (bay 4) bays is a single bay (bay 3) that houses a utility space and the main entrance. Bay 3 has permanent insulation and bay 1, 2, and 4 have operable insulation panels that slide parallel to the house, to expose the glass facade. The overall dimensions of the bays on the east and west sides of the house dictate the length of the panels. When deployed (not covering the façade), they split and nest in a stack against the house, one in front of the other as opposed to side by side (in a north-south orientation to each other as opposed to an east-west configuration to each other). Currently, the insulation panel that covers two bays on the west side of the house (on both the north and south façade) is composed of two smaller panels that have a locking interface and when completely covering the façade, they act as a single homogeneous panel.

1.22 Components

The following sections provide a description of the products (listed beside the manufacturer), which have been found appropriate for developing the insulating “sandwich” in the moveable panel system. The sandwich is composed of an inner wall, an airspace, and an outer wall. The airspace contains the frame of the panels; LED accent light strips; and potentially (depending on which concept is chosen) a drive motor, an actuated gasket, and any wiring needed to power/control any of the aforementioned components.

1.22.1 Gallina – Arcoplus 626™

The Arcoplus line of extruded polycarbonate panels is a modular system that utilizes tongue and groove joinery on the panels to snap into connectors that run the length of the panel. The panels were used in the last house because the cellular extrusions that run the height of the panel are excellent vessels for Nanogel™. These specific panels allow the connector to be integrated directly into the design of the frame and very little to no extra framing or infrastructure is needed. The system allows for the appropriate thickness of wall so that an R-value of 18 is reached.

The total thickness of polycarbonate panel is 60 mm (2.36 in), composed of a 20 and 40 mm thick panel. These panels will be attached to an ash wood frame, by means of a proprietary edging strip that grips the panel in place. The ash wood frame will allow for airspace between the polycarbonate panels further increasing the insulation properties. The sandwich’s total width will be approximately 4.5 in (114.3 mm) wide, so the wood frame will be approximately 2.25 in (77.2 mm) wide.

1.22.2 Haefle/Hawa AG – Variotech 150/H™

This version of the Hawa sliding door track allows for the insulation panel to change direction and orientation where the door slides along the side of the house and then recesses into a pocket at the end of its travel. The 150 line of track can support a door of up to 150 kg (330 lb). The system utilizes a top-hanging configuration, which is to say the door “hangs” from two points and uses a track and trolley system at the top, to guide the orientation of the door. On the bottom, to prevent swaying, a pin attached to the door follows along in a thin slot in the decking of the house.

Hawa also produces a line of motorized sliding doors; and while these doors only move in one axis, as opposed to two, a retrofit of their system may be possible, where motion and controls are included according to Haefle. Otherwise an aftermarket system, described later, may have to be implemented.

1.22.3 Cabot Corporation – Nanogel™

The following are excerpts from Cabot Corporation’s website about aerogel:

“Sometimes called ‘frozen smoke,’ aerogel is the lightest weight solid and one of the best thermal insulators in the world. Its distinguishing characteristics set it apart from common silica products and make aerogels an ideal solution for insulation, coatings, and other applications.”

Aerogel is an ideal insulator that exhibits the following properties:

- high light transmission – 75% per cm
- low thermal conductivity – R-value of 8/in.
- sound attenuation – reduces transmitted noise
- permanence – resists color change, mold and mildew, and performance degradation

The implementation of aerogel in the sandwich structure is possibly the most important factor in the success of this wall system. Its unparalleled thermal resistance-to-weight ratio makes it an ideal material for use in this application where a high performance material is needed. A total of 2.36 in. (60mm) of aerogel will ideally provide an R-18 insulation barrier to outside weather conditions.

1.22.4 Color Kinetics Inc. – iW Cove Powercore™

The iW Cove Powercore™ system is a low wattage high intensity LED cove lighting system that will be used as an accent light placed within the airspace of the insulation panel "sandwich." The light operates using 100-240VAC and only consumes 15 W, thus making it ideal for any interior application. The body of the light is 39 mm (1.53 in) wide. Due to the potential of heat generation and especially regarding the effectiveness of the light "throw angle," adding an extra width to the airspace may be acceptable.

Barring any weight constraints, there are a few deciding factors on the viability of this option. One is delivering power and program control data to the lights. Two solutions exist, one is to use a system of electrified rails to deliver continuous power to the light even while the panel is in motion. A rail extending the length of the bottom of the panel moves with the panel and makes continuous contact with a set of fixed brushes. During a collaborative meeting with the electrical engineering team, an inductive system was also proposed that may enhance the reliability of the "continuously on" solution. Here, a "power cable" that runs the length of the motion of the panel is kept stable and an induction coil attached to the panel delivers continuous power to the lights, independent of the location of the panel along its intended path.

A second solution is to have the panel lighting system only be powered on when in specific positions. This would allow for predetermined contact point to be set along the motion of the panels. For instance, a contact point might be placed at the extremes of the motion of the panel so that the lights can only power on when the panel is fully deployed or fully closed.

A data enabler is also required to power the lights. The dimensions of the data enabler are 246 mm x 89 mm x 81 mm (9.68 in x 3.50 in x 3.18 in). Due to its size it will likely be stored outboard of the actual insulation panel in a fixed location. Depending on the complexity and variability of control, data may have to be transferred to the light modules by means of a wired connection.

1.23 Sealing Systems

A sealing system is a required element that still needs to be defined more clearly. The sealing system is a passive or mechanically actuated sealing device that minimizes infiltration. Originally, thought was given to using a pneumatically controlled gasket; concerns with sealing around corners, reliability against leakages, the need for a compressor and air delivery, and cost ruled this option out.

The gasket may be attached directly to the house and apply pressure on the panel, or it may be attached to the panel and apply pressure to the house; or it may be attached to both. Two options have been determined. One is a product by Sealeze, which is composed of a synthetic bristle material available in various lengths coupled with a rubber film that remains in constant contact with the sliding insulation panel; no pressure is supplied beyond the tolerance between the gasket material and panel. Ease of replacement being a priority the bristle is slid into a holder making removal very simple. The simplicity of the system and minimal space usage are advantages. Sealeze produces this bristle product specifically for large industrial size door, which makes the insulation doors a great test-bed. This brush system is also good for cleaning debris and could aid in keeping the tracks on both the insulation and shade panels clean for smooth operation.

A second option is a solenoid actuated mechanical gasket. When the insulation panel is not in motion, a normally closed solenoid provides constant pressure to the gasket system. Just before the panel begins its motion, the solenoid charges and releases the pressure of the mechanical gasket on the panel. The advantage of this system is that the efficiencies of the Haefle track system are preserved by minimizing friction, the gasket wears less quickly, and a seal can be made accurately at any location that the panel is placed. The complexity of the system still needs to be evaluated, especially in the context of available space.

1.24 Motion Systems

Automation, feedback, and controls will be more specifically linked to the progress made to the energy modeling of the house. Evaluating the impact of any change in the position of the insulation and sun-shading panels with regards to how much energy is required to move the panels and the resulting interior conditions.
The proposed Hawa motorized tracks, previously mentioned, move the insulation panels. Due to the weight of the sun-shading panels the Hawa motorized rail is not an appropriate solution. Two methods of motion are currently proposed. The first is a belt system where-by the panel is attached to a point on a belt that has a stationary motor act on it. As the motor rotates it pulls the belt and panel to a specific location. Danaher Motion produces a load bearing rail system that incorporates a belt or ball-screw driven mounting saddle. This system is convenient because the rail can help to support one side of the sun shading panel while moving it. The rail also has limit switches and locations to mount position switches and indexing systems. The motor that drives such a system, is designed specifically for this system, is be attached to the rail via a drive shaft, and be stationary.
The second option is to mount a motor onto the panel, power it using a similar rail and contact point system as mentioned in the “continuous on” LED light system. This system most closely resembles a subway rail system.
In order to accurately position the panel there are two options. One is to use an indexing system whereby triggered switches cause the panel to stop at predetermined positions. Another is to use a distance sensing device, such as an encoder, where the panel can be placed at any desired position accurately and automatically.

HVAC and Plumbing

1.25 Contest Background

The HVAC and plumbing part of the Solar Decathlon must provide the necessary cooling, heating, and water for the house. The HVAC system has several requirements related to the “Comfort Zone” or the air quality of the supplied air. These requirements are taken from the Solar Decathlon Draft rules and provide the customer needs for the house. The temperature of the house must be stabilized in a 72°F-76°F (22.2°C-24.4°C) range. The relative humidity of the house needs to be kept between 40-55% levels. The plumbing with respect to the hot water also has several requirements, which include that 15 gallons (56.78 liters) of water at an average temperature of 110°F (43.3°C) be delivered within 10 minutes to any plumbing fixture located inside the house. This evaluation will be investigated 20 different times throughout the contest week and will be used as criteria for our design.

1.26 Mechanical System Implementation

The Solar Decathlon house requires several mechanical units that must be incorporated into an overall design. The mechanical units include a water-to-air heat pump, a water-to-water heat pump, a geothermal heat exchanger loop, a circulating pump kit, a hot water tank, and radiant floor heating.

The water-to-air heat pump, model AP025, is being supplied by FHP (Florida Heat Pump) Manufacturing Co. to supply cooling to the HVAC duct system. The heat pump features an internal condenser unit used to cool the air, along with a heat recovery system used to provide domestic hot water production. The condenser unit runs directly off the water-line feed from the geothermal heat exchanger. The heat pump has a left hand return, meaning that the return air comes back into the heat pump on the left side. The heat pump features a 2-stage cycle, in order to accommodate large cooling requirements and yet be able to efficiently meet moderate cooling requirements (i.e. via a single stage). The first stage cycle provides a total capacity of 18.54 kBtu/hr (5.43 kW) for a required power requirement of 1.06 kW (3.62 kBtu/hr) and an entering fluid temperature of 85°F (29.4°C) and an entering air temperature of 75°F (23.89°C) dry bulb and 63°F (17.2°C) wet bulb. This entering air temperature will be set during the competition to provide the zones with the correct temperature for the comfort zone. The heat pump provides air at a flow rate of 750 CFM (21.2 m^3/min) and requires a water flow rate of 8.0 GPM (30.3 LPM). The second stage of the heat pump will be locked out during the competition due its large comparative consumption of power. The second stage consumes 1.73 kW (5.9 kBtu/hr) at a capacity of 24.54 kBtu/hr (7.19 kW) and for the same air specifications of 75°F (23.89°C) dry bulb and 63°F (17.2°C) wet bulb. The second provides air at a flow rate of 950 CFM (26.9 m^3/min), which is only necessary under adverse temperature conditions.

The water-to-water heat pump, model WW024, is also supplied by FHP Manufacturing Co. to provide hot water for the hot water tank and the radiant floor heating. The heat pump requires water from the geothermal heat exchanger and provides heat exchange to the water going to the hot water tank. The heat pump will varies its power input and load capacity, although, it will usually has source water entering at 85°F (29.4^{o}C), and leaving at 44°F (6.7^{o}C) , at a capacity of 24 kBtu/hr (7.03 kW). The power input is 1.72 kW (5.69 kBtu/hr) and the water flow rate is 5.0 GPM (18.92 LPM) for the load and 6.2 GPM for the source water.

The geothermal heat exchanger system, an innovative addition to the mechanical system is essentially a large pool of water which provides energy to the water circulating through. The pool of water is used to mimic a lake or the ground, which stay at a relatively constant temperature year round. The disadvantage of the geothermal pool is the evaporation of the water. Since the pool has a somewhat limited volume, situated, the amount of the water evaporation is relatively important, since it causes a decrease in temperature of overall body of water due to the heat of vaporization. However, the pool is only designed for use during the competition, and thus, the problem of evaporation is minimal. The geothermal design is still under way with a use of polyethylene piping for the geothermal loop.

The hot water tank is a BoilerMate (Model WH-7DW) 41-gallon tank, manufactured by Amtrol™, featuring a polyethylene reservoir surrounded by high-density urethane insulation for maximum heat containment. The hot water tank provides various pressure settings, which correspond to different energy inputs, based on 5 GPM (18.93 LPM) input into the tank. The tank obtains hot water from a supply and then supplies it to the plumbing fixtures. The tank also provides hot water for the radiant floor heating. The hot water tank receives hot water from the water-to-water heat pump.

The radiant floor heating runs underneath all of the floors in the house to provide heating to the different zones of the house. The radiant system makes use of RAUPEX™ O2 Barrier Piping, which is a highly flexible pipe with enhanced temperature transfer capability. The hot water tank supplies hot water to the radiant floor piping, which flows in a closed loop system. The floor heating is distributed through a distribution header, supplies the heating to four different zones in the house. The zones consist of the bedroom, the living room (includes 2 independent zones), and the bathroom. A mixing valve will be installed to mix the outgoing water with the incoming fluid if reheating is not required. The ME team members will be trained on the design and installation of the radiant floor heating by the supplier, REHAU, Inc. The radiant floor heating provides an effective heating system since the heat is delivered at the bottom of each zone and is allowed to rise naturally upwards, as opposed to having to force the heat downwards as in the case of air ducts located in the ceilings of each zone. The radiant floor heating is setup in series with a circulating pump, which is only activated when required to pump heated water from the hot water tank into the piping. The activation of the pump is initiated by the controls algorithm when the thermostatic measurement devices detect a temperature out of the required range.

Each of the mechanical units interacts via piping and circulating pumps. The circulating pumps provide a constant fluid flow rate to the different mechanical units. Check valves in the system ensure that water flows in one direction, specifically from the water-to-water and the water-to-air heat pumps into the hot water tank. A schematic of the collaborative mechanical system is presented in Figure 189.

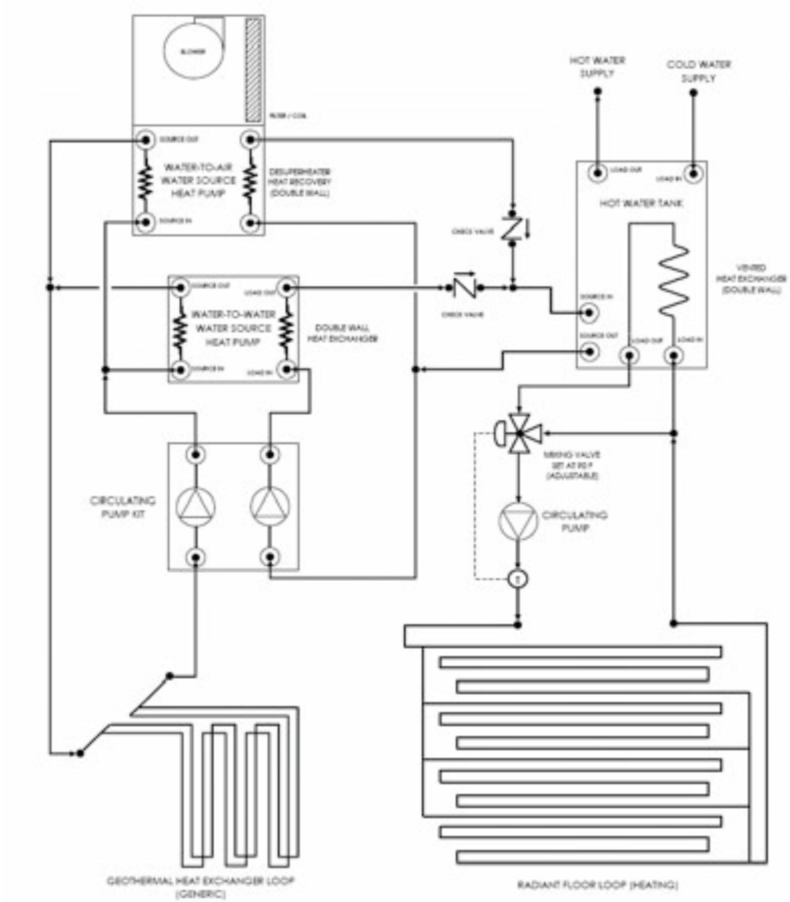

Figure 189. HVAC Schematic (note the implementation of the pumps and valves).

This design layout is still in flux and may change in order to increase efficiency or due to mechanical constraints. However, the interaction between the various components still remains mostly permanent.

1.27 Mechanical Closet

The mechanical closet is located on the east side of the house, with access leading to the outside of the house. The closet houses all of the mechanical equipment (heat pumps, hot water tanks, circulating pumps), the duct work from the water-to-air heat pump supply, the plenum return for the water-to-air heat pump, an energy recovery ventilator (ERV), the piping to and from the water-to-water heat pump, and the solar panel inverters. The height and width of the mechanical closet is known to be 163.36 in (W) x 107 in (H) (4.15 m x 2.72 m), from the layout of the frame of the house. However, the depth of the closet is still in question since the needed space from the mechanical units must be established. An estimated depth of 34 in (86.36 cm) is projected to store all of the components.

The water-to-air heat pump has dimensions of 21.5 in (W) x 26 in (D) x 47.25 in (H) (54.61 cm x 66.04 cm x 120.02 cm) with condensate drain connections of ¾ inch (19.05 mm) Female Pipe Thread (FPT) and heat recovery connections of ½ inch (12.7 mm) FPT. The heat pump has a supply source on top of the unit sized at 15.75 in (40 cm) x 13.75 in (34.93 cm) and a return sized at 22 in x 22 in (55.88 cm x 55.88 cm). The water-to-water heat pump has dimensions of 24.25 in (H) x 32.5 in (W) x 24 in (D) (61.60 cm x 82.55 cm x 60.69 cm) with water connections sized at ¾ inch (19.05 mm) FPT. The hot water tank is 48 in (121.92 cm) high with a 22 inch (55.88 cm) radius. The ERV unit is sized at 24 in x 14.25 in x 20 in (60.96 cm x 36.20 cm x 50.8 cm). The inverters are sized at 6 feet x 6 feet (1.83 m x 1.83 m). With these dimensions, along with a required space of 4 in (10.16 cm) for piping and about 3 in (7.62 cm) for insulation, the mechanical closet needs an approximate depth of 34 in (86.36 cm). All of these units are being sized in AutoCAD and fit into a mechanical closet drawing to more precisely determine the needed dimensions of the mechanical closet.

The ERV unit is an indoor-to-outdoor heat exchanger, which provides flow of fresh outdoor air to the house. The exchanger also recovers energy from the incoming air and delivers it to the outgoing air in order to cool the former.

The inverters are used to invert the electricity from the solar panels from DC to AC power. However, the inverters may generate a large amount of heat when the power load is high (~11 kW) and needs to be cooled. This is accomplished through a ventilation system to pipe the heated air from the insulated space for the inverters to the outside of the house. Since heat lowers the efficiency of the inverters, an effective ventilation system is highly mandatory.

With the given specifications given above, a preliminary concept design was developed arranging all of the units in the mechanical closet. This concept, as shown in Figure 20, portrays the top and side views of the potential mechanical closet arrangement.

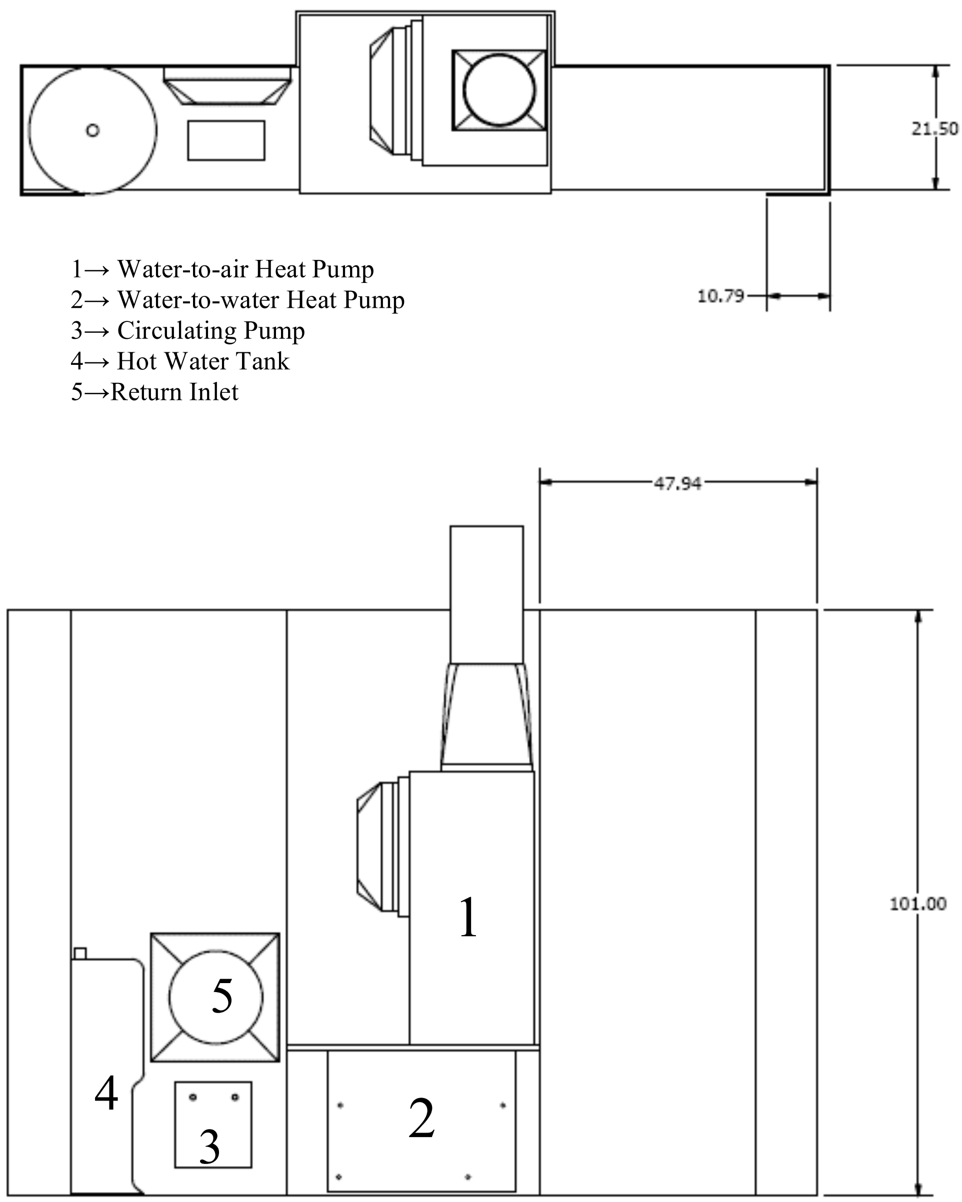

Figure 20. Mechanical closet AutoCAD design (note the mechanical components labels).

As shown, the hot water tank and circulating pump are located on the left wing of the mechanical closet. Both the water-to-air and the air-to-air heat pumps are located in the center alcove. The placements of most of the components are based upon space limitations as well as functionality. The water-to-air heat pump needs to be located in the center of the mechanical closet due to the division of the main trunk to the separate branches. The trunk is the main duct protruding from the top of the heat pump, whereas the branches are the duct work leading the air throughout the house. As the flow of air needs to be balanced to each duct, the proximity to the center of the unit is crucial in the HVAC design. Originally, the water-to-air heat pump was turned towards the center wall so that the return duct could have easy access through the wall. The critique of this idea concluded that the design was unfeasible. Upon revision, the heat pump return filter was turned towards the left wing. In addition, initially, the circulating pump was located on the left wall of the mechanical closet. After consideration of this placement, the circulating pump was moved towards the floor to increase accessibility to the geothermal pond and the other plumbing components conduits.

The hot water tank consumes more space than that is available in the mechanical closet. Two solutions have been posed to remedy this. The first option is to choose a new water tank of greater height and smaller diameter, while maintaining the same volume. The second option is to increase the size of the mechanical closet. After discussion with the architectural team, it has been decided to increase the mechanical closet dimensions. The exact dimensions are not known, however, it is probable that the left corner will be widened to fit the hot water tank.

This mechanical closet concept provides a preliminary layout of the largest mechanical components. However, the addition of some components is still required to complete the design. A return duct must be designed to return air back into the water-to-air heat pump. A return vent is proposed to be placed behind the bed, located on the other side of the wall, facing the bed, in the house. The return duct must connect to the inlet with the use of an “S-turn” style duct piece. The piece is still under design and should be completed by the next week. Another component that must be added to the mechanical closet are the deliveries and returns of the piping system.

1.28 HVAC System

As per the contest rules, the HVAC system must keep the house conditioned to 72-76°F (22.2°C-24.4°C) and 40-55% relative humidity at all times (DOE, 2008). With such small tolerances for temperature and humidity, the HVAC system provides these conditions and uses as little power as possible to do so. Since the solar house is small, and the architectural plans dictate basically where the ductwork can be laid out, the design aspects which the team can affect to make the system as effective as possible are the sizing, shape, and delivery points of the ductwork and the placement of the water-to-air heat exchanger.

To size the ductwork in a building, one first calculates the overall thermal load on each room or zone. Then the flow rate is calculated for peak cooling and peak heating. The desired temperature difference between the air in the space and the air as it leaves the water-to-air heat pump coils is also considered. In the case of the solar house, the space is so small that the smallest water-to-air heat pump available on the market delivers more than enough volumetric flow to condition the space properly. This heat pump is the Aquarius II AP Series Two Stage R-410A, which runs nominally at 750 CFM (21.2 m^3/min). As seen below in Figure 21, there is a main duct branch coming out of the water-to-air heat pump in the mechanical closet, which immediately rises up into the plenum space. From there, based on the architectural placement of plenum spaces, the duct splits off into two branches that run down the north and south sides of the house.

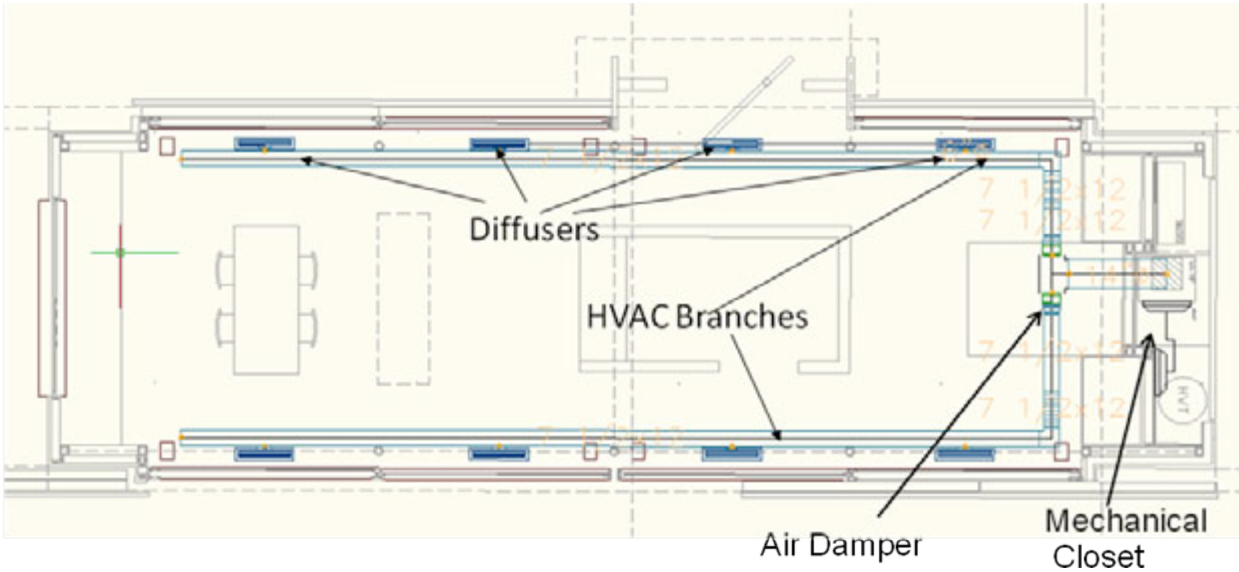

Figure 21. Concept drawing of the ductwork layout in the house for the water-to-air heat pump. The rectangles on the sides of the branches indicate linear slot diffusers.

The ducts used in the HVAC system have been sized according to ASHRAE standards 90.1. These standards (commonly used for building codes) recommend a maximum of 2000 FPM (609.6 m/min) (Reilly and Walsh, 2008) running through terminal ductwork, since higher speeds equate to higher noise levels. The trade-off involved in sizing is that lower air speed (and lower noise level) requires a larger duct size. Since the plenum space is shared with an electrical conduit and cabling, the duct needs to be sized as small as possible while keeping the noise factor in view. . Based on the standards for a residential system, the air velocity through the ducts should not exceed 600 FPM (182.9 m/min). The velocity through the main trunk may not exceed 1000 feet/min (304.8 m/min). These figures are based upon the noise level created by a conventional duct system carrying air at this velocity. In order to determine a duct area from these specifications, the known volumetric flow rate is divided by the velocity, i.e.,

$$A = \frac{Q}{V}, \qquad (10)$$

Where A is the area, Q is the volumetric flow rate, and V is the velocity.

As the water-to-air heat pump is locked out in the first stage in order to reduce power consumption, the flow rate is known to be 750 CFM (21.2 m^3/min) at a maximum. Since there is an abundance of space available in the mechanical closet for the main trunk, a velocity of 900 (274.32 m/min) ft/min is implemented. A higher velocity can be applied to the main trunk compared to the branches since the acoustics of the air is isolated inside the mechanical closet. From the chosen velocity, an area of 120 in^2 (0.077 m^2) is deduced for the main branch of the HVAC system. Based on fluid dynamic principles, the losses in a circular duct are less than in a rectangular duct. However, a rectangular duct is more easily adaptable to a larger variety of spaces. Nonetheless, since the mechanical closet can accommodate a circular duct, this shape is chosen. Based on the derived area, a diameter for the circular duct is determined to be 15.14 in (0.38 m). A short section of this design is shown in Figure 20 of the mechanical closet.

The next design features of the HVAC system needed are the branch sections which circulate the air throughout the house. These are located in the air space above the ceiling. A schematic of the cross section of this air space is shown in Figure 22.

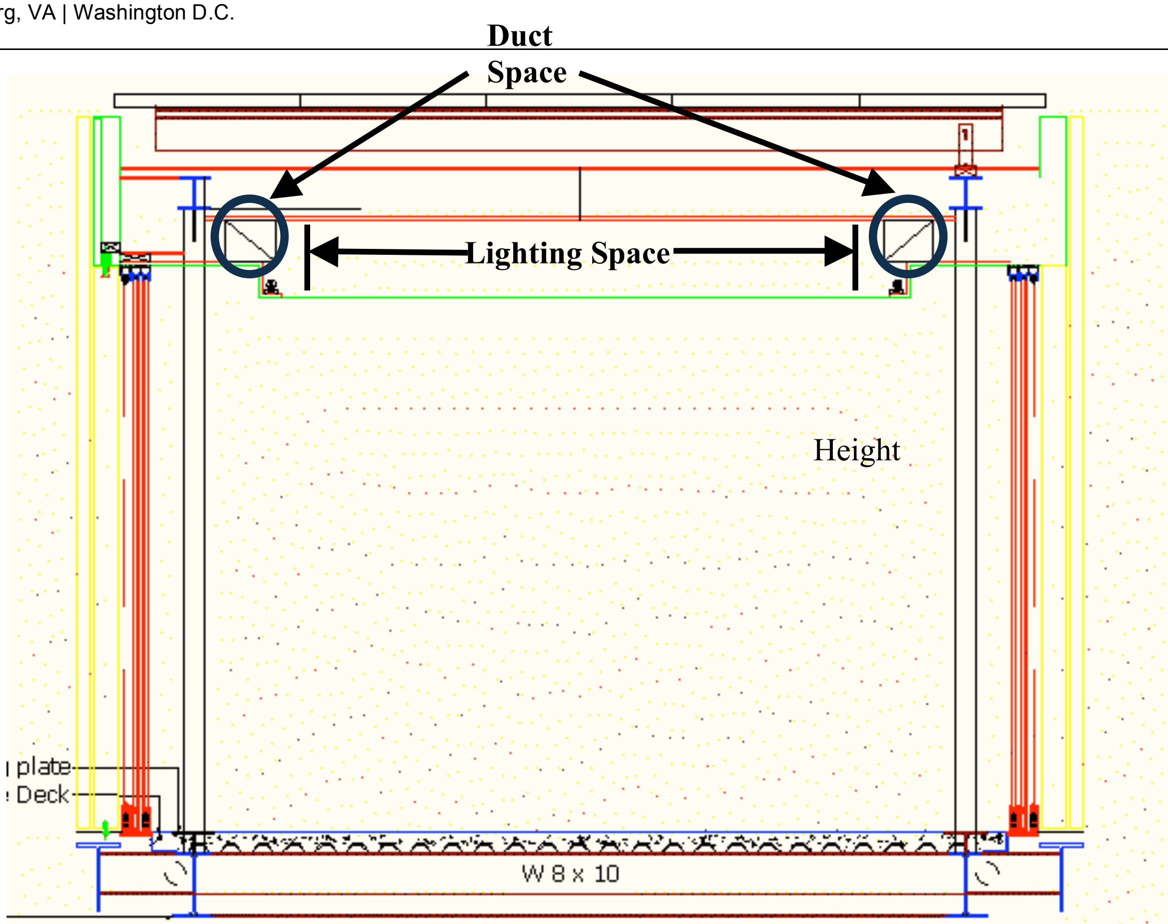

Figure 22. Cross sectional view of the mechanical closet (Note the labeled duct area).

In order to determine the size of the ducts half of the main trunk's flow rate is used, 375 CFM (10.62 m^3/min) The ASHRAE standards for a duct velocity of 600 FPM (182.88 m/min) are used. From this, a total area is calculated to be 0.625 ft^2 (580.64 cm^2) or 90 in^2. From this area, a duct diameter is found to be 10.70 in (27.18 cm). Based on this diameter, a circular duct does not fit inside the enclosed air space. Thus, a rectangular duct with dimensions of 12 in by 7 ½ in (30.48 cm x 19.05 cm) is proposed for the air space. This should just fit inside the space, as long as no other obstructions are present.

Insulation is also needed for the duct system. As energy efficiency is the primary goal of the ventilation system, the loss of energy through the duct walls must be avoided. The type of insulation to use is being researched. An important issue with the insulation is the limited air space above the ceiling. More air space may need to be requested.

After the ductwork layout is established, the type and placement of supply outlets must be determined. Since glass covers such a large portion of the house's envelope, the space adjacent to the North and South windows are areas of concern with respect to heat loss and gains. Linear slot diffusers have been selected for the outlets because this type is the most effective for the perimeter-intensive application that exists in the house. The diffusers will be placed directly in the duct work in the ceiling because of the design of the house and due to the fact that economic reasons favor heating and cooling from overhead for perimeter applications.

The mechanism for conditioning the space with overhead linear diffusers is to project air vertically downward, parallel to the window. This creates a buffer zone between the exterior and the center of the house to stifle heat transfer either in or out of the house, depending on the season. Figure 23 shows the airflow pattern utilized by the linear diffuser system.

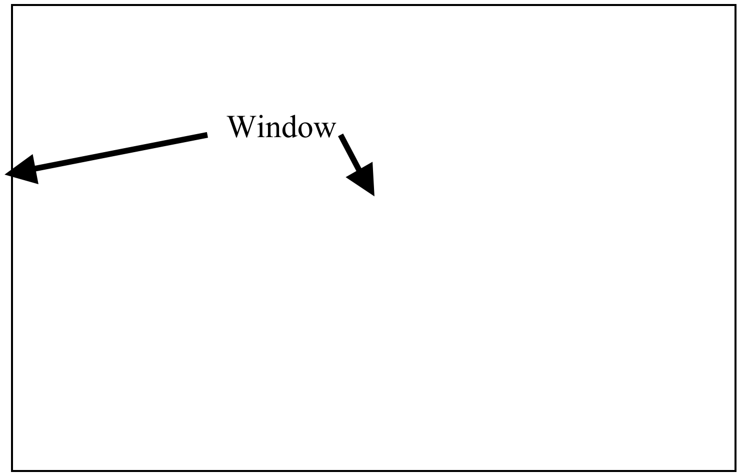

Figure 23. The vertical projection of hot and cold air parallel to a window (note: T_{150} and T_{50} refer to throw velocities of 150 and 50 FPM, respectively).

Using linear diffusers in this fashion, not only is a buffer zone created at the window but, as shown in Figure 23, natural air circulation results. Since linear diffusers will be placed on either side of the house, natural mixing will occur at the center. Also, since the diffusers are aimed parallel to the windows, the potential for drafts is minimized.

Despite the benefits of the linear diffuser system, there are some potential drawbacks. First of all, the mechanical engineering team must be conscious of the ratio of slot area to duct area, because this quantity determines the throw angle, the angle at which air leaves the diffuser. Throw angle is very important because the HVAC system will provide the best conditioning for the space if the air is projected as close to the window as possible. If the air hits the window before it reaches the floor, however, the air pattern will be altered and temperature stratification down the height of the room could occur.

Another concern the team has to be aware of is the noise produced by the diffusers. One factor that influences noise level is the number of diffusers. The noise criteria, a measure of the loudness of the noise level produced from the diffusers as heard by an occupant, increases significantly if there are several diffusers in close proximity. Therefore, the team has designed for as few diffusers as possible and placed them as far from one another as possible. Another factor that influences noise level is the use of flex duct. It is necessary to use flex duct because it is very difficult to machine a piece of rigid duct that aligns correctly with the branch duct and the diffuser. The flexibility of the flex duct allows machining errors to be overcome. The issue with flex duct is that since it is made of such thin material, it is inherently noisy. The noise level can increase tremendously if there is a bend in the flex duct. Therefore, the team has designed the diffusers to be laid out as close to the branch duct as possible in order to minimize the length of the flex duct. The type of diffuser is also chosen based on the acoustics emitted by each individual diffuser. The room criteria (RC), an arithmetic average of the sound pressure levels at 500, 1000, and 2000 Hz, provides a standard for choosing the diffuser. For residential buildings, the RC is to be kept between 25 and 30 in order to restrict speech interference.

From the given criteria for the diffusers, the linear slot diffuser Titus Model ML-37 is chosen for the ventilation system, as shown in Figure 24.

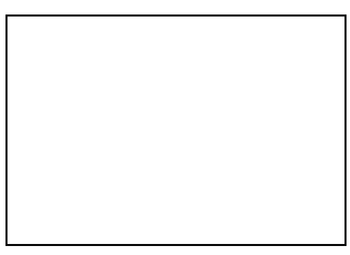

Figure 24. Titus Linear Slot Diffuser (Model ML-37)

The diffuser is designed for the HVAC system with variable air volume (VAV), meaning that the airflow is dynamic based on the loads of the house. Each diffuser is 2 ft (0.6096 m) long and 2 in (50.8 mm) wide. The diffuser implements a 2-slot design in which one slot outputs air parallel to the glass windows and the other blows air down but towards the room. The total volumetric flow rate of each diffuser is 84 CFM (2.38 m^3/min) or 42 CFM/ft (3.902 (m^3/min)/m). Based on an output velocity of 150 fpm, the diffusers throw the air horizontally 14 ft and vertically 16 ft, which will easily suffice for the area of the house.

Another consideration for HVAC design is general ventilation. Even during times when heating and cooling is not necessary, air ventilation is needed for health and safety reasons. Without proper ventilation, sick building syndrome (SBS) can occur, a situation where the house's occupants experience respiratory and other health problems as well as comfort issues. These ailments are usually caused by chemicals and pollutants mostly from within the house, due to adhesives, carpeting, upholstery, and cleaning agents. Also, if stagnant water builds up in ducts, that can be a breeding ground for mold, bacteria, or viruses, which can end up in the living space (EPA, 2008)

The concern for SBS is heightened in the solar house, as the design dictates minimal infiltration and exfiltration from the interior or exterior of the house. In typical houses, the cracks around windows and doors cause enough leakage for proper ventilation. In the solar house, the aim is to seal the house as tightly as possible during the winter and summer months, meaning that a constant supply of outside air is needed and must be pumped through the house in order to maintain proper ventilation. This will be accomplished through the use of an energy recovery ventilator (ERV), which brings in to the house a steady supply of outside air.

Another way to fight SBS is to increase ventilation rates. ASHRAE Standard 62 (for residential buildings) recommends 8.4 air-changes in a 24-hour period or 0.35 air changes per hour. An air change is the process of delivering a volume of air to the space equivalent to the total volume of the space. Since the recommendation is an air change rate, a minimum CFM value for the solar house can be found from:

$$\dot{V}_{min} = \dot{N}_{airchange} V_{total}, \qquad (7)$$

Where V_{min} is the volumetric flow rate, $N_{airchange}$ the rate of the air changes, and V_{total} is the total volume of the house.

Using 0.35 air changes per hour and using interior dimensions of 50 ft x 15 ft x 9 ft (15.24 m x 4.57 m x 2.74 m), the minimum volumetric flow rate can be estimated at 39.4 CFM (1.12 m^3/min). Considering the peak flow rate to the space is 750 CFM (21.24 m^3/min), a value of 39.4 CFM (1.12 m^3/min) for an absolute minimum is very reasonable, but even so, there should be some factor of safety to make sure that the flow rate is always greater than that minimum.

1.29 Plumbing System.

The Solar Decathlon House features a plumbing system to supply cold and hot water throughout the house. The contest rules state that 15 gallons of water at a temperature of 110°F (43.3°C) must be supplied for 10 minutes. This must occur 20 different times during the competition in order to accurately gauge the plumbing capabilities. Domestic hot water runs through a cavity in the concrete floor, supplied by the hot water tank. The hot water tank supplies the water at a rate of 89 GPH to 224 GPH (336.9 LPH to 847.93 LPH), based on the house load. The house's cold water is acquired from an outside cold water supply.

The plumbing system consists of piping, flow valves and various other fittings. PEX piping is chosen over the other options of PVC and copper. PEX is a flexible pipe, meaning that it is more versatile in tracking to the plumbing fixtures. PEX piping can easily be cut e.g., by a hacksaw as opposed to be PVC or copper piping which both need to pre-sized before installation. The flexible nature of the piping allows it to also expand laterally such as in cold conditions. Water is supplied to several different fixtures throughout the house with flows from 2.5 GPM (9.46 LPM) to 5 GPM (18.93 LPM), depending on the desired fixture flow.

1.30 Controls Sequencing

As the project has progressed this semester, the ME design team has worked with Siemens AG to design control mechanisms for the mechanical systems in the house. The APOGEE™ Building Automation system can be used in the solar house to tie the controls into a central personal computer for maintenance and manual control. To this point the team has met with Siemens AG every other Tuesday to synchronize progress with the Siemens representative.

The first step in the design of the control systems is determining the control sequencing. In this process, the flow path of the air, water, electricity, or other appropriate material is written out. This is done for all mechanical systems in the house, including both the airside and waterside of the HVAC, domestic water in the plumbing, power generation with the photovoltaic panels, and actuation of the motion for the insulation and sun shading panels. Once the paths are mapped out, the locations of appropriate controlling and monitoring devices need to be described. For the HVAC and plumbing, flow meters, thermometers/thermocouples, pressure gauges, and humidity sensors are necessary. These sensors are the basis of control and are used for determining how to change dampers and valves in the ductwork and piping in order to control flow rates, and maintain temperatures in the heat exchangers and heat pumps.

The controls system is of vital importance because, if designed and implemented correctly, it is used to maintain the most energy efficient usage of the equipment throughout the entire house. When working properly, the controls force the mechanical systems to run at the most efficient settings possible, while still meeting the energy requirements of the dwelling.

Energy Study and Analysis

1.31 Preliminary Studies

During the summer of 2008, preliminary calculations were completed to provide estimates for the peak cooling and heating loads on the house. First, the materials used in construction are compiled, along with their R-values and thicknesses. Table 2 lists these materials. Next, these materials are entered into DOE-2™, a U.S. Department of Energy (DOE) modeling software; and subsequently, the materials are grouped into "constructions." Constructions in DOE-2™ are walls, floors, roof, windows, and sliding insulation panels that are composed of multiple layers, each layer being a previously-defined material. These constructions are only generic templates meaning that they are just a collection of layers, without any defined dimensions besides layer thicknesses.

The next step is where the actual walls, windows, roof, and floor are created. The surface is named, a construction is selected, and dimensions are specified. Also, coordinates are entered so that the program knows the spatial layout of all the walls, windows, roof, etc. The coordinate system is based on an arbitrary point of origin, usually at a lower corner on the house. Once these are all entered, the program is run and values for heating and cooling load are produced. Also, overall U- and R-values for each exterior surface are produced. The U-value is the overall heat transfer coefficient of a surface, which can be composed of one or more materials. This value is calculated by adding the heat transfer coefficients of all the materials in the surface. The R-value is simply the reciprocal of the U-value. The R-values and U-values of all the exterior surfaces of the solar house can be seen in Table 3.

Table 2. Materials used in the construction of the solar house.

Material	Thickness (in)	R-value (°F-hr-ft^2/Btu)
16-gauge steel	0.06	0.0002
Aerogel filled polycarbonate	1	8
Concrete	4	0.44
Sheathing	0.5	0.78
Isocyurante	1.5	8.3
Single-ply roof membrane	0.375	1.06
SIPS panel	5.5, 7.5	25, 34
Slate	0.5	0.025
North glass	1.023	2.381
South glass	1.019	1.587

Table 3. Overall heat transfer coefficients for the house's exterior surfaces.

	U-value (Btu/hr-ft^2-°F)	R-value
North Wall	0.037	26.7
South Wall	0.037	26.7
East Wall	0.037	26.7
West Wall	0.037	26.7
Roof	0.026	38.5
Floor	0.039	25.4
South Glass	0.630	1.6
North Glass	0.420	2.4
Window Insulation	0.052	19.3

1.32 Creating an Energy Model with EnergyPlus™

EnergyPlus™ is the latest energy modeling software released by the US Department of Energy. Since it is a successor of the DOE-2™ program, the inputs used for the preliminary calculations can be entered directly into EnergyPlus. The materials, constructions, and surfaces are entered into EnergyPlus™ in a manner similar to DOE-2™. The decision to use EnergyPlus™ is based on the fact that it has much greater capabilities than DOE-2™. Since the house employs solar panels, moveable insulation panels, moveable shading panels, and radiant floor heating, these will be needed to accommodate for these technologies.

After entering the surfaces, the next step is to divide the house into thermal zones. A thermal zone is an area in the house with similar temperatures. In a house like this, there are very few zones, but large buildings can have zones composed of four or five entire rooms. EnergyPlus™ sees a thermal zone as a control volume where heat is transferred in and out. Physically speaking, a zone is the area controlled by a single thermostat. Since the bathroom, mechanical closet, and inverter closet are all isolated from the rest of the house and are blocked from the sun, they are given their own zones. Figure 24 below shows the floor plan of the house divided into thermal zones.

Next internal gains are added to the model. The load values reported in the preliminary calculations only took into account solar gains, but the thermal load on the house also includes anything generating heat within the space. Since the solar load accounts for a great majority of the overall load for a small house, some heat producing items within the house can be neglected.

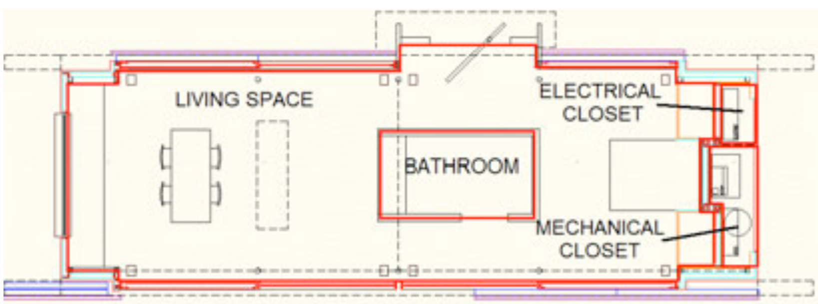

Figure 24. Floor plan of the house separated into thermal zones by the red border.

Since realistically only two people occupy the house most of the time, the heat given off by people can be ignored. Also, any electronic equipment (computers, TV, stereo, etc.) do not produce a significant load either. The lighting, however, more than likely produce enough heat to significantly factor into the overall load. Also, the mechanical equipment in the mechanical closet and the electrical inverters put out sufficient heat to be included as well.

Once the internal gains are in, EnergyPlus™ will give us a more accurate value for the thermal load on the house for both a peak heating and peak cooling day. From there, it calculates the power necessary to condition the space effectively for each of these “worst case scenario” days. The next step is to add in the more advanced features of the house, such as the photovoltaic panels, radiant flooring, and the sliding panels. EnergyPlus™ allows the user to enter what it calls “MovableInsulation” by defining what material is used and the schedule by which the insulation panel is moved. Also in EnergyPlus™, the user can enter moving shading surfaces by assigning it a schedule of varying solar transmittance values.

Thus, the last major step in the energy modeling of the house is adding schedules. Schedules simply are patterns of usage through the year, are used to get a more accurate picture of the energy consumption in the house throughout the year, because all the systems are entered into EnergyPlus™ with nominal or peak values. Since the HVAC system, the sliding panels, the photovoltaic panels, and the lights are not operating at full load for the entire year, schedules set time periods of various levels of usage. For example, during the winter and summer months, the heating and air conditioning may be running at 80% of the peak capacity; but in the spring and fall, there may be no need for heating at all. By adding schedules to the model, the end result of energy usage through the year becomes much more realistic.

1.33 Final Results of the Energy Model

Upon completing the energy model, the mechanical design team intends to have determined the following:

- Determine the energy savings by using movable insulation and shading panels compared to a baseline model with neither type of panel
- Determine if the Solar House is likely to produce a surplus of energy at the end of a year
- Use results of varying iterations of the model to develop a control algorithm for the sliding panels
- Compare energy use using weather data for Washington, D.C. to weather data for Madrid, Spain.

The original version of the energy study completed with DOE-2™ calculated peak heating and cooling loads on the house. The simulation was run with three scenarios: one was a control model that included no shading or insulation, one implemented a shading panel and a third implemented an insulation panel. The results showed that the peak cooling and heating loads are minimized in the insulation panel scenario, and in the shading panel scenario, the peak cooling load was greatly reduced compared to the control scenario. The results of these preliminary studies are presented in Table 4.

Table 4. Peak cooling and peak heating loads for three energy scenarios in DOE-2™.

		Peak Cooling Load (Kbtu/hr)	**Peak Heating Load (Kbtu/hr)**
Control Model			
Trial 1	with skylight	29.023	16.686
Trial 2	without skylight	27.866	16.053
Model with window shading			
Trial 3	with skylight	11.635	19.489
Trial 4	without skylight	9.382	18.831
Model with window insulation			
Trial 5	with skylight	6.488	6.838
Trial 6	without skylight	4.235	6.180

At present, the energy model is based on four separate energy scenarios: one which includes no shading or insulating panels, one which includes the shading panels in their fully closed positions, one which include the insulating panels in their fully closed positions, and one which includes both types of panels in their closed positions. Knowing the heat gains and losses to and from the house for the panels in these four positions gives insight into the amount of additional heating or cooling required by the HVAC system and will eventually lead to a control algorithm that will automatically adjust the panels to optimum positions for a given set of environmental conditions. Table 5 lists the net heat gain into the house over the span of one year for typical Washington, D.C., weather as well as the average mean temperature (without conditioning) in the living space zone of the house.

Table 5. Net energy flow and mean temperature (without conditioning) over a year for the Solar House with shading and insulation panels included and excluded.

Model Iteration	Net Energy Flow (W)	Living Space Mean Temperature (°F)
No shading, no insulation	321.914	98.48
Shading panel	272.301	95.59
Insulation panel	270.027	95.94
Shading and Insulation Panel	269.039	95.97

Table 5 demonstrates that the heat gain on the house decreases significantly with the addition of shading and insulation panels, as expected. These results support the choice to implement the panels, since a lower heat gain translates to less energy required to cool the house. Also, by using the insulation panels in the winter, the house will lose less heat than if the house had bare windows, which also results in less energy required to condition the house. The decrease in mean temperature in the house also shows the ability of the panels to moderate the conditions inside. The temperatures are quite high because the energy model at this point does not include an HVAC system and therefore, air-conditioning is not taken into account.

Overall, when the energy model is completed, it will serve to verify and expand upon the preliminary calculations completed this summer as well as prove that the solar house, as it is planned out now, will efficiently maintain a zero or positive energy balance.

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LIGHTING DESIGN NARRATIVE

Careful consideration has been given to the integration of daylight, electric light, and the corresponding effect on energy conservation, spatial quality, and nighttime identity. Part of our energy conservation strategy to minimize the use of electric light is to maximize the use of daylight. Increasing natural daylight in building is a goal of this design. Studies have shown that people thrive in natural lighting: they are healthier, happier and more productive. Thus, our theme of a *brighter way, brighter day* in which a high quality of space is coupled with energy savings.

An integral feature of the lighting scheme is the *Eclipsis© System* (see architecture narrative) – a network of sliding panels that transform the space though changing natural light values. There is no electric light required from sunrise to sunset. The day lighting strategy of LUMENHAUS offers maximum choice to the users. The *Eclipsis© System* modulates the sun according to the following combinations of sliding panels.

All panels open
- the house functions as a pavilion, open to the air and sun with seamless access to north and south decks – sunlight pours in warming the floor and filling the space with direct light; air flows freely across the space.

Shutter screens closed/insulation panels open
- Sunlight is shielded from the interior space, broken into fractals and reflected by the folded tabs of the shutter screen; dappled light falls into the space; air flows freely across the space.

Insulation panels closed/shutter screens open
- The Nanogel filled polycarbonate panels transmit a beautiful translucent light; even on cloudy days, this highly insulated wall acts as a dematerialized surface, holding light similar to that of a Japanese pagoda; an even glow of soft light fills the space.

In addition to the shutter screens and insulation panels, a set of glass doors and curtains form the interior fenestration. The glass provides acoustical privacy and establishes one layer of the thermal envelope. The curtains have the ability to mix light and air, tossed by gentle breezes when the house is open.

Windows strategically serve activities. Sidelights around the front door and in front of the office are Nanogel filled glass. They admit a soft light, maintain privacy and insulate more than double thermo-pane glass. A horizontal window running the length of the kitchen counter, lights the workspace and provides view. It has an electro-tinted screen process that shields the direct western sun. The light reflecting off the water pool outside splashes dappled sunlight onto the ceiling. A skylight illuminates the innermost room (bathroom). The vertical light of this space contrasts from that of the rest of the house and gives a sense of destination. From this vantage point one can peer up and see the glass encased solar panels above.

Research was conducted regarding the use of LED's (light emitting diodes) for overall lighting. Though these lights have a much longer life span and use less energy, it was found there was less energy draw with fluorescents to achieve the same overall room lighting requirements, thus T - 5 fluorescent tubes with dimmable ballasts provide the overall ambient lighting. They are set above the drop soffit edge of the room and reflect light through the fabric ceiling. This is a high quality light that will fall evenly throughout the space. A modest energy use in relation to its performance, the dimmable ballasts contribute to the economy of the system and quality of light choices.

However, LED's are challenging the present lighting standards and are used for task and accent lighting. They are employed in pairs at each column to create a blanket of warm light (3000°K) at the periphery of the space. LED recessed lights are used for task lighting over the kitchen counter, reading lights over the bed and accent lighting in various areas throughout the house. In addition, the base of the core walls contain LED strip light fixtures. These lights are connected to motion sensors and guide the user throughout the house. When one wakes in the middle of the night and moves toward the bathroom, a set of soft floor lights shifted to a red color will guide him or her there safely.

Task lighting is achieved through the use of a desk LED fixture. For space flexibility and ease of use, two LED floor lamps are placed in the living room for accent and reading. LED's are also placed in the sliding insulation wall assembly (between the polycarbonate panels). This will cause the panels to glow, symbolically radiating out at night the energy that is harvested during day. This light will also serve as general night lighting that provides security around the house. LED house numbers will glow a blue color at the front door throughout the night.

Conservation is an undersubscribed activity. The tendency to leave lights on when they are not needed wastes a considerable amount of energy. The patterns of daily life often result in lights burning when no one is in the room. LUMENHAUS addresses this issue with a system than goes beyond vacancy sensors. Daylight harvesting automatically adjusts the electric lighting levels based on the amount of daylight in the space. It combines daylight and electric light saving energy without user interaction. Remote monitoring and control allows management of the building's light from anywhere in the world.