# SOLAR DECATHLON 2010

# Virginia Tech

As-Built

Project Manual

Sept. 22, 2010

## SUMMARY OF CHANGES

From the dates (09.11.09) to (02.05.10), 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 specific changes made to the project manual (02.05.10):

- Project Manual Table of Contents Added
- Rules and Building Code Compliance Checklist Added
- Construction Specifications Updated
- Construction Drawings Updated
- Detailed Water Budget Revised
- Summary of Reconfigurable Features Revised
- Interconnection Application Form Added
- Energy Analysis and Discussion Revised
- Architecture Narrative Revised
- Acoustic Report Added
- Lighting Design Narrative Revised
- Engineering Design Narrative Revised
- Solar Water Heating Report Added
- Photovoltaic System Report Added
- List of Appliances Added
- Revised Communication Plan
- Industrialization and Market Viability Report Added
- Sustainability Report Added
- Construction Cost Estimate and Project Financial Summary Added
- Dinner Party Menu Added
- Site Operations Plan Added
- Health and Safety Plan Revised

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.

## PROJECT MANUAL TABLE OF CONTENTS


- Cover Page
- Summary of Changes
- Table of Contents
- Rules and Building Code Compliance Checklist
- Construction Specifications
- Structural Calculations
- Detailed Water Budget
- Summary of Unlisted Electrical Components
- Summary of Reconfigurable Features
- Interconnection Application Form
- Energy Analysis Results and Discussion
- Subjective Contest Support Documents
  - Architecture Narrative
  - Acoustic Report
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  - Engineering Design Narrative
  - Solar Thermal Systems
  - Photovoltaic System
  - List of Appliances
  - Communications Plan
  - Industrialization and Market Viability Report
  - Sustainability Report
- Cost Estimate & Project Financial Summary (Not included – Due March 2010)
- Dinner Party Menu
- Site Operations Plan
- Health and Safety Plan (Not included – Due March 2010)

| | | Rule Description | Content Requirement(s) | Drawing(s)/ Report(s) |
|---|---|---|---|---|
| □ | 3.2 | Team Officers and Contact Information | Team officer's contact information completely fulfilled in Table 1 (SDE WAT) | SDE WAT |
| □ | 4.2 | Construction Equipment | Drawing(s) showing the assembly and disassembly sequences and the movement of heavy machinery on the competition site | O-201, SO-30 |
| □ | 4.2 | Construction Equipment | Specs for heavy machinery | |
| □ | 4.3 | Ground Penetration | Drawing(s) showing the locations and depths of all ground penetrations on the competition site | AR-011 |
| □ | 4.4 | Impact on the Ground | Drawing(s) showing the location, contact area and soil-bearing pressure of every component resting directly on the turf | ST-001 |
| □ | 4.5 | Generators | Specifications for generators | |
| | 4.6 | Spill Containment | Drawing(s) showing the locations of all equipment, tanks and pipes that will contain fluids at any point during the event | PL-002, PL-01 |
| □ | 4.6 | Spill Containment | Specifications for all equipment, tanks, and pipes that will contain fluids at any point during the event | |
| □ | 5.2 | Solar Envelope Dimensions | Drawing(s) showing the location of all house and site components relative to the solar envelope | 11, A4-101, A |
| □ | 5.2 | Solar Envelope Dimensions | List of solar envelope exemption requests accompanied by justifications and drawing references | N/A |
| □ | 6.1 | Structural Design Approval | Structural drawings and calculations signed and stamped by a qualified licensed professional | via mail 2/5/1 |
| □ | 6.1 | Electrical Design Approval | Electrical drawings and calculations signed and stamped by a qualified licensed professional | via mail 2/5/1 |
| □ | 6.1 | Codes Design Compliance | List of the country of origin codes complied, properly signed by the faculty advisor, in order to certify compliance and assure safety. | via mail 2/5/1 |
| □ | 6.2 | Maximum Architectural Footprint | Drawing(s) showing all information needed by the Rules Officials to measure the architectural footprint electronically | AR-011 |
| □ | 6.2 | Maximum Architectural Footprint | Drawing(s) showing all movable components that may increase the footprint if operated during contest week | AR-011 |
| □ | 6.2 | Maximum Architectural Footprint | Shading calculations and/or diagrams for components that DO NOT shade the building above its finished floor height between 9 a.m. and 5 p.m. GMT+1 on June 1st (shading calculations and/or diagrams are not necessary for components that are either shorter than finished floor height or obviously do not shade the building) | AR-011 |
| □ | 6.3 | Minimum Conditioned Space | Drawing(s) showing space conditioning means in primary living spaces | AR-051 |
| □ | 6.4 | Entrance and Exit Routes | Drawing(s) showing the accessible public tour route | PT-101 |
| □ | 7.1 | Placement | Drawing(s) showing the location of all vegetation and, if applicable, the movement of vegetation designed as part of an integrated mobile system | AR-012 |
| □ | 7.2 | Watering Restrictions | Drawings showing the layout and operation of greywater irrigation systems | N/A |
| □ | 8.1 | PV Technology Limitations | Specifications for photovoltaic components | PM p.295 |
| □ | 8.1 | PV Technology Limitations | Contractor price quote for photovoltaic components | PM p.443 |
| □ | 8.3 | Thermal Energy Storage | Drawing(s) showing the location of thermal energy storage components | N/A |
| □ | 8.3 | Thermal Energy Storage | Specifications for thermal energy storage components | N/A |
| □ | 8.3 | Thermal Energy Storage | Shading calculations and/or diagrams for thermal energy storage components (if necessary) | N/A |
| □ | 8.4 | Batteries | Drawing(s) showing the location(s) and quantity of stand-alone, PV-powered devices | N/A |
| □ | 8.4 | Batteries | Specifications for all stand-alone, PV-powered devices | N/A |
| □ | 8.4 | Batteries | Drawing(s) showing the location(s) and quantity of hard-wired battery banks components | N/A |
| □ | 8.4 | Batteries | Specifications for hard-wired battery bank components. | N/A |
| □ | 8.5 | Desiccant Systems | Drawing(s) describing the operation of the desiccant system | N/A |
| □ | 8.5 | Desiccant Systems | Specifications for desiccant system components | N/A |
| □ | 8.6 | Village Grid | Electrical and Photovoltaic Chart | PM p.359 |
| □ | 8.8 | Humidification systems | Specifications for humidification systems and corresponding certifications of the different elements. | N/A |
| □ | 9.1 | Tank locations | Drawing(s) showing the location of all the water tanks relative to the conditioned zone(s) and shading(s) | PL-003 |

| | | Rule Description | Content Requirement(s) | Drawing(s)/ Report(s) |
|---|---|---|---|---|
| □ | 9.3 | Grey water reuse | Specifications for grey water reuse systems. | N/A |
| □ | 9.4 | Rainwater Collection | Drawing(s) showing the layout and operation of rainwater collection systems | PL-011 |
| □ | 9.6 | Thermal Mass | Drawing(s) showing the locations of water-based thermal mass systems | N/A |
| □ | 9.6 | Thermal Mass | Specifications for components of water-based thermal mass systems | N/A |
| □ | 9.7 | Grey Water Heat Recovery | Specifications for grey water heat recovery systems. | N/A |
| □ | 9.8 | Water Delivery | Drawing(s) showing the fill location(s), quantity of water requested at each fill location, tank dimensions, diameter of opening(s) and clearance above the tank(s). | PL-003 |
| □ | 9.9 | Water Removal | Drawing(s) showing the quantity of water to be removed from each fill location, tank dimensions, diameter of opening(s) and clearance above the tank(s). | PL-003 |
| □ | 10.2 | Event Sponsor Recognition | Drawing(s) showing the dimensions, materials, artwork, and content of all communications materials, including signage | TBD |
| □ | 10.3 | Team Sponsor Recognition | Drawing(s) showing the dimensions, materials, artwork, and content of all communications materials, including signage | TBD |
| □ | 11.4 | Public Exhibit | Drawing(s) showing the dimensions, materials, artwork, and content of the handout | PT-101, PT-20 |
| □ | 11.5 | Team Uniform | Drawing(s) showing the artwork and content of the team uniform | TBD |
| □ | 36.2 | Lots | Drawing(s) showing the storage and unloading areas | SO-201 |
| □ | 36.2 | Lots | Calculations (Specifications) showing the load of storage element area | SO-201 |
| □ | 36.2 | Lots | Calculations showing that structural design remains compliant even if 0.45 m of vertical elevation change exists | AR-212 |
| □ | 36.2 | Lots | Drawing(s) showing shimming methods and materials to be used if 0.45 m of vertical elevation change exists on the lot | 14 - AR-019, S |
| □ | 38.2 | Instrumentation | Drawing(s) showing the location of bi-directional meters, metering box, sensors and cables. | EL-501 |
| □ | 40.3 | Fire Safety | Specifications for Fire Reaction of Constructive elements | |
| □ | 40.4 | Security against falls | Specifications of compliance with the slipperiness degree classes of floors included in House tour | TBD |
| □ | 40.4 | Security against falls | Drawing(s) showing compliance with conditions for uneven flooring and for floor with different level | R-201 - AR-21 |
| □ | 40.4 | Security against falls | Drawing(s) showing compliance with conditions Restricted Areas stairs, Public Areas Staircases,Restricted Areas Ramps and Public Areas Ramps | R-201 - AR-21 |
| □ | 40.4 | Safety for avoiding trapping and impact risk | Drawing(s) showing compliance with conditions for avoiding trapping and impact risk | EL-701 |
| □ | 40.4 | Safety against the risk of inadequate lighting | Specifications for level of illumination of house tour areas light fittings | TBD |
| □ | 40.5 | Accesibility | Interior and exterior plans showing entire accessible tour route | PT-001, PT-10 |
| □ | 40.6 | Structural Safety | Specifications for using dead loads, live loads,safety factors and load combinations in the structural calculations | PM p.320-321 |
| □ | 40.7 | Electrical and PV System | Drawing(s) showing the locations of the photovoltaics, inverter(s), meter housing, service equipment, and grounding means | EL-501, EL-70 |
| □ | 40.7 | Electrical and PV System | Specifications for the photovoltaics, inverter(s), meter housing, service equipment, and grounding means | -wiring sched |
| □ | 40.7 | Electrical and PV System | Diagram(s) showing Electricity and Pv system | SS- |
| □ | 40.7 | Electrical and PV System | One-line electrical diagram | EL-501 |
| □ | 40.7 | Electrical and PV System | Drawing(s) showing the house, decks, ramps, tour paths, metering box, meter housing, main utility disconnect, and other service equipment | EL-101 |

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# SECTION 01 10 00

# SUMMARY OF WORK

## PART 1 - GENERAL

### 1.01 SUMMARY

A. Specification Includes:

1. Summary of work completed or to be completed for the Solar Decathlon Europe.

### 1.02 PROJECT REQUIREMENTS

A. Project Identification: Virginia Tech Solar Decathlon Europe House, Blacksburg, VA. Project Owner: Virginia Polytechnic Institute and State University.

B. Sustainable Design Intent: Comply with project requirements intended to achieve a certifiable rating, measured and documented according to the LEED for Homes, Green Building Rating System, of the US Green Building Council (USGBC).

C. Project Requirements for Temporary Utilities and Facilities:

1. Utility Costs: The Contractor shall meter and pay for cost of utility services consumed, including electricity, water, gas and temporary heat.

D. Permits and Fees: Apply for, obtain, and pay for permits, fees, and utility company backcharges required to perform the work.

E. Codes for Blacksburg, VA: Comply with applicable codes and regulations of authorities having jurisdiction. Submit copies of inspection reports, notices and similar communications to Architect. Codes for Madrid, Spain: Comply with applicable codes and regulations outlined by the Solar Decathlon Europe Governing Body. Post all inspection reports, notice and similar on Madrid construction site for reference and keep copy for project closeout.

F. Dimensions: Verify dimensions indicated on drawings with field dimensions before fabrication or ordering of materials. Do not scale drawings.

G. Existing Conditions: Notify Architect of existing conditions differing from those indicated on the drawings.

### 1.03 SPECIFICATION INFORMATION

A. These specifications are a specialized form of technical writing edited from master specifications and contain deviations from traditional writing formats. Capitalization, underlining and bold print is only used to assist reader in finding information and no other meaning is implied.

B. Sections are generally numbered in conformance with Construction Specifications Institute Masterformat System. Numbering sequence is not consecutive. Refer to the table of contents for names and numbers of sections included in this Project.

C. Pages are numbered separately for each section. Each section is noted with "End of Section" to indicate the last page of a section.

### 1.04 CODES AND REGULATIONS

A. Comply with all applicable codes, ordinances, regulations and requirements of authorities having jurisdiction.

B. Submit copies of all permits, licenses, certifications, inspection reports, releases, notices, judgments, and communications from authorities having jurisdiction to the Architect. All documentation will be retained for final house placement after the Solar Decathlon Europe Competition.

C. All drawings and documents are to be submitted and approved by the Solar Decathlon Europe Governing Body prior to any construction beginning in Spain. The Event overseers must sign-off and approve all construction prior to the house being open for exhibit or participation in the Solar Decathlon Europe Competition.

1.05 PROCEDURES AND CONTROLS

A. Project Meetings: Arrange for and attend meetings with the Architect and such other persons as the Architect requests to have present. The Contractor shall be represented by a principal, project manager, general superintendent or other authorized main office representative, as well as by the Contractor's field superintendent.

B. Layout: Layout work and be responsible for all lines, elevations, and measurements of the building, grading, utilities and other work executed under the contract.

C. Field Measurements: Verify measurements at the building prior to ordering materials or commencing work. No extra charge or compensation will be allowed because of differences between actual dimensions and measurements indicated on the Drawings. Differences which may be found shall be submitted to the Architect for decision before proceeding with the work.

D. Observation: Notify the Architect and authorities having jurisdiction at least thirty-six hours in advance of concealing any work.

E. Utilities: Prior to interrupting utilities, services or facilities, notify the utility owner and the Owner and obtain their written approval a minimum 48 hours in advance.

F. Furnishings, Fixtures, and Equipment: Cooperate and permit the Owner to install his furnishings and equipment during the progress of the work. Owner's installation of furnishings or equipment does not signify Owner's acceptance of any portion of the work.

G. Clean-Up: Frequently clean-up all waste, remove from site regularly, and legally dispose of offsite.

H. Installer's Acceptance of Conditions: All installers shall inspect substrates and conditions under which work is to be executed and shall report in writing to the Contractor all conditions detrimental to the proper execution and completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means installer accepts previous work and conditions.

1.06 WARRANTIES

A. Warranties Required: Refer to individual trade sections for specific product warranty requirements.

B. Procurement: Where a warranty is required, do not purchase or subcontract for materials or work until it has been determined that parties required to countersign warranties are willing to do so.

C. Warranty Forms: Submit written warranty to Owner through Architect for approval prior to execution. Furnish two copies of executed warranty to Owner for his records; furnish two additional conformed copies where required for maintenance manual.

D. Work Covered: Contractor shall remove and replace other work of project which has been damaged as a result of failure of warranteed work or equipment, or which must be removed and replaced to provide access to work under warranty. Unless otherwise specified, warranty shall cover full cost of replacement or repair, and shall not be pro-rated on basis of useful service life.

E. Warranty Effective Starting Date: Guarantee period for all work, material and equipment shall begin on the date of substantial completion, not when subcontractor has completed his work nor when equipment is turned on. In addition to the one-year guarantees for the entire work covered by these Contract Documents, refer to the various sections of the specifications for extended guarantee or maintenance requirements for various material and equipment.

1.07 TEMPORARY FACILITIES AND UTILITIES

A. Scope of Temporary Work: This article is not intended to limit the scope of temporary work required under the Contract. Provide all temporary facilities and utilities needed.

B. Permits and Fees: Obtain and pay for all permits, fees and charges related to temporary work.

C. Codes and Authorities Having Jurisdiction for Temporary Facilities and Utilities: Comply with all requirements of authorities having jurisdiction, codes, utility companies, OSHA, and industry standards including, but not limited to the following:

1. Solar Decathlon Europe Building Code
2. IBC, International Building Code
3. NFPA Code 241, Building Construction and Demolition Operations.
4. ANSI-A10 Series, Safety Requirements for Construction and Demolition.
5. NECA National Joint Guideline NJG-6, Temporary Job Utilities and Services.
6. Electrical Service: NEMA, NECA, and UL.

D. Equipment and Tools: Provide all equipment including, but not limited to, hoists, lifts, scaffolding, machines, tools and the like, as needed for execution of the work. Provide safe access to all parts of the work.

E. Temporary Enclosures: Provide temporary enclosures to maintain proper temperatures and to prevent weather damage. Always maintain legal means of egress.

F. Streets, Walks and Grounds: Maintain public and private roads and walks clear of debris caused by construction operations. Repair all damage caused to streets, drives, curbs, sidewalks, fences, poles and similar items where disturbed or damaged by building construction and leave them in as good condition after completion of the work as before operations started.

G. Protection: Protect nearby property and the public from construction activities. Provide and maintain barricades, warning signs and lights, railings, walkways and similar items. Immediately repair damaged property to its condition before being damaged.

H. Construction Fencing: Provide construction fencing and barriers as applicable to the project and as required by code to protect personnel, the public, and to control access on the Somerville, MA building site.

I. Fire Prevention: Take every precaution to prevent fire. Provide and maintain in good operating condition suitable and adequate fire protection equipment and services, and comply with recommendations regarding fire protection made by the representative of the fire insurance company carrying insurance on the Work or by the local fire chief or fire marshal. The area within the site limits shall be kept orderly and clean, and all combustible rubbish shall be promptly removed from the site.

J. Egress: Maintain safe and legal means of egress at all times. At all times, provide at least two separate means of egress.

1.08 DELIVERY, STORAGE AND HANDLING

A. Manufacturer's Instructions: Strictly comply with manufacturer's instructions and recommendations and prevent damage, deterioration and loss, including theft. Minimize long term storage at the site. Maintain environmental conditions, temperature, ventilation, and humidity within range permitted by manufacturers of materials and products used.

1.09 RECORD DOCUMENTS

A. General: Keep record documents neatly and accurately. Record information as the work progresses and deliver to Architect at time of final acceptance. Include in record documents all field changes made, all relevant dimensions, and all relevant details of the work. Keep record documents up to date with all field orders and change orders clearly indicated.

B. Drawings: One set of current, complete construction documents shall be kept and submitted to the Solar Decathlon Europe Governing Body for competition purposes. Neatly and accurately note all deviations from the Contract Documents and the exact actual location of the work as installed. Marked-up and colored prints will be used as a guide to determine the progress of the work installed. Requisitions for payment will not be approved until the record documents are accurate and up-to-date.

1. At completion of the work, submit one complete set of marked-up prints for review. After acceptance these marked-up prints shall be used in the preparation of the record drawings.
2. A record set shall be submitted to Virginia Polytechnic Institute and State University.

C. Operating and Maintenance Manuals: Manuals shall be submitted which contain the following:

1. Description of the system provided; mark each copy to show which choices and options are applicable to project.
2. Handling, storage, and installation instructions.
3. Detailed description of the function of each principal component of the systems or equipment.
4. Operating procedures, including prestartup, startup, normal operation, emergency shutdown, normal shutdown and troubleshooting.

5. Maintenance procedures including lubrication requirements, intervals between lubrication, preventative and repair procedures, and complete spare parts list with cross reference to original equipment manufacturer's part numbers.
6. Safety and environmental considerations.

1.10 FINAL CLEANING AND REPAIR

A. Clean Up: Immediately prior to the Architect's inspection for Substantial Completion, the Contractor shall completely clean the premises and clean and prepare the completed work in order for it to be used for its intended purpose in accordance with the Contract Documents. Such work shall include, but not be limited to the following:
   1. Concrete and ceramic surfaces shall be cleaned and washed.
   2. Resilient coverings shall be cleaned, waxed and buffed as applicable.
   3. Woodwork shall be dusted and cleaned.
   4. Sash, fixtures and equipment shall be thoroughly cleaned.
   5. Stains, spots, dust, marks and smears shall be removed from all surfaces.
   6. Hardware and metal surfaces shall be cleaned and polished.
   7. Glass and plastic surfaces shall be thoroughly cleaned by professional window cleaners.
   8. Damaged, broken or scratched glass or plastic shall be replaced by the Contractor at the Contractor's expense.
   9. Vacuum carpeted and soft surfaces with high efficiency particulate arrestor (HEPA) vacuum.
   10. Use low-emitting, environmentally friendly cleaning agents and procedures.

B. Repairs: Repair and touch-up all damaged and deteriorated products and surfaces.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

<u>END OF SECTION</u>

# SECTION 01 31 23

# PROJECT WEBSITE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Summary of Virginia Tech Solar House website.

1.02 DESCRIPTION

A. 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.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION

www.lumenhaus.com

# SECTION 02 43 13
# BUILDING RELOCATION

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes

1. Specification for the methods, equipment and schedules necessary for the transportation of the Virginia Tech LUMENHAUS from Blacksburg, VA to Madrid, Spain and back.

### 1.02 SUBMITTALS

A. Transportation schedule including shipping schedules as set by the company

B. Building Permits

C. Weight Calculations

D. Assembly Diagrams

### 1.03 SYSTEM DESCRIPTION

A. The transportation system is inspired by and integrated into the double drop lowboy trailer. It includes removable components (axle/wheel assembly on the back and hitch hookup on the front) that allow for simple truck transport, flexible suspension, and higher height clearances than conventional modular transportation methods.

B. Torque boxes, installed in the structure below the house, contain a removable gooseneck and bogey (typically fixed components for trucking trailers).

## PART 2 PRODUCT

### 2.01 PRODUCT TYPE

A. Custom Modular Home Moving Equipment

### 2.02 MANUFACTURERS

A. Fountaine Specialized Co.

### 2.03 BASIS OF DESIGN

A. Design Requirements

1. The House is designed to use an innovative transportation system, built into its structure, which allows for a quick, affordable, and efficient transition from site to site.

   a. A series of diagonal beams shall serve to brace the house while in transit. These diagonals will reside between each column and help to prevent racking of the entire structure.

   b. A removable gooseneck and bogey shall be attached to the House while in transit. Both shall be removed and stored onsite once the House has been leveled.

2. Dimensions of the entire structure shall not exceed the allowable dimensions for highway transportation under federal highway laws.

B. Performance Requirements

1. The House as a whole must perform identically before and after transportation and re-construction.
2. The House shall be transported as one movable unit with minimal assemblage.
3. Movable parts of the House shall be secured so as to not cause any damage to the House or the surrounding environment.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. The House and all of its components shall be disassembled, reassembled, packed, secured, and shipped by designated individuals in accordance with the specified instructions.

END OF SECTION

http://www.fontainetrailer.com/

# SECTION 03 24 00

# FIBROUS REINFORCING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification 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. Tensile strength of 203,000 psi (1400 MPa).

B. 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.

C. 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 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 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 03 31 13

# 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.

### 1.05 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 PRODUCT TYPE

A. Poured in place concrete.

2.02 MANUFACTURERS

A. LCJ Enterprises – Concrete Contractors

2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities

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

2.04 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 ENVIRONMENTAL 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 PRODUCT TYPE

A. Polished concrete and sealant.

2.02 MANUFACTURERS

A. HTC Professional Floor Systems

2.03 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.

2.04 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 INSTALLERS

A. HTC Professional Floor Systems

B. Virginia Tech Solar Decathlon Team

3.02 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.

3.03 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.

3.04 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.

3.05 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 03 35 19

# COLORED CONCRETE FINISHING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:
   1. Specification for integrally colored concrete.
   2. Specification for the curing of integrally colored concrete.

### 1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. ACI 301 "Specification for Structural Concrete for Buildings."
   2. ACI 302 IR "Recommended Practice for Concrete Floor and Slab Construction."
   3. ACI 303.1 "Standard Specification for Cast-In-Place Architectural Concrete."
   4. ACI 304 "Recommended Practice for Measuring, Mixing, Transporting and Placing of Concrete."
   5. ACI 305R "Recommended Practice for Hot Weather Concreting."
   6. ACI 306R "Recommended Practice for Cold Weather Concreting."

B. American Society for Testing and Materials (ASTM):
   1. ASTM C309 "Liquid Membrane-Forming Compounds for Curing Concrete."
   2. ASTM C494 "Standard Specification for Chemical Admixtures for Concrete."
   3. ASTM C979 "Standard Specification for Pigments for Integrally Colored Concrete."

C. American Association of State Highway and Transportation Officials (AASHTO):
   1. AASHTO M194 "Chemical Admixtures."

### 1.03 SUBMITTALS

A. Product Data
   1. Submit manufacturer’s complete technical data sheets for the following:
      a. Colored admixture.
      b. Curing compound.

B. Design Mixes
   1. For each type of integrally colored concrete.

C. Samples for Initial Selection
   1. Manufacturer's color charts showing full range of colors available.

D. Qualification Data
   1. For firms indicated in "Quality Assurance" Article, including list of completed projects.

### 1.04 QUALITY ASSURANCE

A. Manufacturer Qualifications
   1. Manufacturer with 10-years experience in the production of specified products.

B. Comply with the requirements of ACI 301.

C. Obtain each specified material from same source and maintain high degree of consistency in workmanship throughout Project.

D. Notification of manufacturer's authorized representative shall be given at least 1-week before start of work.

1.05 DELIVERY, STORAGE AND HANDLING

A. Colored Admixture

1. Comply with manufacturer's instructions. Deliver colored admixtures in original, unopened packaging. Store in dry conditions.

B. Schedule delivery of concrete to provide consistent mix times from batching until discharge. Mix times shall meet manufacturer’s written recommendations.

1.06 ENVIRONMENTAL CONDITIONS

A. Schedule placement to minimize exposure to wind and hot sun before curing materials are applied.

B. Avoid placing concrete if rain, snow, or frost is forecast within 24-hours. Protect fresh concrete from moisture and freezing.

C. Comply with professional practices described in ACI 305R and ACI 306R.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Integrally Colored Concrete

B. Integrally Colored Concrete Curing Agent

2.02 MANUFACTURERS

A. L.M. Scofield Co.

2.03 MATERIALS

A. Colored Admixture for Integrally Colored Concrete: Chromis P Admixture and Chromix ML

1. Admixture shall be a colored, water-reducing, admixture containing no calcium chloride with coloring agents that are limeproof and ultra-violet resistant.

2. Colored admixture shall conform to the requirements of ACI 303.1, ASTM C979, ASTM C494 and ASSHTO M194.

B. Substitutions

1. The use of products other than those specified will be considered providing that the Contractor requests its use in writing within 14-days prior to bid date. This request shall be accompanied by the following:

a. A certificate of compliance from material manufacturer stating that proposed products meet or exceed requirements of this Section, including standards ACI 303.1, ASTM C979, ASTM C494 and AASHTO M194.

C. Concrete Color

1. Cement: Color shall be gray.

2. Sand: Color shall match Architect’s sample.

3. Aggregate: Concrete producer's standard aggregate complying with specifications.
4. Colored Admixture: As selected by Architect from Scofield Color Chart A-312.

D. Concrete Mix Design

1. Minimum Cement Content: 5 sacks per cubic yard of concrete.
2. Slump of concrete shall be consistent throughout Project at 4-inches or less. At no time shall slump exceed 5-inches.
3. Do not add calcium chloride to mix as it causes mottling and surface discoloration.
4. Supplemental admixtures shall not be used unless approved by manufacturer.
5. Do not add water to the mix in the field.
6. Add colored admixture to concrete mix according to manufacturer's written instructions.

PART 3 EXECUTION

3.01 INSTALLERS

A. L.M. Scofield Co.

3.02 INSTALLATION

A. Install concrete according to requirements of Division 3 Section "Cast-In-Place Concrete."

B. Do not add water to concrete mix in the field.

C. Surfaces shall be finished uniformly with the following finish:

1. Trowel: Precautions should be taken to ensure that the surface is uniformly troweled so that it will not be slippery. Do not over-trowel or burnish the surface.

3.03 CURING

A. Integrally Colored Concrete: Apply curing compound for integrally colored concrete according to manufacturer's instructions using manufacturer’s recommended application techniques. Apply curing compound at consistent time for each pour to maintain close color consistency.

B. Curing compound shall be same color as the colored concrete and supplied by same manufacturer of the colored admixture.

C. Precautions shall be taken in hot weather to prevent plastic cracking resulting from excessively rapid drying at surface as described in CIP 5 *Plastic Shrinkage Cracking* published by the National Ready Mixed Concrete Association.

D. Do not cover concrete with plastic sheeting.

3.04 TOLERANCES

A. Minor variations in appearance of integrally colored concrete, which are similar to natural variations in color and appearance of uncolored concrete, are acceptable.

END OF SECTION

http://www.scofield.com/coloredconcrete_colors.html

# SECTION 03 63 00

# EPOXY GROUTING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specifications for Euclid “Euco 700” semi-rigid, industrial floor joint filler for interior concrete construction and control joints.

B. Products Furnished

1. Semi-rigid, industrial concrete floor joint filler.

### 1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM C 109, Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens).
2. ASTM D 570 – Water Absorption of Plastics.
3. ASTM D 638 – Tensile Properties of Plastics.
4. ASTM D 2240 – Rubber Property – Durometer Hardness.

### 1.03 QUALITY ASSURANCE

A. Qualifications

1. ISO 9001/9002 registered or provide proof of documented quality assurance system. Quality assurance system shall be registered by independent registrar accredited by ANSI Registrar Accreditation Board (ANSI-RAB) or by another internationally recognized body.

### 1.04 DELIVERY, STORAGE, AND HANDLING

A. Delivery

1. Deliver materials to site in manufacturer’s original, unopened containers and packaging, with labels clearly identifying product name and manufacturer.

B. Storage

1. Store materials in clean, dry area in accordance with manufacturer’s instructions.
2. Keep containers sealed until ready for use.

C. Handling

1. Protect materials during handling and application to prevent damage or contamination.

### 1.05 ENVIRONMENTAL CONDITIONS

A. Ambient Conditions

1. Do not apply joint filler when concrete surface or air temperatures are below 40 degrees F (4 degrees C).

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Euclid Euco 700 – semi-rigid, industrial floor joint filler

2.02 MANUFACTURERS

A. The Euclid Chemical Company

2.03 MATERIALS

A. Type: 2-component, semi-rigid epoxy.

B. Compliance: ACI 302.1R recommendations for joint fillers used in control and construction joints.

C. Compressive Strength, ASTM C 109, 72 Hours: 3,000 psi (20.7 MPa).

D. Tensile Strength, ASTM D 638, 7 Days: 690 psi (4.6 MPa).

E. Elongation, ASTM D 638, 7 Days: 55 percent.

F. Water Absorption, ASTM D 570, 72-Hour Immersion: 1.1 percent.

G. Shore D Hardness, ASTM D 2240, 7 Days: 55.

H. Shore A Hardness, ASTM D 2240: Greater than 100.

I. USDA approved.

PART 3 EXECUTION

3.01 PREPARATION

A. Prepare joints in accordance with manufacturer's instructions.

B. Ensure joints are clean, dry, and sound.

C. Remove from joints and joint edges dirt, dust, debris, oil, grease, paint, curing, compounds, sealers, residue, and other materials that may act as a bond breaker.

D. Floor Cracks: Rout-out and clean cracks. Square crack edges.

E. Based on ACI 302.1R recommendations, joint filler should be deferred as long as possible to allow for minimal additional slab shrinkage. Consult ACI 302.1R comments regarding concrete shrinkage, joint filling, and user expectations.

F. Ensure concrete is a minimum of 28 days old.

3.02 APPLICATION

A. Apply joint filler to control and construction joints in concrete floors in accordance with manufacturer's instructions.

B. Mix components in accordance with manufacturer's instructions.

C. Fill joint or crack full depth with joint filler for proper load transfer. Do not use backer rod, sand, or other fill material to reduce volume.

D. Pour joint filler into joints in accordance with manufacturer's instructions. Fill joints 2/3 full and allow filler to settle. Complete filling within 1 hour to level of floor or overfill joints.

E. Cut or grind joint filler flush with floor within 24 hours after placement.

F. Do not use joint filler in expansion or isolation joints.

END OF SECTION

http://www.euclidchemical.com/product_detail.asp?id=116&pselect=236&cselect=261&tselect=288

# SECTION 05 12 00

# STRUCTURAL STEEL FRAMING

## 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 PRODUCT TYPE

A. Steel Members

1. W8x10, ASTM A572

2. W6x15, ASTM A572
3. W12x25, ASTM A572
4. W12x26, ASTM A572
5. HSS 4x5/16 Round, ASTM A500
6. HSS 4x4x5/16 Rectangular, ASTM A500
7. HSS 10x4x3/16 Rectangular, ASTM A500
8. 3x3x3/16 Angled
9. 4x4x5/16 Angled
10. 1.5x2.5 Tubular
11. 1/4x2.5 Bar

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.

B. Ace 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 "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 "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 00

# 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 REFERENCES

A. Steel Deck Institute (SDI)

1. "Steel Roof Deck Design Manual."

B. American Iron and Steel Institute (AISI)

1. AISI-02 - "Specifications for Design of Light Gauge Cold-Formed Steel Structural Members."

C. American Welding Society

1. (AWS) D1.3 - "Structural Welding Code-Sheet Steel"

D. ASTM – American Society for Testing & Inspection

1. A-653 - "Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc Iron Alloy-Coated Galvannealed) by the Hot-Dip Process.

2. A-780 – "Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings"

3. A-924 – "Specification for General Requirements for Sheet Steel, Metallic-Coated by the Hot-Dip Process"

### 1.03 SUBMITTALS

A. Shop Drawings

1. Shop Drawings: Show complete erection layouts, connection details, welds, and anchorages. Indicate framing and support locations, dimensions and marking of decking sections to correspond with installation sequence and procedure; show connections with adjoining construction and materials, types of welds and locations of all holes and/or openings in decking.

B. 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 PRODUCT TYPE

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 PREPARATION

A. Examine the areas and conditions under which metal decking is to be installed and provide written notification of conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions have been corrected in a manner acceptable to the installer.

3.03 INSTALLATION

A. General: Install deck units and accessories in accordance with manufacturer's recommendations and final shop drawings, and as specified herein. Place deck units on supporting steel framework and adjust to final position with ends accurately aligned and 2" minimum bearing on supporting members before being permanently fastened. Do not stretch or contract side lap interlocks. Place deck units flat and square and provide solid level bearing at steel supports and secured to adjacent framing without warp or excessive deflection. Coordinate and cooperate with structural steel erector in locating decking bundles to prevent overloading of structural members.

1. Do not use floor deck units for storage or working platforms until permanently secured in position.

B. Fastening deck units: Fasten composite deck units to steel supporting members by not less than 3/4" diameter fusion welds, spaced not more than 12" o.c. at supports. Comply with AWS requirements and procedures for manual shielded metal arc welding, the appearance and quality of welds, and the methods used in correcting welding work. Button punch interlocking side laps of adjacent deck units between supports, at intervals not exceeding 30" o.c.

C. Cutting and fitting: Cut and neatly fit deck units and accessories around other work projecting through or adjacent to the decking, as shown on the drawings.

D. Reinforcement at openings: Provide additional metal reinforcement and closure pieces as required for strength, continuity of decking and support of other work shown. Reinforce decking around openings 6" to 12" in size by means of flat galvanized steel sheet placed over opening on top of decking and fusion welded to surface of deck. Provide 18 gauge steel sheet of same quality as deck units at least 12" wider and longer than opening. Space welds at each corner at not more than 12" o.c. along each side.

E. Install 6" minimum wide sheet steel cover plates, of same thickness as decking where deck changes direction. Puddle weld 12" on center maximum.

F. Shear connections: Weld shear connectors to supports through decking units in accordance with manufacturer's instructions. Do not weld shear connectors through two layers (lapped ends) of decking units. Weld only on clean, dry deck surfaces.

G. Closure strips: Provide metal closure strips at all open uncovered ends and edges of decking, and in the voids between decking and other construction. Weld into position to provide a complete decking installation. Weld screed angles to spandrel beams for complete perimeter forming.

H. Touch-up painting: After decking installation, wire brush, clean and paint scarred areas, welds and rust spots on the top and bottom surfaces of decking units and supporting steel members. Touch-up galvanized surfaces with the same type of shop paint used on adjacent surfaces per ASTM A780-80. Touch-up painted surfaces with the same type of shop paint used on adjacent surfaces. In areas where shop-painted surfaces are to be exposed, apply touch-up paint to blend into the adjacent surfaces.

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

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# 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 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.

### 1.03 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.

### 1.04 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.

### 1.05 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 MANUFACTURERS

A. Unirac, Inc.

### 2.03 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.

2.04 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 53 00

# METAL GRATINGS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specifications for aluminum I-Bar grating.

### 1.02 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.

### 1.03 QUALITY ASSURANCE

A. 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). Aluminum: ASTM B221, Aluminum Alloy, Extruded Bars, Rods, Wire, Shapes and Tubing.

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

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. 11-SGI-4 1" Mill Aluminum I-Bar Swaged Grating

B. 7-SGI-4 1" Mill Aluminum I-Bar Swaged Grating

### 2.02 MANUFACTURERS

A. Ohio Gratings, Inc.

### 2.03 MATERIALB / DESIGN CRITERIA

A. Grating: Aluminum I-bar SGI Series by Ohio Gratings, Inc., or approved equal.

B. Bearing Bars: I-Bar section with 1/4" flanges on a maximum of 1 3/16" centers.

C. Cross Bars: Locked at right angles to bearing bars at a maximum of 4" on center.

D. Surface: Flanges to have a striated surface.

E. 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 1/4".

F. Finish: Mill finished.

G. Fabrication and Tolerances: in accordance with the NAAMM metal Bar Grating Manual.

## PART 3 EXECUTION

### 3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 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 grating placement.

B. Install grating in accordance with shop drawings and standard installation clearances as recommended by the 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. Wherever grating is pierced by pipes, ducts and structural members, cut openings neatly and accurately to size and weld a rectangular band bar of the same height and material as bearing bars.
3. Cutouts for circular obstructions are to be at least 2" larger in diameter than the obstruction. Cutouts for all piping 4" or less shall be made in the field.
4. All rectangular cutouts are to be made to the next bearing bar beyond the penetration with a clearance not to exceed bearing bar spacing.
5. 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 approved insulating material.

END OF SECTION

http://www.ohiogratings.com/pdfs/OhioGratings-NewProductCatalog.pdf

# SECTION 05 58 00

# FORMED METAL FABRICATIONS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for movable stainless steel shade screens.

### 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.

C. Shop Drawings

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

### 1.03 QUALITY ASSURANCE

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

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Stainless steel sunshade screen. The custom metal panel assemblies are part of a system that passively cools the house. The design will include comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

### 2.02 MANUFACTURERS

A. Panel Fabricator: Select metal panel fabricator that has the equipment and personnel capable of providing quality stainless steel wall panel profiles and finishes as indicated on the drawings. Manufacturers offering custom metal wall panel assemblies and finishes that may be incorporated in the work include:

1. Ryerson Co.
2. LPF High Performance Coatings

### 2.03 MATERIALS

A. Screen Façade

1. 16-Gauge Stainless Steel

B. Framing

1. 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.

C. Finish

1. Angel Hair: Multidirectional abrasive finish with random grit lines.

2.04 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 stainless steel.

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

B. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

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.

C. Ensure that cleaning by other trades working in proximity to custom panel assembly installation is in accordance with the recommendations of the panel 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.ryerson.com/

http://www.lpfcoatings.com/default.htm

# SECTION 06 10 53

# MISCELLANEOUS ROUGH CARPENTRY

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for framing with dimension lumber.
2. Specification for wood blocking and nailers.
3. specification for 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. Specification for Structural Insulated Panels (SIPs).

### 1.02 REFERENCES

A. ACSE 7 - Minimum Loads for Buildings and other Structures.

B. ASTM C578 – Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation.

C. DOC PS2 – Performance Standard for Wood-based Structural-Use Panels.

D. ICC ES AC04 – Acceptance Criteria for Sandwich Panels.

E. ICC ES AC05 – Acceptance Criteria for Sandwich Panel Adhesives.

F. ICC ES AC12 – Acceptance Criteria for Foam Plastic Insulation.

G. ICC ES AC239 – Acceptance Criteria for Termite-Resistant Foam Plastics.

H. AWPA E1 - Standard Method for Laboratory Evaluation to Determine Resistance to Subterranean Termites.

I. AWPA E12- Standard Method of Determining Corrosion of Metal in Contact with Treated Wood.

J. ASTM D3273 - Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber.

K. EPA - Registered products listing.

L. Greenguard Environmental Institute (GEI) - Standard for Low-Emitting Products.

### 1.03 SUBMITTALS

A. Product Data: Submit product data for specified products.

1. SIP Code Compliance: Provide ICC ES code report for SIP with evidence of compliance with code requirements as an alternate method of construction. Submit current compliance report number from ICC ES showing conformance to the International Building Code (IBC) and International Residential Code (IRC). Code report shall include compliance with ICC ES AC04 (Sandwich Panels) dated May 2006.

2. EPS Code Compliance: Provide ICC ES code report for EPS foam with evidence of compliance with code. Submit current compliance report numbers from ICC ES with conformance to the International Building Code (IBC) and International Residential Code (IRC). Code report shall include compliance with ICC ES AC12 (Foam Plastic) dated June 2006 and ICC ES AC239 (Termite-Resistance) dated June 2008.

3. Manufacturer’s Instructions: SIP Manufacturer’s Construction Manual and load design charts.

B. Calculations: Provide structural calculations by a registered architect or professional engineer qualified to perform such work.

C. Shop Drawings: Submit shop drawings for SIPs showing layout, elevations, product components and accessories.

D. Quality Assurance Submittals: Submit the following:

1. Certificate: Product certificate showing compliance to Third Party Quality Control program of PFS Corp.

E. Fire Resistant Assemblies: UL or PFS construction number for each fire-rated assembly

F. Warranty: Warranty documents specified herein.

1.04 SYSTEM DESCRIPTION

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

1.05 DESIGN REQUIREMENTS

A. 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.

1.06 QUALITY ASSURANCE

A. Installer Qualifications: 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.

B. Source Limitations: Obtain all SIPs through one source. All accessories to be as furnished or recommended by the SIP manufacturer.

1.07 REGULATORY REQUIREMENTS:

A. SIPs shall be recognized for compliance with International Residential Code in a current ICC ES evaluation report

B. Pre-installation Meeting: Conduct pre-installation meeting to verify project requirements, foundation/structural system/substrate conditions, SIP manufacturer’s installation instructions and SIP manufacturer’s warranty requirements. Comply with Division 1 Project Management and Coordination (Project Meetings) Section.

1.08 DELIVERY, STORAGE & HANDLING

A. Ordering: Comply with SIP manufacturer’s ordering instructions and lead time requirements to avoid construction delays.

B. Delivery: Deliver materials from SIP manufacturer with identification labels or markings intact.

C. Off-load SIPs from truck and handle using fork lift or other means to prevent damage to SIPs.

D. 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.

E. 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. SIPs shall be stored in a protected area.

1.09 WARRANTY

A. Project Warranty: Refer to Conditions of the Contract for project warranty provisions.

B. Manufacturer's Warranty: 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.

1. Warranty Period: 20 years commencing on Date of Substantial Completion.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Structural Insulated Panels (SIP)

2.02 MANUFACTURER

A. AFM Corporation, 17645 Juniper Path, Suite 260, Lakeville, MN 55044

2.03 MATERIALS

A. SIPs consisting 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 – Acceptance Criteria for Sandwich Panel Adhesives

4. FrameGuard 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 percent relative humidity.

d. Termite resistance: Minimum rating of 7.0, tested to AWPA E-1.

e. Corrosion potential for metals in contact with treated wood: Maximum 2 mils per year, tested to AWPA E12 for minimum of 60 days on aluminum 2024, carbon steel, hot-dip galvanized steel, and G90 galvanized steel.

f. Equivalent lateral resistance and tooth holding capacity as untreated wood.

2.04 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.

a. Wood Screws for attachment to wood members

b. Heavy Duty Metal Screws for attachment to metal members (16 gauge to 3/16")

c. Light Duty Metal Screws for attachment to metal decks (18 gauge or thinner)

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. Dimensional Lumber: SPF, #2 or better, or engineered equivalent unless otherwise required by structural drawings.

E. 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.

2.05 FABRICATION

A. Sizes: SIPs shall be fabricated in accordance with approved Shop Drawings

B. Thermal Resistance, R-value

1. 4 1/2” (114 mm) thick SIP with R-value of 15 at 75$^{o}$F (16 at 40$^{o}$F)
2. 6 1/2” (165 mm) thick SIP with R-value of 23 at 75$^{o}$F (24 at 40$^{o}$F)
3. 8 1/4” (210 mm) thick SIP with R-value of 29 at 75$^{o}$F (32 at 40$^{o}$F)

2.06 PRODUCT SUBSTITUTIONS

A. Substitutions: No substitutions permitted without fourteen day (14) prior approval.

2.07 RELATED MATERIALS

B. Related Materials: Refer to other sections for related materials as follows:

1. Dimensional Lumber: SPF #2 or better or pre-engineered equivalent: Refer to Division 6 Carpentry Sections.

2.08 SOURCE QUALITY

A. Source Quality Assurance: Each SIP component required shall be supplied by SIP manufacturer and shall be obtained from selected SIP manufacturer or its approved supplier.

1. Each SIP shall be labeled indicating PFS Third Party certification.
2. Provide evidence of UL Third Party inspection and labeling of all insulation used in manufacture of SIPs.
3. SIP manufacturer shall provide Lamination, R-Value and mold/mildew/termite resistance warranty documents for building owner acceptance and execution. Manufacturer’s standard forms will be submitted.
4. Provide SIPs with Foam-Control EPS with Perform Guard treated EPS for termite resistance. Treatment shall be EPA registered with treatment efficacy substantiated by independent research and ongoing in-plant testing.
5. Provide SIPs with FrameGuard treatment for mold. Mildew, and termite resistance. Treatment shall be EPA registered with treatment efficacy substantiated by independent research and ongoing in-plant testing.
6. Dimensional Tolerance - shall comply with values listed in the manufacturer’s Quality Control Manual.

B. Source Quality: Obtain SIPs from a single manufacturer.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 MANUFACTURER'S INSTRUCTIONS

A. Compliance: Comply with manufacturer's ICC ES report, Load Design Charts, Detail Book, Shop Drawings, and product data, including product technical bulletins, for installation.

B. 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.

3.03 EXAMINATION

A. Site Verification of Conditions: Verify substrate conditions (which have been previously installed under other sections) are acceptable for product installation in accordance with manufacturer's instructions.

1. 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.

3.04 INSTALLATION

A. SIP Installation:

1. SIP Supports: 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.

2. SIP Fastening: 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.

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

4. Vapor Retarders: 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.

5. Thermal Barriers: 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.

6. Restrictions: Do not install SIPs directly on concrete. Do not put plumbing in SIPs without consulting SIP manufacturer. Do not overcut skins for field-cut openings and do not cut skins for electrical chases. SIPs shall be protected from exposure to solvents and their vapors that damage the EPS foam core.
7. 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.

3.05 FIELD QUALITY REQUIREMENTS

A. Manufacturer's Field Services: Upon Owner's request, provide manufacturer's field service consisting of product use recommendations and periodic site visits for inspection of product installation in accordance with manufacturer's instructions.

3.06 PROTECTION

A. Protection: Protect installed product and finish surfaces from damage during construction.
   1. Roof SIPs: 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.
   2. After installation, cover SIPs to prevent contact with water on each exposed SIP edges and faces.

END OF SECTION

http://www.r-control.com/

# SECTION 06 15 33

# WOOD PATIO DECKING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for wood used for exterior patio decking.
2. Specification for hardware used for fasteners.
3. Specification for wood used for framing.

### 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 D143, Standard Test Methods for Small Clear Specimens of Timber
3. ASTM C1028-07 Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method

### 1.03 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. 5/4” Ipe

1. Description: Ipe is an exotic hardwood that is naturally resistant to rot and decay, is 8 times harder than California Redwood, and is guaranteed for 20 years without preservatives.
2. Ipe Decking is responsibly harvested from managed forest to provide a truly renewable resource.

B. Powder Coated Deckmaster Fastening System

1. Description: All fasteners are hidden beneath the deckboards. There is no surface penetration of the deckboards or joists. No moisture can enter deckboards or joists and

cause nail or screw pop-ups or deck rot. No stains or splinters form around fastener holes.

C. Wood Preservative Treated Materials

1. Preservative Treatment by Pressure Process: AWPA C2, except that lumber that is not in contact with the ground and is continuously protected from liquid water may be treated according to AWPA C31 with inorganic boron (SBX).

a. Preservative Chemicals: Acceptable to authorities having jurisdiction and containing no arsenic or chromium.

2. Kiln-dry lumber after treatment to a maximum moisture content of 19 percent. Do not use material that is warped or does not comply with requirements for untreated material.

3. Mark lumber with treatment quality mark of an inspection agency approved by the ALSC Board of Review.

4. Application: Treat the following items.

a. Wood cants, nailers, curbs, equipment support bases, blocking, stripping, and similar members in connection with roofing, flashing, vapor barriers, and waterproofing.

b. Wood sills, sleepers, blocking, furring, stripping, and similar concealed members in contact with masonry or concrete.

c. Wood framing and furring attached directly to the interior of below-grade exterior masonry or concrete walls.

d. Wood framing members that are less than 18 inches above the ground in crawl spaces or unexcavated areas.

e. Wood floor plates that are installed over concrete slabs-on-grade

2.02 MANUFACTURERS

A. Advantage Trim and Lumber Co.

B. Grabber Construction Products

C. Heavener Hardware, Lumber & Rental

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. Lag Bolts

1. Federal Specifications FF-B-561

D. 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

http://www.advantagelumber.com/ipedecking.htm

http://www.grabberman.com/Deckmaster/

# SECTION 06 16 36

# WOOD PANEL PRODUCT SHEATHING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes

1. Specification for Oriented Strand Board (OSB) sheathing.

### 1.02 REFERENCES

A. American Society for Testing of Materials (ASTM):

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
3. ASTM C518, Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus.
4. ASTM E72, Standard Test Methods of Conducting Strength Tests of Panels for Building Construction.
5. ASTM E96, Standard Test Methods for Water Vapor Transmission of Materials.

B. Forest Stewardship Council (FSC-US), Information on FSC in LEED Projects

### 1.03 SUBMITTALS

A. Product Data

1. Manufacturer’s specifications and installation instructions for each product specified.
2. Include data for wood-preservative and fire-retardant treatment from chemical treatment manufacturer and certification by treating plant that treated materials comply with requirements.

### 1.04 DELIVERY, STORAGE AND HANDLING

A. Store panels in clean, dry areas off the ground.  If possible, store indoors.  If stored outside, cover with plastic sheets or tarps.  Keep cover open and away from the sides and bottom of panels to allow for air circulation.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. General Oriented Strand Board (OSB) Sheathing

1. Construction Panel Standards: Comply with PS 2 and CSA-0325 for OSB construction panels.
2. Trademark: Furnish construction panels that are each factory-marked with a certification mark evidencing compliance with grade requirements.
3. Where construction panels are indicated for the following concealed types of applications, provide APA, TECO, PFS, or PSI performance based panels complying with

requirements designated under each application for grade designation, span rating, glue bond classification, edge detail (where applicable), and thickness.

a. Wall Sheathing: PS 2 or CSA-0325 PERFORMANCE BASED SHEATHING.

1) Exposure Durability Classification: EXPOSURE 1.

2) Span Rating: As required to suit stud spacing indicated.

3) Span Rating: 12/0, 16/0, 20/0 or Wall-16 for stud spacing of 16 inches or less.

4) Span Rating: 24/0 of 24 inches or less.

4. Manufacturing process must use wood certified under Sustainable Forestry Initiative standards.

a. Wood comes from small, fast growing trees, and the entire log is used.

5. OSB must contain no urea-formaldehyde, and use only low-emitting, safe resins as a binder.

2.02 MATERIALS / DESIGN CRITERIA

A. Oriented Strand Board Sheathing

1. Thickness: 1/2 inch.

2. Width: 4 feet.

3. Length: 8 feet.

4. Edges: Square.

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 EXAMINATION

A. Proceed with installation only after unsatisfactory conditions have been corrected and installation area properly prepared.

3.03 PREPARATION

A. Layout installation by marking extents of each item, and anchoring / fastening locations coordinated with blocking or other structural support.

3.04 INSTALLATION

A. Install composite wood panel sheathing per ANSI / AF&PA NDS-2005, manufacturer's written instructions.

1. Place composite wood panels to indicated levels and lines, with surfaces plumb, aligned, cut, and fitted.
2. Fit composite wood panels to other construction; scribe and cope as needed for accurate fit, but allowing for movement forces.
3. Provide blocking and framing as indicated and as required to support facing materials, fixtures, specialty items, and trim.
4. Fasten or anchor composite wood panel materials in a manner with fasteners appropriate to use and anticipated durability. Attach composite wood panel work to substrate securely by anchoring and fastening as indicated in drawings.

END OF SECTION

# SECTION 06 41 13

# WOOD VENEER FACED ARCHITECTURAL CABINETS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for custom fabricated built-in casework located in the kitchen, bedroom and central core.

### 1.02 REFERENCES

A. American National Standards Institute (ANSI), ANSI/HPVA HP-1 American National Standard for Hardwood and Decorative Plywood

B. Forest Stewardship Council (FSC-US), Information on FSC in LEED Projects

C. Hardwood Plywood and Veneer Association (HPVA), Hardwood Plywood Handbook

D. LEED: US Green Building Council, Leadership in Energy and Environmental Design Green Building Rating System

### 1.03 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 DELIVERY, STORAGE AND HANDLING

A. Store decorative hardwood plywood and fabricated products in interior locations where temperature is maintained between 60 and 90 degrees Fahrenheit and relative humidity is maintained between 30 and 55 percent.

B. Remove or loosen plastic wrappings.

C. Cover decorative hardwood plywood panels and fabricated products to protect from exposure to light until installed.

D. Protect decorative hardwood plywood from edge and surface damage.

### 1.05 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. Purebond® process veneer-core hardwood plywood

1. Panel:

a. Manufacture according to ANSI/HVPA HP-1.

b. Core construction: FSC-certified veneer core.

2. Thickness: As shown on drawings

3. Veneers:

a. Face:

1) Species: hard maple

2) Color selection: natural

3) ANSI/HPVA HP-1 grades: AA

4) Cut: quarter sliced

5) Veneer match: book-matched

b. Back:

1) Species: hard maple

2) Color selection: natural

3) ANSI/HPVA HP-1 grades: B

4) Cut: rotary

5) Veneer match: plank match

4. Factory Finish: Clear UV cured acrylic coating on both sides.

1) Gloss Level: Medium

B. All hardware, door handles, and hinges.

1. Salice C7P6AD9 Silentia Hinge Model # 329.17.400

a. Description: Self closing, 110 degree, full overlay hinge.

b. Material: Steel

c. Finish: Nickel-plated

2. Salice BAR3R09 Clip Mounting Plate Model # 329.71.500

a. Material: Steel, Zinc

b. Finish: Nickel-plated

3. Accuride C3832 Model # 432.23.955

a. Description: Side mounted ball bearing shelf slide; 22” full extension

b. Material: Steel

c. Finish: Nickel-plated

4. Cabinet Door Handle Model # 117.05.600

a. Material: Steel

b. Finish: Matt Stainless Steel

c. Length: 96 mm

5. Cabinet Door Handle Model # 117.05.630

a. Material: Steel

b. Finish: Matt Stainless Steel

c. Length: 224 mm

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.columbiaforestproducts.com/PureBond.aspx

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

# SECTION 06 42 16

# WOOD VENEER PANELING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for wood veneer paneling hung on bathroom core
2. Specification for wood veneer paneling located in the bedroom.

### 1.02 REFERENCES

A. American National Standards Institute (ANSI), ANSI/HPVA HP-1 American National Standard for Hardwood and Decorative Plywood

B. Forest Stewardship Council (FSC-US), Information on FSC in LEED Projects

C. Hardwood Plywood and Veneer Association (HPVA), Hardwood Plywood Handbook

D. LEED: US Green Building Council, Leadership in Energy and Environmental Design Green Building Rating System

### 1.03 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 DELIVERY, STORAGE AND HANDLING

A. Store decorative hardwood plywood and fabricated products in interior locations where temperature is maintained between 60 and 90 degrees Fahrenheit and relative humidity is maintained between 30 and 55 percent.

B. Remove or loosen plastic wrappings.

C. Cover decorative hardwood plywood panels and fabricated products to protect from exposure to light until installed.

D. Protect decorative hardwood plywood from edge and surface damage.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Purebond® process veneer-core hardwood plywood

1. Panel:
   a. Manufacture according to ANSI/HVPA HP-1.
   b. Core construction: FSC-certified veneer core.
2. Thickness: As shown on drawings
3. Veneers:

a. Face:
   1) Species: hard maple
   2) Color selection: natural
   3) ANSI/HPVA HP-1 grades: AA
   4) Cut: quarter sliced
   5) Veneer match: book-matched

b. Back:
   1) Species: hard maple
   2) Color selection: natural
   3) ANSI/HPVA HP-1 grades: B
   4) Cut: rotary
   5) Veneer match: plank match

B. Arreis® Art Diffusion Panel
   1. Description: Arreis® is a sustainable medium density fiberboard (MDF) panel manufactured from 100% post-industrial recycled wood residuals, meets the most stringent formaldehyde emission standards in the world. Pattern is CNC milled into panel.
      a. Art Diffusion pattern SOT002.

2.02 MANUFACTURERS
   A. Columbia Forest Products
   B. Interlam Inc.

2.03 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.

2.05 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/PureBond.aspx

http://www.interlam-design.com/Art_Product_List.cfm?id=SOT002

# SECTION 06 46 00

# WOOD TRIM

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for interior wood trim.
2. Specification for interior baseboard trim.

### 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.

### 1.04 DELIVERY, STORAGE AND HANDLING

A. Inspect the materials upon delivery to assure specified products are free of defects. Store products in a safe area, away from construction traffic. Store under cover and off the ground, protected from moisture.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Hardwood Maple

1. Thickness: ¾”

B. Maple Faced Veneer Plywood

1. Thickness: ¼”

### 2.02 MANUFACTURERS

A. Plywood & Plastics Inc.

### 2.03 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.

### 2.04 TREATMENT

A. Water based polyurethane.

### 2.05 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 PREPARATION

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

B. Clean surfaces thoroughly prior to installation.

C. Prepare surfaces using methods recommended by the manufacturer for achieving the best result for the substrate under the project conditions.

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.

B. Finish materials on all ends and sides. Apply touch up coating on new cuts.

END OF SECTION

# SECTION 06 60 00

# PLASTIC FABRICATIONS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for custom fabricated acrylic cone.

### 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.

C. Shop Drawings

### 1.03 DELIVERY, STORAGE AND HANDLING

A. Inspect the fabrication upon delivery to assure specified product is free of defects. Store product in a safe area, away from construction traffic.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Custom Fabricated Acrylic Cone

### 2.02 MANUFACTURERS

A. Subject to compliance with requirements.

### 2.03 MATERIALS / DESIGN CRITERIA

A. ¼” acrylic

B. Sand-blasted finish or finish of similar characteristics.

## PART 3 EXECUTION

### 3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

# SECTION 07 21 13

# 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 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.

### 1.04 ADMINISTRATIVE REQUIREMENTS

A. Pre-installation Meetings

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

### 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 19

# FOAMED IN PLACE INSULATION

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for self-supported, spray-applied cellulosic insulation.

### 1.02 SUBMITTALS

A. Product Data

B. Samples

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

C. Test and Evaluation Reports

### 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 21 23

# LOOSE FILL INSULATION

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for 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.

END OF SECTION

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 27 19

# PLASTIC SHEET AIR BARRIERS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for Weather Barrier membrane
2. Specification for Seam Tape
3. Specification for fasteners for Weather Barrier Assembly

### 1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM C920, Standard Specification for Elastomeric Joint Sealant
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 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

### 1.04 ADMINISTRATIVE REQUIREMENTS

A. Pre-installation Meetings

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

### 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 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

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

3.03 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.

3.04 PROTECTION

A. Protect installed weather barrier from damage.

END OF SECTION

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

# SECTION 07 46 19

# STEEL SIDING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for Rheinzink steel panel siding.

### 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, attachment 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 EXAMINATION

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.

E. 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 54 19

# POLYVINYL CHLORIDE ROOFING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for Polyvinyl Chloride (PVC) roofing membrane.
2. Specification for Vent Roof System (VRS).

B. Products Furnished

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.

### 1.02 REFERENCES

A. American Society for Testing and Materials:

1. ASTM D4434M-09, Standard Specification for Poly(vinyl Chloride) Sheet Roofing.

### 1.03 SUBMITTALS

A. Product Data

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

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.

C. 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 Acrylife 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 Acrylife standard SR Detail Drawings must be shown as to their anticipated construction.

D. Samples

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

### 1.04 QUALITY ASSURANCE

A. Qualifications

1. Apply roofing system using a Acrylife authorized roofing applicator. Applicator must have written certification from Acrylife for approval to install the VRS System.
2. Acrylife PVC 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. Acrylife PVC Membranes meet the ASTM D4434 specification for PVC-based roofing material.

B. Testing

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

1.05 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements

1. All materials provided by Acrylife 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 Acrylife VRS Warranty unless the complete Request for Warranty (RFW) has been received and approved by Acrylife prior to job start.
2. A Acrylife representative shall inspect the installation for compliance with applicable Acrylife specifications upon completion of the roofing system.
3. Acrylife will warranty the system on approved applications for a period of 10 years from time of completion. Acrylife, Inc. will repair or cause to be repaired leaks which are a result of materials or workmanship supplied by Acrylife subject to cost of the original installation.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Acrylife 3000 System, mechanically-attached Polyvinyl-Chloride membrane and Vented Roof System.

B. V²T Venturi Vent System

2.02 MANUFACTURERS

A. Acrylife, Inc.

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.

2.04 MATERIALS

A. Membrane shall be .045-in., .060-in. or .080-in. (Acrylife EP-XL) nominal thickness overall, scrim-reinforced, Polyvinyl-Chloride-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. Color: white chosen for its reflective quality.

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

PART 3 EXECUTION

3.01 INSTALLERS

A. An installer will be provided by Acrylife, Inc.

3.02 EXAMINATION

A. Evaluation and Assessment

1. Job start training by a Acrylife Technical Representative is mandatory for all VRS installations. Upon completion of the installation, an inspection shall be performed by a representative of Acrylife to ascertain that the roofing membrane system has been installed according to Acrylife 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 Acrylife PVC 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 Acrylife PVC 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 Acrylife PVC membrane shall be sealed and mechanically attached with appropriate Acrylife 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 Acrylife fasteners and approved insulation plates or bonded to the structural concrete deck with a Acrylife-supplied insulation adhesive.

4. At all perimeters which are to receive a gravel stop or metal edging after installing approved air seal, the Acrylife 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. Acrylife VRS Valves are to be installed as per Acrylife detail SRV-1E at pre-specified locations determined by Acrylife 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 Acrylife 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 Acrylife PVC 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 Acrylife, excessive patching as a result of damage to the Acrylife PVC membrane or caused by faulty installation may require total recover in those areas.

END OF SECTION

http://www.acrylife.com/products/s3000.htm
http://www.acrylife.com/products/s3500.htm

# SECTION 07 76 00

# DECK PEDESTALS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for adjustable deck pedestal.

### 1.02 SUBMITTALS

A. Product Data: Manufacturer's data sheets on each product to be used, including:

B. Preparation instructions and recommendations.

C. Storage and handling requirements and recommendations.

D. Installation methods.

E. Shop Drawings: Submit shop drawings detailing the installation methods. Coordinate placement with locations noted on the Contract Drawings.

### 1.03 QUALITY ASSURANCE

A. Manufacturer Qualifications: All primary products specified in this section will be supplied by a single manufacturer with a minimum of ten (10) years experience.

B. Installer Qualifications: The deck support system installer must have a minimum of two (2) years proven construction experience, be capable of estimating and building from blueprint plans and details, determine elevations, and properly handle materials. All Work must comply with the Bison installation application procedures for deck support work specified herein.

### 1.04 DELIVERY, STORAGE, AND HANDLING

A. Deliver and store Bison Deck Supports and system components with labels intact and legible.

B. Inspect all delivered materials to insure they are undamaged and in good condition.

C. Store and dispose of solvent-based materials such as construction adhesive, and materials used with solvent-based materials, in accordance with requirements of local authorities having jurisdiction.

### 1.04 WARRANTY

A. At project closeout and upon request, Bison Deck Supports can provide to the Owner or Owners Representative, an executed copy of the manufacturer’s standard document outlining the terms, conditions and limitations of their limited warranty against manufacturing defect for a period of three (3) years.

B. The Contractor warrants that his work will remain free from defects of labor and materials used in conjunction with his work in accordance with the General Conditions for this project or a minimum of three (3) years.

C. It is the responsibility of the Contractor installing the product listed in this section to coordinate warranty requirements with any related sections or adjacent Work. Notify the Architect immediately of any potential lapses or limitations in warranty coverage.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Adjustable Deck Pedestal.

2.02 MANUFACTURERS

A. Bison Deck Supports

2.03 MATERIALS

A. Screwjack Desk Pedestals
   1. Typical Height Range 0-16 inches
   2. Weight Bearing Design Capacity 1000 lbs/pedestal FS:2
   3. Integral 4.5 mm (3/16 inch) spacer tabs.
   4. Made in the USA

B. Base Leveler Disks:
   1. Model: LD4 - Placed beneath pedestals to compensate for slopes up to 1 inch per foot.
   2. Slope: 1/4 inch per foot. Stack up to four LD4's under one pedestal for up to 1 inch of slope compensation.
   3. Dimensions: Center point thickness 3/8 inch (9.5mm).
   4. Material: Mineral Filled High Density Copolymer Polypropylene.
      a. Contains 20% Postindustrial recycled material.

C. Shims:
   1. Model: B11 Flexible Shim 1/16 inch
   2. Material: (1.5mm) Sanaprene.
   3. Model: PS1 Rigid Poly Shims 1/8 inch (3.175mm)
   4. `Material: Mineral Filled High Density Copolymer Polypropylene.
      a. Contains 20% Postindustrial recycled material

D. Base Pads:
   1. Model FFB: Pedestal base pad for on grade use, provides a large 12 inch by 12 inch x ¼ inch (305mm x 305mm x 6 mm) base bearing surface for on grade installations.
   2. Model FIB: Pedestal base pad for use on roofing and waterproofing installations over low density insulation, provides a large 12 inch by 12 inch x 11/16 inches (305mm x 305mm x 17.5mm) base bearing surface.
   3. Material: Mineral Filled High Density Copolymer Polypropylene. FIB also contains galvanized metal pad. Contains 20% Post industrial recycled material.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Do not begin installation until substrates have been properly prepared.

B. If substrate preparation is the responsibility of another installer, notify Architect of unsatisfactory preparation before proceeding.

C. Verify all elevations, required pedestal heights and deck dimensions before commencing work.

3.03 PREPARATION

A. Establish accurate lines, levels and visual pattern.

B. The substrate surface that will receive the deck supports must be well compacted (on grade) and structurally capable of carrying the dead and live loads anticipated.

C. The substrate must be clean and free of projections and debris that could impair the performance of the pedestals or the total deck system.

D. Decks on Grade: verify that installation conforms to section 1.7(I) of this specification.

E. Installation requirements vary for each individual project site. Deck materials used, pattern, grid layout, starting point, and finished elevation should be shown on plan view shop drawings which have been prepared and approved by the designer, installing contractor and/or owner.

F. Once a starting point and the finished elevation of the deck surface have been determined, the support system elevation (finished elevation minus deck material thickness) is established and marked around the perimeter using a transit “torpedo” water level or laser leveling device.

G. Precise measurements should be taken and deck area should be accurately defined. Mark off and square all outside edges with control lines (chalk lines or spray paint). Install two (2) lines that are perpendicular to each other across the deck area. Continue to mark a grid of lines in both directions marking the location of each pedestal. To assure a square layout, use the control lines as references to periodically check the layout during installation.

3.04 INSTALLATION

A. Install in accordance with Bison and other contributing manufacturer's instructions.

B. If required, place a Floating Insulation Base (FIB) board or Floating Foundation Base (FFB) in the location on the grid of each pedestal.

C. Next, a deck support must be placed where each measured grid line meets the perimeter. Remove two (2) spacer tabs in line with one another on top of each deck support placed around the perimeter. Remove all four (4) spacer tabs at corners.

D. Adjust each deck support to a “top of pedestal” elevation marked around the perimeter. Normally the deck support is positioned as close to the perimeter as possible, with the two remaining spacer tabs aligned with the grid line. Using the “top of pedestal” elevation marked on the perimeter, stretch a mason’s line along and slightly ahead of the second row of deck supports. A laser leveling device may also be used for this purpose.

E. As the deck supports located along the grid lines are loaded with pavers or tiles, fine vertical adjustment can be made by rotating the base or bottom of the deck support. Clockwise rotation of the pedestal base will raise the bearing surface and the deck. Counter-clockwise rotation will lower the top bearing surface.

F. Slight irregularities in decking panel thickness can be compensated for by using one to two shim segments. Place on top of the pedestal, under the corner(s) of the decking tile or paver. Use no more than two (2) shims on top of the pedestal and always adhere quartered (1/4) wedges with construction adhesive.

G. Stackable Fixed Height Pedestals: Complete deck and grid layout as instructed above. Stack no more than four (4) fixed height pedestals together and place in lieu of adjustable pedestals where needed. Spacer tabs can be removed to accommodate perimeter and corner support locations.

3.05 DECK SUPPORT PLACEMENT AND FINAL ADJUSTMENT

A. Deck supports and the deck surface panels must be placed as the manufacturer directs in these written instructions. Use of labor saving devices, such as paver lifters, is encouraged, especially on large jobs.

B. Pedestals are designed to be rotated for final slight adjustment when pedestals are fully loaded. Deck supports should be leveled in each succeeding row as the installation proceeds. Final height adjustment or maintenance is easily made by simply rotating the Screwjack support in a clockwise or counter-clockwise direction to raise or lower the deck surface material.

C. Additional sections of shims may be used and should be available for regular maintenance. Shims may be used in multiples, whole or segmented, and placed under the base or on top the pedestal to level the deck support.

3.06 PERIMETER CONTAINMENT

A. Any area of a deck that is not restrained by a parapet or foundation wall must be ‘boxed-in’ and contained. The deck panels will move if all sides are not adequately restrained. Perimeter framing and edging boards located at the outside of the deck perimeter must be installed to provide restraint. No movement should be allowed at the perimeter of the deck system greater than one tab width.

3.07 FIELD QUALITY CONTROL

A. Inspect often during installation to assure that grid spacer lines are being maintained in a straight and consistent pattern and that deck panels or pavers are level and not rocking.

B. Confirm that deck pedestal height does not exceed the specified height of 16 inches (406.4mm).

3.08 PROTECTION

A. Protect installed products until completion of project.

B. Touch-up, repair or replace damaged products before Substantial Completion.

3.09 IMMEDIATELY FOLLOWING INSTALLATION

A. The Owner, or the Owner’s Agent, shall carefully inspect the deck system to be positive that:

1. The new deck system is adequately blocked on all sides to contain the surface decking and related components.

2. There is no more than one tab width spacing between any deck panels and at all sides of the deck perimeter.
3. There is no ballasting rock used to fill in any perimeter voids.
4. There is no ‘rocking’ of deck panels as foot traffic is applied to the surface decking.
5. All required spacer tabs are in place and visible.

3.10 ROUTINE MAINTENANCE AND CARE

A. Installer and/or Architect has a duty to instruct the deck owner about performing routine maintenance of the deck. Check for rocking pavers and adjust or shim immediately. Pedestals can settle and may have to be realigned. Failure to do so can cause a tripping hazard. Periodically check spacer tabs and immediately replace broken tabs to limit deck movement. Make sure the edge restraint stays intact and structurally sound.

END OF SECTION

www.BisonDeckSupports.com

# SECTION 07 92 13

# ELASTOMERIC JOINT SEALANTS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes

1. Specification for joint sealants for both vertical and horizontal surfaces.

### 1.02 REFERENCES

A. American Society for Testing of Materials (ASTM) C-834

### 1.03 SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for each joint sealant product indicated.

B. Manufacturer's Instructions

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

### 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.

### 1.06 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

A. Alex Plus Acrylic Latex Caulk Plus Silicone or comparable latex caulk.

1. Color: Clear

### 2.02 MANUFACTURERS

A. DAP Products Inc.

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Provides a durable, flexible seal while being mildew resistant.
2. Prevents air and moisture from passing through cracks and joints.

3. Latex Caulk is paintable with an acrylic or oil based paint.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 PREPARATION

A. Surface must be clean, dry and free of all dirt, dust, grease, old caulk and debris.

B. Cut nozzle at 45º angle to desired bead size. Load cartridge into caulking gun. Puncture inner foil seal.

3.03 INSTALLATION

A. Fill gap with sealant.

B. Smooth the bead of caulk for a neat finish.

C. Reseal for storage and reuse.

D. Sealant guns out white and turns clear when fully cured. Dries clear in 7-14 days.

3.04 CLEANING

A. Clean up excess caulk with a damp cloth before it skins over (15 minutes).

END OF SECTION

http://www.dap.com/product_details.aspx?BrandID=12&SubcatID=3

# SECTION 08 14 33

# STILE AND RAIL WOOD DOORS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for custom fabricated stile and rail hardwood door.
2. Specification for door hardware.

### 1.02 SUBMITTALS

A. Shop Drawings

1. Sets of blue-line shop / fabrication drawings, showing all internal and surrounding details and conditions of the stile and rail wood door.

B. Product Data

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

C. Manufacturer's Instructions

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

### 1.04 DELIVERY, STORAGE AND HANDLING

A. Inspect the materials upon delivery to assure specified products are free of defects. Store products in a safe area, away from construction traffic. Store under cover and off the ground, protected from moisture.

### 1.05 WARRANTY

A. Manufacturer Warranty

1. Rixson Specialty Door Controls: Products have a 2-year, full replacement warranty if product fails unless otherwise specified.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Front Door

B. Hinges and Mounting Hardware

C. Keyed Entrance Lock and Lever.

### 2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

B. Rixson Specialty Door Controls

C. Ingersoll Rand Co.

### 2.03 MATERIALS

A. Hardwood Maple

B. Hinges and Mounting Hardware:

1. Rixson Pivot Set. Model #195.
2. Rixson Intermediate Pivot. Model #119.
   A. Finish: 626 LH

C. Keyed Entrance Lock and Lever.
1. Shlage Manhattan. Model #F51 MNH 626.
   A. Finish: Satin Chrome

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

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

B. 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.assaabloydss.com/library/catalogs/RIXSON/pdf/44006.pdf
http://consumer.schlage.com/products/ProductDetail.asp?styleID=123&functionID=28&finishID=8

# SECTION 08 32 13

# SLIDING ALUMINUM GLASS DOORS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

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

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

C. Sliding Door Fitting EKU Divido

2.02 MANUFACTURERS

A. FLEETWOOD Aluminum Products, Inc.

B. FLEETWOOD Aluminum Products, Inc.

C. Hafele America 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.

C. 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

D. Bathroom Door Hardware

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 additions required by the drawings.

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.hafele.com/us/documents/HAC_SlidingDoorFittings7F812.pdf

# 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 REQUIREMENTS

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).

5. 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 71 00

# DOOR HARDWARE

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes

1. Specification for joint protection for sliding glass doors.

### 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.

### 1.03 SUBMITTALS

A. Product Data

1. Provide manufacturer's product and complete installation data for each joint sealant product indicated.

B. Manufacturer's Instructions

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

C. Shop Drawings

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

### 1.04 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.

### 1.05 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.

### 1.06 ENVIRONMENTAL CONDITIONS

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

1.07 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. Model #D482CLA09BL, D45XCLA09BL.

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)

B. Model #D482CLA09BL

1. Length: 8'-8"
2. Width: 3/4"
3. Total: 8 pieces

C. Model #D45XCLA09BL

1. Lengths: 7'-10" and 17’-10”
2. Width: 3/4"
3. Total: 4 pieces of each length

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 71 13

# AUTOMATIC DOOR OPENERS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for belt-driven linear actuators.
2. Specification for shafting assembly.
3. Specification for servo motors.
4. Specification for servo drives.
5. Specification for cable set.
6. Specification for 10:1 gearbox.

### 1.02 SUBMITTALS

A. Shop Drawings

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

B. Product Data

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

C. Manufacturer's Instructions

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

### 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 M55, prism-guided, belt-driven, linear motion system. Model #TG07B130-C137X438.

B. Rapidtrak M75, prism-guided, belt-driven, linear motion system. Model #TG07B130-C274X849.

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

D. 440C stainless steel shafting

E. Kollmorgen S300 series brushless servo drive. Model #S30361-NA.

F. Danaher AKM series brushless servo motor. Model #AKM42G-ANCNR-01.

G. Danaher cable set. Model #CS-SS-RHR1HE-15.

H. Micro 10:1 gearbox. Model #NT34-010-0-RM090-40.

2.02 MANUFACTURERS

A. Thomson Industries, Inc.

B. Danaher Motion

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

http://www.kollmorgen.com/website/com/eng/products/drives/ac_servo_drives/s300.php

http://www.kollmorgen.com/website/com/eng/products/motors/brushless_motors/conventional_rotary_servomotors/akm_series.php

# SECTION 08 81 00

# GLASS GLAZING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for self-flashing unit skylights with integral curb.
2. Specification for 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 PRODUCT TYPE

A. Lisec Enviro-Seal Laminated Glass

1. Thickness: 1”.
2. Color: Colorless, Transparent.

3. Single-Glazing Profile: as indicated on drawings.

B. 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.

C. 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.

2.02 MANUFACTURERS

A. Glass Dynamics, Inc.

2.03 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.

2.04 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.

2.05 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 83 00

# MIRRORS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Annealed monolithic glass mirrors (frameless) for the bathroom.

### 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.

C. Shop Drawings

1. Include mirror elevations, edge details, mirror hardware, and attachments in the drawings.

### 1.03 QUALITY ASSURANCE

A. Glazing Publications: Comply with GANA's "Glazing Manual" and GANA Mirror Division's "Mirrors, Handle with Extreme Care: Tips for the Professional on the Care and Handling of Mirrors" unless more stringent requirements are indicated.

B. Preconstruction Mirror Mastic Compatibility Test: Submit mirror mastic products to mirror manufacturer for testing to determine compatibility of mastic with mirror backing and substrates on which mirrors are installed.

### 1.04 DELIVERY, STORAGE, AND HANDLING

A. Comply with mirror manufacturer's written instructions for shipping, storing, and handling mirrors as needed to prevent deterioration of silvering, damage to edges, and abrasion of glass surfaces and applied coatings. Store indoors, protected from moisture including condensation.

### 1.05 PROJECT CONDITIONS

A. Environmental Limitations: Do not install mirrors until ambient temperature and humidity conditions are maintained at levels indicated for final occupancy.

### 1.06 WARRANTY

A. Manufacturer's standard form, made out to Owner and signed by mirror manufacturer agreeing to replace mirrors that deteriorate, f.o.b. the nearest shipping point to Project site, within specified warranty period indicated in second subparagraph below.

1. Deterioration of Mirrors: Defects developed from normal use that are attributable to the manufacturing process and not to causes other than glass breakage and practices for

maintaining and cleaning mirrors contrary to mirror manufacturer's written instructions. Defects include discoloration, black spots, and clouding of the silver film.

2. Warranty Period: 10 years from date of installation.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. General Clear Glass Mirrors.

1. Nominal Thickness: ¼"

2. Dimensions: As specified in drawings.

2.02 MANUFACTURERS

A. Subject to compliance with requirements.

2.03 MATERIALS

A. Edge Sealer: Coating compatible with glass coating and approved by mirror manufacturer for use in protecting against silver deterioration at mirrored glass edges.

B. Mirror Mastic: An adhesive setting compound, produced specifically for setting mirrors and certified by both mirror manufacturer and mastic manufacturer as compatible with glass coating and substrates on which mirrors will be installed.

C. Hardware:

1. Mirror Bottom Clips: As indicated. If not indicated, as recommended by the installer and approved by the Architect.

2. Mirror Top Clips: As indicated. If not indicated, as recommended by the installer and approved by the Architect..

3. Fasteners: Fabricated of same basic metal and alloy as fastened metal and matching it in finished color and texture where fasteners are exposed.

4. Anchors and Inserts: Provide devices as required for mirror hardware installation. Provide toothed or lead-shield expansion-bolt devices for drilled-in-place anchors. Provide galvanized anchors and inserts for applications on inside face of exterior walls and where indicated.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Examine substrates, over which mirrors are to be mounted, with Installer present, for compliance with installation tolerances, substrate preparation, and other conditions affecting performance.

1. Verify compatibility with and suitability of substrates, including compatibility of mirror mastic with existing finishes or primers.

2. Proceed with mirror installation only after unsatisfactory conditions have been corrected and surfaces are dry.

3.03 INSTALLATION

A. General: Install mirrors to comply with mirror manufacturer's written instructions and with referenced GANA publications. Mount mirrors accurately in place in a manner that avoids distorting reflected images.

B. Provide a minimum air space of 1/8 inch (3 mm) between back of mirrors and mounting surface for air circulation between back of mirrors and face of mounting surface.

C. For wall-mounted mirrors, install with mastic and mirror hardware, except at locations with cleanouts or other access requirements located behind mirrors.

   1. Attach mirror hardware securely to mounting surfaces with mechanical fasteners installed with anchors or inserts as applicable. Install fasteners so heads do not impose point loads on backs of mirrors.
   2. For metal or plastic clips, place a felt or plastic pad between mirror and each clip to prevent spalling of mirror edges.
   3. Where indicated, install bottom and top clips at locations indicated symmetrically placed and evenly spaced.
   4. Install mastic as follows (except at mirrors that require removal for maintenance access):
      a. Apply barrier coat to mirror backing where approved in writing by manufacturers of mirrors and backing material.
      b. Apply mastic to comply with mastic manufacturer's written instructions for coverage and to allow air circulation between back of mirrors and face of mounting surface.
      c. After mastic is applied, align mirrors and press into place while maintaining a minimum air space of 1/8 inch (3 mm) between back of mirrors and mounting surface.

D. Protect mirrors from breakage and contaminating substances resulting from construction operations.

E. Do not permit edges of mirrors to be exposed to standing water during installation. Mount mirrors above wet counters and backsplash tops to provide a space of at least 1/4" between the bottom of mirror and potentially wet service conditions.

F. Maintain environmental conditions that will prevent mirrors from being exposed to moisture from condensation or other sources for continuous periods of time.

END OF SECTION

# SECTION 08 87 13

# SOLAR CONTROL FILMS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for SageGlass, electrically tint-able insulating glass units for dynamic light and heat control.

### 1.02 REFERENCES

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 PRODUCT TYPE

A. Laminated Sealed Insulating Glass Unit

2.02 MANUFACTURERS

A. SAGE Electrochromics, Inc.

2.03 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 28 00

# CEMENTITIOUS BACKER BOARDS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for cement board and accessories installed in bathroom.

### 1.02 REFERENCES

A. American National Standards Institute (ANSI):

1. A108.11, American National Standard for Interior Installation of Cementitious Backer Units.
2. A118.9, Test Methods and Specifications for Cementitious Backer Units.
3. A136.1, American National Standard Specifications for Organic Adhesives for Installation of Ceramic Tile.

B. American Society for Testing and Materials (ASTM):

1. C 473, Test Methods for Physical Testing of Gypsum Panel Products.
2. C 1325, Specification for Fiber-Mat Reinforced Non-Asbestos Cement Interior Substrate Sheets.
3. C 1002, Specification for Steel Drill screws for the Application of Gypsum Panel Products or Metal Plaster Bases.

### 1.03 SUBMITTALS

A. Product Data

1. Manufacturers' specifications and installation instructions for each product specified.

### 1.04 DELIVERY, STORAGE, AND HANDLING

A. Packaging and Shipping: Have materials shipped in manufacturer's original packages showing manufacturer's name and product brand name.

B. Storage and Protection: Store materials inside and protected from damage by the elements. Protect ends, edges, and faces of cement boards from damage.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Cementious Backer Board

### 2.02 MANUFACTURERS

A. Subject to compliance with requirements.

### 2.03 MATERIALS

A. Cement Board:

1. Backer Board: Cementitious, water durable, board; surfaced with fiberglass reinforcing mesh on front and back; long edges wrapped; and complying with ANSI A118.9 and ASTM C 1325.

a. Thickness: ½”, 5/8”

b. Width: 4 ft.

c. Length: 8 ft.

d. Edges: Tapered.

e. Compressive Strength: Not less than 2250 lbs. per sq. in. when tested in accordance with ASTM D 2394.

f. Water Absorption: Not greater than 8 percent when tested for 24 hours in accordance with ASTM C 473.

2. Fasteners:

a. Screws: Hi-Lo thread screws (No. 8) wafer head, corrosion-resistant, 1-1/4” or 1-5/8” long, and complying with ASTM C 1002.

3. Joint Treatment:

a. Tape: Alkali-resistant fiberglass mesh tape intended for use with cement board.

4. Bonding Materials:

a. Mortar: Dry-set portland cement mortar in accordance with ANSI A118.1.

b. Mortar: Latex-portland cement mortar in accordance with ANSI A118.4.

c. Adhesive: Organic adhesive in accordance with ANSI A136.1, Type 1.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 INSTALLATION

A. General: In accordance with the following reference standards and manufacturer's recommendations: ANSI A108.11.

END OF SECTION

# SECTION 09 31 13

# THIN SET CERAMIC TILE

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for ceramic mosaic tile, grout and thin set adhesive.

### 1.02 REFERENCES

A. American National Standards Institute:

1. ANSI A108.1B, Specifications for Installation of Ceramic Tile on a Cured Portland Cement Mortar Setting Bed with Dry-Set or Latex Portland Cement Mortar.
2. ANSI A108.10, Specifications for Installation of Grout in Tilework.
3. ANSI A118.1, Standard Specification for Dry-Set Portland Cement Mortar.
4. ANSI A118.3, Chemical-Resistant, Water-Cleanable, Tile-Setting and Grouting Epoxy and Water-Cleanable Tile-Setting Epoxy Adhesive.
5. ANSI A136.1, 1999 - Organic Adhesives for Installation of Ceramic Tile.
6. ANSI A137.1, Specifications for Ceramic Tile.

B. American Society for Testing of Materials

1. ASTM C50, Standard Specification for Portland Cement.
2. ASTM C1028, Test method for Determining the Static Coefficient of Friction or Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull meter Method.

C. TCA (HB) - Handbook for Ceramic Tile Installation; Tile Council of America, Inc.

### 1.03 SUBMITTALS

A. Product Data

1. Manufacturer's data sheets on each product to be used, including:
   a. Preparation instructions and recommendations.
   b. Storage and handling requirements and recommendations.
   c. Installation methods.

B. Shop Drawings

1. Indicate tile layout, patterns, color arrangement, perimeter conditions, junctions with dissimilar materials, control and expansion joints, thresholds, ceramic accessories, and setting details.

C. Selection Samples

1. Color charts illustrating full range of colors and patterns.
2. Samples of actual tiles for selection.

D. Maintenance Data

1. Include recommended cleaning methods, cleaning materials, stain removal methods, and polishes and waxes.

1.04 QUALITY ASSURANCE

A. Single Source Responsibility:

1. Obtain each type and color of tile from a single source.

2. Obtain each type and color of mortar, adhesive and grout from the same source.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver and store products in manufacturer's unopened packaging until ready for installation.

B. Protect adhesives and liquid additives from freezing or overheating in accordance with manufacturer's instructions.

C. Store tile and setting materials on elevated platforms, under cover and in a dry location and protect from contamination, dampness, freezing or overheating.

1.06 ENVIRONMENTAL REQUIREMENTS

A. Do not install adhesives in an unventilated environment.

B. Maintain ambient and substrate temperature of 50 degrees F (10 degrees C) during installation of mortar materials.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Ceramic Mosaic Tile

2.02 MANUFACTURERS

A. DalTile Corporation

2.03 MATERIALS

A. General: Provide tile that complies with ANSI A137.1 for types, compositions and other characteristics indicated. Provide tile in the locations and of the types colors and pattern indicated on the Drawings and identified in the Schedule and the end of this Section. Tile shall also be provided in accordance with the following:

1. Factory Blending: For tile exhibiting color variations within the ranges selected under Submittal of samples, blend tile in the factory and package so tile taken from one package shows the same range of colors as those taken from other packages.

2. Mounting: For factory mounted tile, provide back or edge mounted tile assemblies as standard with the manufacturer, unless otherwise specified.

3. Factory Applied Temporary Protective Coatings: Where indicated under tile type, protect exposed surfaces of tile against adherence of mortar and grout by precoating with a continuous film of petroleum paraffin wax applied hot. Do not coat unexposed tile surfaces.

B. Unglazed Ceramic Mosaic Tile: ANSI A137.1, and as follows:

1. Product: Daltile Keystones.

2. Moisture Absorption: 0 to 0.5 percent.

3. Size and Shape: 1 inch (25 mm) by 2 inch (50 mm), nominal.

4. Thickness: 1/4 inch (6.4 mm).

5. Edges: Cushioned.
6. Surface Finish: Unglazed without abrasive admixture, coefficient of friction equal to or exceeding 0.6 wet.
7. Colors: Suede Gray.
8. Pattern: As specified in drawings.
9. Mounted Sheet Size: 12 by 24 inches (305 by 610 mm).
10. Trim Units: Matching bead, cove, and surface bullnose shapes in sizes coordinated with field tile.

C. Setting Materials

1. Organic Adhesive: ANSI A136.1, thinset bond type; use Type I in areas subject to prolonged moisture exposure.
2. Mortar Bed Materials:
   a. Water: Clean and potable.
3. Mortar Bond Coat Materials:
   a. Dry-Set Portland Cement type: ANSI A118.1.
4. Standard Grout: Cement grout, sanded or unsanded, as specified in ANSI A118.6; color as selected.
5. Metal Lath: ASTM C847, Flat expanded diamond mesh, not less than 2.5 lbs/SY, galvanized finish.
6. Cementitious Backer Board: ANSI A118.9; High density, cementitious, glass fiber reinforced with 2 inch (50 mm) wide coated glass fiber tape for joints and corners:
   a. Thickness: 5/8 inch (16 mm).

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Verify that wall surfaces are free of substances which would impair bonding of setting materials, smooth and flat within tolerances specified in ANSI A137.1, and are ready to receive tile.

B. Verify that sub-floor surfaces are dust-free, and free of substances which would impair bonding of setting materials to sub-floor surfaces, and are smooth and flat within tolerances specified in ANSI A137.1.

C. Verify that concrete sub-floor surfaces are ready for tile installation by testing for moisture emission rate and alkalinity; obtain instructions if test results are not within limits recommended by tile manufacturer and setting materials manufacturer.

D. Verify that required floor-mounted utilities are in correct location.

3.03 PREPARATION

A. Protect surrounding work from damage.

B. Remove any curing compounds or other contaminates.

C. Vacuum clean surfaces and damp clean.

D. Seal substrate surface cracks with filler. Level existing substrate surfaces to acceptable flatness tolerances.

E. Install cementitious backer board in accordance with ANSI A108.11 and board manufacturer's instructions. Tape joints and corners, cover with skim coat of dry-set mortar to a feather edge.

F. Prepare substrate surfaces for adhesive installation in accordance with adhesive manufacturer's instructions.

3.04 INSTALLATION

A. Install tile and grout in accordance with applicable requirements of ANSI A108.1 through A108.13, manufacturer's instructions, and TCA Handbook recommendations.

B. Lay tile to pattern indicated. Arrange pattern so that a full tile or joint is centered on each wall and that no tile less than 1/2 width is used. Do not interrupt tile pattern through openings.

C. Cut and fit tile to penetrations through tile, leaving sealant joint space. Form corners and bases neatly. Align floor joints.

D. Place tile joints uniform in width, subject to variance in tolerance allowed in tile size. Make joints watertight, without voids, cracks, excess mortar, or excess grout.

E. Form internal angles square and external angles bullnosed.

F. At tiled shower receptors install in accordance with TCA Handbook Method B415, mortar bed floor, and W244, thin-set over cementitious backer unit walls.

G. At bathtub walls install in accordance with TCA Handbook Method B412, over cementitious backer units with waterproofing membrane.

H. Grout with standard grout as specified above.

3.05 CLEANING

A. Clean tile and grout surfaces.

END OF SECTION

http://www.daltileproducts.com/home.cfm

# SECTION 09 54 43

# STRETCHED FABRIC CEILING SYSTEMS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes

1. Specification for stretched membrane ceiling systems complete with accessories for interior installations.

### 1.02 REFERENCES

A. Requirements, abbreviations and acronyms for reference standards are defined in Section 01095.

B. Fire Rating: Barrisol stretched ceiling shall have a fire hazard of Class 1 in the USA within the requirements of the ASTM E84 Flame Spread Test.

C. Other Testing: Barrisol stretched ceiling shall successfully meet criteria for: UBC 17-5 Room Fire Test Standard, N.Y.S. Pittsburgh Protocol Toxicity Test, City of New York Budding Department.

D. Stretched ceiling system must be UL approved.

### 1.03 SUBMITTALS

A. Product Data: Shall be clearly marked to indicate all technical information which specifies full compliance with requirements of this Section, Contract Documents, and the manufacturers' published installation recommendations, including but not limited to the following: samples and printed materials.

B. Dealer Certification: Submit in writing the manufacturers' certification.

C. Samples for Initial Selection Purpose: Submit samples of all standard colors and finishes for membranes and rails.

D. Samples for Verification Purpose: Submit 6' square samples of each type and color of membrane and rail specified.

E. Certified Test Reports: Submit test data from an independent testing agency, acceptable to authorities having jurisdiction, evidencing that ceiling assembly comply with requirements indicated for fire performance characteristics.

### 1.04 QUALITY ASSURANCE

A. The work of this section shall be performed by a company which specializes in the type of stretched ceiling system required by this project, with a minimum of 5 years documented successful experience and shall be performed by skilled workmen thoroughly trained in the necessary craft.

1. Work shall be performed in compliance with Owner's insurance, underwriters requirements and UL Approvals and Testing for materials, assemblies and procedures.

B. The membrane shall be stretched over the subsurface and hooked into the BARRISOL rails without glue or clips.

C. The stretch ceiling membrane shall be removable by hand and approved tools for visible inspection, to provide access above the stretched membrane, and to provide for subsequent re-installation.

D. The membrane shall not be less than 17/100 mm thick and shall not have a weight of more than 20g per square foot for all finishes except Brushed Suede. Brushed Suede membrane shall not be less than 35/100 mm thick and shall not have a weight of more than 32g per square foot.

E. The width of sheeting between two factory welds shall not be less than 5’ 6”.

F. All membranes / sheets (except Brushed Suede) shall be washable and antibacterial.

1.05 DELIVERY, STORAGE AND HANDLING

A. Store all materials off the ground and protected from dirt and dust of construction operations.

B. Materials are to be acclimated to installation conditions for 48 hours prior to installations.

C. Handle all materials in a manner that will protect them from damage.

1.06 WARRANTY

A. Warranty: Limited warranty against defeats in product, harpoon welds, sheet welds and colorfastness for a period of two years and workmanship for a period of ten years.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Stretch PVC (polyvinyl chloride base, guaranteed cadium free) membrane-ceiling sheet: A ceiling membrane will be custom produced according to exact field measurements. The membrane will be connected together by factory welds to achieve the appropriate size.

B. Seams / Welds: The seams will be lapped and factory welded. The seam location will be specified by the architect.

C. Rails:

1. Aluminum Barrisol Star concealed rails.

2.02 MANUFACTURER

A. Barrisol USA

PART 3 EXECUTION

3.01 INSTALLERS

A. Barrisol USA

B. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Install Barrisol Stretch Ceiling System in accordance with approved submittals, reflected ceiling plan in Architectural Drawings, manufacturer’s published recommendations and Contract Documents.

B. Examine the condition of the installation site and the conditions. Notify the Contractor or Architect in writing of any unsatisfactory conditions. Do not proceed with the work until such conditions have been corrected in a manner satisfactory to the Barrisol installers.

C. Survey the installation site for exact field measurements for custom production of the ceiling membrane. Take actual field measurements for each ceiling.

D. Inspect each space which is to receive wall fixed mounted rails. The surface where the rails will be fixed must be smooth, flat, and finished prior to installation of the rails.

E. The stretched ceiling should only be installed if the wet work is completed and dry, the space is enclosed and weather tight, all painting and wall covering is completed and dry, the work of other trades is completed included electrical work, sprinkler systems, HVAC, etc.

3.03 INSTALLATION

A. Field measure each space to receive a stretch ceiling.

B. Fasten the rails at the perimeter of each ceiling using mitered cut corners and the appropriate fixing technique for each type of surface as recommended by Barrisol.

C. Heat the ceiling membrane to release the sheet for installation purposes.

D. Extend the membrane into the rails with the appropriate Barrisol tool.

E. After the membrane is completely secured, the heating source should be removed to allow the membrane to recover to its designated size, free of wrinkles.

F. Make all required penetrations for lights. HVAC, sprinkler systems, etc. and secure the opening with a Barrisol reinforcement ring or square using the appropriate technique for each item as recommended by Barrisol.

3.04 CLEANING

A. Clean the complete ceiling installation and adjoining construction as required.

B. Provide a written recommendation for cleaning and maintenance procedure including alist of approved cleaning products.

END OF SECTION

http://www.barrisolusa.com/index.html

# 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.
2. Specification for highly resilient synthetic rubber stair nosing.

### 1.02 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

B. Johnsonite Roundel Rubber Stair Nosing

### 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 exterior substrates:

1. Steel

### 1.02 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

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# 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 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 INSTALLERS

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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# SECTION 10 28 00

# TOILET BATH LAUNDRY ACCESSORIES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for bathroom and kitchen accessories.

### 1.02 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. Kohler plumbing products are warranted to be free of defects in material and workmanship for one year from date of installation. Kohler Co. will, at its election, repair, replace or make appropriate adjustment where Kohler Co. inspection discloses any such defects occurring in normal usage within one (1) year after installation. Kohler Co. is not responsible for removal or installation costs. Use of in-tank toilet cleaners will void the warranty.
2. Kohler Co. warrants all aspects of the faucet or accessories to be free of defects in material and workmanship during normal residential use for as long as the original consumer purchaser owns his or her home. If a defect is found in normal residential use, Kohler Co. will, at its election, repair, provide a replacement part or product, or make appropriate adjustment

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Stillness Toilet Tissue Holder. Model #K-14458.

B. Stillness Soap Dish. Model #14461.

C. Stillness Robe Hook. Model #14458.

D. Stillness Towel Ring. Model #14456.

E. Stillness Towel Bar. Model #14450.

F. Stillness Thermostatic Valve Trim. Model #K-T10940-4.

G. WaterTile Square Rain Overhead Showering Panel. Model #K-8030.

H. Stillness Wall Mount Lavatory Faucet Trim. Model #K-T944-4.

I. Karbon Articulating Deck Mount Kitchen Faucet. Model #K-3325.

J. Conical Bell Vessels Above Counter Lavatory. K-6227.

K. Undertone Extra Large Squared Under Counter Kitchen Sink. Model #K-2200.

2.02 MANUFACTURER

A. Kohler Co.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Stillness Toilet Tissue Holder
   1. Dimensions: 3” W x 4” D x 6-5/16” H
   2. Finish: Polished Chrome

B. Stillness Soap Dish
   1. Dimensions: 4-3/4” W x 6” D x 1-7/8” H
   2. Finish: Polished Chrome

C. Stillness Robe Hook
   1. Dimensions: 1-7/8” W x 1-1/2” D x 1-3/8” H
   2. Finish: Vibrant Polished Nickel

D. Stillness Towel Ring
   1. Dimensions: 8-7/8” W x 2-1/2” D x 6” H
   2. Finish: Polished Chrome

E. Stillness Towel Bar
   1. Dimensions: 19-11/16” W x 2-1/2” D x 1-7/8” H
   2. Finish: Polished Chrome

F. Stillness Thermostatic Valve Trim
   1. ADA compliant lever.
   2. Finish: Polished Chrome

G. WaterTile Square Rain Overhead Showering Panel
   1. Fully adjustable sprayface.
   2. Finish: Polished Chrome

H. Stillness Wall Mount Lavatory Faucet Trim
   1. Finish: Polished Chrome

I. Karbon Articulating Deck Mount Kitchen Faucet
   1. Finish: Polished Chrome

J. Conical Bell Vessels Above Counter Lavatory
   1. Dimensions: 16-1/4” W x 16-1/4” D x 6-3/8” H
   2. Finish: Biscuit

K. Undertone Extra Large Squared Under Counter Kitchen Sink
   1. Dimensions: 23” W x 17-1/2” D x 9-1/2” H
   2. Finish: 18-Gauge Stainless Steel

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.us.kohler.com/onlinecatalog/section.jsp?section=1&nsection=1&nsubsection=3&nitem=

# SECTION 10 44 16
# FIRE EXTINGUISHERS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:

1. Specification for portable fire extinguishers.

### 1.02 REFERENCES

A. American Society for Testing of Materials (ASTM)

1. E814, Standard Test Method for Fire Tests of Through-Penetration Fire Stops.

B. National Fire Protection Association (NFPA)

1. NFPA 10, Portable Fire Extinguishers

### 1.03 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 QUALITY ASSURANCE

A. NFPA Compliance: Fabricate and label fire extinguishers to comply with NFPA 10.

B. Fire Extinguishers: Listed and labeled by Underwriter's Laboratory (UL) or Factory Mutual (FM) for type, rating, and classification.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Portable Fire Extinguisher

### 2.02 MANUFACTURERS

A. Subject to compliance with requirements.

### 2.03 MATERIALS

A. Portable Fire Extinguisher

1. General: Provide fire extinguishers of type, size, and capacity for each cabinet and other locations indicated.

   a. Product: A 10 lbs, multi-purpose, UL listed, dry chemical fire extinguisher with a minimum rating of 4-A:40-B:C.

B. Mounting Brackets: Manufacturer's standard steel bracket, designed to secure extinguisher, of sizes required for types and capacities of fire extinguisher indicated, with plated or baked-enamel finish.

C. Fire extinguishers installed outside shall be located in approved weather-tight fire extinguisher cabinets.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION

A. Examine walls and partitions for suitable framing depth and blocking where recessed and semirecessed cabinets are to be installed. Verify that rough openings for cabinets are correctly sized and located.

B. Examine fire extinguishers for proper charging and tagging. Remove and replace damaged, defective, or undercharged units.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.03 INSTALLATION

A. Comply with manufacturer's written instructions for installing fire extinguishers and mounting brackets.

B. Mounting Height: Install extinguishers at heights indicated below.

1. Install fire extinguishers mounted on hangers or brackets attached to a wall so that the top of the fire extinguisher is not more than 3½ ft. above the floor.

2. In no case shall the clearance between the bottom of the fire extinguisher and the floor be less than 4 inches.

C. Locations: Install extinguishers at locations indicated below.

1. Install fire extinguishers at locations specified on the drawings or as directed by the authority having jurisdiction.

2. Fire extinguishers shall be conspicuously located, along normal paths of travel, including exits from areas. Extinguishers shall not be obstructed or obscured from view.

D. Install portable fire extinguishers on the hanger or in the bracket supplied, or place in the fire extinguisher cabinets provided. Verify that the extinguisher operating instructions face outward.

3.04 ADJUSTING, CLEANING, AND PROTECTION

A. Adjust cabinet doors that do not swing or operate freely.

B. Refinish or replace cabinets and doors damaged during installation.

C. Provide protection and maintain conditions that ensure that cabinets and doors are without damage or deterioration at the time of Construction Completion.

<u>END OF SECTION</u>

# SECTION 10 57 00

# WARDROBE AND CLOSET SPECIALTIES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for bedroom accessories.

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

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Synergy Pants Rack. Model #805.58.233.

B. Synergy Hamper. Model #807.52.233.

C. Ironfix Self Mounted Ironing Board. Model #568.60.781.

D. Wardrobe Lift. Model #805.31.202.

E. Synergy Tie Rack. Model #807.54.233.

F. Synergy Belt Rack. Model #807.54.231.

G. Synergy Shoe Rail. Model #805.87.210.

H. Synergy Shoe Rail Bracket. Model #805.87.993.

I. Synergy Closet Valet. Model #808.70.231.

### 2.02 MANUFACTURER

A. Hafele.America Co.

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Synergy Pants Rack

1. Description: 24" long with full extension
2. Material: Aluminum
3. Finish: Polished Chrome Plate

B. Synergy Hamper

1. Description: 24" long with full extension; 2 nylon bags included
2. Material: Aluminum
3. Finish: Polished Chrome Plate

C. Ironfix Self Mounted Ironing Board
    1. Dimensions: 20-1/2” W x 13-3/4” D x 5-1/8” H
    2. Material: Steel
    3. Finish: Epoxy White
D. Wardrobe Lift
    1. Description: 26” x 35-1/16”; load capacity of 26 lbs.
    2. Material: Aluminum
    3. Finish: Polished Chrome Plate
E. Synergy Tie Rack with Slide
    1. Description: Black plastic supports; 14-1/8” long
    2. Material: Steel
    3. Finish: Black Chrome Plate
F. Synergy Belt Rack with Slide
    1. Description: Black plastic supports; 14-1/8” long
    2. Material: Aluminum
    3. Finish: Polished Chrome Plate
G. Synergy Shoe Rail
    1. Description: 36” length x ¾” diameter
    2. Material: Aluminum
    3. Finish: Polished Chrome Plate
H. Synergy Shoe Rail Bracket
    1. Material: Plastic
    2. Finish: Polished
I. Synergy Closet Valet
    1. Description: Black plastic; 14-1/4” long
    2. Material: Aluminum
    3. Finish: Polished Chrome Plate

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

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

# SECTION 10 71 13

# ROLLING EXTERIOR SHUTTERS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes specifications for the following:

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 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 28 13
# OFFICE EQUIPMENT

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for computers and computing equipments.

### 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

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 or comparable

B. 24" Desktop Computer or comparable

C. iPhone Smartphone

### 2.02 MANUFACTURERS

A. Fujitsu

B. Apple Inc.

C. Apple Inc.

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. 12" Fujitsu Lifebook T2010 Tablet PC Notebook

1. 1.2 GHz Intel Core 2 Duo Processor Ultra Low Voltage U7600
2. Four GB Memory
3. 120 GB 5400 rpm hard drive
4. Mobile Intel GMA X3100 with Intel Clear Video Technology enabling DX10 and MPEG-2 graphics card

B. 24” 2.66 GHz iMac Desktop Computer Model #MB418LL/A
1. 2.66 GHz Intel Core 2 Duo Processor
2. Four GB memory
3. 640 GB hard drive
4. NVIDIA GeForce 9400M graphics card

C. 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 30 00

# RESIDENTIAL EQUIPMENT

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for kitchen accessories.

### 1.02 SUBMITTALS

A. Product Data

1. Provide manufacturer's product data.

B. Manufacturer's Instructions

1. The product manufacturer shall provide written maintenance data.

### 1.05 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. Pull Down Shelf Mechanism. Model #504.58.200.

B. Rail. Model #547.51.236.

C. Folding Step Stool. Model #505.04.210.

D. Waste Bin. Model #502.70.252.

E. Base Storage Unit Pull Out. Model #545.48.262.

F. Spice Rack. Model #543.34.830.

G. Pull Out Slide for Spice Rack. Model #543.34.800.

H. Pull Out Arena. Model #547.12.822.

I. Concealed Under Mount Slide. Model #420.01.954.

J. Base Plate. Model #557.46.001.

K. Triangular Post. Model #557.46.011.

L. Utensil Holder Drawer Insert. Model #556.96.204.

M. Cutlery Tray. Model #556.91.334.

N. Silverware Trey. Model #556.91.352.

O. Container Holder. Model #556.91.381.

P. Container Set. Model #556.92.320.

Q. Knife Block. Model #556.91.391.

R. Cutlery Tray. Model #556.91.321.

S. Tray Set Arena. Model #543.34.851.

T. Tray Set Arena. Model #543.34.852.

2.02 MANUFACTURER

A. Hafele.America Co.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Pull Down Shelf Mechanism
   1. Dimensions: 600-900 mm
   2. Material: Stainless Steel
   3. Finish: Matt

B. Rail
   1. Dimensions: 348 x 39 mm
   2. Material: Steel
   3. Finish: Chrome Plate

C. Folding Step Stool
   1. Dimensions: 465 mm
   2. Color: Black

D. Waste Bin
   1. Description: Bottom mounted; 2 x 15 L.
   2. Material: Steel
   3. Color: Grey

E. Base Storage Unit Pull Out
   1. Description: 3 baskets; 274 x 495 x 507 mm
   2. Material: Steel
   3. Finish: Polished Chrome

F. Spice Rack
   1. Dimensions: ¾” W x 10” D x 23-1/2” H
   2. Material: Steel
   3. Color: Champagne

G. Pull Out Slide for Spice Rack
   1. Description: 9-7/8” long
   2. Material: Steel

H. Pull Out Arena
   1. Dimensions: 12-7/8” W x 20-5/8” D x 4-5/16” H
   2. Material: Steel and Maple
   3. Color: Champagne

I. Concealed Under Mount Slide
   1. Description: Accuride Eclipse C3132EC; full extension, soft closing; 21” extended; 100 lbs. load capacity
   2. Material: Steel

3. Finish: Zinc Plated

J. Base Plate
1. Dimensions: 533 x 610 x 10 mm
2. Material: Beech

K. Triangular Post
1. Dimensions: 160 x 35 mm
2. Material: Beech

L. Utensil Holder Drawer Insert
1. Dimensions: 450 mm
2. Material: Stainless Steel and Beech

M. Cutlery Tray
1. Dimensions: 495 x 360 x 57 mm
2. Material: Beech

N. Silverware Tray
1. Dimensions: 445 x 250 x 57 mm
2. Material: Beech

O. Container Holder
1. Dimensions: 464 x 100 x 57 mm
2. Material: Beech

P. Container Set
1. Description: 4 pieces in a set
2. Material: Glass

Q. Knife Block
1. Dimensions: 464 x 200 x 57 mm
2. Material: Beech

R. Cutlery Trey
1. Dimensions: 495 x 100 x 50 mm
2. Material: Beech

S. Tray Set Arena
1. Dimensions: 3” W x 9-7/8” D x 2-3/4” H
2. Material: Steel and Maple
3. Color: Champagne

T. Tray Set Arena
1. Dimensions: 5” W x 9-7/8” D x 2-3/4” H
2. Material: Steel and Maple
3. Color: Champagne

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

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

# SECTION 11 31 13

# RESIDENTIAL KITCHEN APPLIANCES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes specifications for the following:

1. Cooktops.
2. Wall Oven.
3. Refrigerators/freezers.
4. Dishwashers.
5. 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. Diva 24” 3 Burner Electromagnetic Induction Cooktop. Model #DDP-3.

B. Wall Oven or comparable model.

1. 120V Advantium 27” Wall Oven. Four oven modes: Speedcook, True European Convection, Warming/Proofing, Sensor Microwave. Model #PSB1001NSS.

C. Refrigerator/Freezer

1. Liebherr 24” Fully Integrated Refrigerator Freezer. Model #HC-1011 Right hinge Without Ice Maker.

D. Dishwasher

1. Fisher and Paykel Single Integrated Dish Drawer Dishwasher. Model #DD24S16.

E. Espresso Machine

1. Nespresso Essenza on-counter residential espresso machine with pre-packaged capsule brewing system. Model #D100 GS.

2.02 MANUFACTURERS

A. Diva Induction

B. G.E. Appliances

C. Liebherr Appliances

D. Fisher & Paykel

E. Nespresso, U.S.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Cooktop

1. Color: Black, Frameless
2. Energy Star Compliant
3. Over-Heat Safety and Over-Flow Safety Sensors
4. Efficiency: 90% of heat transferred to cooking utensil; compared to 50% for gas and 60% for other electric technologies.

B. Microwave

1. Speedcook technology: Delivers oven-quality food up to four times fasten than a conventional oven.
2. Sensor Microwave Oven: 975-watt sensor microwave oven mode automatically delivers exceptional cooking results.
3. Warming Oven: Keeps prepared foods warm and fresh, and retains superb moistness and crispness.
4. Glass Touch Controls: Features a smooth glass design that is easy to operate and easy to clean.
5. Multi-Level Cooking: Removable pedestal rack allows cooking of multiple dishes at once.

C. Refrigerator/Feezer

1. Finish: Custom Paneled
2. System: Dual Refrigeration featuring SoftClose

3. Energy Star Compliant
4. LED lighting systems

D. Dishwasher
1. Finish: Custom Paneled
2. Capacity: 6 Plate settings for plates as large as 12" and long stemmed wine glasses.
3. Energy Star Compliant featuring 'Eco Option' wash program using as little as 1.95 gallons of water per use.
4. Flow through detergent dispenser.
5. Load sensors for optimum performance.

E. Espresso Machine
1. Compact Brewing Unit technology using Thermoblock heating element and 19 Bar pressure pump.
2. Capsule container for up to 14 used capsules.
3. Automatic and programmable coffee quality with backlit buttons.

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://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SpecPage&Sku=PSB1001NSS#FEATURES
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 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. Model #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.

5. SteamWash™ system for better washing performance and higher water and energy efficiency.
6. Allergiene™ cycle.
7. SteamFresh™ cycle for reducing wrinkles and refreshing clothes.
8. TrueSteam™ generator.
9. Vent-less condensing drying system.
10. SenseClean™ & sensor dry system for intelligent fabric care, water and energy efficiency.
11. RollerJets™ & forced water circulation.

2.04 FINISHES

A. Finish Materials

1. Large chrome rimmed door with clear glass.
2. Porcelain top.
3. White painted steel cabinet.
4. Plastic control panel.

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.lge.com/us/appliances/pdf/WM3988HWAss.pdf

# SECTION 12 22 00

# CURTAINS AND DRAPES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for drapery.

### 1.02 SUBMITTALS

A. Product Data

B. Manufacturer's Instructions

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

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Verosol Fabrics 812

### 2.02 MANUFACTURERS

A. Specialty Drapery

### 2.03 COMPONENTS

A. Verosol Fabrics:

1. Metallic 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 metallic 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.

## PART 3 EXECUTION

### 3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.specialtydrapery.com/drapery/shadeworks/Sun_Control/Sun_Control_Draperies.aspx

# SECTION 12 25 13

# MOTORIZED DRAPERY RODS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specifications for electronic drive drapery track systems.
2. Specification for drapery control system.

### 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. Controls: Wall mounted.

### 1.04 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.

2.02 MANUFACTURERS

A. Lutron Electronics Co., Inc.

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.

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

# SECTION 12 36 19

# WOOD COUNTERTOPS

## PART 1 GENERAL

### 1.01 SUMMARY

- A. Section Includes:
  - 1. Specifications for custom fabricated kitchen and bathroom countertops.

### 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.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

- A. Custom Fabricated bathroom countertop designed and manufactured by the Virginia Tech Solar Decathlon Team.
- B. Custom Fabricated kitchen countertop designed and manufactured by the Virginia Tech Solar Decathlon Team.

### 2.02 MANUFACTURERS

- A. Virginia Tech Solar Decathlon Team
- B. Virginia Tech Solar Decathlon Team

### 2.03 PERFORMANCE / DESIGN CRITERIA

- A. Custom Fabricated bathroom countertop designed and manufactured by the Virginia Tech Solar Decathlon Team.
  - 1. Dimensions as specified in drawings.
- B. Custom Fabricated kitchen countertop designed and manufactured by the Virginia Tech Solar Decathlon Team.
  - 1. Dimensions as specified in drawings.

### 2.04 MATERIALS

- A. Bathroom Countertop:
  - 1. 5/4” Ipe
    - a. Manufacturer: Advantage Trim and Lumber Co.
    - b. Description: Ipe is an exotic hardwood that is naturally resistant to rot and decay, is 8 times harder than California Redwood, and is guaranteed for 20 years without preservatives.
- B. Kitchen Countertop:

1. Hardwood Maple
   a. Manufacturer: Plywood & Plastics Inc.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.advantagelumber.com/ipedecking.htm

# SECTION 12 36 40

# STONE COUNTERTOPS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specifications for entry and kitchen countertops.
2. Specifications for kitchen backsplash.

### 1.02 REFERENCES

A. ASTM C 119-04: Terminology Relating to Dimension Stone

B. ASTM C 170-90 (1999): Test Method for Compressive Strength of Dimension Stone

C. ASTM C 615-03: Specification for Granite Dimension Stone

D. ASTM C 880-98: Test Method for Flexural Strength of Dimensional Stone

### 1.03 SUBMITTALS

A. Product Data: For each stone type, stone accessory, and other manufactured products.

1. Each stone type: Physical properties.

B. Shop Drawings: Include plans, sections, details, and attachments to other work. Show fabrication and installation details for dimension stone cladding:

1. Include dimensions and profiles of stone units.
2. Show locations and details of joints.
3. Show locations and details of anchors and supports.

C. Stone Samples: (2) Sets for each stone required, exhibiting the full range of color characteristics expected; not less than 12 inches square.

D. Sealant Compatibility Test Report: Submit test report from sealant manufacturer, in accordance with Division 07 Section "Joint Sealants" stating that sealants will not stain stone.

E. Provide maintenance manuals for stone countertops. Include stone-care products recommended by stone source.

### 1.04 QUALITY ASSURANCE

A. Fabricator Qualifications: Skilled workers who custom-fabricate stone countertops similar to work of this Project.

B. Source Limitations for Stone: Obtain each variety of stone from a single quarry.

1. Obtain each variety of stone from a single quarry, whether specified in this Section or in another Section of the Specifications.
2. Make stone slabs available for Architect to examine for appearance characteristics.
   a. Architect will select aesthetically acceptable slabs and will indicate aesthetically unacceptable portions of slabs.

C. Mockup: Build mockup to demonstrate aesthetic effects and set quality standards for materials and execution.

1. Build mockup of typical countertop as shown on Drawings.
2. Approved mockup may become part of the completed Work.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Granite Stone for entry and kitchen countertops.

2.02 MANUFACTURERS

A. Luck Stone Corporation

2.03 MATERIALS

A. Granite: ASTM C 615.

B. Cut stone from one block or contiguous, matched blocks in which natural markings occur.

C. Match Architect's samples.

D. Granite

1. Stone Variety by Luck Stone Center
2. Location: Entry and Kitchen countertops.
3. Finish: Polished
4. Thickness: Not less than 1-3/16"

2.04 ACCESSORIES

A. General: Use only adhesives formulated for stone and recommended by manufacturer for the application shown on Drawings.

B. Water-Cleanable Epoxy Adhesive: ANSI A118.3, with a VOC content of 65 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. Water-Cleanable Epoxy Grout: ANSI A118.3, chemical-resistant, water-cleanable, tile setting and -grouting epoxy, with a VOC content of 65 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

D. Stone Adhesive: 2-part epoxy or polyester adhesive, formulated specifically for bonding stone to stone, with an initial set time of not more than 2 hours at 70 deg F, and with a VOC content of 65 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

1. Color: Match stone.

E. Sealant for Countertops: Manufacturer's standard sealant of characteristics indicated below that comply with applicable requirements in Division 07 Section "Joint Sealants" and will not stain the stone it is applied to.

1. Single-component, neutral-curing silicone sealant.
2. Color: As selected by Architect.
3. Use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

F. Stone Cleaner: Cleaner specifically formulated for stone types, finishes, and applications indicated, as recommended by stone producer. Do not use cleaning compounds containing acids, caustics, harsh fillers, or abrasives.

G. Stone Sealer: Colorless, stain-resistant sealer that does not affect color or physical properties of stone surfaces, as recommended by stone producer for application indicated.

2.05 FABRICATION

A. General: Fabricate stone per requirements, including Drawings and Shop Drawings
   1. Granite: NBGQA's "Specifications for Architectural Granite."

B. Select stone for intended use to prevent fabricated units from containing cracks, seams, and starts that could impair structural integrity or function.
   1. Repairs that are characteristic of the varieties specified are acceptable provided they do not impair structural integrity or function and are not aesthetically unpleasing, as judged by Architect.

C. Grade and mark stone for final locations to produce assembled countertop units with an overall uniform appearance.

D. Fabricate stone countertops in sizes and shapes required to comply with requirements indicated, including details on Drawings and Shop Drawings.
   1. Clean sawed backs of stones to remove rust stains and iron particles.
   2. Dress joints straight and at right angle to face, unless otherwise indicated.
   3. Cut and drill sinkages and holes in stone for anchors, supports, and attachments.
   4. Provide openings, reveals, and similar features as needed to accommodate adjacent work.
   5. Fabricate molded edges with machines having abrasive shaping wheels made to reverse contour of edge profile to produce uniform shape throughout entire length of edge and with precisely formed arris slightly eased to prevent snipping, and matched at joints between units. Form corners of molded edges as indicated with outside corners slightly eased, unless otherwise indicated.
   6. Finish exposed faces of stone to comply with requirements indicated for finish of each type of stone required and to match approved Samples and mockups. Provide matching finish on exposed edges of countertops, splashes, and cutouts.

E. Carefully inspect finished stone units at fabrication plant for compliance with requirements for appearance, material, and fabrication. Replace defective units.

2.06 COUNTERTOPS

A. General: Comply with recommendations in MIA's "Dimension Stone-Design Manual."

B. Nominal Thickness: Gage backs to provide units of identical thickness.
   1. 1-3/16”

C. Edge: Straight, slightly eased at top.

D. Splashes: Provide 13/16 inch thick backsplashes and side splashes.
   1. Height: Dimensions as specified in drawings.
   2. Top Edge Detail: As specified in drawings.

E. Joints: Fabricate countertops in sections for joining in field, with joints at locations shown on Drawings and as follows:
   1. Joints: 1/16” in width
F. Cutouts and Holes:
   1. Under counter Fixtures: Make cutouts for under counter fixtures in shop using template or pattern furnished by fixture manufacturer. Form cutouts to smooth, even curves.
   2. Counter-Mounted Fixtures: Prepare countertops in shop for field cutting openings for counter-mounted fixtures. Mark tops for cutouts and drill holes at corners of cutout locations.
   3. Fittings: Drill countertops in shop for plumbing fittings, counter mounted soap dispensers, and similar items

PART 3 EXECUTION

3.01 INSTALLERS
A. Virginia Tech Solar Decathlon Team

3.02 EXAMINATION
A. Examine substrates indicated to receive stone countertops and conditions under which stone countertops will be installed, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance.
   1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.03 PREPARATION
A. Clean dirty or stained stone surfaces by removing soil, stains, and foreign materials before setting. Clean stone by thoroughly scrubbing with fiber brushes and then drenching with clear water. Use only mild cleaning compounds that contain no caustic or harsh materials or abrasives. Allow stone to dry before installing.

3.04 CONSTRUCTION TOLERANCES
A. Variation from Plumb: For vertical lines and surfaces, do not exceed 1/16 inch in 48 inches.
B. Variation from Level: Do not exceed 1/8 inch in 96 inches, 1/4 inch maximum.
C. Variation in Joint Width: Do not vary joint thickness more than 1/4 of nominal joint width.
D. Variation in Plane at Joints (Lipping): Do not exceed 1/64-inch difference between planes of adjacent units.
E. Variation in Line of Edge at Joints (Lipping): Do not exceed 1/64-inch difference between edges of adjacent units, where edge line continues across joint.

3.05 INSTALLATION
A. Install countertops over plywood subtops with full spread of water-cleanable epoxy adhesive.
B. Do not cut stone in field. If stone countertops or splashes require additional fabrication not specified to be performed at Project site, return to fabrication shop for adjustment.

C. Set stone to comply with requirements shown on Drawings and Shop Drawings. Shim and adjust stone to location shown. Install countertops with uniform joints of widths shown and with edges and faces aligned.

D. Bond joints with stone adhesive and draw tight as countertops are set. Mask areas of countertops adjacent to joints to prevent adhesive smears.

E. Space joints with 1/16-inch gap for filling with grout or sealant. Use temporary shims to ensure uniform spacing.

F. Install backsplash and end splash by adhering to wall with water-cleanable epoxy adhesive. Leave 1/16-inch gap between countertop and splash for filling with sealant. Use temporary shims to ensure uniform spacing.

G. Grout joints to comply with ANSI A108.10. Remove temporary shims before grouting. Tool grout uniformly and smoothly with plastic tool.

3.06 CLEANING

A. In-Progress Cleaning: Clean countertops as work progresses. Remove adhesive, grout, mortar, and sealant smears immediately.

B. Remove and replace stone countertops of the following description:

1. Broken, chipped, stained, or otherwise damaged stone. Stone may be repaired if methods and results are approved by Architect.
2. Defective countertops.
3. Defective joints, including misaligned joints.
4. Interior stone countertops and joints not matching approved Samples and mockups.
5. Interior stone countertops not complying with other requirements indicated.

C. Replace in a manner that results in stone countertops matching approved Samples and mockups, complying with other requirements, and showing no evidence of replacement.

D. Following installation and after sealants are cured, clean stone countertops using clean water and soft rags.

E. Sealer Application: Apply stone sealer to comply with stone producer's and sealer manufacturer's instructions.

END OF SECTION

http://www.charlesluck.com/products

# SECTION 12 40 00

# FURNISHINGS AND ACCESSORIES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for paperclip holder.
2. Specification for letter opener.
3. Specification for paper holder.
4. Specification for penholder.
5. Specification for magnetic board.

### 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 use and care guide for owner.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Wave by Steve McGugan

B. Letter Opener by Allan Scharff

C. Wave by Steve McGugan

D. Wave by Steve McGugan

E. Memory board by Designlt

### 2.02 MANUFACTURERS

A. Georg Jensen

### 2.03 MATERIALS

A. Paperclip Holder

1. Materials: Stainless steel

B. Letter Opener

1. Materials: Stainless steel

C. Paper Holder

1. Materials: Stainless steel and plastic

D. Penholder

1. Materials: Stainless steel and plastic

E. Magnetic Board

1. Materials: Stainless steel, magnets and plastic

## PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.georgjensenstore.com/index.php?do=product.catalogue&catalogid=58

# SECTION 12 42 16

# FLATWARE

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

   1. Specification for flatware.

### 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 use and care guide for owner.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Heller Dinnerware Set by Massimo Vignelli

B. Caravel Cutlery Pattern by Henning Koppel

### 2.02 MANUFACTURERS

A. Heller Co.

B. Georg Jensen

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Dinnerware Set

   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"

### 2.04 MATERIALS

A. Dinnerware Set

   1. Melamine plates and bowls.

   2. Polycarbonate mugs.

B. Silverware

   1. Stainless Steel

## PART 3 EXECUTION

### 3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

# SECTION 12 42 19

# HOLLOWWARE

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for salad bowl and servers.
2. Specification for saltcellar and scoop.
3. Specification for salt and pepper set.
4. Specification for cocktail shaker.
5. Specification for pitcher.

### 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 use and care guide for owner.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Caravel by Henning Koppel

B. Twist by Phillip Bro Ludvigsen

C. Castors by Henning Koppel

D. Cocktail Shaker by Helle Damkjaer

E. Koppel Pitcher by Henning Koppel

### 2.02 MANUFACTURERS

A. Georg Jensen

### 2.03 MATERIALS

A. Salad Bowl and Servers

1. Materials: Stainless steel and black polycarbonate

B. Saltcellar and Scoop

1. Materials: Stainless steel

C. Salt and Pepper Set

1. Materials: Stainless steel

D. Cocktail Shaker

1. Materials: Stainless steel and silicon

E. Pitcher

1. Materials: Stainless steel

## 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

http://www.georgjensenstore.com/index.php?do=product.catalogue&catalogid=58

# SECTION 12 42 23

# GLASSWARE

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for glassware.

### 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 use and care guide for owner.

### 1.03 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. Stacking Glasses

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

END OF SECTION

# SECTION 12 43 13

# PORTABLE LAMPS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for portable floor lamp.
2. Specification for portable office lamp.

### 1.02 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. Portable Floor Lamp
   a. Product is guaranteed for a period of one year following the original purchase date. 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. Portable Office Lamp
   a. Product is guaranteed for a period of one year following the original purchase date. Warranty covers all parts and labor to repair or replace any part of the product, which proves to be defective in materials or workmanship.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Portable Floor Lamp

1. i-Tower High Power LED Floor Lamp. Model #HL5000D-MBK.

B. Portable Office Lamp

1. Z-Bar High Power LED Desk Lamp. Model #HL3001D-MBK.

### 2.02 MANUFACTURER

A. Koncept

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Portable Floor Lamp

1. Finish: Metallic black
2. LED Color: Daylight white
3. Built in four-step dimmer.
4. Six next generation high power LEDs.
5. Consumption: 9 watts

B. Portable Office Lamp

1. Finish: Metallic Black
2. LED Color: Daylight white
3. Built in four-step dimmer.
4. Six next generation high power LEDs.
5. Consumption: 9 watts

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.konceptech.com/highpoweritower.html

http://www.konceptech.com/highpowerzbar.html

# SECTION 12 45 00

# BEDROOM FURNISHINGS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for bed linens, pillow shams, and sheets.
2. Specification for bed pillows.

### 1.02 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. Tamara Bed Linens

B. Feather-down Bed Pillows

### 2.02 MANUFACTURERS

A. Marimekko

B. Crate & Barrel

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Bed Linens

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.

B. Bed Pillows

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. Bed Linens

1. 100% Cotton

B. Bed Pillows

1. 100% Cotton Pillow Shell
2. 80% white duck feather, 20% snow-white domestic down.

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

http://www.crateandbarrel.com/family.aspx?c=1627&f=11504

# 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. Daniel Donnelly Armless Sofa

### 2.02 MANUFACTURERS

A. Daniel Donnelly Modern Design Studio

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Capacities / Characteristics

1. Length: 80"

### 2.04 MATERIALS

A. Armless Sofa

1. Button tufted seat with loose feather cushion back.
2. Polished brass legs.

## PART 3 EXECUTION

### 3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

http://www.danieldonnelly.com/pop/10_4/dd_sofa.htm#

# SECTION 12 58 16

# RESIDENTIAL CHAIRS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for living room chairs.

### 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 WARRANTY

A. Manufacturer Warranty

1. None specified.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Eames Soft Pad Group Lounge Chair and Ottoman (EA423 and EA43X). Model #HML1185.

### 2.02 MANUFACTURERS

A. Herman Miller

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Lounge Chair and Ottoman

1. Lounge Chair Dimensions: 34.25-38.5" H x 24.75-26" W x 29.25-31" D
2. Ottoman Dimensions: 19.75" H x 21.5" W x 21.5" D
3. Textiles are made from post-industrial/post-consumer recycled content or pure fabrics.
4. 100% recyclable materials.

### 2.04 MATERIALS

A. Lounge Chair and Ottoman

1. Aluminum-ribbed frame.
2. Leather upholstered 2” thick foam cushions.

## PART 3 EXECUTION

### 3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

# 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 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. Series 7 Chair

1. 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.

B. Emeco Stools

1. Manufacturer warrants, to the original purchaser, all chairs and stools to be free from defects in material and workmanship under normal use and conditions for life. This warranty does not apply to chairs damaged by accident, abuse, neglect, or misuse, nor does it apply if repairs are attempted by purchaser or by anyone other than an authorized Emeco agent or the Emeco factory.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Fritz Hansen Series 7 Chair by Arne Jacobsen. Model #3107.

B. Emeco Stools by Starck. Model #STOL-18 and #STOL-24.

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. Emeco

C. Virginia Tech Solar Decathlon Team

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Series 7 Chair

1. Dimensions: 20.5” L x 31” H x 20” D

B. Emeco Stools

1. STOL-18
   a. Dimensions: 14” L x 18” H x 14” D
   b. Weight: 4.5 lbs.
   c. Made from 80% recycled content.
2. STOL-24
   a. Dimensions: 14” L x 24” H x 14” D
   b. Weight: 6 lbs.
   c. Made from 80% recycled content.

C. Dining Room Table

1. Dimensions as specified in drawings.

2.04 MATERIALS

A. Series 7 Chair

1. The shell is in laminated, molded veneer.
2. The outer veneer is sliced cherry, walnut, maple, ash, beech or dark-stained oak.
3. The base is 14 mm steel tubes with 4 legs with leg ferrules of black-grey synthetic material.

B. Emeco Stools

1. Brushed aluminum finish.

C. Dining Table

1. Hardwood maple.

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.emeco.net/productline/emecostool.html

# SECTION 12 58 29

# BEDS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for bed frame and mattress.

### 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 maintenance data.

### 1.03 WARRANTY

A. Manufacturer Warranty

1. Manufacturer’s warranty covers costumer from the day of purchase and continues according to the “Warranty Schedule” found on mattress tag. In the event that Sealy, Inc. repair or replace the mattress, warranty shall continue protection from the original date of purchase.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Posturepedic by Sealy

B. Custom fabricated bed frame designed and manufactured by the Virginia Tech Solar Decathlon Team.

### 2.02 MANUFACTURERS

A. Sealy, Inc.

B. Virginia Tech Solar Decathlon Team

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Posturepedic Queen Sized Mattress

1. Cushion firm model.
2. Unicase design provides a solid perimeter around the edge.
3. 10” depth
4. 60” W x 80” L

B. Custom fabricated bed frame designed and manufactured by the Virginia Tech Solar Decathlon Team.

1. Dimensions as specified in drawings.

### 2.04 MATERIALS

A. Mattress

1. Pressure relief inlay that has 3 zones with foam in the center.

B. Bed Frame

1. Hardwood maple.
2. General Lumber (See specification 06 10 53 – Miscellaneous Rough 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.sealy.com/Posturepedic/posturepedic.aspx

# SECTION 12 58 83

# CUSTOM RESIDENTIAL FURNITURE

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for movable kitchen island, and sliding desk.

### 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.

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. Custom fabricated movable kitchen island designed and manufactured by the Virginia Tech Solar Decathlon Team.

B. Custom fabricated sliding office desk designed and manufactured by the Virginia Tech Solar Decathlon Team.

### 2.02 MANUFACTURERS

A. Virginia Tech Solar Decathlon Team

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Movable Kitchen Island.

1. Dimensions as specified in drawings.

B. Sliding Office Desk

1. Dimensions as specified in drawings.

### 2.04 MATERIALS

A. Movable Kitchen Island.

1. Hardwood maple.

B. Sliding Office Desk

1. Hardwood maple.

## PART 3 EXECUTION

### 3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

END OF SECTION

# SECTION 12 93 00

# SITE FURNISHINGS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for exterior tables and lounge chairs.

### 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 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.  Model #1966-25

B. Adjustable Chaise Lounge.  Model #1966-42

C. Coffee Table with Porcelain Top.  Model #1966-21.

### 2.02 MANUFACTURERS

A. Richard Schultz Design

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Lounge Chair

1. Silver frame with a white mesh seat.
2. 26” W x 26” H x 28.25” D
3. Frame constructed from 95% recycle aluminum.

B. Adjustable Chaise Lounge

1. White frame with a white mesh seat.
2. 25.5” W x 14” H x 76” D
3. Frame constructed from 95% recycle aluminum.

C. Coffee Table

1. White table top with a white frame.
2. 28” W x 15.5” H x 28” D

3. 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 22 11 16

# DOMESTIC WATER PIPING

## PART 1 GENERAL

### 1.01 SUMMARY

A. This section includes specifications for the following:

1. Water-distribution piping
2. Fittings and valves
3. Manifolds

### 1.02 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 specifications for the following:

1. UP15-10SU7P/TLC
2. J5S
3. Taco 005-F

### 1.02 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 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

B. H2 Pro WWT

### 2.02 MANUFACTURERS

A. Buderus

B. Flexicon

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Hot water storage tank

1. 77 gallon tank.
2. Maximum water temperature of 203°F.
3. Maximum operating pressure of 145 psi.

B. Diaphragm pressure tank

1. 33.4 gallon tank
2. Maximum water temperature- 140°F.
3. Maximum operating pressure 125 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.

C. 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 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

END OF SECTION

# SECTION 22 13 19

# AIR ADMITTANCE VALVE

## PART 1 GENERAL

### 1.01 SUMMARY

A. This section includes the specifications of air admittance valves

### 1.02 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 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 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.  Model #K-3564.

### 2.02 MANUFACTURERS

A. Kohler, Co.

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. 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.

2.04 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. Specification for shower drain.
2. Specification for shower valve.

### 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 use and care guide for owner.

### 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..

F. 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.

G. 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 PRODUCT TYPE

A. Quick Drain linear shower drain. Model #LDBO30SS or comparable product.

B. MasterShower ½” Thermostatic Valve. Model #K-679-KS.

### 2.02 MANUFACTURERS

A. Quick Drain USA

B. Kohler Co.

### 2.03 PERFORMANCE / DESIGN CRITERIA

A. Shower Drain

1. Low profile, liner trench shower drain.
2. Dimensions: 32” length x 1.5” width
3. Finish: Brush stainless steel

B. Shower Valve

1. 1/2" inlet
2. Thermostatic valve allows bather to set and maintain precise temperature.
3. Factory-calibrated comfort setting at 104 degrees Fahrenheit.
4. High temperature safety stop ensures that water temperature does not exceed 120 degrees Fahrenheit.

## 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.quickdrainusa.com/index.html

http://www.us.kohler.com/onlinecatalog/detail.jsp?item=10080602&prod_num=679-KS

# 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 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 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 00

# INSTRUMENTATION AND CONTROL FOR HVAC

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes

1. General specification for the instrumentation and controls involved in the HVAC.

### 1.02 SUBMITTALS

A. Product Data

## PART 2 PRODUCTS

### 2.01 PRODUCT TYPE

A. General Listing of Parts Involved with HVAC Control.

1. Control Valves:
    a. Siemens – 261-02000
    b. Siemens – 261-02065
    c. Siemens – 171C-10209
    d. Siemens – 171C-10256
2. APOGEE Insight Software:
    a. Siemens – 571-010-391-USB
    b. Siemens – 571-188
    c. Siemens – 571-305
    d. Siemens – 571-317
    e. Siemens – 571-620
    f. Siemens – 571-633-391
3. Controller Material:
    a. Siemens – PXA-ENC34
    b. Siemens – PXA-SB115V19VA
    c. Siemens – PXC100-E96.A
    d. Siemens – PXC100-PE96.A
    e. Siemens – PXX-485.3
    f. Siemens – TXA1.K24
    g. Siemens – TXM1.16D
    h. Siemens – TXM1.6R-M
    i. Siemens – TXM1.8X
    j. Siemens –TXM1.8X.ML
    k. Siemens – TXS1.12F4
    l. Siemens – TXS1.EF4
    m. Siemens – 567-351

n. Siemens – 540-110

o. Siemens – 540-505

4. Wireless Communications:

a. Dlink – DAP-1522

b. Dlink – DIR-655

5. Space Sensors:

a. Siemens – QFA3071.FWU

b. Siemens – QFA3171

c. Siemens – QPA2062

d. Siemens – QPA2062D

6. Duct Sensors

a. Siemens – 533-376-4

b. Siemens – 533-376-8

c. Siemens – QFM3101

7. Slab and Immersion / Water Sensors

a. Siemens – 536-767-25

8. Power Monitoring

a. Siemens – 538-992

b. Veris – H721LC

c. Veris – H822-20

d. Veris – H931

9. Relays:

a. Functional Devices – RIB2401B

b. Functional Devices – RIB2401SB

c. Functional Devices – RIB24P

d. Functional Devices – RIB24P30

e. IDEC – RH2B-U-24VAC

f. Veris – H548

10. Low Voltage Cable:

a. Anixter – A7F30024324

b. Anixter – H-3C18-CMP

c. Anixter – H-TP18-CMP

d. Anixter – H-TP20-CMP-BOX

PART 3 EXECUTION

3.01 INSTALLERS

A. Siemens

END OF SECTION

# SECTION 23 09 13

# CONTROL VALVES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes specifications for the following:

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 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 SUMMARY

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 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. 03 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.)

1.04 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 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

# 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

# BASE-MOUNTED, CENTRIFUGAL HYDRONIC PUMPS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for 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

# 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.

<u>END OF SECTION</u>

# SECTION 23 33 46

# FLEXIBLE DUCT

## PART 1 GENERAL

### 1.01 SUMMARY

A. This section includes specifications for flexible ducting

### 1.02 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 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 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

# CLOSED CIRCUIT, FORCED DRAFT COOLING TOWERS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specification for Geothermal Fluid Cooler.

### 1.02 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 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.

<u>END OF SECTION</u>

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 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.

<u>END OF SECTION</u>

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 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 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 SUMMARY

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

A. 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 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. Coordinate location of equipment and conduit with other trades to minimize interferences.

1.08 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.

1.09 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.

1.10 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.

1.11 SINGULAR NUMBER

A. 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.

1.12 ACCEPTANCE TESTS AND CHECKS

A. The contractor shall furnish the instruments, materials and labor for field tests.

1.13 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.

<u>END OF SECTION</u>

# 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.

END OF SECTION

# 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 09 43

# ADDRESSABLE FIXTURE LIGHTING CONTROL

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section Includes:

1. Specifications for distributed fluorescent lighting control system.

### 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. 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.

D. International Organization for Standardization (ISO)

1. 9001:2000 – Quality Management Systems.

E. National Electrical Manufacturers Association (NEMA)

1. WD1 (R2005) - General Color Requirements for Wiring Devices.

F. Underwriters Laboratories, Inc. (UL)

1. 508 (1999) - Standard for Industrial Control Equipment.
2. 924 (2003) - Emergency Lighting and Power Equipment
3. 935 (2005) - Fluorescent Ballasts
4. 1472 (1996) - Solid-State Dimming Controls.

### 1.03 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. Shop Drawings

1. Schematic of System.

### 1.04 QUALITY ASSURANCE

A. Manufacturer: Minimum 10 years experience in manufacture of architectural lighting controls.

B. Manufacturer's Quality System: Registered to ISO 9001:2000 Quality Standard, including in-house engineering for product design activities.

C. Lighting control system components:

1. Listed by UL specifically for the required loads. Provide evidence of compliance upon request.

1.05 ENVIRONMENTAL CONDITIONS

A. Do not install equipment until following conditions can be maintained in spaces to receive equipment:

1. Ambient temperature: 0 degrees to 40 degrees C (32 degrees to 104 degrees F).
2. Relative humidity: Maximum 90 percent, non-condensing.
3. Lighting control system must be protected from dust during installation.

1.06 WARRANTY

A. Provide manufacturer's warranty covering 5 years with Lutron startup on EcoSystem modules from date of purchase.

B. Provide manufacturer's Enhanced 8 Year Limited Warranty for daylight sensors, occupancy sensors, wall stations, bus supply, and infrared receivers:

1. 8-year limited parts warranty for the replacement of defective lighting components from the date of system startup completion.
2. 2-year Silver Level Support and Maintenance Plan that covers 100 percent parts and labor from the date of the system startup completion.

C. Provide manufacturer's full 4 year warranty covering 100 percent parts and 100 percent labor from the date of system startup completion.

1. Silver Level Support and Maintenance Plan: includes 100 percent parts and labor coverage, 24 hours per day, 7 days per week telephone technical support, and can be renewed annually.

PART 2 PRODUCTS

2.01 PRODUCT TYPE

A. Lutron EcoSystem Dimming Ballasts and Switching Modules

B. Occupancy and Daylight Sensors

2.02 MANUFACTURERS

A. Lutron Electronics Co., Inc.

2.03 PERFORMANCE

A. Daylight Harvesting, Occupant Detection and Personal Control to control lighting with the following hierarchy:

1. Emergency (Highest priority): Ignores all other inputs.
2. Programming: During system programming, sensor inputs are ignored.
3. Occupant sensor: Allows lights to be on/off.

4. Daylight sensor: Imposes a high end limit for light output.
5. Personal control: Fine tune light levels up to the daylight sensor limit.

B. Response to a single sensor can be unique on fixture by fixture basis.

C. Power failure recovery – All devices return to their previous light level prior to power loss.

D. All programmable devices have integral power failure memory to maintain settings for a minimum of 10 years during power loss.

E. Wall station and sensor replacement is accomplished without programming.

2.04 ECOSYSTEM DIMMING BALLAST AND SWITCHING MODULES

A. Product: C5-BMJ-16A and C5-XPJ-16A

B. General
1. Continuous 3-Wire signal dimming to Lutron 3-Wire electronic dimming ballast.
2. Connect without interface to:
   a. Occupant sensor (motion detector).
   b. Daylight sensor.
   c. Personal control input (wall station or infrared receiver).
3. Generate digital communication commands to distribute ballast and sensor data on the digital bus.
4. If power is interrupted and subsequently returned, lights automatically return to the setting prior to power interruption.
5. Each ballast modules responds independently to:
   a. Up to 32 occupant sensors.
   b. Up to 64 personal control inputs.
   c. 2 daylight sensors.
6. Unique internal reference number visibly displayed on module cover.
7. Averages 2 independent daylight harvesting inputs internally.
8. Responds to digital load shed command
   a. Sets high end trim.
   b. Automatically scales light output proportional to load shed command.
      1) Example: If light output is at 30 percent and a load shed command of 10 percent is received, the ballast automatically sets the maximum light output at 90 percent and lowers current light output by 3 percent to 27 percent.
9. Electrical: Dimmer to meet limited short circuit test as defined in UL 20.
10. Provide integral fault protection to prevent ballast module failure in the event of a mis-wire.

C. 16 Amp (BMJ) 3-Wire Ballast Module
1. Ballast module to integrate up to 16 amps of Lutron 3-wire electronic dimming ballast into an EcoSystem control system as a single zone.

D. 16 Amp (XPJ) Switching Ballast Module
   1. Module to integrate up to 16 amps of high in-rush lighting load (magnetic fluorescent ballast, electronic fluorescent ballast, HID, incandescent, magnetic low-voltage, electronic low-voltage, neon/cold cathode and motor loads) into an EcoSystem control system as a single zone.

2.05 SENSORS

A. Ceiling and Wall Mount Occupancy / Vacancy Sensors
   1. Product: LOS-CDT-500R-WH
   2. Sensing mechanism:
      a. Dual technology:
         1) Utilize multiple segmented lens, with internal grooves to eliminate dust and residue build-up.
         2) Utilize an operating frequency of 32kHz or 40kHz that shall be crystal controlled to operate within plus or minus 0.005 percent tolerance.
   3. Connect directly to EcoSystem ballast and modules without the need of a power pack or other interface
   4. Sensors shall turn off or reduce lighting automatically after reasonable time delay when a room or area is vacated by the last person to occupy the space
   5. Sensor shall accommodate all conditions of space utilization and all irregular work hours and habits.
   6. Sensors shall be UL listed (as appropriate).
   7. Sensors shall be fully adaptive and adjust their sensitivity and timing to ensure optimal lighting control for any use of the space
   8. Sensors shall have field adjustable controls for time delay and sensitivity to override any adaptive features.
   9. Power failure memory:
      a. Controls incorporate non-volatile memory. Should power be interrupted and subsequently restored, settings and learned parameters saved in protected memory shall not be lost.
   10. Provide all necessary mounting hardware and instructions.
   11. Sensors shall be Class 2 devices.
   12. Indicate viewing directions on mounting bracket for all Ceiling mount sensors.
   13. Provide customizable mask to block off unwanted viewing areas for all ceiling mounted sensors using infrared technology.
   14. Provide swivel mount base for all wall mount sensors.

B. Sensor Power Packs
   1. For ease of mounting, installation and future service, power pack(s) shall be able to mount through a 1/2" knock-out in a standard electrical enclosure and be an integrated,

self-contained unit consisting internally of an isolated load switching control relay and a transformer to provide low-voltage power. Transformer shall provide power to a minimum of three (3) sensors.

2. Power pack shall be plenum rated
3. Control wiring between sensors and control units shall be Class 2, 18-24 AWG, stranded U.L. Classified, PVC insulated or TEFLON jacketed cable suitable for use in plenums, where applicable

C. Infrared Receivers

1. Use Class 2 wiring for low voltage communication
2. Can be replaced without reprogramming
3. 360 degree reception of wireless infrared remote controls
4. Immediate local LED response upon reception of hand held transmitter communication
5. Constructed with plastic meeting UL94 HB
6. Mountable on lighting fixtures or recessed acoustical ceiling tiles
7. Constructed via sonic welding
8. Color:
   a. Match NEMA WD1, Section 2 White
   b. Color variation in same product family: Maximum ΔE=1, CIE L*a*b color units
   c. Visible parts: Exhibit ultraviolet color stability when tested with multiple actinic light sources as defined in ASTM D4674. Provide proof of testing upon request.

D. Interior Daylight Sensors

1. Product: EC-DIR-WH
2. Use Class 2 wiring for low voltage communication
3. Can be replaced without reprogramming
4. Open-loop basis for daylight sensor control scheme
5. Stable output over temperature from 0 degrees to 40 degrees C
6. Partially shielded for accurate detection of available daylight to prevent fixture lighting and horizontal light component from skewing sensor detection
7. Provide linear response from 0 to 500 foot-candles
8. Integral IR receiver for programming
9. Constructed with plastic meeting UL94 HB
10. Mountable on lighting fixtures or recessed acoustical ceiling tiles
11. Constructed via sonic welding
12. Color:
    a. Match NEMA WD1, Section 2 White
    b. Color variation in same product family: Maximum ΔE=1, CIE L*a*b color units
    c. Visible parts: Exhibit ultraviolet color stability when tested with multiple actinic light sources as defined in ASTM D4674. Provide proof of testing upon request.

2.06 SOURCE QUALITY CONTROL

A. Perform full-function testing on all completed assemblies at end of line. Statistical sampling is not acceptable.

B. Diagnostics and Service – Tiered control scheme for dealing with component failure that minimizes loss of control for occupant.

1. Bus failure: Lights go to emergency level for safety.
2. Failure of one sensor type: Ballast still controllable via other sensors.
3. Ballast failure: Only impacts one fixture – remainder of system operates as programmed.

PART 3 EXECUTION

3.01 INSTALLERS

A. Virginia Tech Solar Decathlon Team

B. Lutron Electronics Co., Inc.

3.02 INSTALLATION

A. Install equipment in accordance with manufacturer's installation instructions.

B. Provide complete installation of system in accordance with Contract Documents.

C. Provide equipment at locations and in quantities indicated on Drawings. Provide any additional equipment required to provide control intent.

D. Ensure that daylight sensor placement minimizes sensors view of electric light sources; ceiling mounted and fixture-mounted daylight sensors shall not have direct view of luminaries.

3.03 STARTUP AND PROGRAMMING

A. Provide factory-certified field service engineer to ensure proper system installation and operation under following parameters:

1. Qualifications for factory-certified field service engineer:
   a. Minimum experience of 2 years training in the electrical/electronic field.
   b. Certified by the equipment manufacturer on the system installed.
2. Site visit activities:
   a. Verify connection of power feeds and load circuits.
   b. Verify connection of controls.
   c. Verify system operation control by control, circuit by circuit.
   d. Obtain sign-off on system functions.
   e. Demonstrate and educate Owner's representative on system capabilities, operation and maintenance

B. Tech Support

1. Provide factory direct technical support hotline 24 hours per day, 7 days per week.

3.04 MAINTENANCE

A. Capable of providing on-site service support within 24 hours anywhere in continental United States and within 72 hours worldwide except where special visas are required.

B. Offer renewable service contract on yearly basis, to include parts, factory labor, and annual training visits. Make service contracts available up to ten years after date of system startup.

END OF SECTION

http://www.lutron.com/CMS400/default.aspx?app=ecosystem

# SECTION 26 24 16

# PANEL BOARDS

## 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 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 27 41 13

# ARCHITECTURALLY INTEGRATED AUDIO / VIDEO EQUIPMENT

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes

1. Specifications for the following audio/visual equipment:

a. Living Room LED Television

b. Bedroom LED Television

c. Home Theater System

d. Game Console / Blu-Ray Player

e. Game Console

f. Game Console Accessory

### 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. 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.

2. 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. 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) or comparable product.

D. PLAYSTATION®3 80GB System (CECHP01)

E. Nintendo Wii (ABC)

F. Nintendo WiiFit with Wii Balance Board

2.02 MANUFACTURERS

A. Samsung Electronics America, Inc.

B. Samsung Electronics America, Inc.

C. Samsung Electronics America, Inc.

D. Sony Computer Entertainment America Inc.

E. Nintendo of America Inc.

F. Nintendo of America Inc.

2.03 PERFORMANCE / DESIGN CRITERIA

A. Televisions:

1. 5,000,000:1 Dynamic Contrast Ratio.
2. AutoMotion Plus 240Hz.
3. Full HD 1080p resolution.
4. Ultra-slim (1.2” deep) Touch of Color design.
5. Energy Star compliant; LED TVs use up to 40% less power than conventional LCD TVs.
6. Fast 2ms response time minimizes blurring of fast motion in high action programs.

B. Home Theater System

1. 2.6 inches deep and accented with Samsung’s Touch of Color (ToC) design.
2. “Smart Volume” technology for automatic volume level adjustments and the ability to change audio sources without the need to continually pick up the remote.
3. Each speaker has built in I-pod Dock.
4. "Bio kelp speaker" eco-friendly and improves sound production
5. Integrated connectivity and can connect to wireless networks for streaming internet radio.

C. Game Console / Blu-Ray Player

1. Hard Drive: 2.5’ Serial ATA (80GB)
2. Ethernet (10BASE-T, 100BASE-TX, 1000BASE-T) IEEE 802.11 b/g Wi.Fi
3. Bluetooth 2.0 (EDR)
4. Wireless Controller Bluetooth (up to 7)
5. Screen size: 480i, 480p, 720p, 1080i, 1080p
6. HDMI: HDMI out – (x1 / HDMI)
7. Analog: AV MULTI OUT x 1

8. Digital audio: DIGITAL OUT (OPTICAL) x1
9. Blu-ray/DVD/CD DRIVE “read only”
10. I/O: USB 2.0 x 2
11. Dimensions: Approximately 325mm (W) x 98mm (H) x 274mm (D)
12. Weight: Approximately 5 kg
13. CPU: Cell Broadband Engine™
14. GPU: RSX
15. Memory: 256MB XDR Main RAM, 256 GDDR3 VRAM

D. Game Console
1. Accessories: Remote x 1, Nunchuk, AC Adaptor, A/V Cable, Batteries x 2
2. Size: 44mm (W) x 157mm (H) x 215.4mm (D)
3. Wireless LAN IEEE802.11b/g or LAN Adapter Optional
4. Disc: 12cm Wii Disc or 8cm Game Cube Disc
5. USB 2.0 x 2
6. SD Card Slot x 1
7. Game Cube Controller Port x 4
8. Game Cube Memory Slot x 2
9. A/V Multi Output x 1

E. Game Console Accessory
1. WiiFit Disc
2. WiiFit Balance Board
3. AAA Batteries x 4

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.
2. Install according to manufacturers’ provided instructions.

END OF SECTION

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

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 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 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 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 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

ARUP



# Solar Decathlon Spain – Structural Calculations
# Virgina Tech College of Architecture & Urban Studies

**Table of Contents**


| | | |
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| **1.** | **Structure, Materials, Loading & Codes** | **S-01** |
| **2.** | **Floor Framing** | **S-06** |
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| **5.** | **Bracing** | **S-17** |
| **6.** | **SIP Walls and Roof** | **S-18** |
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ARUP

**Calculation Sheet**

| Job title | Virginia Tech Solar Decathlon | Job number | Sheet number | Revision |
|---|---|---|---|---|
| | | 75948-74 | S0.0 | |
| Calc title | | Member/Location | | |
| | | Drg. Ref. | | |
| | | Made by P67 | Date 02/02/10 | Chd. |

## Introduction

The house has been designed for two in-service conditions. The first is when the house is being transported, and the second is when the house is in place and being occupied. The structural system used for the in transit condition is a modification of the structure for the permanent or static condition.

The static structure will be described first. The house is single story consisting of a roof, a suspended floor and perimeter walls. The floor consists of concrete on composite metal deck supported on partially composite steel floor beams. Gravity loads on the roof and floor are supported by beams spanning across the short dimension of the house. The roof beams are supported on columns..
Lateral loads are resisted by shear panels located near the corners and arranged on all four perimeter walls. The superstructure is supported on closely spaced footings when in service.

When the house is being transported axles are attached directly to the floor structure at either end. A tractor unit then engages the front axle to haul the house. Therefore the house spans from front to back axle. To accomplish this temporary diagonal steel members are bolted to the permanent structure to create longitudinal trusses on each side of the house.

The materials used for the structure of the house include concrete, steel and SIPs (Structural Insulated panels). The latter are manufactured from a rigid insulation (foamed polystyrene) core and oriented strand board skins. The mechanical properties of the materials are described in the calculations.

All loadings are described in the calculations including diagrams of the wind pressures.
Allowable stress design was used for the structural steel elements. The load combinations are as follows:
A1 = D+L
A2 = 0.6D+W
A3 = D+S,
where D = dead load, L = live load, W = wind load and S = snow load.

Generally hand calculations were used to justify the design. Some use was made of the analysis program GSA, distributed by OASYS ( http://oasys.intranet.arup.com/products/ ).

Stress and deformation checks are included in the calculations for the house in place.
The transportation case is not covered by building codes and was not required to be submitted for the USA version of the Solar Decathlon.

Structural fire resistance calculations have not been completed, because the building occupancy does not require them.

ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-1 | |

Member-Location

Job Title Solar Decathlon
Virginia Tech Entry

Drg. Ref.

Made by P6T Date Dec 08 A07 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 A 572-Gr 50 | 50 | |
| HSS square & rectangular | ASTM A 500-Gr B | 46 | |
| HSS round | " " | 42 | |
| Pipe | ASTM A 53-Gr B | 35 | |
| Plate | ASTM A 572-Gr 50 | 50 | $t \leq 2''$ |

- Welding Electrodes E7018 — $F_u$ [ksi] 70
- Normal weight concrete
  - $f'_c$ 3,000 psi
  - $\gamma_c$ 150 pcf

- Allowable bearing pressures
  - Temporary Installation 1500 psf
  - Permanent 2000 psf

ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-2 | |

Member-Location

Job Title: Solar Decathlon VT

Drg. Ref.

Made by PGT Date Dec '08 Chd.

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 windspeed (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 |

ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-2.1 | |

Member-Location

Job Title Solar Decathlon VT

Drg. Ref.

Made by PGT Date Dec '08 Chd. PGT

## 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 | $h$ | $\leq 15$ 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

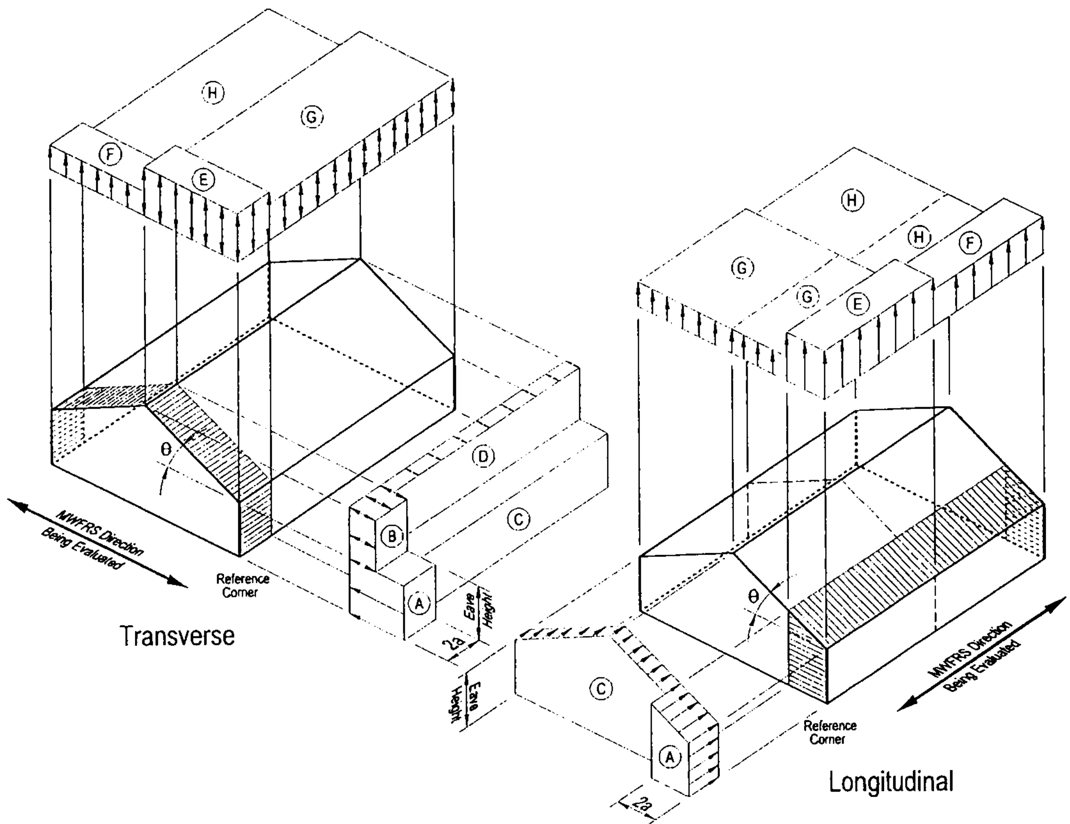
$= -10.8$ F

$= -13.3$ G

$= -8.4$ H

see S-2.2 for code diagram

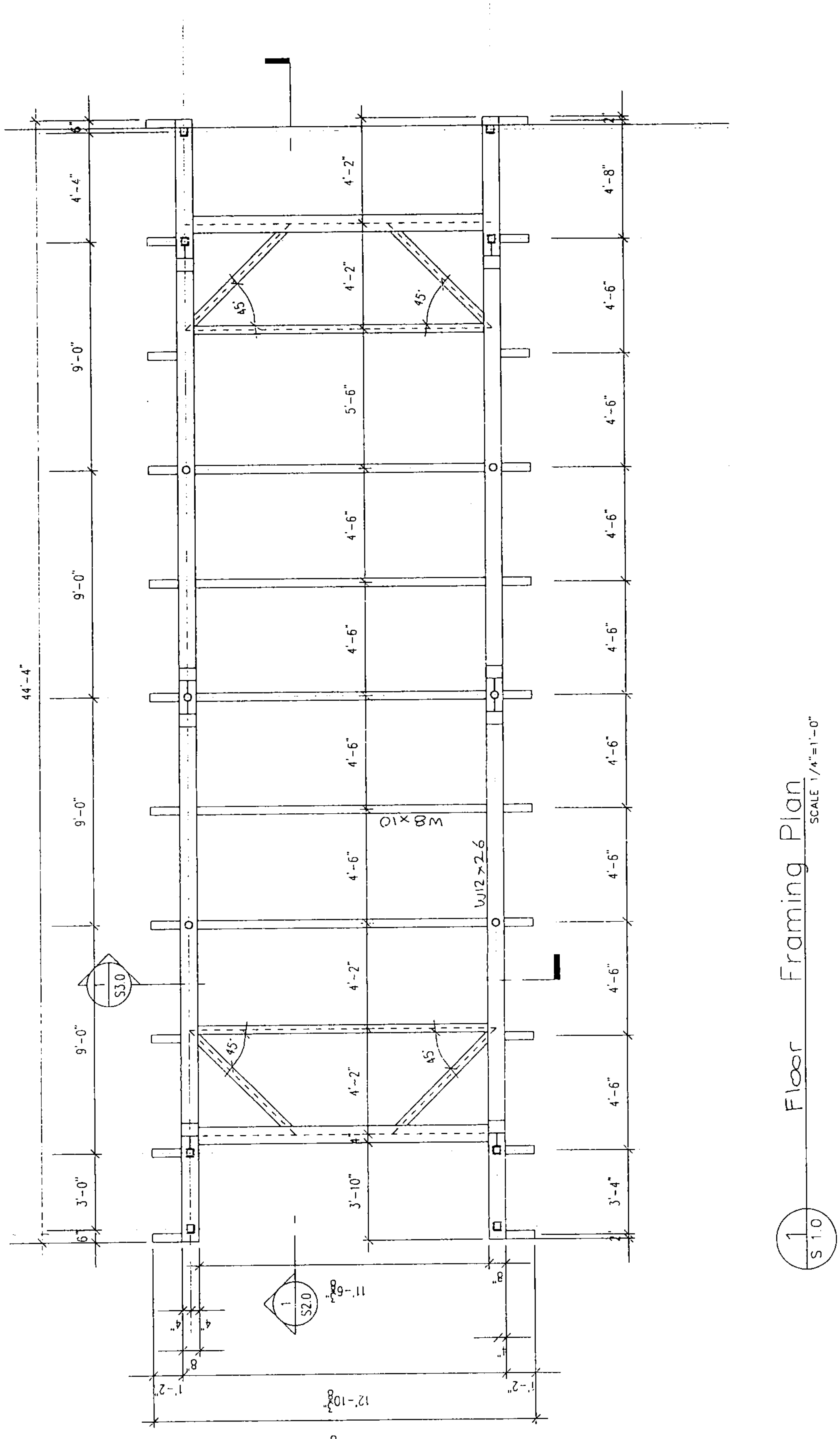
| Main Wind Force Resisting System – Method 1 | | h ≤ 60 ft. |
|---|---|---|
| **Figure 6-2** | **Design Wind Pressures** | **Walls & Roofs** |
| **Enclosed Buildings** | | |




Notes:

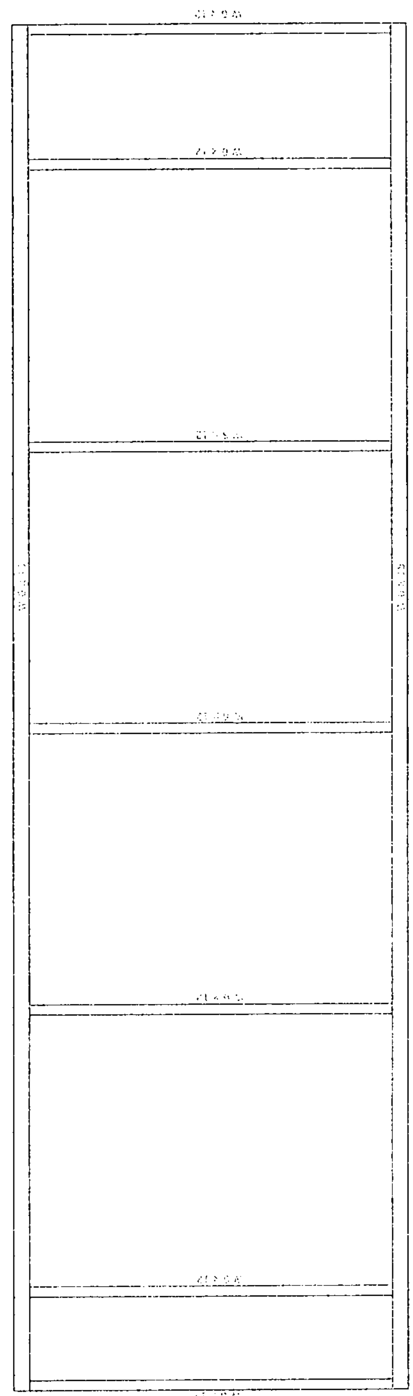
1. Pressures shown are applied to the horizontal and vertical projections, for exposure B, at h=30 ft (9.1m), I=1.0, and $K_{zt}$ = 1.0. Adjust to other conditions using Equation 6-1.
2. The load patterns shown shall be applied to each corner of the building in turn as the reference corner. (See Figure 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.

FIGURE 6-1C BASIC WIND SPEED—MID AND NORTHERN ATLANTIC HURRICANE COASTLINE


Floor Framing Plan
SCALE 1/4"=1'-0"
1
S1.0
44'-4"
4'-4"
9'-0"
9'-0"
9'-0"
9'-0"
3'-0"
4'-2"
4'-2"
5'-6"
4'-6"
4'-6"
4'-6"
4'-6"
4'-2"
4'-2"
3'-10"
4'-8"
4'-6"
3'-4"
W8x10
W12x26
45°
1
S3.0
1
S2.0
11'-6 3/8"
12'-10 3/8"
15'-2 3/8"
1'-2"
8"
4"

S-4

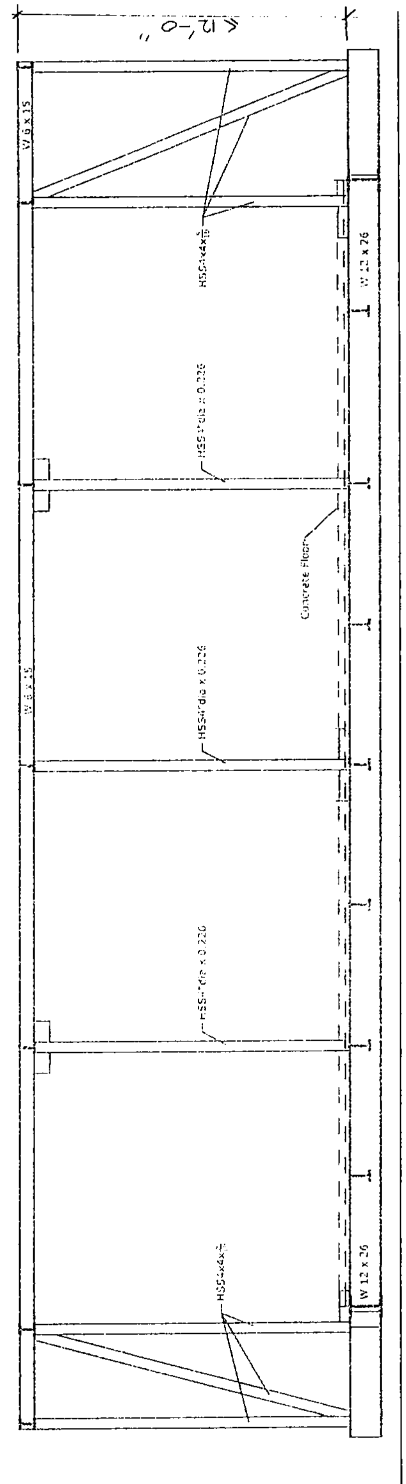
S-4



Roof Framing Plan

S-5

S-5




Typical Elevation

ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S2.3 | |
| Member-Location | | |
| Drg. Ref. | | |
| Made by PGT | Date Dec '08 | Chd. |

Job Title Solar Decathlon

VT

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 | $T$ | $\leq 0.1$ sec |
| Importance | $I$ | 1.0 |

Seismic Force Resisting System

- SIPS panel across building $R = 2.0$
- Concentrically braced frame along building, $R = 3.25$

| ARUP | Job No. 75948-74 | Sheet No. S-6 | Rev. |
|---|---|---|---|
| | 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 [illegible] Manual
$M_n/\Omega_b$ = 22 [illegible]

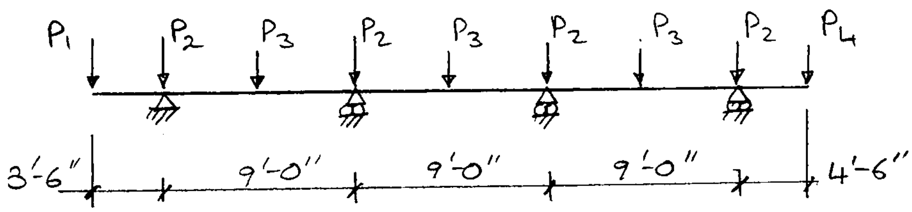
| Typical Stub |
|---|
| W8×10 |

ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-7 | |
| Member-Location | | |
| Drg. Ref. | | |
| Made by PGT | Date Dec '08 | Chd. |

Job Title Solar Decathlon
VT

## 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

**Edge Beam**
**W12×26**

ARUP

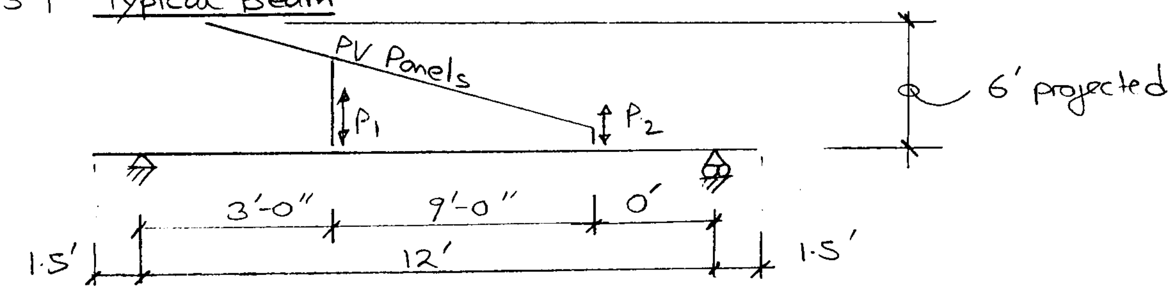
| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-8 | |
| Member-Location | | |
| Drg. Ref. | | |
| Made by AGT | Date Dec '08 | Chd. |

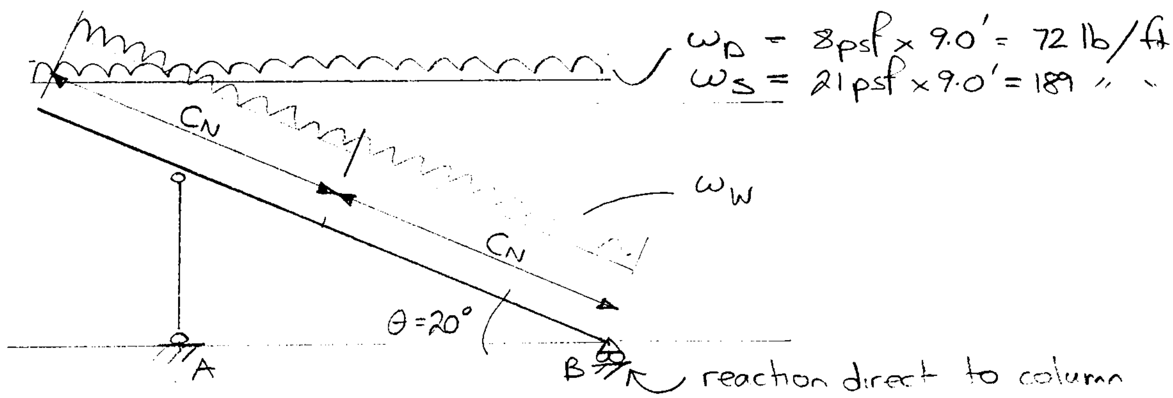
Job Title Solar Decathlon
VT

## 3.0 Roof Framing

SIPS panels provide lateral restraint to top flange of beams. Panels span parallel to typical beam

### 3.1 Typical Beam




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:

$P = C_N G q$

$$q_h = 0.00256 K_z K_{zt} K_d V^2 I$$ ASCE 7 Eq 6-15

$$= 0.00256 \times 0.57 \times 1.0 \times 0.85 \times 100^2 \times 1.0$$

$$= 12.4 \text{ psf}$$

$$p = C_N \times 0.85 \times 12.4 = 10.5 C_N \text{ psf}$$

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

$$L_b = 12' > L_r = 1.95 r_{ts}\left(\frac{E}{.7F_y}\right)\sqrt{\frac{J_c}{S_x h_o}}\left[1+\left(1+6.76\left(\frac{.7F_y}{E}\cdot\frac{S_x h_o}{J_c}\right)^2\right)^{1/2}\right]^{1/2}$$

$$\simeq \pi r_{ts}\left(\frac{E}{.7F_y}\right)^{1/2} = 98''$$

$$\Rightarrow M_n = F_{cr} S_x \le M_p$$

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_{ts}}\right)^2}\left(1 + 0.078\frac{J_c}{S_x h_o}\left(\frac{L_b}{r_{ts}}\right)^2\right)^{1/2}, \quad C_b = 3.0$$

for W6 x 12 :

$r_{ts}$ = 1.08"

$J_c$ = 0.0903 in$^4$

$h_o$ = 5.75"

$S_x$ = 7.31 in$^3$

$$F_{cr} = 96.3 \text{ ksi} > F_y$$

$$\Rightarrow M_n = F_y Z_x = 50 \times 8.3 = 415 \text{ k-in}$$

$$M_n/\Omega_b = 415/1.67 = 248 \text{ k-in} \gg M_a \quad \text{OK}$$

$\boxed{\text{Typical Beam W6 x 12}}$

| ARUP | Job No. | Sheet No. | Rev. |
|---|---|---|---|
| **Soalr Decathlon**<br>Structural Frame<br>PV Panel Supports | 75948-74 | S-10 | |
| | Drg. Ref. | | |
| | Made by<br>PGT | Date<br>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 30.38.1.18 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 | z | | |
| 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***

| | | | | |
|---|---|---|---|---|
| 3 | 12.00 | 0.0 | 0.0 Global | z |
| 1 | 0.0 | 0.0 | 0.0 Global | Pin |
| 4 | -0.2160 | 0.0 | 4.446 Global | |

***Minima***

| | | | | |
|---|---|---|---|---|
| 4 | -0.2160 | 0.0 | 4.446 Global | |
| 1 | 0.0 | 0.0 | 0.0 Global | Pin |
| 1 | 0.0 | 0.0 | 0.0 Global | Pin |

## Supports

| Node | Constraint Axis | Total Restr. | Trans. Stiffness Kx [kip/ft] | Trans. Stiffness Ky [kip/ft] | Trans. Stiffness Kz [kip/ft] | Rotational Stiffness Kxx [kip-ft/rad] | Rotational Stiffness Kyy [kip-ft/rad] | Rotational Stiffness Kzz [kip-ft/rad] |
|---|---|---|---|---|---|---|---|---|
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | Global | z | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ***Maxima*** | | | | | | | | |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ***Minima*** | | | | | | | | |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | Global | Pin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Elements

Element types tagged with * are dummy elements and are not analysed
Element list: 1 2

| Elem | Type | Property | Group | Orient. Node | Orient. Angle [°] | Vertical | Length /Area [ft] | Topology | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Beam | W6x12 | 1 | 0 | 0.0 | | 3.000 | 1 | 2 |
| 2 | Beam | W6x12 | 1 | 0 | 0.0 | | 9.000 | 2 | 3 |
| ***Maxima*** | | | | | | | | | |
| 1 | Beam | W6x12 | 1 | 0 | 0.0 | | 3.000 | 1 | 2 |
| 2 | Beam | W6x12 | 1 | 0 | 0.0 | | 9.000 | 2 | 3 |
| ***Minima*** | | | | | | | | | |
| 1 | Beam | W6x12 | 1 | 0 | 0.0 | | 3.000 | 1 | 2 |
| 1 | Beam | W6x12 | 1 | 0 | 0.0 | | 3.000 | 1 | 2 |
| ***Totals*** | | | | | | | | | |
| | | | | | | | 12.00 | | |

## Element Releases

*This table is empty.*

## Standard Materials

| | Name | Description | Young's Modulus [kip/in²] | Poisson's Ratio | Shear Modulus [kip/in²] | Density [lb/ft³] | Thermal Expansion Coeff. [/°F] | Yield Stress [kip/in²] | Ultimate Stress [kip/in²] | Hardening Modulus [kip/in²] | Hardening Parameter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 2 | Concrete short term | Concrete | 4061. | 0.2000 | 1692. | 149.8 | 5.556E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 3 | Concrete long term | Concrete | 2031. | 0.2000 | 846.1 | 149.8 | 5.556E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 4 | Aluminium | N/A | 10150. | 0.3400 | 3788. | 169.2 | 12.78E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 5 | Glass | N/A | 10200. | 0.2200 | 4179. | 154.2 | 4.444E-6 | Infinity | Infinity | 0.0 | 0.0 |
| ***Maxima*** | | | | | | | | | | | |
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 4 | Aluminium | N/A | 10150. | 0.3400 | 3788. | 169.2 | 12.78E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 4 | Aluminium | N/A | 10150. | 0.3400 | 3788. | 169.2 | 12.78E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |
| ***Minima*** | | | | | | | | | | | |
| 3 | Concrete long term | Concrete | 2031. | 0.2000 | 846.1 | 149.8 | 5.556E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 2 | Concrete short term | Concrete | 4061. | 0.2000 | 1692. | 149.8 | 5.556E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 3 | Concrete long term | Concrete | 2031. | 0.2000 | 846.1 | 149.8 | 5.556E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 2 | Concrete short term | Concrete | 4061. | 0.2000 | 1692. | 149.8 | 5.556E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 5 | Glass | N/A | 10200. | 0.2200 | 4179. | 154.2 | 4.444E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |
| 1 | Steel | Steel | 29730. | 0.3000 | 11440. | 490.1 | 6.667E-6 | Infinity | Infinity | 0.0 | 0.0 |

## Beam Sections

Properties listed are analysis values, modified from base values where indicated. Refer to the Beam Sections Definitions output for modification details.
Iyz is reported only for non-symetrical sections. Iyz is enclosed by brackets where the section has been flagged to 'Ignore Iyz'.

| | Name | Material | Description | Mod. | A [in²] | Iyy [in4] | Izz [in4] | Iyz [in4] | J [in4] | Ky | Kz | Type | Cost [USD/lb] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | W6x12 | Steel | W6x12 | | 3.550 | 22.10 | 2.979 | | 0.09034 | 0.5278 | 0.3470 | N/A | 0.0 |
| ***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 |
| 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 |
| 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 |
| 1 | W6x12 | Steel | W6x12 | | 3.550 | 22.10 | 2.979 | | 0.09034 | 0.5278 | 0.3470 | N/A | 0.0 |
| ***Minima*** | | | | | | | | | | | | | |
| 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 |
| 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 |
| 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 |
| 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 |
| 3 | 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* | | | | | | | | | |
| 3 | 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 |
| 3 | 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*

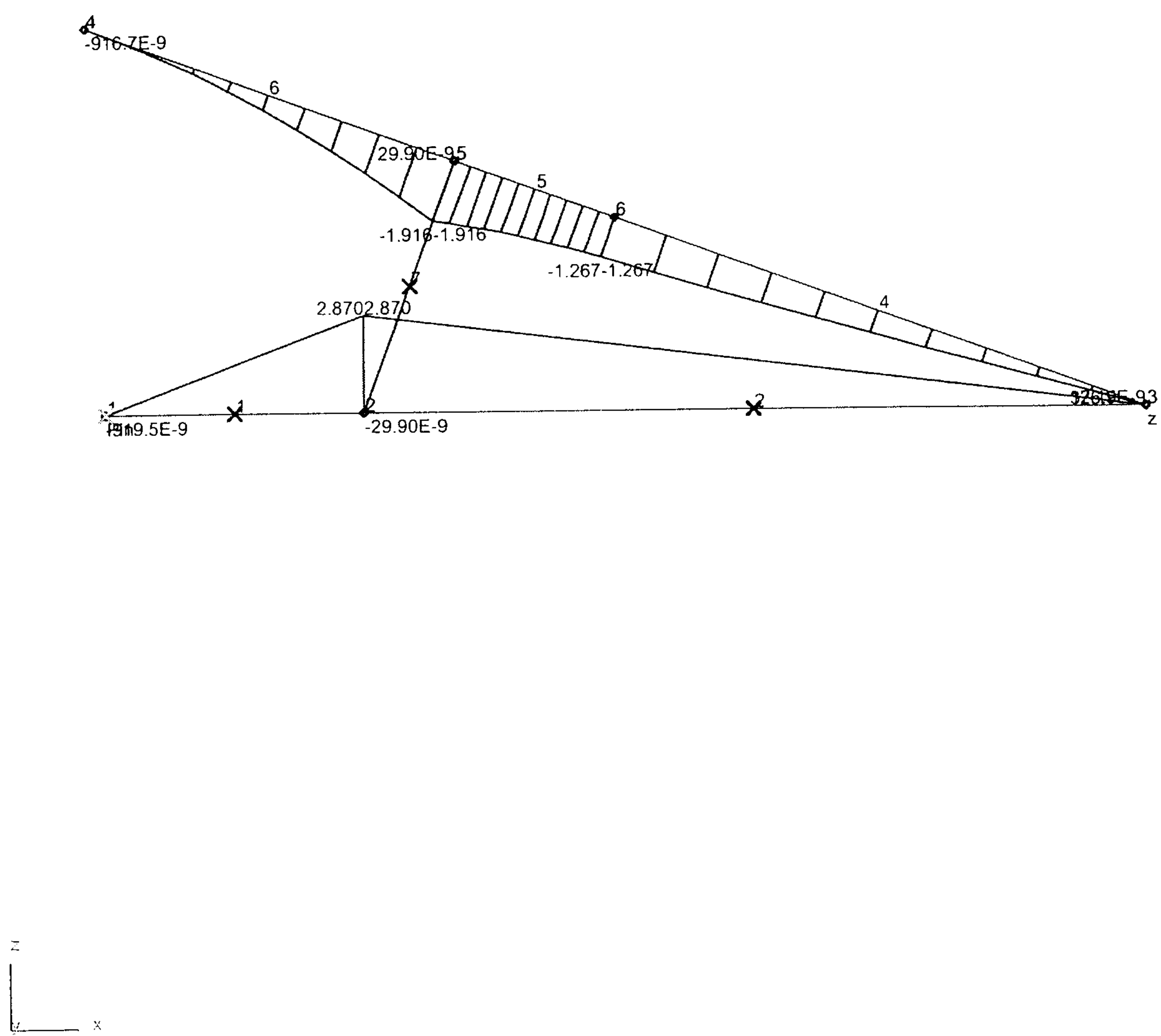
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 A3 | 2 | -0.03862 | 0.0 | -0.4181 | 0.0 | 3.763 | 0.0 |
| 1 A1 | 1 | 0.0 | 0.0 | -0.4963 | 0.0 | -344.9E-9 | 0.0 |
| 1 C2 | 1 | 0.0 | 0.0 | -1.747 | 0.0 | 66.15E-9 | 0.0 |
| 1 A1 | 1 | 0.0 | 0.0 | -0.4963 | 0.0 | -344.9E-9 | 0.0 |
| 1 C2 | 2 | 0.0 | 0.0 | -1.747 | 0.0 | -5.241 | 0.0 |
| 1 A1 | 1 | 0.0 | 0.0 | -0.4963 | 0.0 | -344.9E-9 | 0.0 |

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



# ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-15 | |

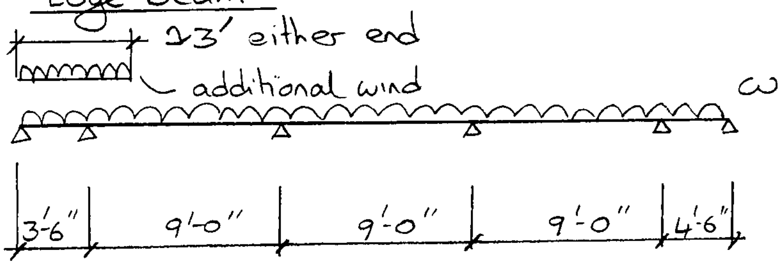
Member-Location

Job Title Solor Decathlon
VT

Drg. Ref.

Made by PGT Date Dec '08 Chd.

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

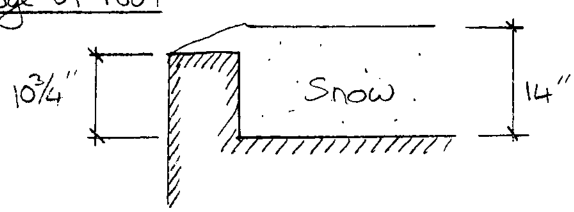
$\omega_S: = 7.5' \times 21 = 158$ lb/ft

$p_f = 21$ psf

snow depth: $\gamma = 0.13 p_g + 14 \leq 30$ pcf
$= 0.13 \times 30 + 14$
$= 17.9$ pcf

$h_s = \dfrac{21}{17.9} = 14''$

edge of roof




$h_c/h_b < 0.2 \Rightarrow$ do not consider drifting

$\omega_W$

| Zone | pw [psf] | $\omega_W^{\perp}$ [lb/ft] | $\omega_W''$ [lb/ft] |
|---|---|---|---|
| E | -19.1 | -143 | -57 → -117 |
| F | -10.8 | -81 | -32 |
| G | -13.3 | – | -60 |
| H | -8.4 | – | -38 → -70 |

Govern

ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-16 | |

Member-Location

Job Title Solar Decathlon

VT

Drg. Ref.

Made by PGT Date Dec '08 Chd.

treating beam as simply supported over 9'-0" (conservative)

$\omega_a^{max} = \omega_D + \omega_S \quad = 103 + 60 + 158 \quad = 321 \text{ lb/ft}$

$M_a^{max} = \frac{1}{8} \omega_a L^2 \quad = 39 \text{ k-in } (3.25 \text{ k-ft})$

$V_a^{max} = \frac{1}{2} \omega_a L \quad = 1.44 \text{ k}$

$\omega_a^{min} = .6\omega_D + \omega_W \quad = (.6 \times 103) + (-143) = -81 \text{ lb/ft}$

$M_a^{min} = \quad = 9.8 \text{ k-in } (0.82 \text{ k-ft})$

$V_a^{min} = \quad = 0.365 \text{ k}$

for uplift $L_b = 4.5 \text{ ft} = 54''$

top flange is braced by SIPS panels.

capacities of W6 x15

positive moment $M_n/\Omega = 224 \text{ k-in}$ OK

$L_p = 1.76 r_y \sqrt{\frac{E}{F_y}} = 1.76 \times 1.45 \left(\frac{29000}{50}\right)^{1/2} = 61''$

$\Rightarrow L_b < L_p$

$M_n \triangleq S_x F_y \quad = 486 \text{ k-in}$

$M_n/\Omega \quad = 291$ " " OK

| Edge Beam |
|---|
| W6 x15 |

**ARUP**

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-17 | |
| Member-Location | | |
| Drg. Ref. | | |
| Made by PGT | 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
Ø 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

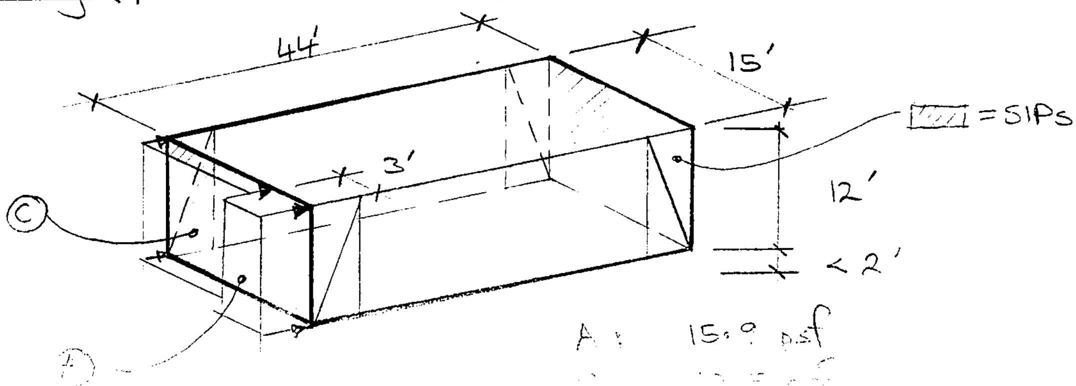
$= -0.73^k$ (ie tension)

Axial compression capacities

$\left.\begin{array}{lll} \text{HSS } 4.0 \times 0.226 & P_n/\Omega_c = & 38.5^k \\ \text{HSS } 4.0 \times 4.0 \times 5/16 & P_n/\Omega_c = & 73.1^k \end{array}\right\}$ Both OK

| Columns |
|---|
| HSS 4.0 × 0.226 |
| or HSS 4.0×4.0×5/16 |

## 5.0 Bracing (permanent installation, V = 100 mph)



ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-18 | |

Member-Location

Drg. Ref.

Job Title: Solar Decathlon VT

Made by: PGT Date: Dec '08 Chd.

Maximum wind force at corner of roof

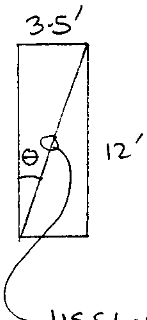
$$P_W = (3' \times 12/2)\,15.9 + (7.5' - 3')\,\frac{12'}{2} \times 10.5$$

$$= 570\ \text{lbs}$$

⇒ Sharing force between 2 brace elements

$$C_{brace} = \frac{\tfrac{1}{2} P_W}{\sin\theta} = 1.0\ \text{kip}$$

OK by inspection




$\theta = 16°$

HSS4.0x4.0 x5/16

| 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/ $\Delta \le L/360$

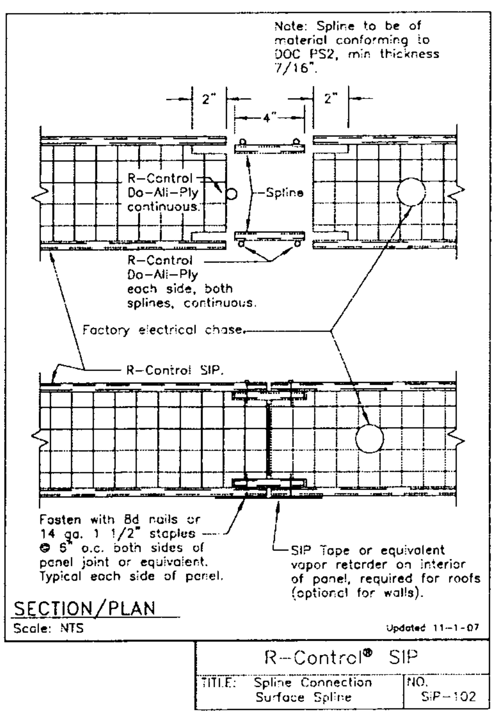
See sheet S-19 for product data

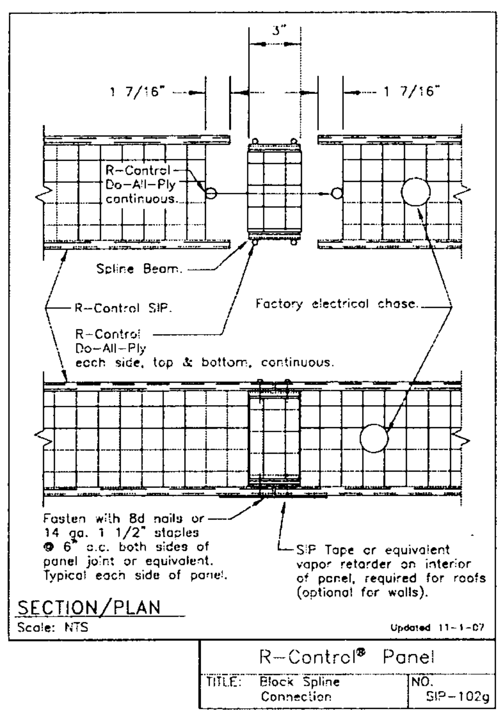
## Roof/Floor - Transverse Loading
## LOAD DESIGN CHART #1
### (SEE SPLINE DETAILS SIP-102 or SIP-102g)

| 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.



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# ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-20 | |

Member-Location

Job Title: Solar Decathlon VT

Drg. Ref.

Made by: PGT Date: Dec'08 Chd.

## 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 $a = 3ft$

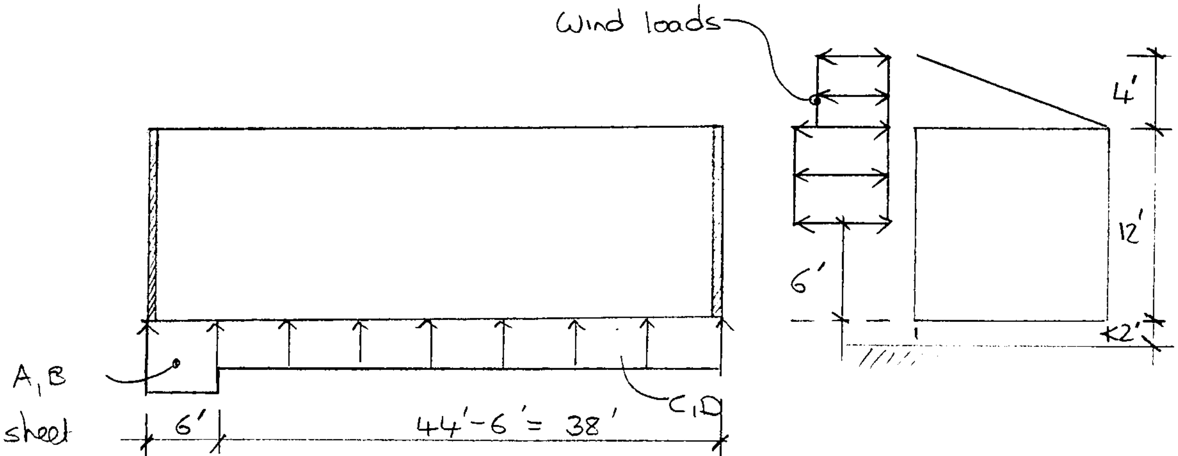
$= -27$ psf

$h = 12ft$ 6 1/2" SIP

$p_{all} = 38$ psf w/ $\Delta \leq L/240$ OK

- **In-Plane (Rocking) Loads**

If end walls resist all lateral loads & PV panels are in place




Zones from sheet S2.2

PLAN

SECTION

| Zone | Pressure |
|---|---|
| A | 15.9 |
| B | -8.2 |
| C | 10.5 |
| D | -4.9 |

← neglect (conservative

Maximum shear on end wall $V_w = (22-6)6 \times 10.5 + 6.6 \times 15.9$

$= 1.58^k$

With SIP-140 Fore' $\sigma_{allow} = 335$ lb/ft

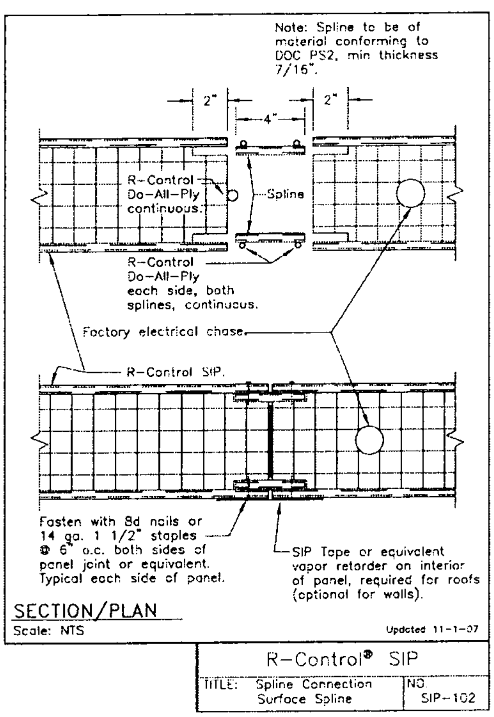
→ > 47 ft OK

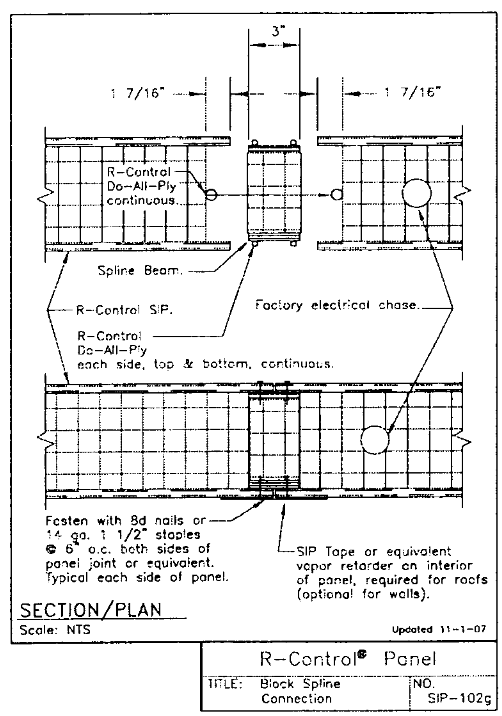
## Wall - Transverse Loading
## LOAD DESIGN CHART #4
## (SEE SPLINE DETAILS SIP-102 or SIP-102g)

| 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

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-22 | |
| Member-Location | | |

| | | |
|---|---|---|
| Job Title | Solar Decathlon | Drg. Ref. |
| | VT | Made by PGT Date Dec '08 Chd. |

## 7.0 Overall Stability & Foundations (Temporary Installation)

### 7.1 Overturning & Sliding Due To Wind

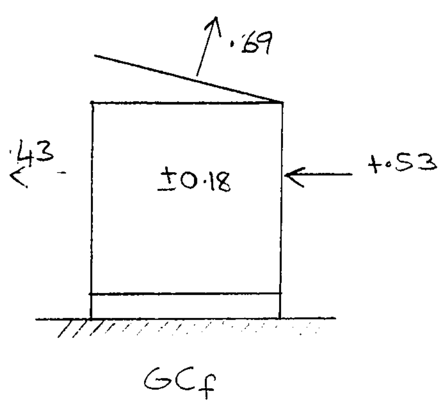
Total Wind Loads ($V = 60$ mph)

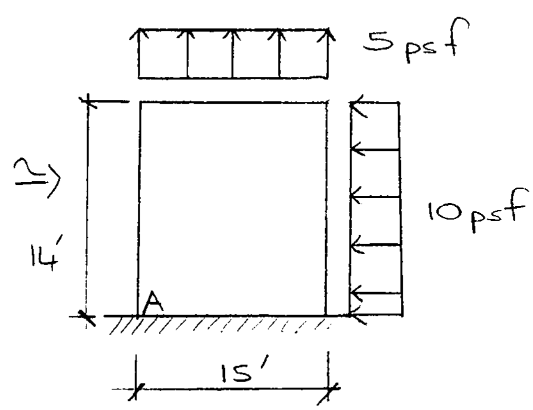
$h = 15$ ft

Exposure C:

$$q_h = 0.00256 \times 0.85 \times 1.0 \times 0.85 \times 60^2 \times 1.0$$
$$= 6.66 \text{ psf}$$

$$p = q\,GC_p - q_i\,(GC_{pi})$$
$$\equiv q_h\,(GC_{pf} - GC_{pi})$$
$$= 6.66 \times (.53 - (-.43))$$
$$= 6.4 \text{ psf} \quad < p_{min} = 10 \text{ psf} \quad \text{ASCE 7 6.1.4.1}$$




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 | [illegible] = | $31.0^k$ |

Restoring moment: $M_R = .6(5.9 + 21.2 + 31) \times \frac{15}{2} = 262$ k-ft

$FoS = \frac{M_R}{M_W} = 3.95 > 2.0$ OK

Uplift $.6 P_D = 34.5^k$

$FoS \quad \frac{.6 P_D}{P_W} = \frac{34.5}{3.3} = 10.6 > 2.0$

Sliding: Coefficient of friction (static)

$\mu_s \geq \frac{V_W \, FoS^{MIN}}{.6 P_D} = \frac{6.2 \times 2.0}{34.5}$

$= 0.36$

This should be achievable with plywood on grade/concrete

$\mu_s^{\text{concrete - soil}} = 0.30 - 0.75$

$\mu_s^{\text{steel - steel}} = 0.30$

$\mu_s^{\text{wood - wood}} = 0.48$

7.2 Temporary Foundation Bearing Pressure

Consider load combinations

$A_1 = 0.6D + W$

$A_2 = 1.0D + W$

$A_3 = D + L$ ; $\quad A_4 = D + .75(L + S) \leftarrow$ not critical

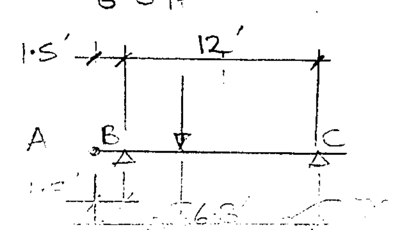
(1). 0.6D + W

Lever arm between foundations $= 12'$

about A $\quad M_W + 0.6 M_D = -66.2 + 262 = +196$ k-ft

$P_W + 0.6 P_D = -3.3 + 34.5 = 31.2^k$

$e = M_a / P_a = \frac{196}{31.2} = 6.3$ ft



ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948-74 | S-24 | |

Member-Location

Job Title Solar Decathlon VT

Drg. Ref.

Made by PGT Date Dec'08 Chd.

$\Rightarrow$ 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 No

2'-6" × 2'-6"

ARUP

| Job No. | Sheet No. | Rev. |
|---|---|---|
| 75948 - 74 | S-25 | |
| Member-Location | | |
| Job Title Solar Decathlon VT | Drg. Ref. | |
| | Made by P6T Date Dec '08 | Chd. |

7·3 Check Localized Uplift

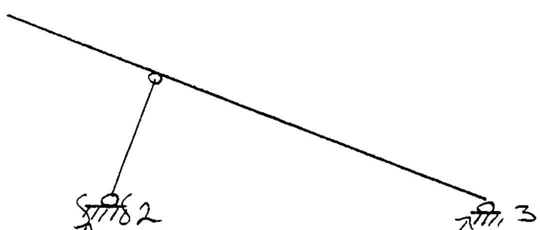
from sheet S-23

$$R_{ac}^{min} = \frac{31.2}{5} \cdot \frac{12-7.2}{12} = 4.2^{k} \text{ compression}$$

⇒ 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:

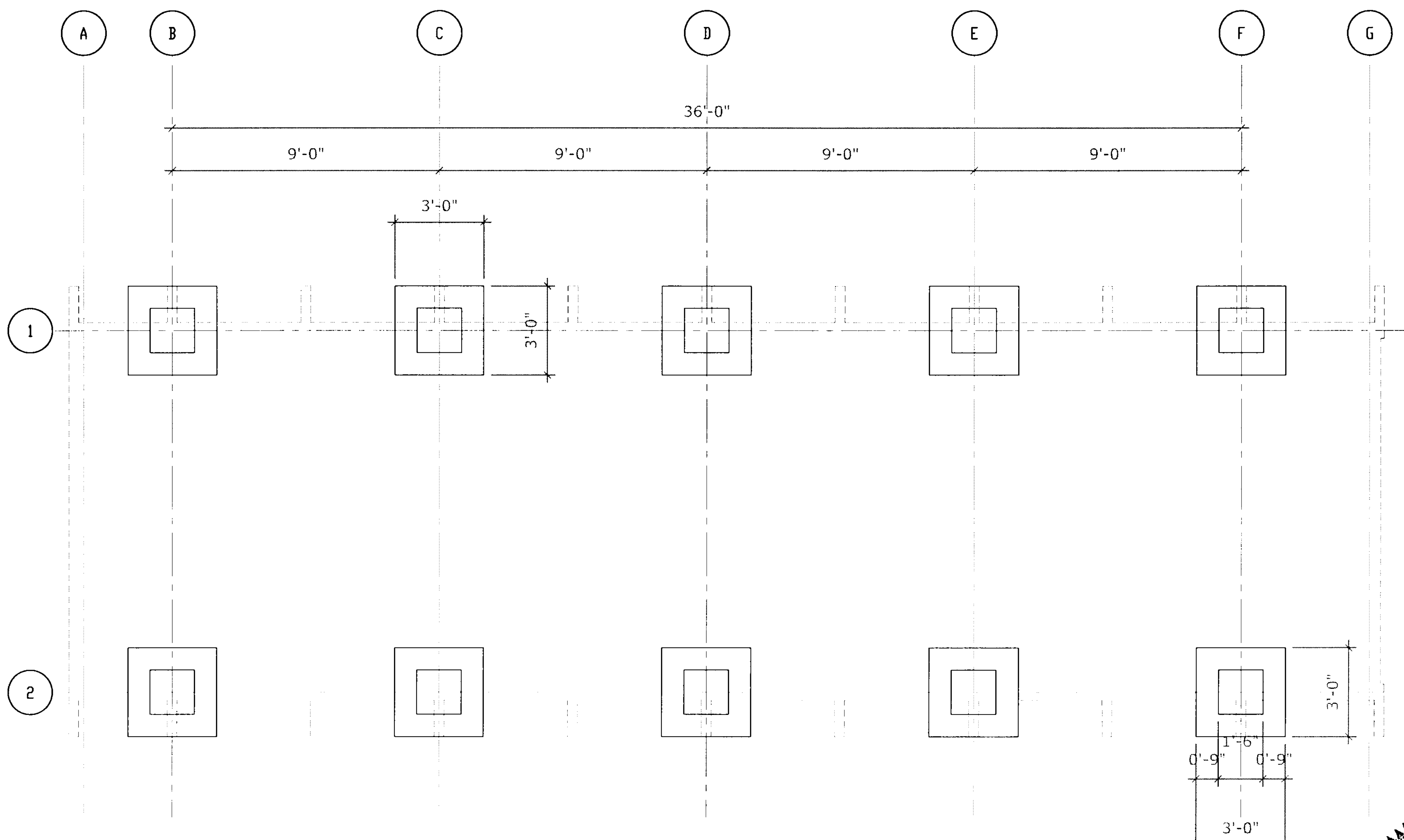
$\frac{1}{2}'' \phi$ $F_{nv}/\Omega = 2.35^k$

$\frac{5}{8}'' \phi$ $= 3.68^k$ ← selection

| Provide |
|---|
| 1- 5/8 $\phi$ A307 bolt in single or double shear |

000781

*NOTE:
STRUCTURAL WIND LOAD CALCULATIONS DETERMINE THE DEAD LOAD OF THE HOUSE IS SUFFICIENT TO OVERCOME ANY WIND LOADS THUS FOUNDATION TIE DOWNS ARE NOT REQUIRED.




## 1 ST-001 TEMPORARY FOUNDATION PLAN

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

0 5 10 15

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Approved: JHW

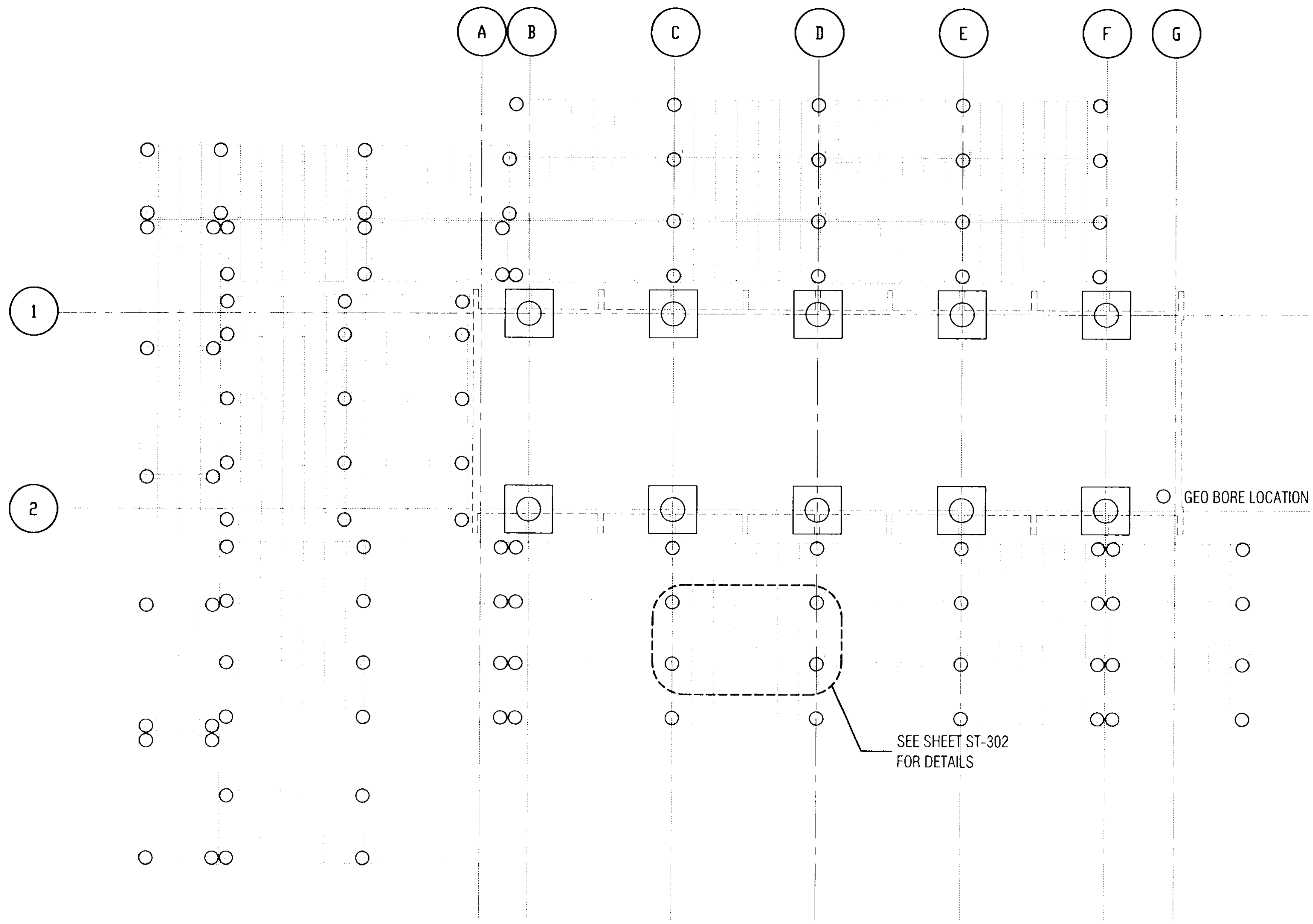
TEMPORARY FOUNDATION PLAN

ST-001

348

000782

*NOTE:
STRUCTURAL WIND LOAD CALCULATIONS DETERMINE THE DEAD LOAD OF THE HOUSE IS SUFFICIENT TO OVERCOME ANY WIND LOADS THUS FOUNDATION TIE DOWNS ARE NOT REQUIRED.




1 / ST-002 PERMANENT FOUNDATION PLAN
SCALE: 1/8" = 1'-0"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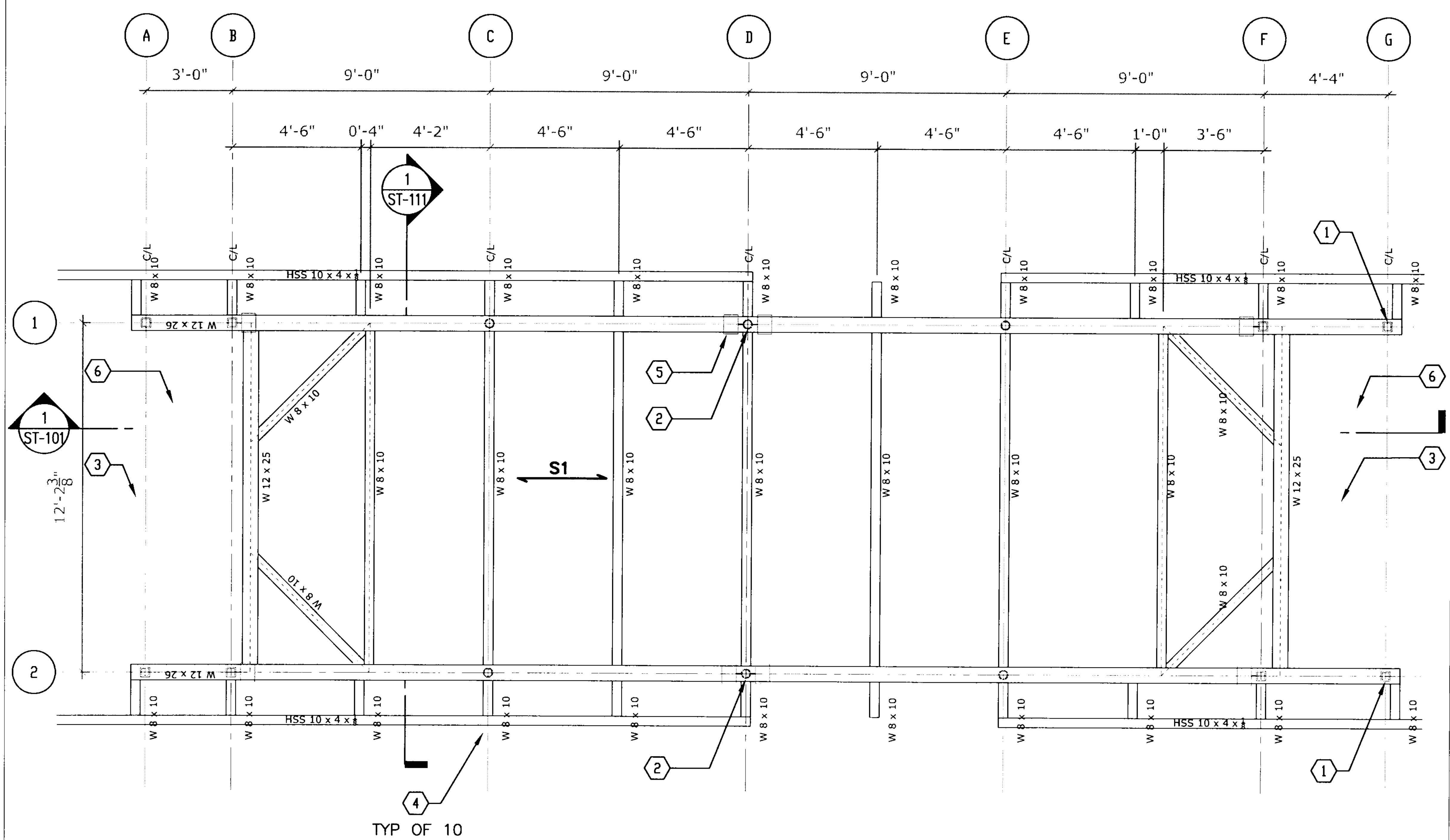
| Approved: | JHW |

PERMANENT FOUNDATION PLAN

ST-002

349

000783




# FIRST FLOOR STRUCTURAL PLAN

1 / ST-011

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

0 5 10 15

## GENERAL SHEET NOTES

- S1 → $2\frac{1}{2}$" NWC ON $1\frac{1}{2}$"–20ga COMPOSITE METAL DEC (LOK–FLOOR MANUFACTURED BY UNITED STEEL DECK)
- ALL W8X10 BEAMS SHALL HAVE $\frac{3}{4}$"ø×4"lg HEADED SHEAR STUDS 12" O.C.
- CONCRETE STRENGTH SHALL BE f'c=3000psi
- FLOOR HAS BEEN DESIGNED TO SUPPORT THE FOLLOWING LOADS:
  GENERAL AREAS–
  SUPER IMPOSED DEAD LOAD: 15psf
  LIVE LOAD: 50psf
  MECHANICAL AREAS–
  SUPER IMPOSED DEAD LOAD: 15psf
  EQUIPMENT LIVE LOAD: 100psf
  EGRESS ROUTE–
  SUPER IMPOSED DEAD LOAD: 0psf
  LIVE LOAD: 100psf
- ALL STEEL SHALL BE THE FOLLOWING GRADES:
  ROLLED SHAPES–
  ASTM A572 GR.50 fy=50ksi
  ROUND HSS–
  ASTM A500 GR.B fy=42ksi
  RECTANGULAR HSS–
  ASTM A500 GR.B fy=46ksi

## SHEET KEYNOTES

1. HSS 4x4x$\frac{5}{16}$
2. HSS 4x$\frac{5}{16}$ ROUND
3. SHEAR WALL SIP PANELS
4. STEEL GRATE FOUNDATION PLATFORM
5. FLOOR PLATES TO RECEIVE TEMPORARY DIAGONALS
6. TORQUE BOX ASSEMBLY

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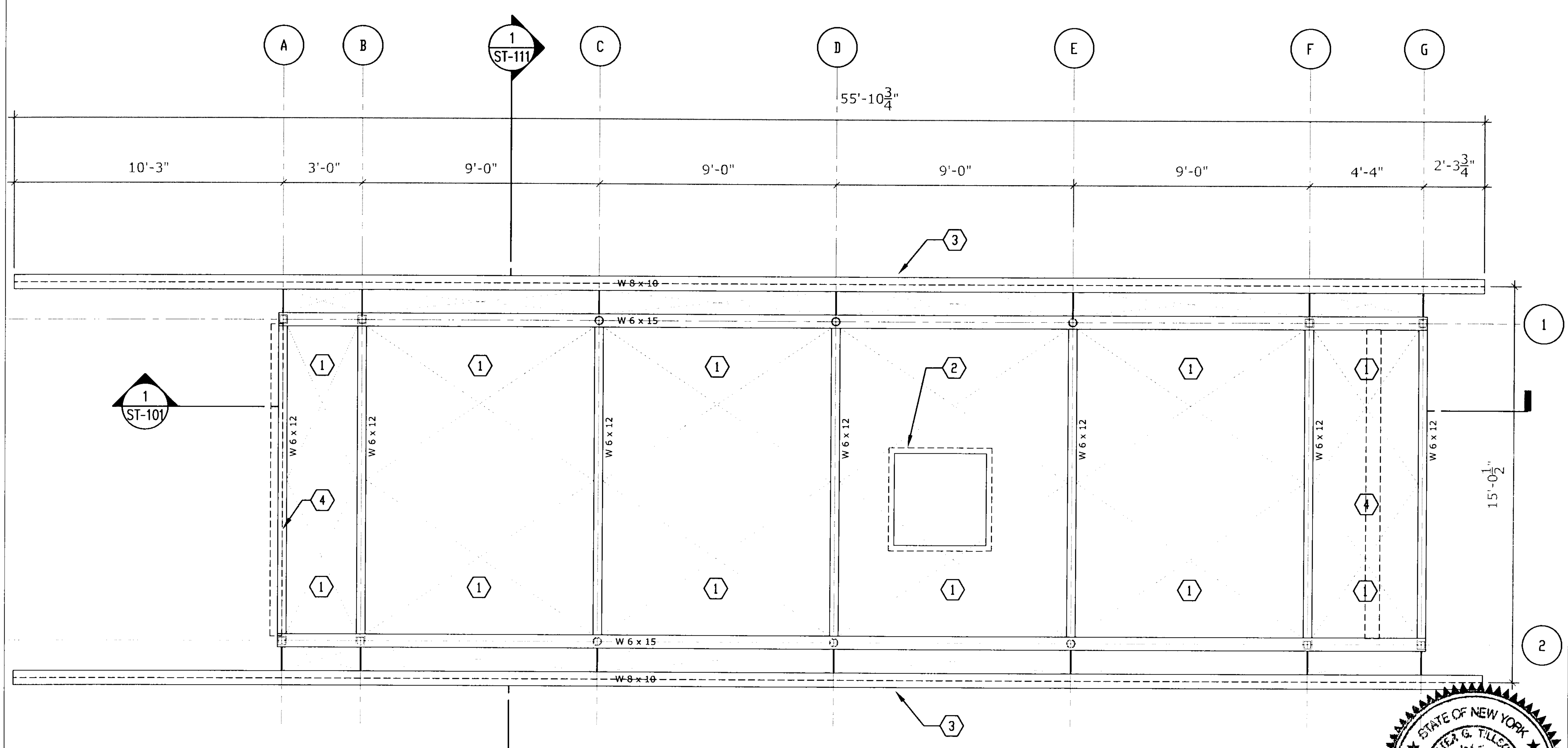
FIRST FLOOR PLAN

ST-011

000784

## SHEET KEYNOTES

1. SIPS ROOF PANEL PROVIDED DIAPHRAGM SUPPORT
2. UNIT SKYLIGHT
3. OUT RIGGER BEAMS
4. SHEAR WALL PANELS BELOW




1 ST-021

# ROOF FRAMING PLAN

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

0 5 10

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| Approved: | JHW |

ROOF FRAMING PLAN

ST-021

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STEEL FRAME

PREFABRICATED

INCREASED MANUFACTURING PRECISION AND EFFICIENCY

REDUCED MANUFACTURING WASTE OUTPUT

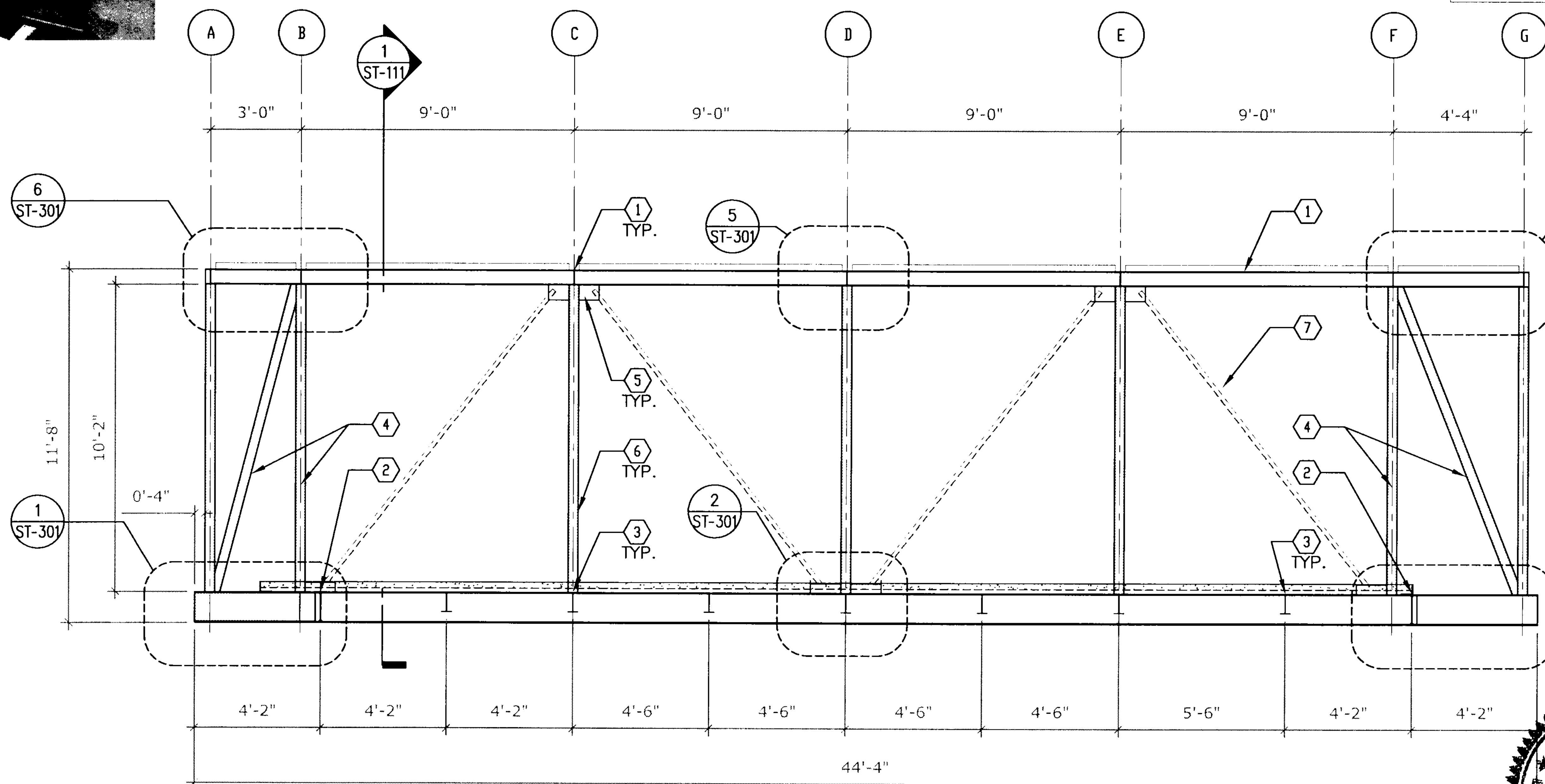
LOW EMBODIED ENERGY IN PRODUCTION

EASILY RECYCLED

MADE FROM RECYCLED MATERIAL

SHEET KEYNOTES

1. W6x12
2. W12x26
3. W8x10
4. HSS 4"x4"x$\frac{5}{16}$" TUBE
5. 6"x8"x$\frac{5}{16}$" GUSSET PLATE
6. HSS ROUND 4"DIAx$\frac{5}{16}$"
7. 3"x3"x$\frac{3}{16}$" ANGLES REMOVEABLE AFTER TRANSPORT




1 ST-101 **STRUCTURAL LONGITUDINAL SECTION**

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

0 5 10 15

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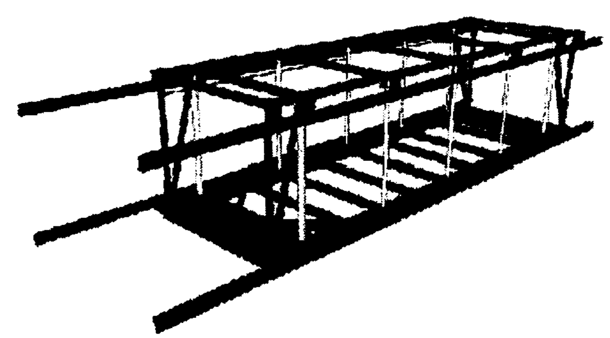
LONGITUDINAL SECTION

ST-101

000786



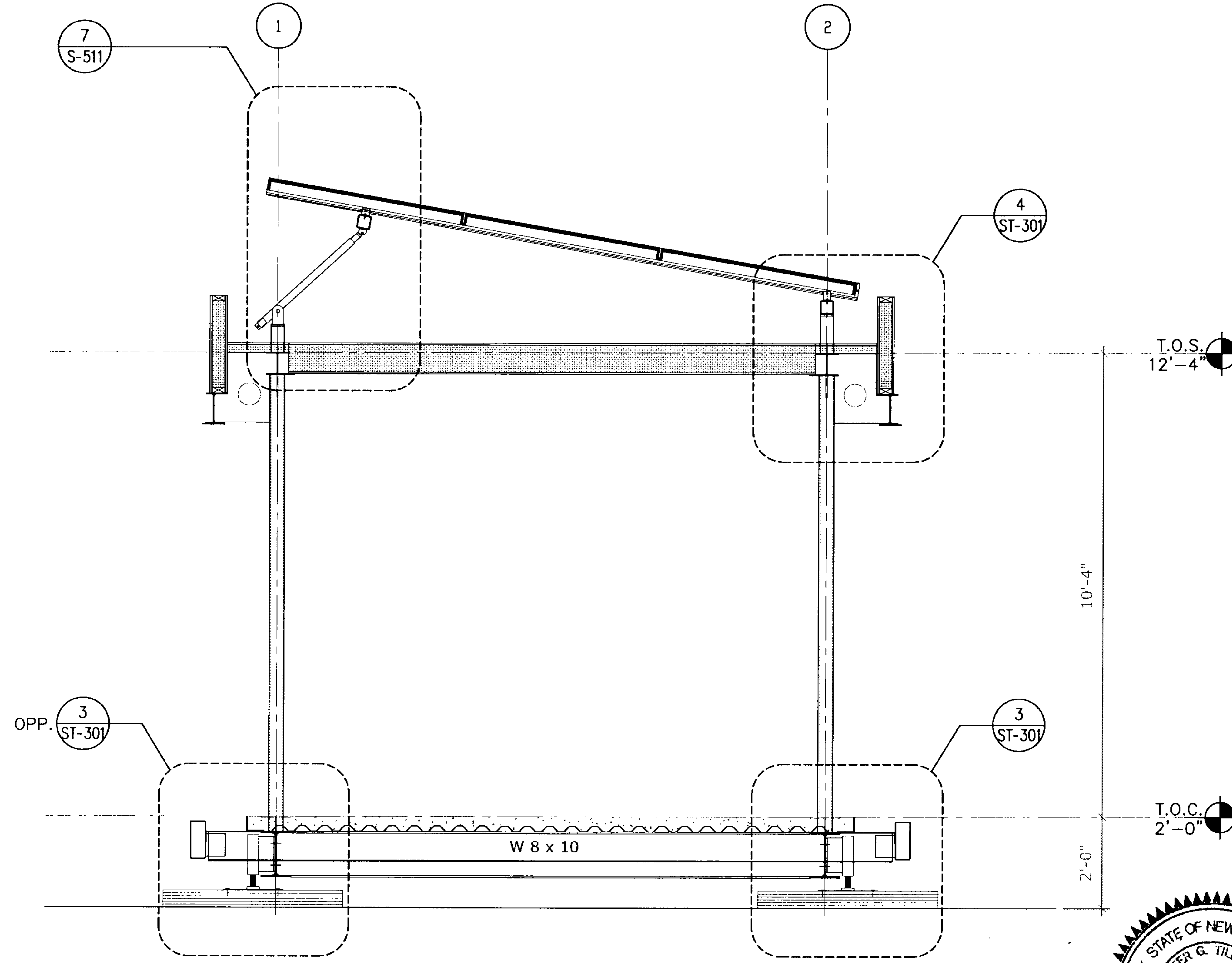
PREFABRICATION

STURDY AND PERMANENT CONSTRUCTION SYSTEM

RECYCLABLE MATERIAL

FRAMES PREFABRICATED AT KULLMAN BUILDING CORPS

*NOTE: THESE DRAWINGS AND CALCULATIONS WERE APPROVED AND STAMPED IN THE LAST SUBMITTAL ON DECEMBER 13, 2008 BY ARUP ENGINEERS




1 ST-111 STRUCTURAL TRANSVERSE SECTION

SCALE: 3/8" = 1'-0"

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|---|---|
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| Approved: | JHW |

FIRST FLOOR SECTION

ST-111

000787

*NOTE:
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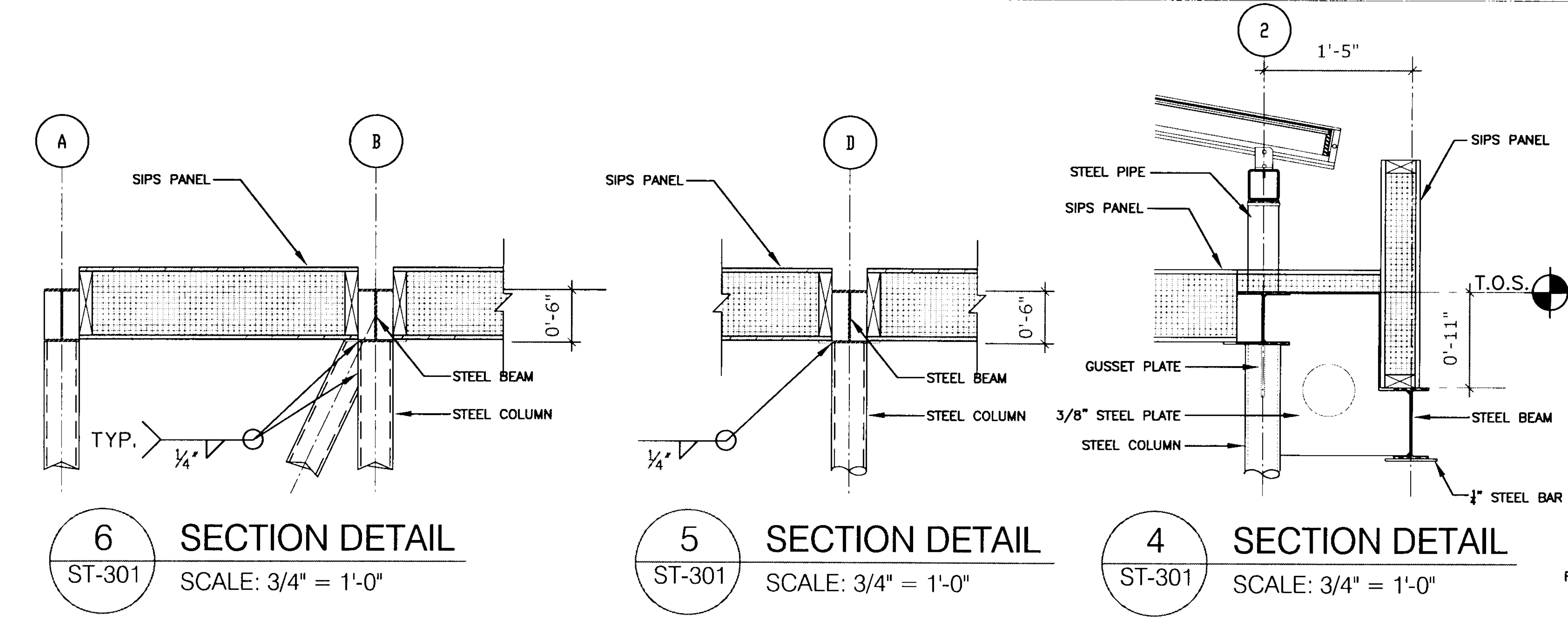


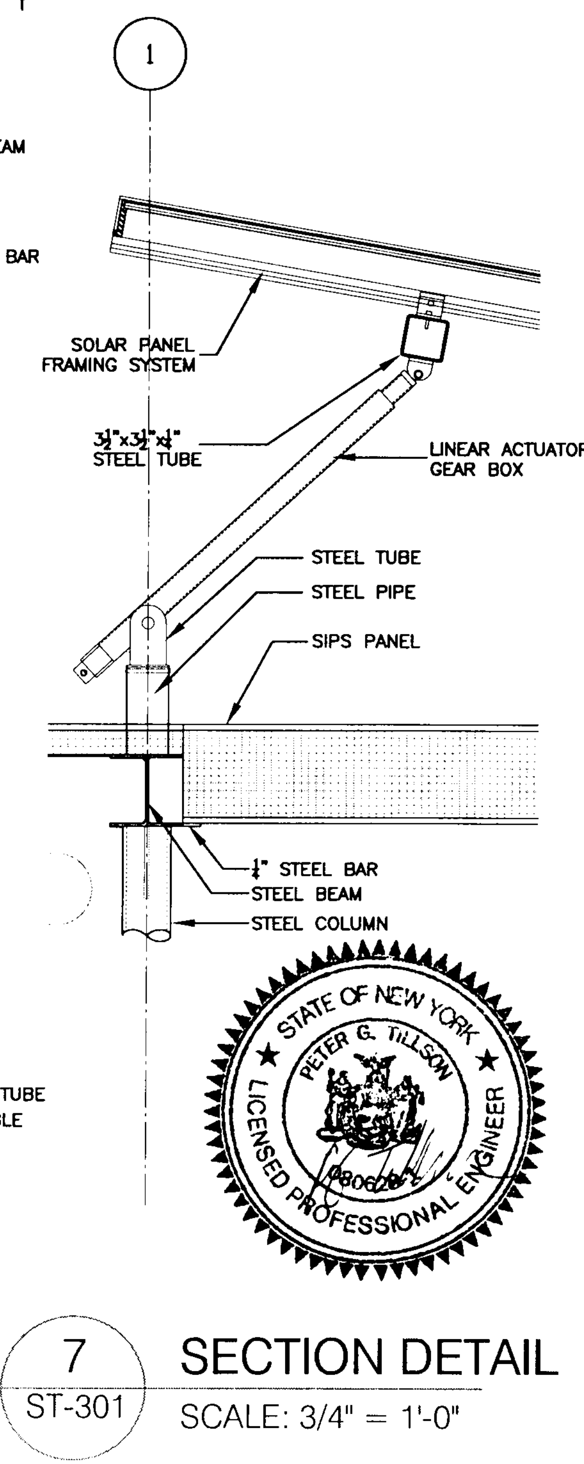


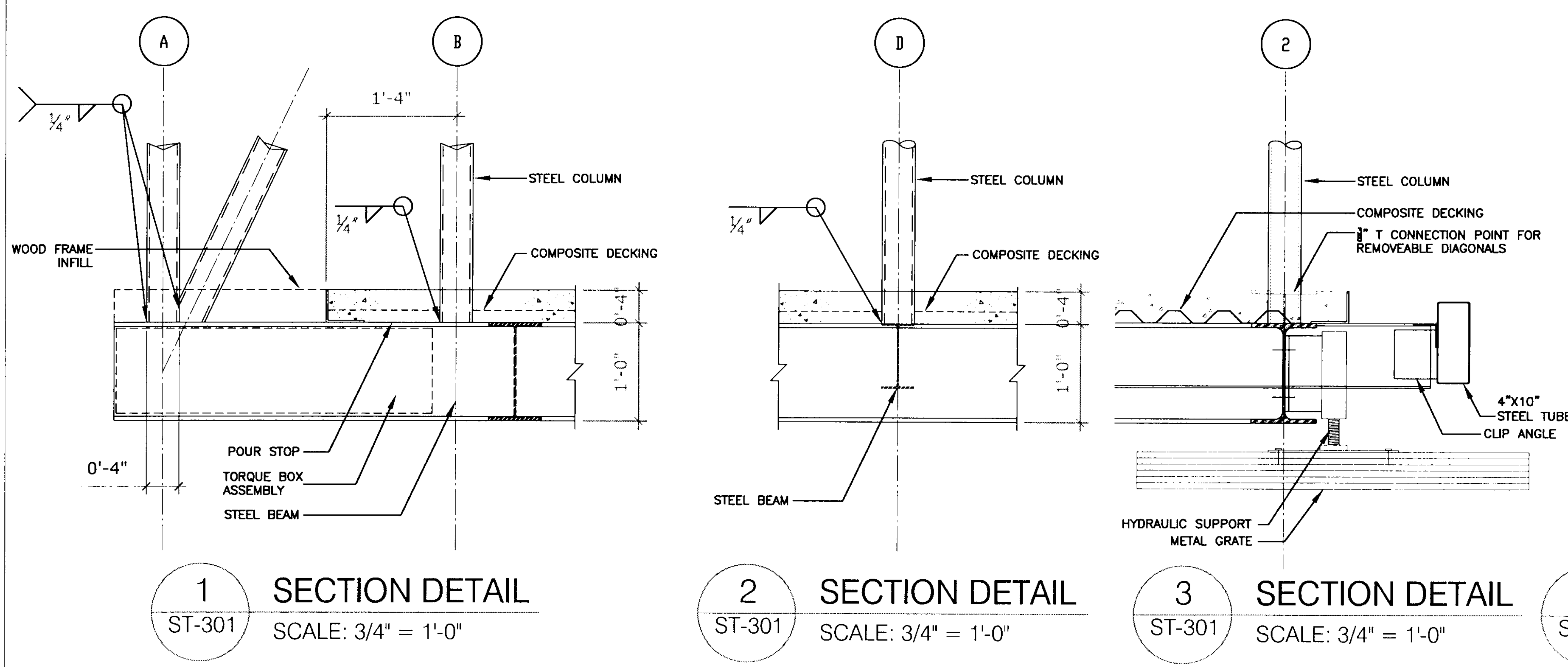


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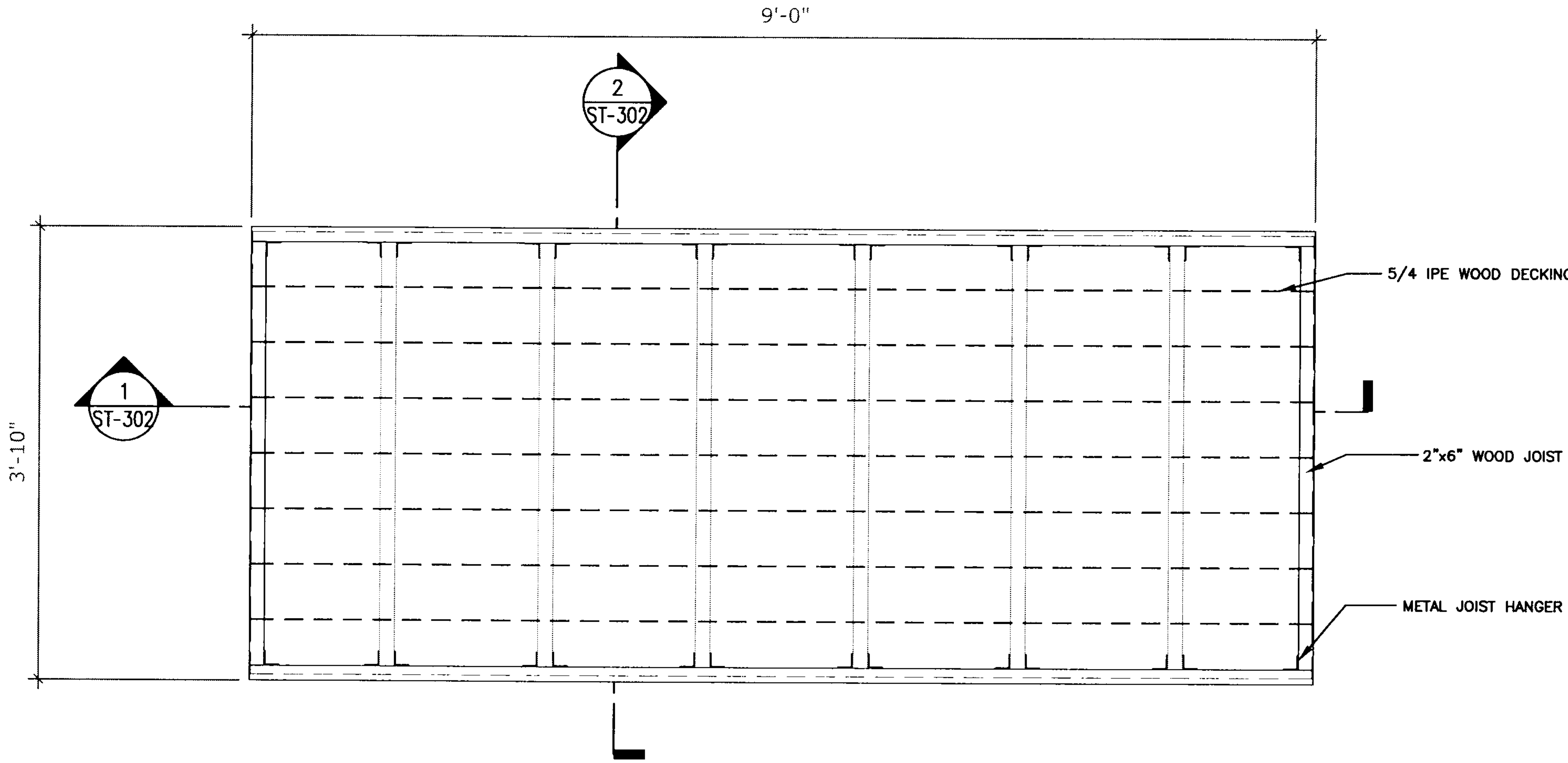
| Approved: | JHW |

FIRST FLOOR DETAILS

ST-301




3 ST-302 DECK MODULE FRAMING
SCALE: 3/4" = 1'-0"

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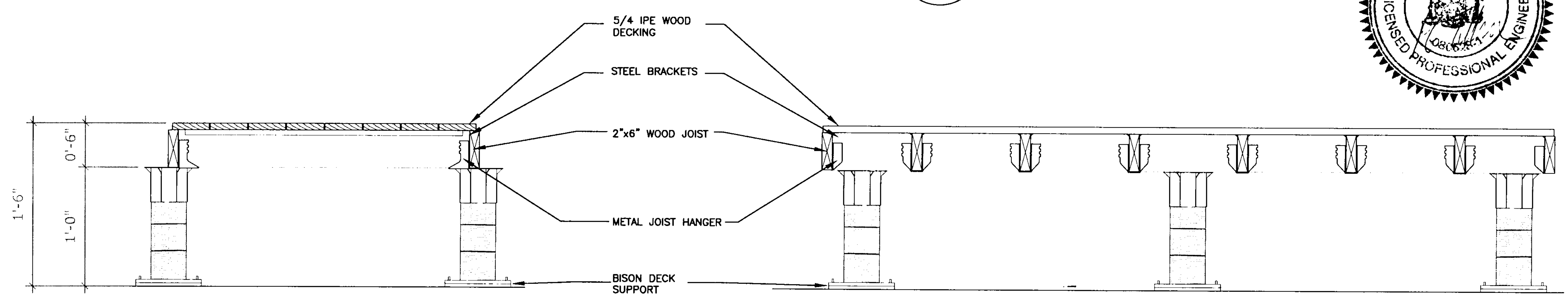


2 ST-302 DECK TRANVERSE SECTION DETAIL
SCALE: 3/4" = 1'-0"

1 ST-302 DECK LONGITUDINAL SECTION DETAIL
SCALE: 3/4" = 1'-0"

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Drawn: CEM + OO
Approved: JHW

DECK DETAILS
ST-302

## DETAILED WATER BUDGET

500 gallon potable water tank

300 gallon reservoir for charging the system

3000 gallon geothermal tanks

2500 Landscape Pools

---

6300 gallons

## Summary of Unlisted Electrical Components

-Custom Sliding Insulation Panel Door System (4 total)

-Custom Sliding Shading and Privacy Screen Door System (4 total)

## Summary of Reconfigurable Features

The Virginia Tech Solar Decathlon LumenHAUS is equipped with a series of large, operable insulation panels and sun screens (8 panels total). When the panels and screens are open to their maximum positions, they will not infringe upon the site boundaries/solar envelope established in the SDE rules. A measured drawing showing panel limits can be found in drawing AR-041 of the construction documents. For safety consideration and per electrical code requirements, emergency stop devices are installed in the system.

The photovoltaic array is mounted on an adjustable frame which will allow optimal seasonal solar orientation. During the competition, the array will be fixed at a $120^0$ angle which will fit within the 18 foot height limitation. Detail section can be found on sheet AR-102 of the construction documents.

The interior furnishings at the kitchen can be relocated in several different arrangements, Plan details can be found on sheet IN-402 of the construction documents.

*TEAMS ARE REQUIRED TO FILL IN THE FOLLOWING FORM AND SEND IT AS AN INDEPENDENT DOCUMENT, TOGETHER WITH DELIVERABLE #4 (CONSTRUCTION DRAWINGS AND PROJECT MANUAL)*

UNIVERSITY: Virginia Tech
TEAM: *LumenHAUS*

| | |
|---|---|
| GENERAL ELECTRICAL AND PHOTOVOLTAIC INSTALLATIONS: | |
| - Electrical supply voltage (phase-neutral) for which both installations have been designed (unit: V) | 408VDC/240VAC |
| - Electrical supply frequency for which both installations have been designed (unit: Hz) | 60HZ |
| ELECTRICAL INSTALLATION:<br>*[Notes:*<br>*- No details are required in this document about interior circuits, due to the fact that these shall adapt to the minimum requirements given by the Spanish standard REBT for a highly electrified house.*<br>*- The Organisation will supply the teams with a one-line diagram with the distribution and protections of the interior circuits, according to the Spanish REBT.*<br>*- Teams are reminded of the fact that the electrical installations shall be designed for a single-phase supply with a maximum power of 15 kW, equivalent to 63 A (230 V / 50 Hz). For other voltages and/or frequencies the equivalent limit shall apply, by making use of the corresponding transformation relation.]* | |
| - House inner surface (unit: $m^2$) | 74.32 |
| - Expected maximum power (unit: W) | 7980 |
| - Individual branch:<br>o Type of cable<br>o Cross-section (unit: $mm^2$) | <br>MC3<br>4 |
| - General magnetothermic protection:<br>o Nominal current (unit: A)<br>o Circuit-breaking capacity (unit: A) | <br>21<br>30 |
| - General differential protection:<br>o Nominal current (unit: A)<br>o Sensibility / Trip value (unit: mA) | <br>N/A<br>N/A |
| PHOTOVOLTAIC INSTALLATION: | |
| - Nominal power of the inverter, or sum of the nominal power of inverters in case several inverters are used) (unit: W)<br>[Note: nominal power of the inverter is the maximum output power without time limitations] | 10,000 |
| - Brand and model of inverter(s). | Sunnyboy 5000 |
| *(Optional, only for teams that are considering the use of a hard-wired battery bank together with a battery inverter)*<br>HARD-WIRED BATTERY BANK + BATTERY INVERTER: | |
| - Nominal operation voltage of the battery bank (unit: V) | N/A |
| - Nominal capacity of the battery bank (unit: Ah) | N/A |
| - Nominal power of the inverter (unit: W)<br>[Note: nominal power of the inverter is the maximum output power at the AC side without time limitations] | N/A |
| - Brand and model of inverter. | N/A |

## COMPREHENSIVE ENERGY ANALYSIS AND DISCUSSION REPORT

A thermal energy load analysis of the house was performed using two energy simulation programs: eQuest™ and Trace 700™. The goals of this analysis include the following:

- Determine the optimal configuration of the shading and insulation panels for the heating and cooling seasons.
- Compare energy use over an entire year using weather data for Madrid, Spain.

This analysis uses ASHRAE values for typical building materials and product specifications provided by manufacturers. This information was used to compile the material properties for input into eQuest and is represented in Table 1.1 and 1.2

**Table 1.1** Conductivity, density, and specific heat values of the building materials

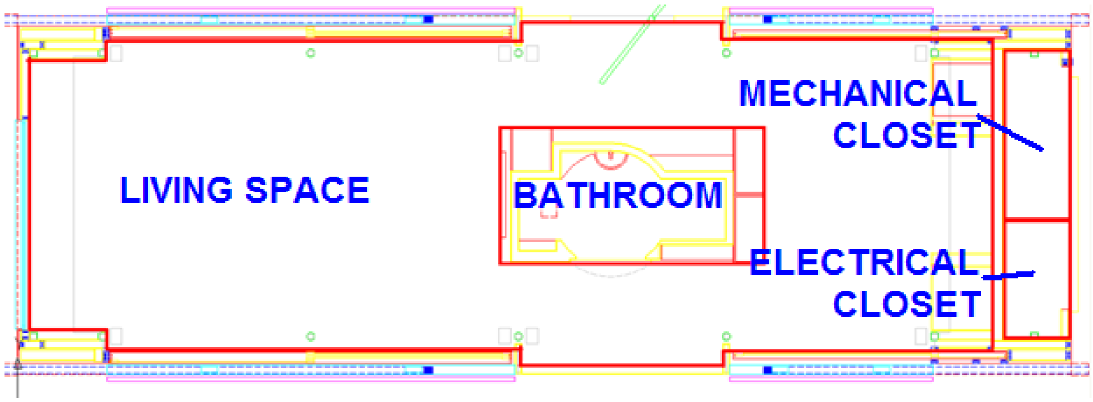
| NAME | CONDUCTIVITY (Btu/hr-ft-°F) | DENSITY ($lb/ft^3$) | SPECIFIC HEAT (btu/lb-°F) |
|---|---|---|---|
| 4.5″ SIPS | 0.0287 | 2 | 0.2 |
| 6.5″ SIPS | 0.0233 | 2 | 0.2 |
| 10.5″ SIPS | 0.023 | 2 | 0.2 |
| 18 GA. METAL | 24 | 1684 | 0.1 |
| MECH. ROOM DOOR | 0.016 | 1 | 0.2 |
| BATHROOM WALL | 0.0227 | 1 | 0.2 |
| 4″ CONCRETE | 2.27 | 153 | 0.18 |

**Table 1.2** Optical properties of glass panes and sliding panels

| 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 |

In the eQuest and Trace 700™ models, each of the areas in Figure 1.0 is a zone. A zone is all the rooms that are tied to a single thermostat. Since the entire living space in the house must all fall within a 73.4°-77°F range during the competition, the main room and the bedroom are in the same zone. This is necessary because the open-plan layout of the house makes it is impossible to condition the living room space independently of the bedroom space.

**Figure 1.0** Room allocation scheme for the energy model.




The bathroom and mechanical and electrical closets are isolated from the rest of the house so they are placed in their own zones to account for the fact that they are not exposed to direct sunlight and have to be treated separately. The closets are ventilated but not conditioned so they are placed in separate zones. Since the mechanical and electrical closets are separated by a partition and are expected to generate different internal loads, they are each given their own zone.

The zones are assigned to systems. The zone containing the living space and bathroom is assigned to a "Water Source Heat Pump"-type system. This "system" is comprised of the airside portion of our HVAC (i.e., the ductwork, water-to-air heat pump, ventilation system, and energy recovery ventilator). The radiant floor heating has its own system, a "Radiant – Heating Only"-type system. Since the mechanical and electrical closets use only fans to cool mechanical and electronic devices, these zones are assigned to separate systems. The mechanical and electrical closets are assigned to systems of type "Unit Ventilator."

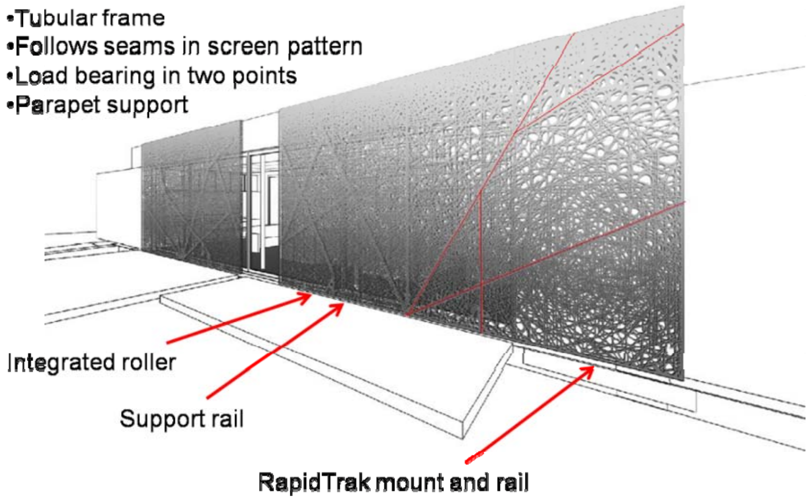
This analysis focused on the three architectural strategies utilized as part of the envelope to control solar radiation. These strategies include:

1. Exterior shading panels
2. Aerogel insulation panels
3. Interior blinds

### 1. Exterior Shading Panels

The exterior shading panels, illustrated in Figure 2.1, will be used on the solar house north and south facades as a method of partial shading, as well as a means for extra privacy, while maintaining the potential to allow light and air to pass. The partial shading serves to influence the solar gain on the concrete floor inside. The shading screens are composed of panelized segments, which are cut out of pieces of sheet metal. Each panel is an assembly composed of two layers that are separated by two inches. The concept is that this separation will provide a louver effect. There are two screens on either side of the house (four screens total) that open and close either via a user interface or due to the measured outside conditions and energy requirements of the house.

**Figure 1.1** Shading Panel Concept

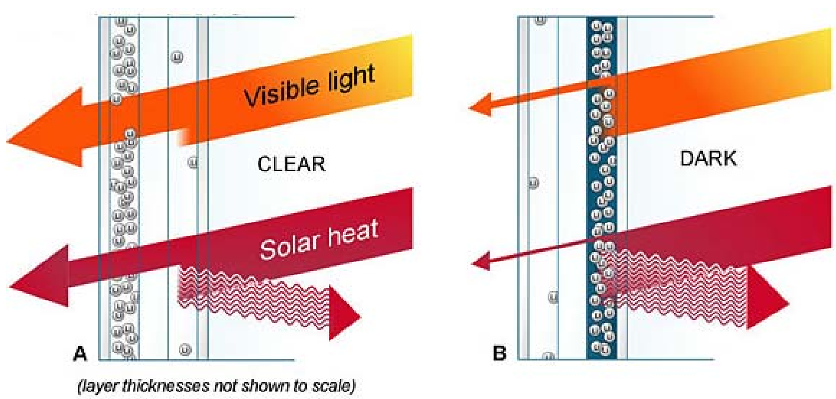



For the energy simulation, the exterior shading panels are employed based on a seasonal schedule. The schedule is divided into two seasons, representing the cooling season and heating season. The shading panels are placed in front of the windows from 10:00 am to 8:00 pm during the cooling season. The panels permit 40% of direct (beam) solar radiation to fall on the windows. During the heating season, 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 the heating season. The value of 0.4 is used to represent the presence of the panels in front of the windows during the cooling season.

The west facing window also requires shading during the cooling season. This is accomplished using SAGEglass panels for the window. SAGEglass is an electrochromic glass system. This system is illustrated in Figure 1.2.

**Figure 1.2** SAGEglass Operation



The SAGEglass coating on the glass is made up of five layers. When voltage [less than 5V DC] is applied to these layers in their "clear" state (A), they darken as lithium ions and associated electrons transfer from the counter electrode to the electrochromic electrode layer (B). Reversing the voltage polarity causes the ions and associated electrons to return to their original layer, the counter electrode, and the glass untints. This solid state electrochromic reaction is controlled through a low voltage DC power supply. When the SageGlass coating darkens, the sun's light and heat are absorbed and subsequently reradiated from the glass surface – much the way low-emissivity glass also keeps out unwanted heat.

To model the SAGEglass in eQuest, the glass is assigned two values: The value of 0.9 (full transmittance) is used to indicate the transparent state of the glass in the heating season. The value of 0.2 is used to represent the opaque state of the glass during the cooling season.

Note: The PV panels and entrance canopy are modeled as fixed building shades with no transmittance.

## 2. Aerogel Insulation Panels

The insulation panels are composed of a double layer translucent polycarbonate panel system filled with Aerogel, creating an insulating "sandwich". The sandwich is composed of an inner wall, airspace, and an outer wall as seen in Figure 2.1. The airspace contains the frame of the panels; LED accent light strips; and potentially a drive motor, an actuated gasket, and any wiring needed to power/control the aforementioned components. The insulation panels will slide parallel to the house's long axis to expose the glass façade. When deployed, or not covering the façade, the insulation panels split as seen in Figure 2.2.

**Figure 2.1** Section of the bottom layout of the insulation panel showing the major components and its relation to the shading screen

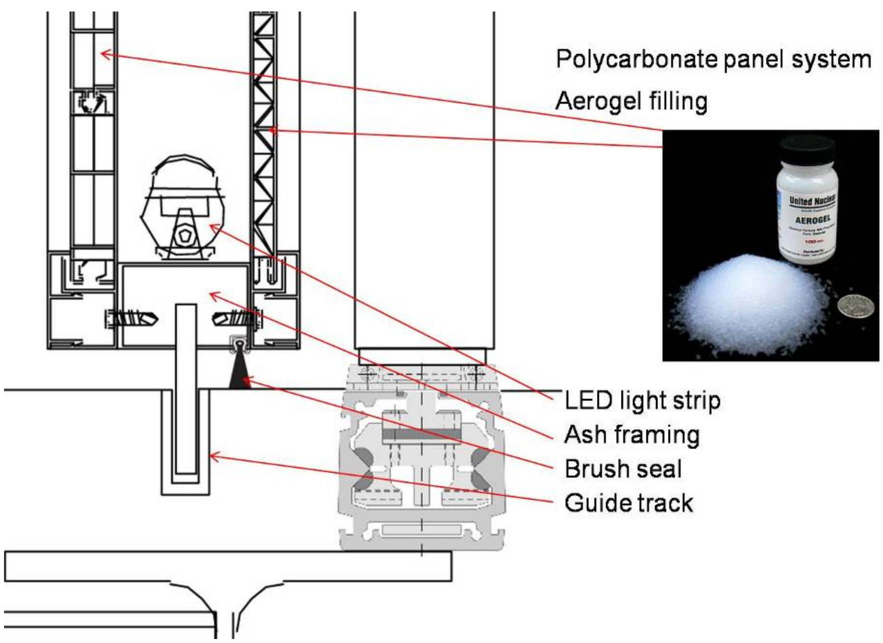
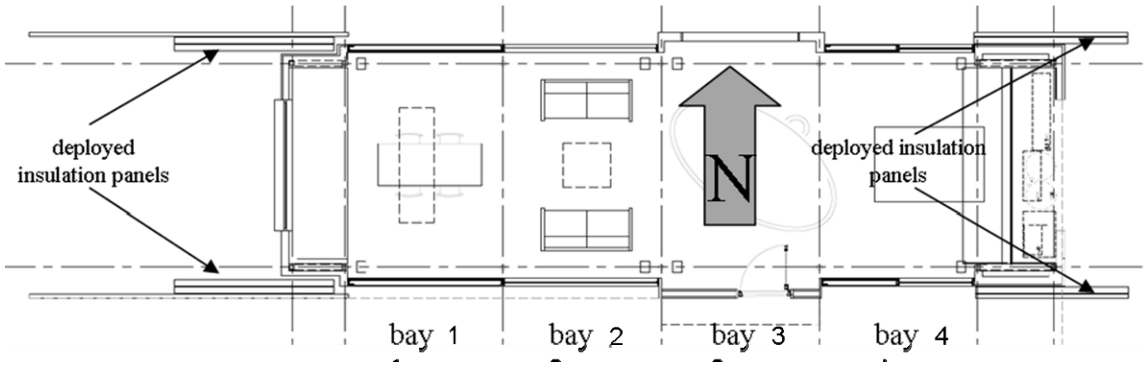


**Figure 2.2** Positions of the deployed insulation panels.




The operation of the insulation panels is triggered by a set-point temperature of 70°F. This means that the panels will be retracted whenever the outside dry-bulb temperature drops below 70°F. Using a solar gain factor of 0.36, the panels reduce 64% of the solar gain through the windows when in place. A conductance factor of 0.532 changes the original conductance of double-glazed windows from 0.39 Btu/h-ft$^2$-°F to 0.0207 Btu/h-ft$^2$-°F. These factors were assembled from product specifications.

Note: Each aerogel insulation panel is defined as a building shade when it is retracted from the windows and located to the sides of the building.

### 3. Interior Blind

There are two different approaches used for modeling the interior blind.

The first approach modeled each interior blind as a movable interior blind. This approach is the conventional method used to model interior blinds. In the energy analysis, the operation of the blinds 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 cooling season and heating season. The set-point solar radiation level for the cooling season is 40 Btu/hr-ft$^2$. This means the blinds will close if the solar radiation measured on the outside surface of the window exceeds 40 Btu/h-ft2. This set-point provides an opportunity to take advantage of solar gain for space heating. In heating season, the set-point solar radiation level is 20 Btu/hr-ft$^2$ to reduce solar gain.

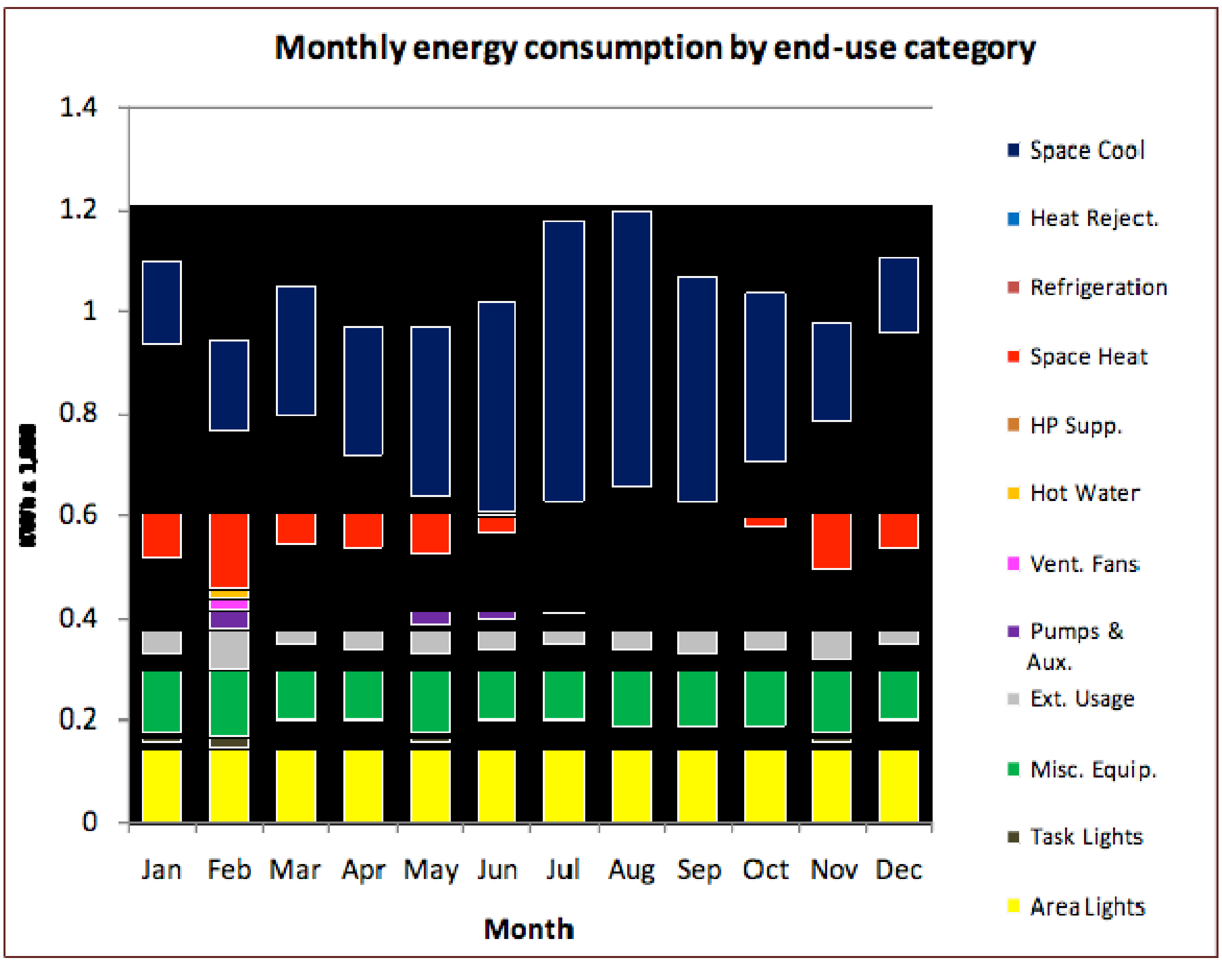
The second approach was used to confirm the findings from the first approach. This is necessary because eQuest allows a window assembly to have only one blind layer, which was already used for modeling the exterior insulation panels. Therefore, a switchable glazing function was used in the model can to simulate interior blind. The switchable glazing function allows the windows to be switched only in the day time. From the blind schedule, a blind will shutdown if the radiation level exceeds the control point which will not occur during the night time. Therefore, the switch glazing method can be applied. An alternative window assembly was selected from the provided window library where the window properties are in the same range as the original window assembly with interior blind. In this case, four layers of glasses filled with argon is defined. This method does not allow two season scheduling which was used in 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 as set-points for the switched glazing.

The results of two models were almost identical. Therefore, 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.

### 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. The following charts illustrate the results of these simulations.

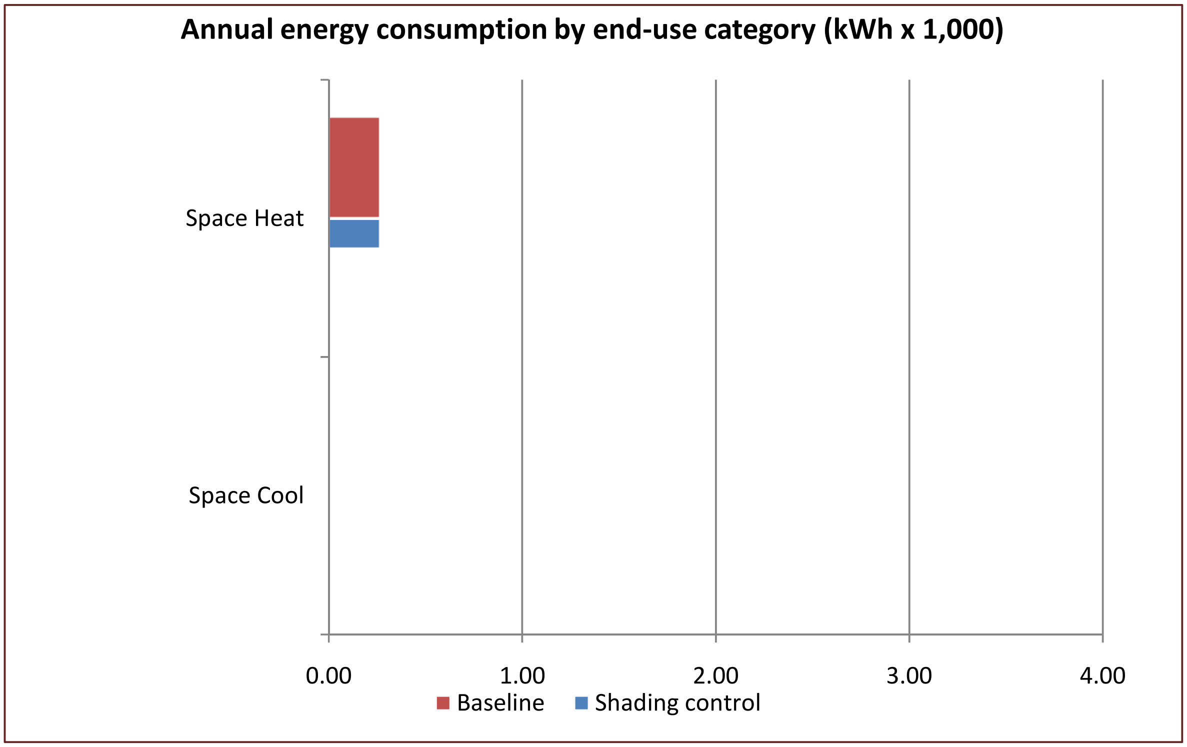
**Table 1.3** Baseline Monthly Energy Consumption by End-use Category (KWh x 1,000)




### Exterior Shading Panels

Shading devices are closed during the summer cooling months and opened during the heating months from 10:00 am to 8:00 pm.

**Table 1.4** Annual energy consumption for space heating and cooling with Exterior Shading

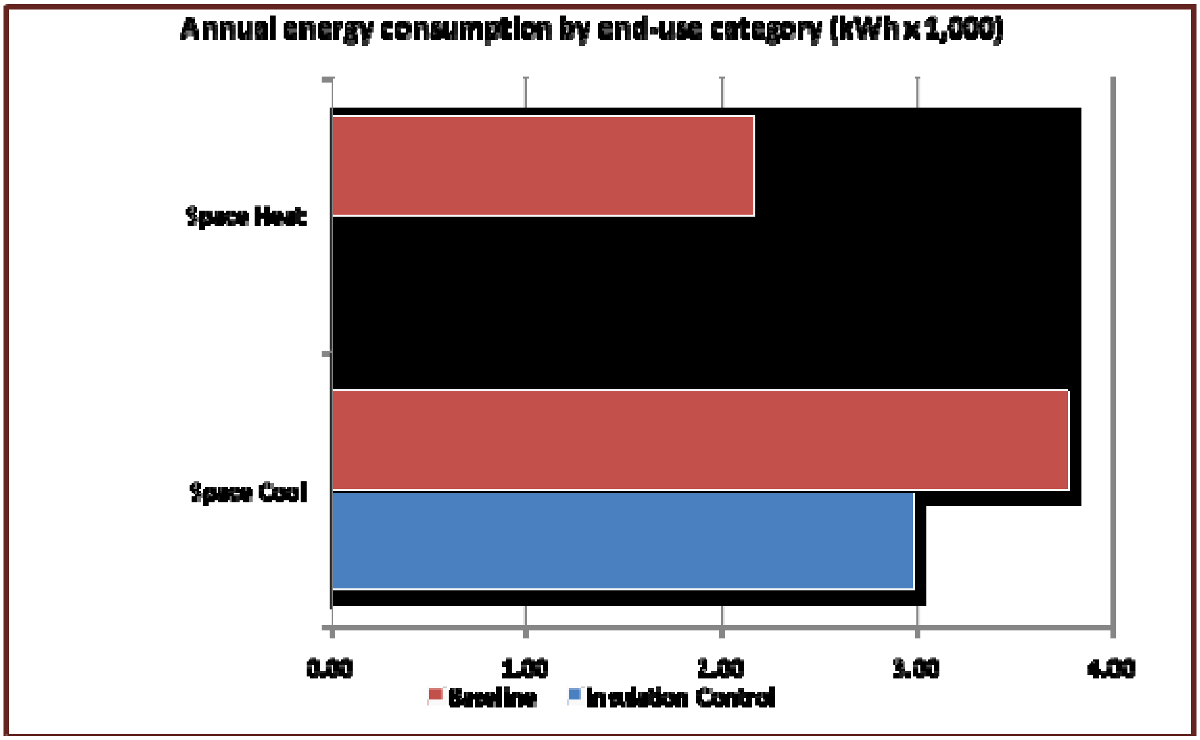



Results - The exterior shading panels reduced space cooling requirements by approximately 32%. A slight increase in space heating requirements denotes that further refinement is needed for the set point values for shading panel control. This will be accomplished using data gathered from the house the once construction is complete.

**Insulation Panel Strategy**

Insulation panels will close over the windows whenever the ambient dry-bulb temperature is lower than 70 °F.

**Table 1.5** Annual energy consumption for space heating and cooling with Insulation Panels

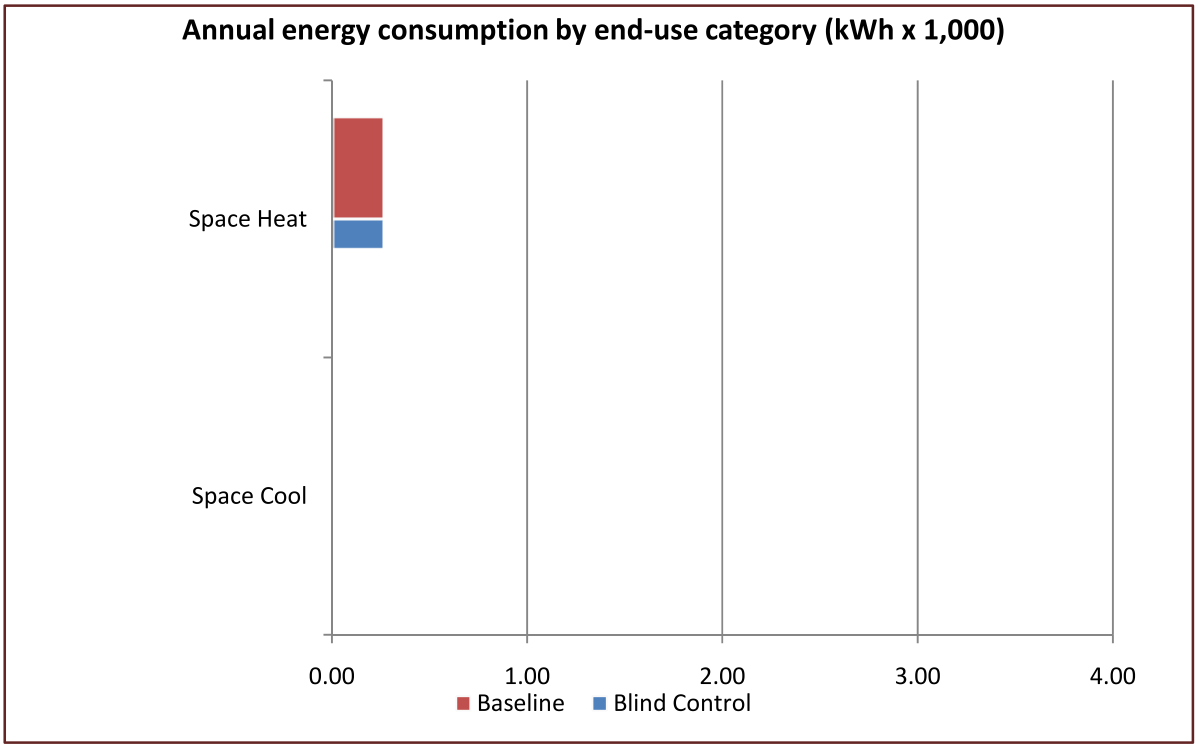



Results - The exterior insulation panels reduced space heating requirements by approximately 55% and space cooling requirements by 21%.

**Interior Blind Strategy**

Blinds will close whenever the solar radiation is higher than 10 Btu/h-ft$^2$ in summer and 30 Btu/h-ft$^2$ in winter.

**Table 1.5** Annual energy consumption for space heating and cooling with Interior Blinds




Results - The interior blinds reduced space heating requirements by approximately 28%. A slight increase in space heating requirements denotes that further refinement is needed for the set point values for interior control. This will also be accomplished using data gathered from the house the once construction is complete.

**Energy Consumption and Demand Relative Comparison**

Table 1.6 shows the recalculated monthly energy consumption when using all three control strategies. Integrating all three strategies reduced space heating requirements by approximately 49% and space cooling requirements by 51%. Tables 1.7 and 1.8 show the reduction in projected annual energy consumption and peak energy demand for the house for each individual strategy when compared the baseline energy consumption for all equipment presented in Table 1.1

**Table 1.6** Baseline Monthly Energy Consumption by End-use Category (KWh x 1,000)

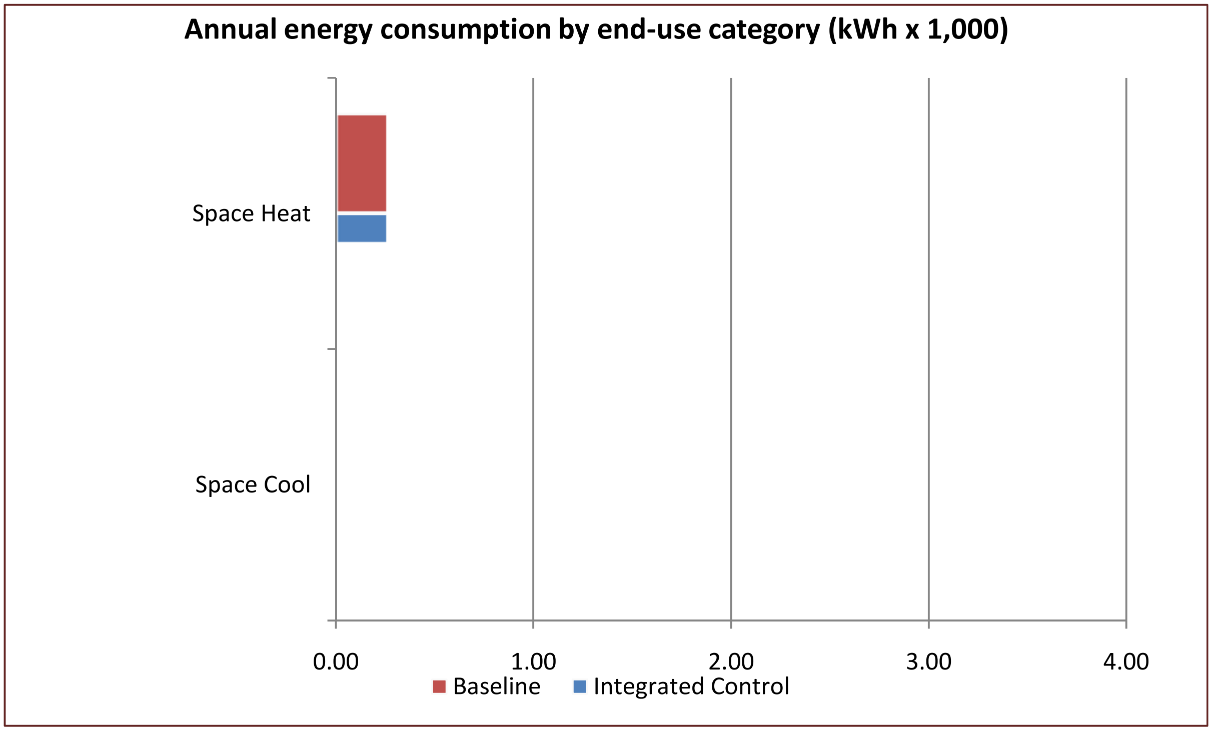



**Table 1.7** Annual Energy Consumption (kWh x 1,000)

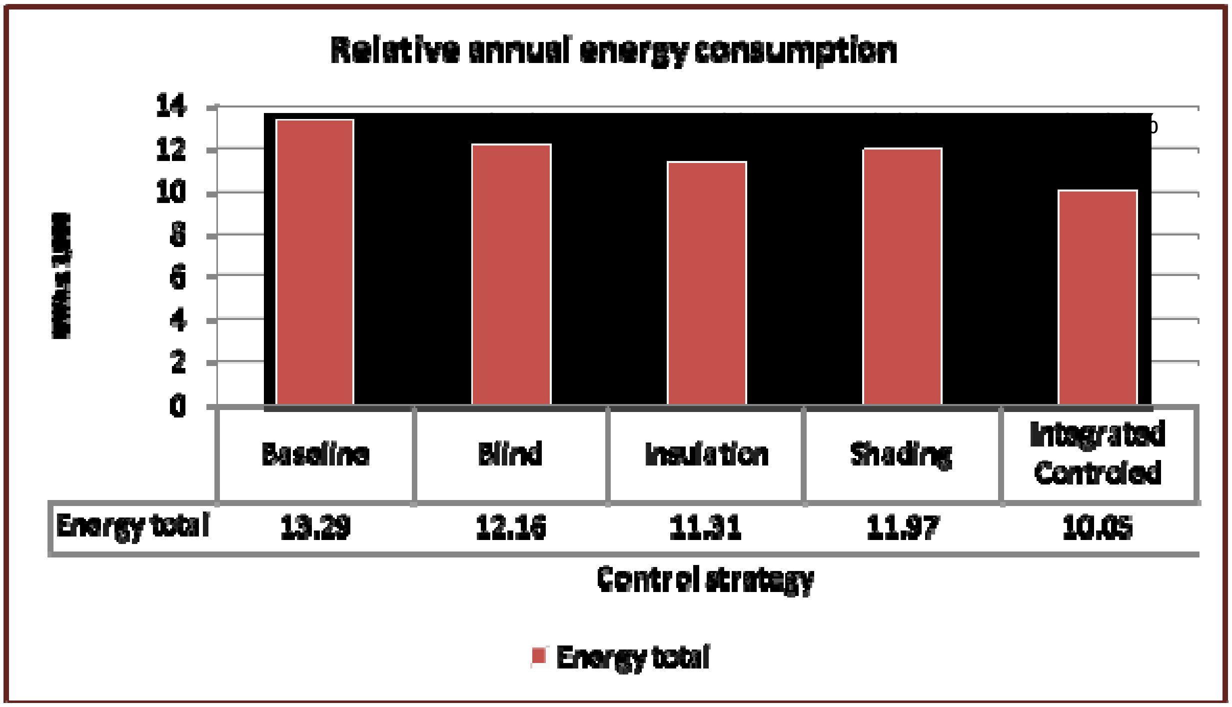
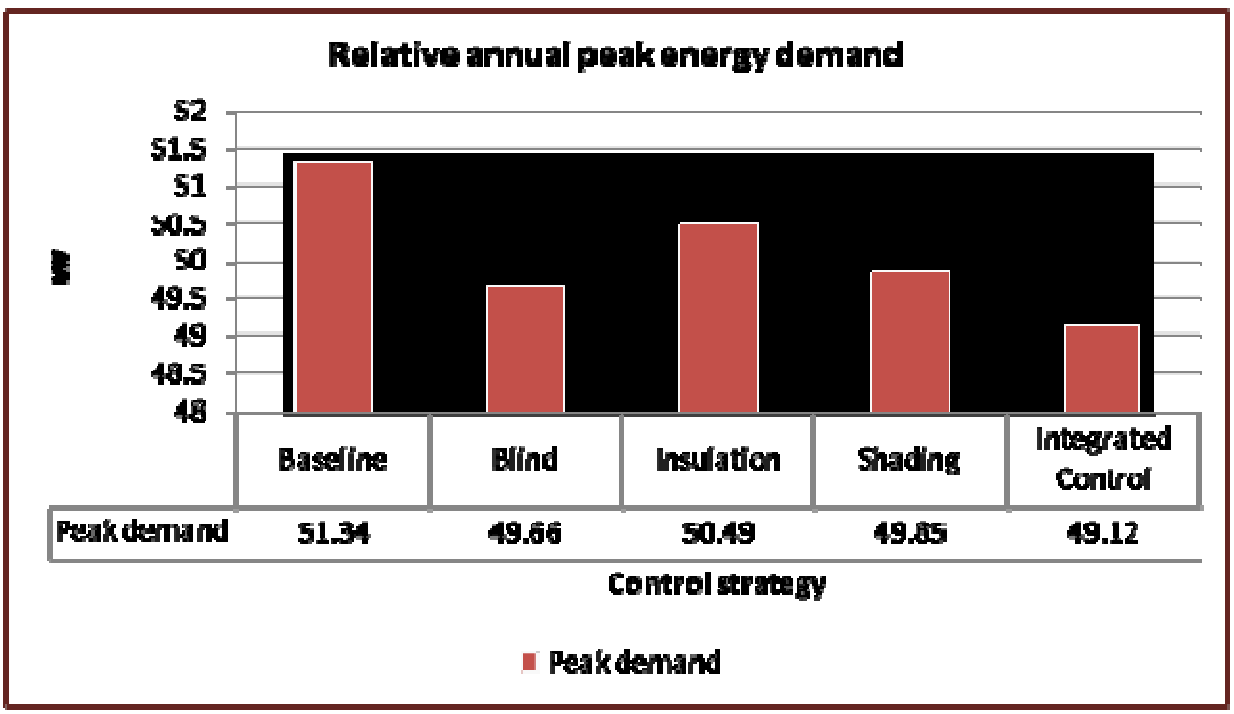



**Table 1.8** Peak Energy Demand (kW)



# Architecture Design Narrative

## Introduction

The best way to address energy issues is to use as little as possible. With this as inspiration, the Virginia Tech Solar Team has chosen the architectural type of the pavilion and developed the theme of *Responsive Architecture* integrating design and technology. Conservation is woven within innovation; natural ventilation, passive heating and daylight work in conjunction with new technologies that are sustainable and beautiful.

As pathfinders in design research we are pushing the envelope to explore new ideas regarding residential construction and the use of energy in buildings. We are harnessing technology in a better way, to build a brighter day. Our elements are bold, our thoughts tempered, our decisions reasoned, and our work is with passion. A provocative house for a conservative market, our aspirations are set to Daniel Burnham's polemic, "Make no small plans, they fail to stir the hearts of men."

## Mission

The mission is to inform and educate the public about issues regarding energy 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:

- Illustrate how solar energy improves the quality of life without compromise
- Increase public awareness of energy use in daily life and energy consumption of daily activities
- Promote conservation
- Establish a home that is responsive to its environment by integrating passive heating and natural ventilation
- Demonstrate the importance of natural light in residential building
- Introduce market-ready technologies and how they can meet energy requirements of daily activities by tapping into the sun's power
- Demonstrate that sustainable materials and technologies can comprise a beautiful structure in which to live, work, and play
- Challenge conventional architectural practice through interdisciplinary collaboration and corporate partnerships

## Design Concept and Philosophy

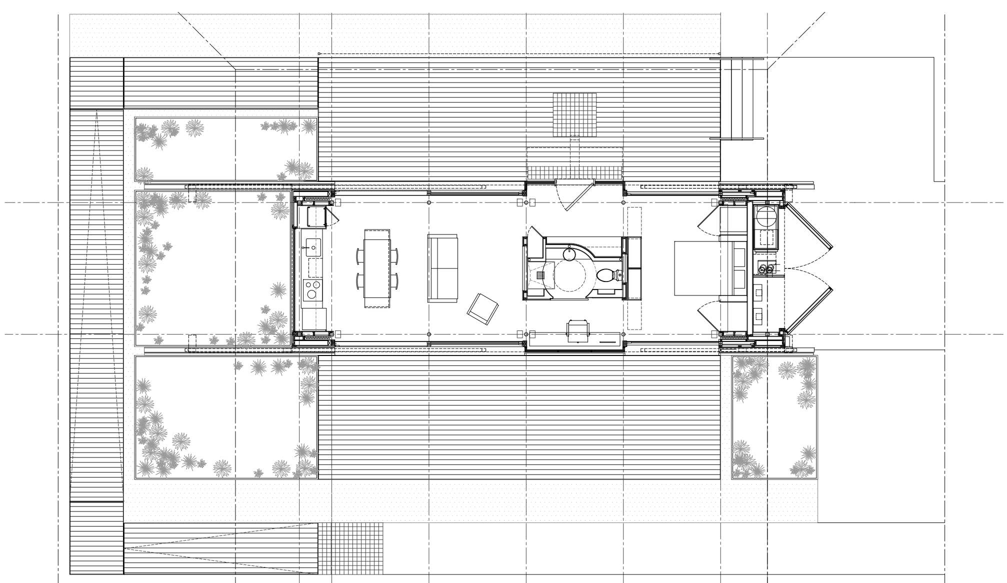
The Virginia Tech Solar House is driven by a **multidisciplinary approach** that challenges research through application. It harnesses the tension created by the dualities of calculation and intuition; technological innovation and architectural expression; optimized performance and sensible materials; 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 is 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. To this end the following **architectural concepts** have been developed:

- A house that responds to changing environmental conditions and user requirements
- A house larger than itself – a small footprint and volume offering the amenity of a much larger house
- Every technical decision is measured in terms of its contribution to spatial effect
- Material considered for its technical capacity, sustainability and expressive qualities
- The landscape and architecture are one
- Enriched patterns of daily life find expression in a celebration of energy awareness and resource conservation.
- Marketability and innovation – simultaneous awareness of public taste and the need for something meaningfully challenging 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. Dual characteristics of open and closed are possible through a sophisticated integration of the architecture and the technology.



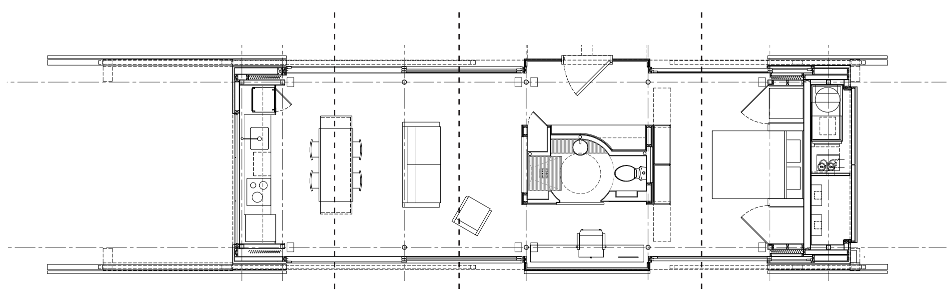
Site Plan showing decks and water features

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 east façade; the kitchen is embedded in the west wall. These elements serve as bookends inflecting the space to the north and south decks. A ribbon window contiguous with the kitchen counter drops daylight onto work space. Bouncing off the west water pond, the yellow glow of dappled sunlight splashes on the ceiling. The window is composed of electrochromaic tinted glass that adjusts to the intensity of the sun similar to self-tinting sunglasses.

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.



**Plan** - the north and south walls can be open as a pavilion or closed, depending on external conditions

A central core comprising the bathroom and office areas plays an important functional and spatial role. It separates the living area from the bedroom yet its lower ceiling gives a full reading of the entire 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.

The north and south walls are comprised of four sliding layers. Outermost is the Eclipsis System (see below) of stainless steel shutter screens and polycarbonate insulating panels. Large sliding glazing doors and interior curtains fill out the layers. 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. 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 respond to climactic conditions.

### Pavilion Living

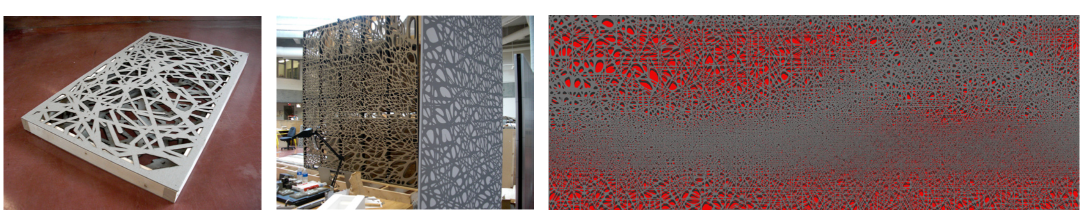
Where most energy conscious houses are closed with strategic openings to resist heat transfer, this house has flowing spaces linking inside and outside. Sliding glass on the north and south facades allows for cool breezes to flow across the space. Our studies show that with this moving air, comfort is maintained at least five degrees above the temperature range required by the competition. In addition, the dark massive floor absorbs considerable solar energy in winter requiring less active systems to acclimate the house. When exterior conditions do not benefit, the two outer sliding layers (Eclipsis System) provide a full range of protection. The duality of open and closed is possible through a sophisticated integration of the architecture and the technology.

As a pavilion, the house is filled with natural light. In addition reducing energy demand the functionality of the building can be improved. People are healthier, happier and simply function better in natural light.  But “Day lighting” should not be confused with sunlight.  Day lighting is the result of effectively managing sunlight. If sunlight is not managed or mitigated it can result in distracting glare or uncomfortable solar heat gain. To address these conditions, the Eclipsis System was invented,

Pavilion living - view from living room with shutter screens partially deployed and all sliding systems open.

### Eclipsis System/Design Research

The house adapts to optimize energy efficiency, and articulates the architectural space though combinations of sliding panels. It is designed to be flexible and fluid addressing 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 the shutter screen - a stainless steel panel assembly. The initial design for was based on algorithms generated from patterns of plant transformation and the geometric growth of crystals.



Detailed prototype, full scale prototype and digital model of early shutter screens

Scripting, a software that allows for the development of variables within the pattern, was utilize to explore various patterns that would be cut by laser or water jet. This gave an amorphic, vital image to the industrialized process of the screen. However, fabrication issues and the difficulty of reconciling competing criteria proved difficult. Though the design was dynamic and visually stimulating, its performance, particularly regarding sunshading was not satisfactory, thus alternatives were explored.

The design search re-focused, emphasizing fabrication processes and material availability. A simple, repetitive circular pattern was chosen that could be easily fabricated and met the multiple performance criteria of the shutter screen. Prototypes were developed and tested - at first small panels were produced and later full-scale mock-ups. An innovative aspect of the new approach is the circular geometry of laser-cut holes with tabs folded at calculated degrees. This system allows a four-fold role: to keep the summer sun off the façade; to offer degrees of privacy while providing views 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 to 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.

View of north shutter screen and stainless steel prototype.

It was decided to paint only one side of the screen (interior), leaving the stainless steel exposed on the facade. Depending on the intensity and angle of the sun, and the position of the viewer, a dynamic quality of movement is achieved. From outside the color is revealed in staccato like moments as one walks by. From inside the color presents itself as an enclosing wall, partially transparent yet giving a sense of security and privacy.

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 wall section gives an R-24 insulation value while transmitting a beautiful translucent light. The 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 (Eclipsis System) open.

**Architecture and Technology**

Though the concept of *Responsive Architecture* and the innovative use of computer monitoring and controls, the 2010 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 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 dinner time 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. 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 appropriately 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.


Setting the radiant floor and polishing the concrete slab

- 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 wood screen found in Middle Eastern countries) – it integrates technical function and cultural implications.
- The structural frame is factory assembled of recyclable steel. The transport carriage is integral to the structure of the house. Structural insulated panels (SIPs) comprise the roof and end walls. With high insulation values, these panels also serve as lateral support to resist sheer. Removable 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 of mass produced units.

Frame in transport and the torque box that connects to the rear wheel assembly

### Landscape and Architecture

The landscape is designed as a fully integrated and seamless component of a comprehensive architectural expression. The LUMENHAUS landscape is built to demonstrate the use of water conservation techniques through development of a system that integrates the exterior and interior environments inclusive of rainwater harvesting, grey water management, constructed wetlands and carbon dioxide sequestration. The goals of the landscape plan are:

- Create an innovative landscape system that utilizes nature to support and enhance the off-grid systems and the team's commitment to conservation and self sufficiency.
- 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 to aid in $CO_2$ sequestration.
- 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 while aiding in reducing the residents' carbon footprint.

This design is intended to define a new aesthetic for the contemporary landscape that will integrate into a comprehensive architectural expression. Rainwater is harvested, stored, and purified in order to create a self-sufficient water supply for LUMENHAUS. The collected rainwater can be used two ways - untreated, it can supplement the grey water system in maintaining the health of biological systems while rainwater treated using chlorine injection becomes potable for drinking and washing uses.

### Scalability and Mass Production

Though designed as a single family small house, accommodation is made for expanded plan types as well as mass production for multiple units (see marketability and industrialization). Variations regarding number of bedrooms and module configuration are embedded within the single plan. Expanded flats as well as two story dwellings are possible through attachable stair, entry and transition elements. The frame of the house allows for vertical stacking and integrates the unique transportation system. Further development involves *Lumenocity*, a fully sustainable, high density neighborhood. (see AR 801, 802, 803 and *Industrialization and Marketability* for further information)

The structure of the house is also the carriage of the transportation system. Students and faculty met with trucking industry designers and discovered the lowboy double-drop trailer. In this equipment the wheels lie outboard of the heavy load in order to keep the cargo as low as possible on the highway. The chassis, serving as the house floor and foundation structure, is designed to receive a detachable gooseneck and rear axles for transport. These elements are reused again and again to transport other modules to their respective sites. This transforming technique facilitates moving the house as potential exhibition/education piece (as in our 2005 Solar Decathlon house), but more importantly, serves as a model for the potential shipment of units with the roof in place and the dwelling intact.

Transport System showing rear wheel bogey assembly and gooseneck and house on temporary foundations

## 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.

lumenHAUS
a brighter way. everyday.

# ACOUSTIC REPORT

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## THEORETICAL CALCULATIONS

### 1.1. SOUND INSULATION

**NOTE: BECAUSE OF THE RESPONSIVE NATURE OF THE ARCHITECTURE, FROM AN ACOUSTICAL POINT OF VIEW, THE SOUTHERN WALL OF THE HOME HAS TWO ACOUSTIC FINGERPRINTS, ONE WITH THE INSULATIVE DOORS RETRACTED AND ONE WITH THEM DEPLOYED. IN THE RETRACTED MODE, THE ACOUSTICALLY WEAKEST PORTION OF THE WALL—THE ONE LIKELY TO CONTROL IN A TRANSMISSION LOSS TEST—IS BELIEVED TO BE THE LARGE ½" GLASS SLIDING DOORS. IN THE DEPLOYED MODE, WHICH IS THE MODE INTENDED FOR ON-SITE TESTING, THE ½" GLASS DOORS ARE COVERED WITH AN AIRSPACE, AN AEROGEL-FILLED POLYCARBONATE PANEL, ANOTHER AIRSPACE, AND ANOTHER AEROGEL-FILLED POLYCARBONATE PANEL. IN THE DEPLOYED MODE, THE ENTRANCE DOOR, RATHER THAN THE SLIDING GLASS DOOR, IS ASSUMED TO BE THE WEAKEST ACOUSTIC LINK—THE ONE THAT CONTROLS TRANSMISSION LOSS PERFORMANCE. WHAT FOLLOWS IS AN ANALYSIS OF THE RETRACTED MODE.**

The southern façade of the building is a Fleetwood Norwood 3000 Series aluminum sliding glass door assembly. The glass consisted of a 12.7 mm laminated glass. The following TL data were obtained from the manufacturer and performed by Western Electro-Acoustic Lab, Inc. (See appendix A)

In the following figure the measured data shows the third-octave Transmission Loss (TL) values obtained from the lab, as well as the maximum STC contour that satisfies the conditions, STC 37. TL values were then adjusted with the room absorption and area of the wall to obtain the Noise Reduction (NR) values.

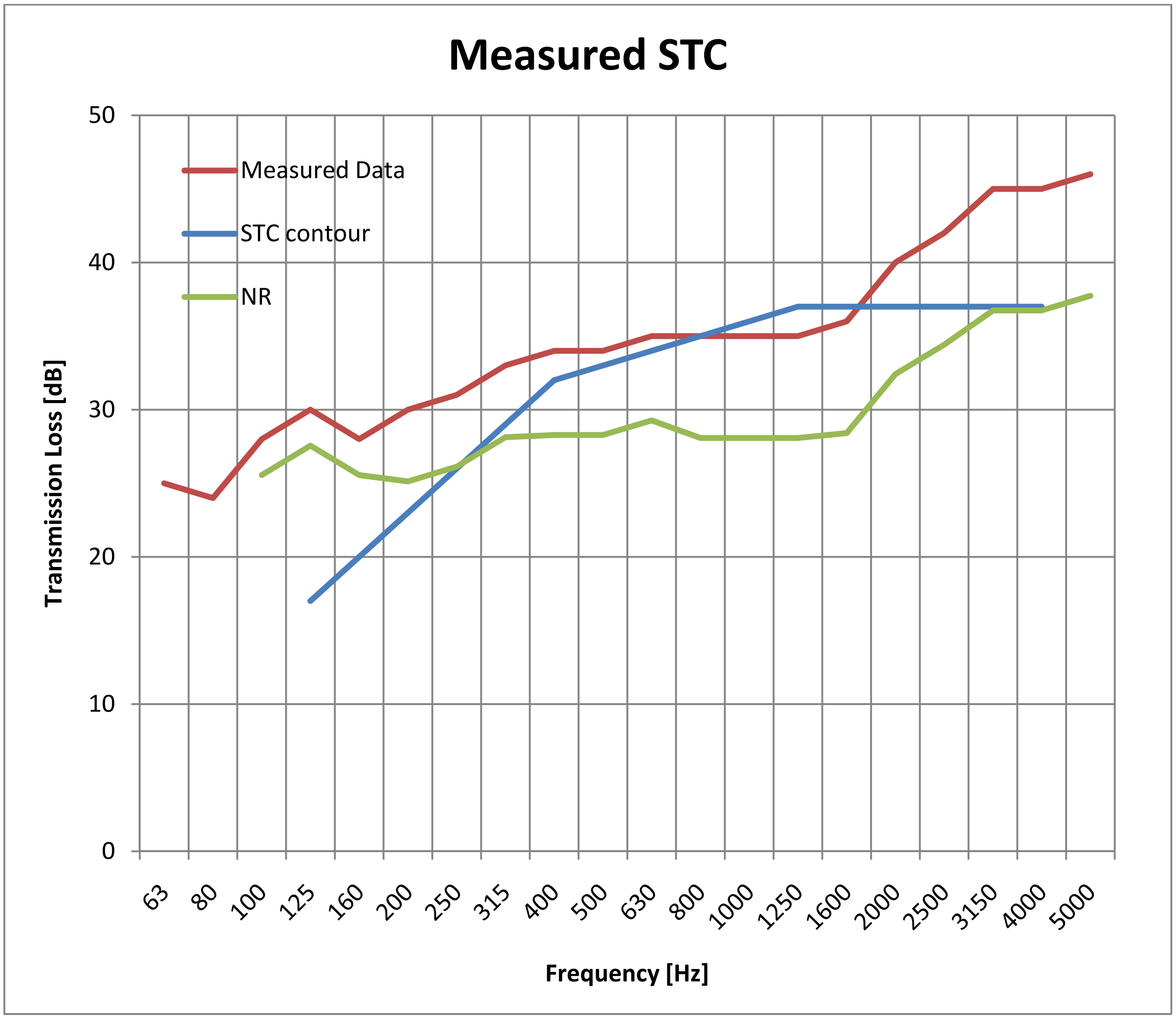



**Figure 1. TL and STC values from lab measurement per one third frequency octave band.**

| Freq | 63 | 80 | 100 | 125 | 160 | 200 | 250 | 315 | 400 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| TL | 25 | 24 | 28 | 30 | 28 | 30 | 31 | 33 | 34 | 34 |
| NR | - | - | 26 | 28 | 26 | 25 | 26 | 28 | 28 | 28 |

| 630 | 800 | 1000 | 1250 | 1600 | 2000 | 2500 | 3150 | 4000 | 5000 | STC |
|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 35 | 35 | 35 | 36 | 40 | 42 | 45 | 45 | 46 | 37 |
| 29 | 28 | 28 | 28 | 28 | 32 | 34 | 37 | 37 | 38 | 30 |

**Table 1. TL and STC values from lab measurement.**

The measured STC for the glass doors of the house, without the insulative panel deployed would not be appropriate for an urban setting with traffic noise less than 18 meters away.

### 1.2. REVERBERATION TIME

| | | | ABSORPTION COEFFICIENT | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SURFACE** | **MATERIAL** | **AREA (m2)** | **125** | **250** | **500** | **1000** | **2000** | **4000** |
| Wall | Glass | 0,32 | 0,10 | 0,08 | 0,06 | 0,04 | 0,02 | 0,32 |
| Wall | Plywood | 0,30 | 0,20 | 0,15 | 0,13 | 0,10 | 0,08 | 0,30 |
| Bed | Absorptive | 0,38 | 0,60 | 0,78 | 0,80 | 0,78 | 0,70 | 0,38 |
| Window | Glass | 0,32 | 0,10 | 0,08 | 0,06 | 0,04 | 0,02 | 0,32 |
| Ceiling | Plywood | 0,28 | 0,22 | 0,17 | 0,09 | 0,10 | 0,11 | 0,28 |
| Floor | Polished Concrete | 0,01 | 0,01 | 0,02 | 0,02 | 0,02 | 0,02 | 0,01 |

Table 2. Absorption coefficient values of building materials.

| | ABSORPTION IN SABINES | | | | | |
|---|---|---|---|---|---|---|
| | **125** | **250** | **500** | **1000** | **2000** | **4000** |
| | 18,83 | 5,88 | 4,71 | 3,53 | 2,35 | 1,18 |
| | 14,37 | 9,58 | 7,18 | 6,23 | 4,79 | 3,83 |
| | 1,13 | 1,78 | 2,31 | 2,37 | 2,31 | 2,08 |
| | 0,54 | 0,17 | 0,13 | 0,10 | 0,07 | 0,03 |
| | 10,93 | 8,58 | 6,63 | 3,51 | 3,90 | 4,29 |
| | 0,34 | 0,34 | 0,69 | 0,69 | 0,69 | 0,69 |
| Total Absorption | 46,13 | 26,34 | 21,66 | 16,43 | 14,11 | 12,10 |
| RT | 0,75 | 1,31 | 1,59 | 2,10 | 2,45 | 2,85 |
| Rtmid | **1,85** | | | Volume | | **214,41** |

Table 3. Calculated Absorption and Reverberation Time values from Sabines formula.

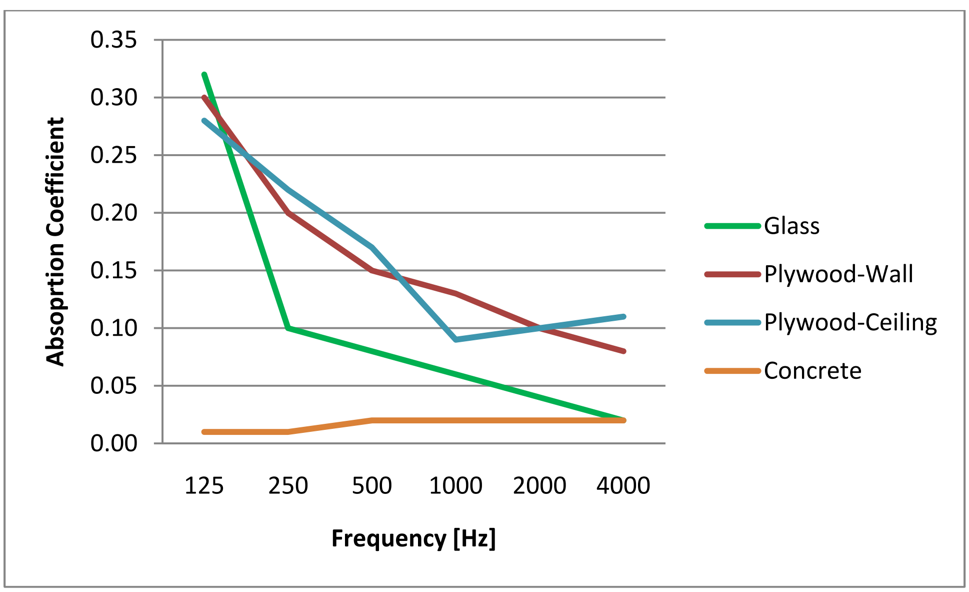



Figure 2. Absorption Coefficients of building materials per frequency octave band.

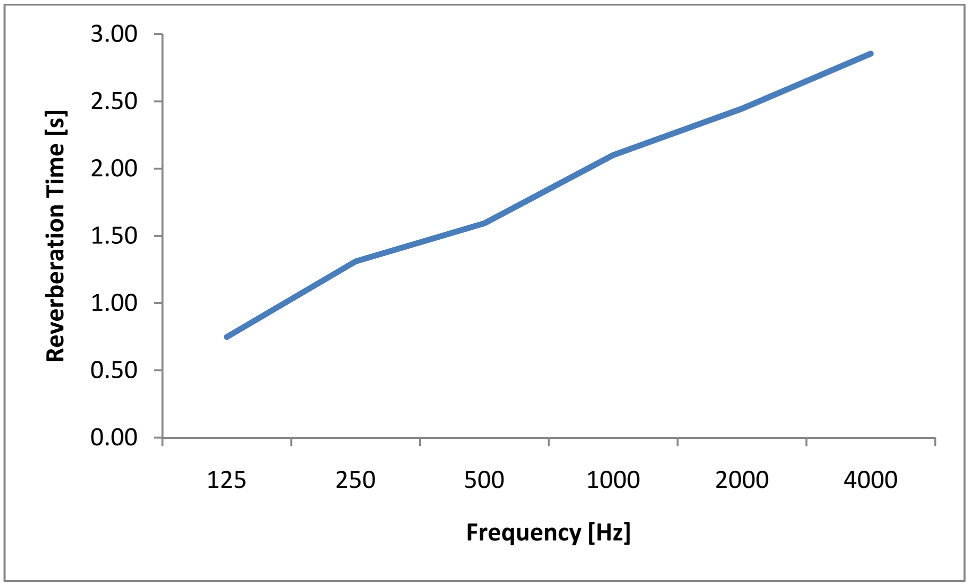



Figure 3. Reverberation Time per frequency octave band.

Reverberation time values were calculated with data taken from bibliography[1] and not manufacturers. The obtained $RT_{mid}$ exceeds the desirable value for a small residential building due to the highly reflective construction materials, though with curtains deployed, furniture in place, or window-walls open, reverberation times are expected to drop. The RT values show an unusual increase in reverberation with frequency. Typically, in contemporary construction, thin materials tend to be more absorptive in the lower frequencies.

[1] Egan, D. "Architectural Acoustics".

### 1.3. ACOUSTIC MODES

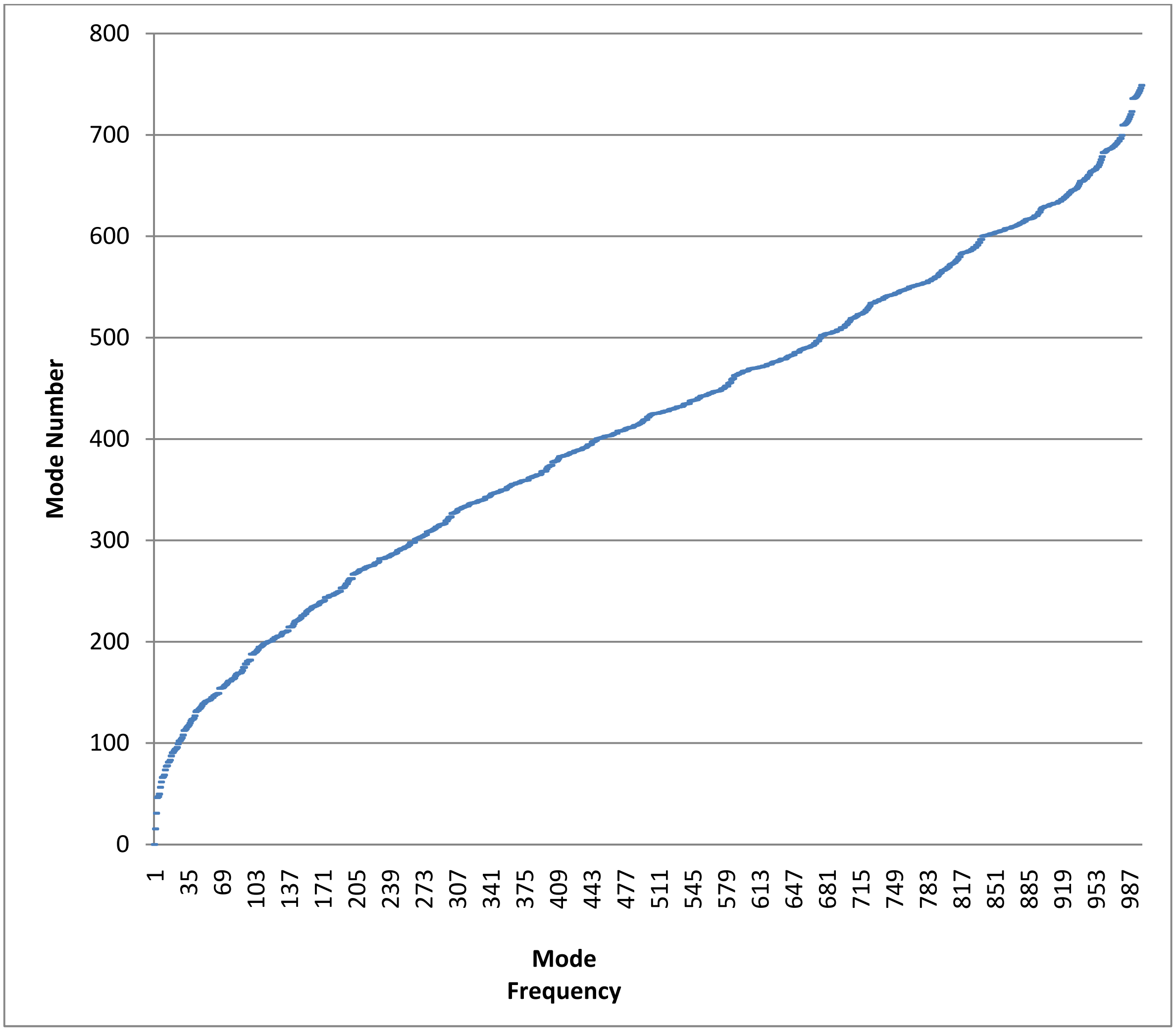
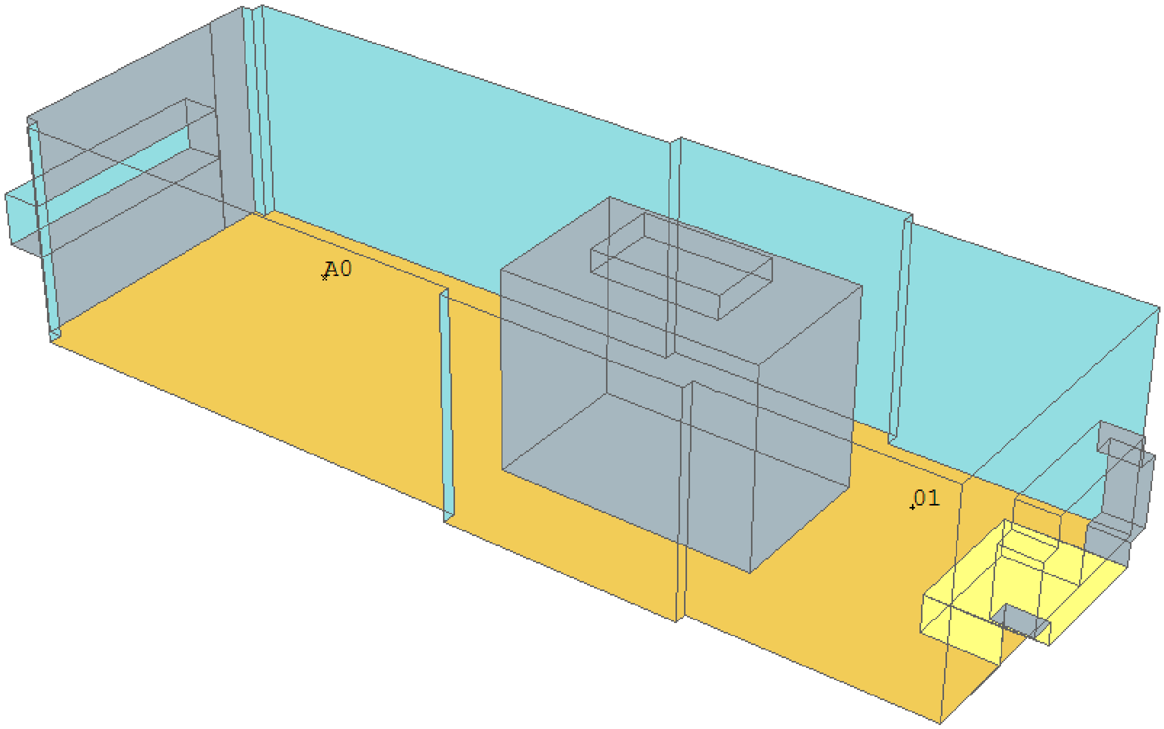



Figure 4. One thousand first Acoustic Modes of building.

Acoustic modes are evenly distributed, not producing any coloration of sound inside the building.

## 2. ACOUSTIC MODEL

The following data was obtained by an acoustic model developed with CATT-acoustic software.




Main acoustic parameters are mapped to understand the qualities of the building. Reverberation Time values appear lower than in the calculated results, and Clarity and Definition in a medium range for speech but good for music reproduction.

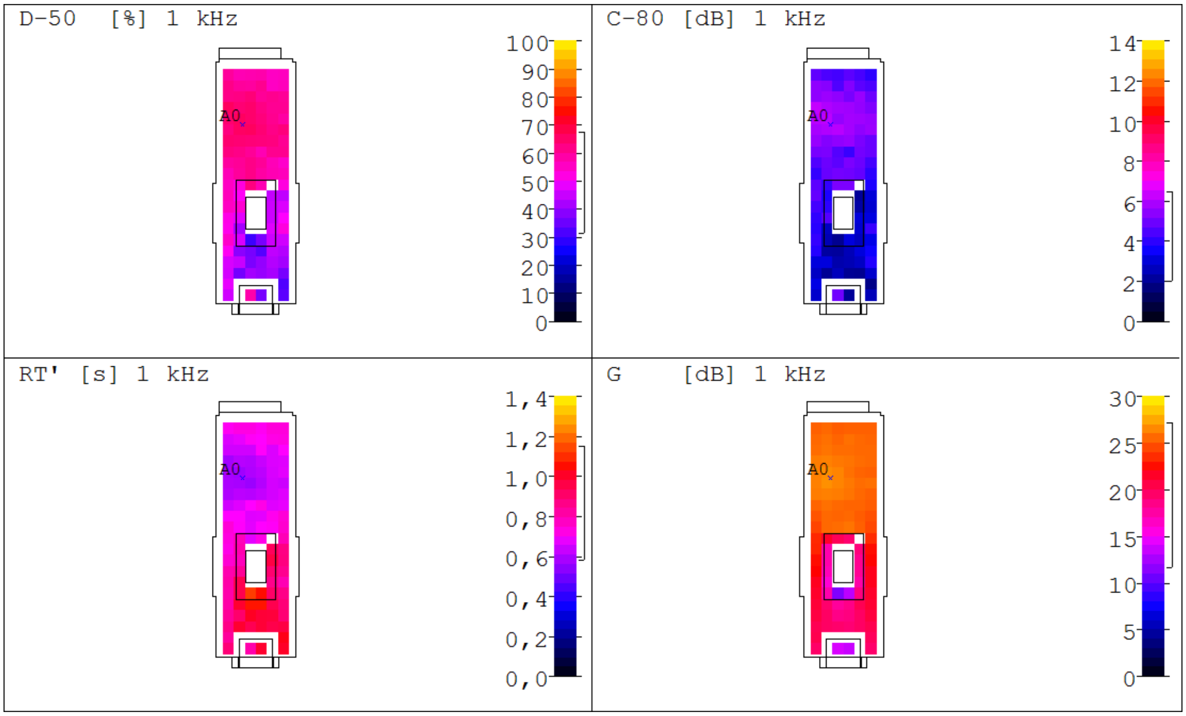



Figure 5. Main acoustic parameters mapped at 1 KHz.

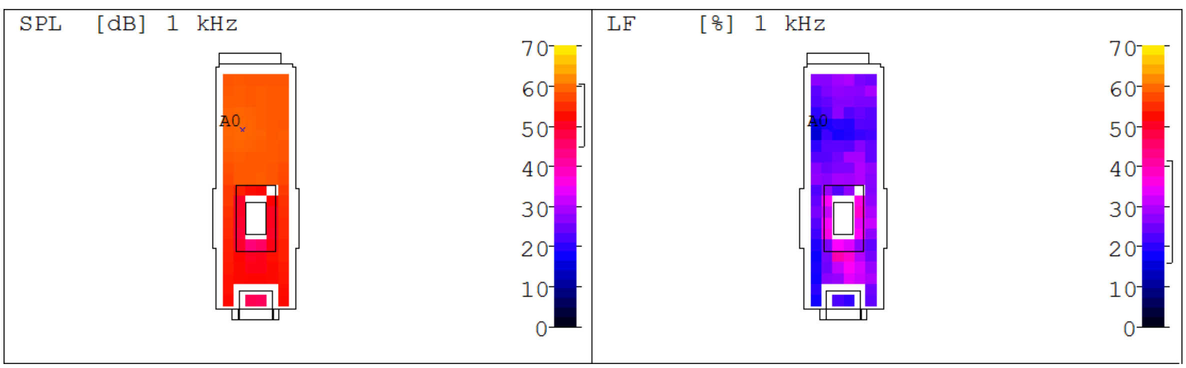



Figure 6. Main acoustic parameters mapped at 1 KHz.

In the following figure, represented by sound roses, we find an even distribution of reflections especially after 80ms. Before 80ms, the sound source direction is clearly seen as the main focus of sound incident at the receiver.

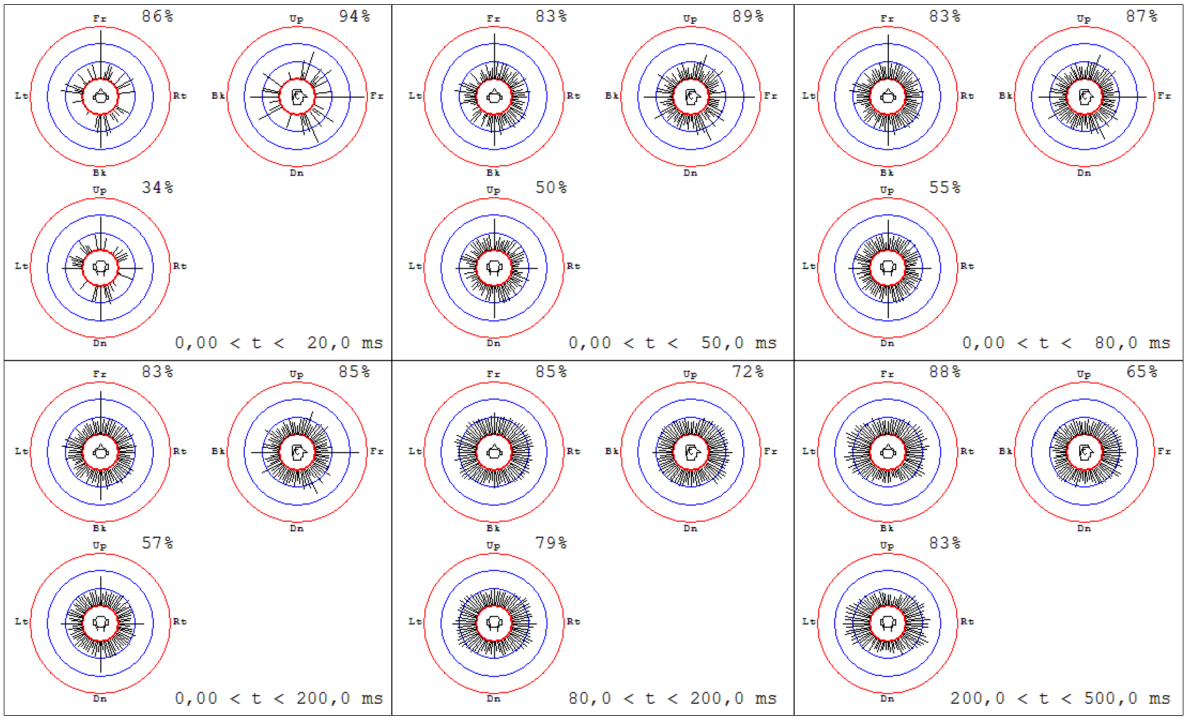
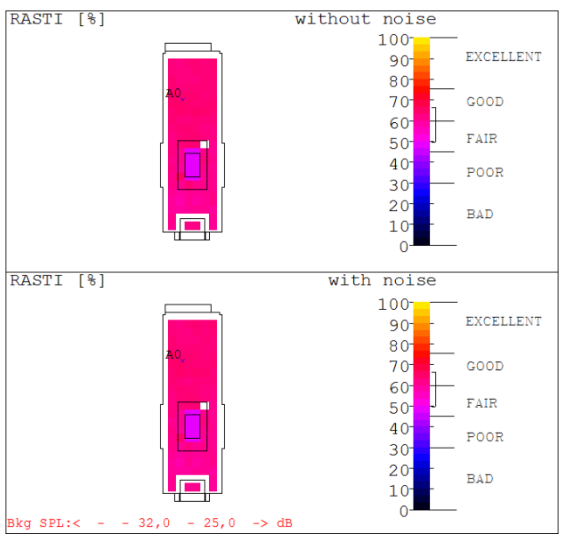



**Figure 7. Sound Roses. Analysis of sound reflections in the building.**

RASTI values lie between the “fair” and “good” subjective ratings. Speech would be intelligible under average noise conditions.



# Appendix A:

# Lab report for 1/2” glass used in sliding door assembly

WESTERN ELECTRO - ACOUSTIC LABORATORY, INC.

TESTING • CALIBRATION • RESEARCH • CONSULTING

25132 Rye Canyon Loop Santa Clarita, California 91355

Tel: (661) 775-3741 Fax: (661) 775-3742 www.weal.com

# SOUND TRANSMISSION LOSS TEST REPORT NO. TL01-555



15 November 2001

CLIENT: FLEETWOOD
2485 Railroad Street
Corona, California 91720

TEST DATE: 13 November 2001

## INTRODUCTION

The methods and procedures used for this test conform to the provisions and requirements of ASTM E 90-99, *Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions*. Details of the procedure will be furnished upon request. The test chamber source and receiving room volumes are 204 and 148.4 cubic meters respectively. Western Electro-Acoustic Laboratory is accredited by the United States Department of Commerce, National Institute of Standards and Technology under the National Voluntary Accreditation Program (NVLAP) Lab Code 100256-0 for this test procedure. This test report relates only to the item(s) tested. Any advertising that utilizes this test report or test data must not imply product certification or endorsement by WEAL, NVLAP, NIST or the U.S. Government.

## DESCRIPTION OF TEST SPECIMEN

The test specimen was a Fleetwood Norwood 3000 Series aluminum sliding glass door assembly. The specimen was sealed into the test chamber opening with a heavy duct seal putty around the entire perimeter on both sides. The glazing consisted of 1/2 inch (12.7 mm) laminated glass. The laminated glass utilized a .030 inch (0.76 mm) interlayer. The fixed unit and the operable unit were glazed into their individual frames with a vinyl wrap around gasket. The weather stripping used on the operable panel was a vinyl sweep seal on the exterior bottom rail, 290 high 270 back (.290 inch x .270 inch) fin seal on the interlock and an additional strip on the interlock adapter. In addition, on the frame, 290 high 270 back fin seal was located on the interior sill, and both sides of the jamb and head. The weather stripping used on the fixed panel was 290 high 270 back fin seal on the interlock and an additional strip on the interlock adapter. In addition, on the frame two finger vinyl was located at the interior jamb and a 290 high 270 back fin seal was located on both sides of head. A head cap was installed on the top open channel opposite the fixed panel. The net outside frame dimensions of the window assembly were 71-1/2 inches (1.82 m) wide by 79-1/2 inches (2.02 m) high by 4-1/2 inches (114.3 mm) deep. The overall weight of the assembly was 282 lbs. (127.9 kg) for a calculated surface density of 7.14 lbs./ft$^2$ (34.9 kg/m$^2$). There were no weep holes. The operable portion of the assembly was opened and closed five times immediately prior to the test.

## RESULTS OF THE MEASUREMENTS

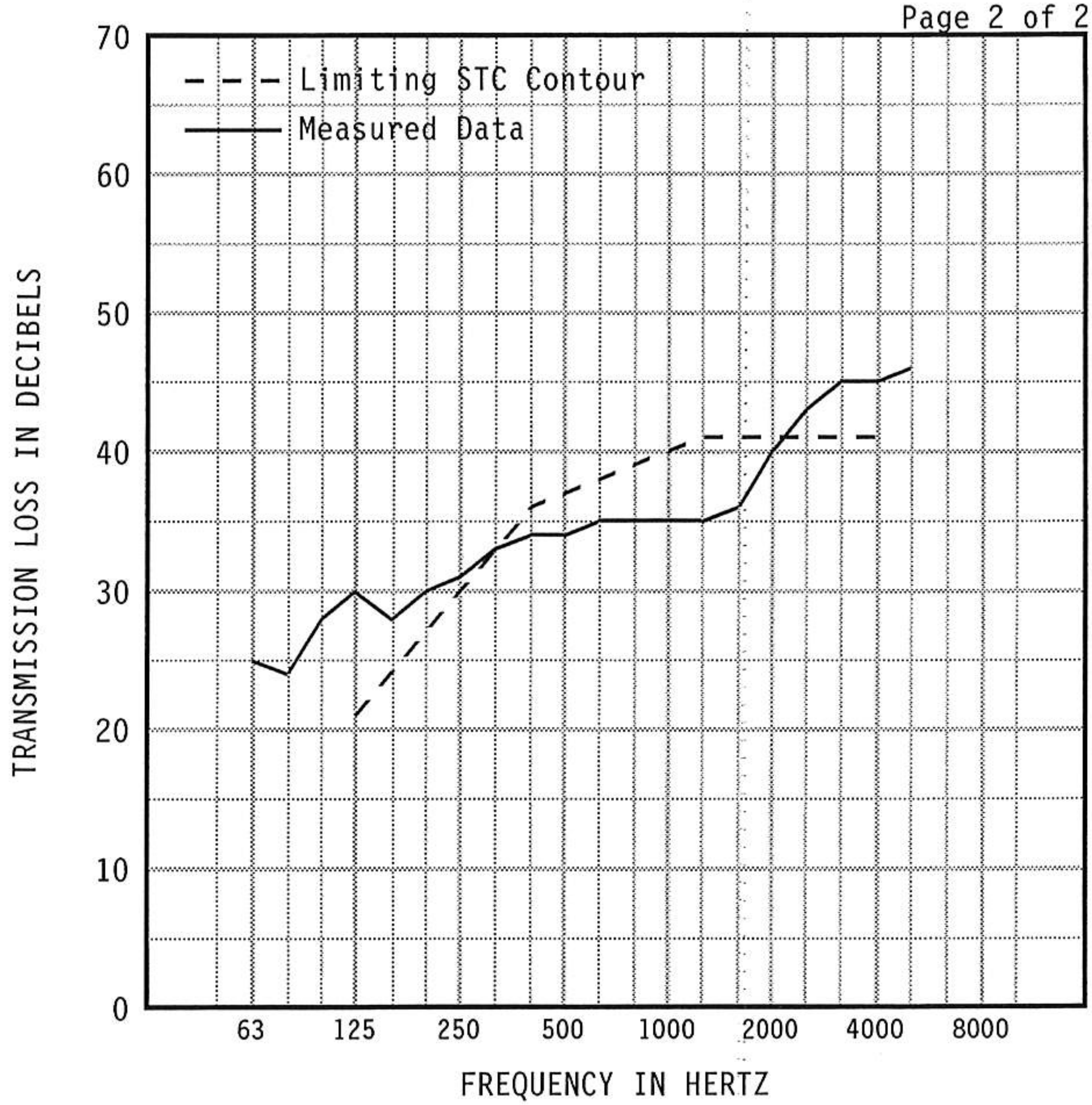
One-third octave band sound transmission loss values are tabulated on the attached sheet. ASTM minimum volume requirements are met at 80 Hz and above. The Sound Transmission Class rating determined in accordance with ASTM E 413-87 (Reapproved 1999) was STC-37.

Respectfully submitted,
Western Electro-Acoustic Laboratory, Inc.

Approved:

Gary E. Mange
Laboratory Manager

Leo Amezcua
Acoustical Test Technician




| 1/3 OCT BND CNTR FREQ | 63 | 80 | 100 | 125 | 160 | 200 | 250 | 315 | 400 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| TL in dB | 25 | 24 | 28 | 30 | 28 | 30 | 31 | 33 | 34 | 34 |
| 95% Confidence in dB | 2.81 | 2.84 | 1.95 | 2.96 | 2.08 | 1.66 | 1.07 | 0.64 | 0.89 | 0.64 |
| deficiencies | | | | | | | | (0) | (2) | (3) |

| 1/3 OCT BND CNTR FREQ | 630 | 800 | 1000 | 1250 | 1600 | 2000 | 2500 | 3150 | 4000 | 5000 |
|---|---|---|---|---|---|---|---|---|---|---|
| TL in dB | 35 | 35 | 35 | 35 | 36 | 40 | 43 | 45 | 45 | 46 |
| 95% Confidence in dB | 0.69 | 0.84 | 0.76 | 0.74 | 0.93 | 0.48 | 0.42 | 0.44 | 0.36 | 0.47 |
| deficiencies | (3) | (4) | (5) | (6) | (5) | (1) | | | | |

| EWR | OITC |
|---|---|
| 38 | 33 |

Specimen Area: 39.47 sq.ft.
Temperature: 73.4 deg. F
Relative Humidity: 58 %
Test Date: 13 November 2001

| STC |
|---|
| 37 |
| (29) |

# LIGHTING DESIGN NARRATIVE

In the lighting design of Virginia Tech's LumenHAUS, careful consideration has been given to the integration of daylight, electric light, and the corresponding effect on energy conservation, spatial quality, and nighttime identity. A primary focus of our energy conservation strategy to minimize the use of electric light is to maximize the use of natural daylight. 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* suggests a high quality of space, coupled with energy savings. An integral feature of the lighting scheme is the *Eclipsis© System*, a network of sliding panels that transform the space though changing natural light values. There is no electric light required from sunrise to sunset. When electric light is used, we optimize the use of electricity by providing the user with a lighting system that is easy to program and use to concentrate the light use only where it is needed throughout the day and night. We also utilize only the most efficient lighting fixtures, LEDs, dimmable fluorescents, and electroluminescent strips.

**Natural Daylighting**
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 over the expansive glass walls and doors.

> **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. The controls of the Sivoya QED curtain system are incorporated into the Lutron QS lighting control system and are easy to program and control.

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 (R-7). A horizontal window running the length of the kitchen counter, lights the workspace and provides view. It has an electrochromaic glass assembly which shields the direct western sun and provides privacy when needed. 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 solar panels above. These glass mounted Sanyo Hit Double photovoltaic panels are semi-translucent and allow natural daylight to enter the bathroom space.

**Electric Lighting**

Research was conducted regarding the use of LED's (light emitting diodes) for overall lighting. It was found there was less energy draw with fluorescents to achieve the same overall room lighting requirements, thus Elliptipar asymmetrical distribution fixtures with T5 fluorescent lamps and dimmable eco-ballasts by Lutron provide the overall ambient lighting. They are set above the drop soffit edge of the room, lighting the upper, matte white ceiling, and reflecting 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. Daylight sensors adjust the dimming throughout the day so assure minimum energy waste.

Vacancy sensors are installed throughout the house to conserve energy when the house is not occupied.

These fixtures programmed to maximize output at ½ dim, make up the overall ambient lighting load of the house to be 208 watts max. Selective choices can be made for local task and area lighting using the low energy LED fixtures.

LED's are challenging the present lighting standards and are used for task and accent lighting. A low voltage dimmable track lighting system employ 16 track heads with LED MR16 lamps, having a color temperature of 3000k which provide a flexible blanket of warm light at the periphery of the space. These adjustable fixtures serve as accent lighting primarily intended to highlight the soft character of the curtains and perceptually expand the space when the curtains are drawn. 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.

The bathroom skylight fixture is also backlit with low energy leds illuminating the space from above, similar to daylight.

Office task lighting is achieved through the use of the Koncept Z-bar, a 9 watt dimmable LED desk fixture. The Koncept i-tower, a 9 watt dimmable LED floor lamp is placed in the living room for accent and reading. This fixture provides energy efficiency, quality light, space flexibility and ease of use. The color temperature of the LEDs is also 3000k.

Concealed electroluminescent baseboard night-lighting, activated by timed motion sensors, guide the user throughout the house for nighttime navigation. The light strips provide a glowing blue soft floor light which guides the occupant through the dark house safely.

**Exterior Electric Lighting**

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. The RGB fixtures installed in the panels allow the full spectrum of color programmable through Philips Color Kinetics i-Player hardware and Colorplay software. The flexibility of colors available plays a psychological and physiological role in the occupants comfort and health.

An LED doorbell will glow a blue color at the front door throughout the night consumes less than 1 watt of power.

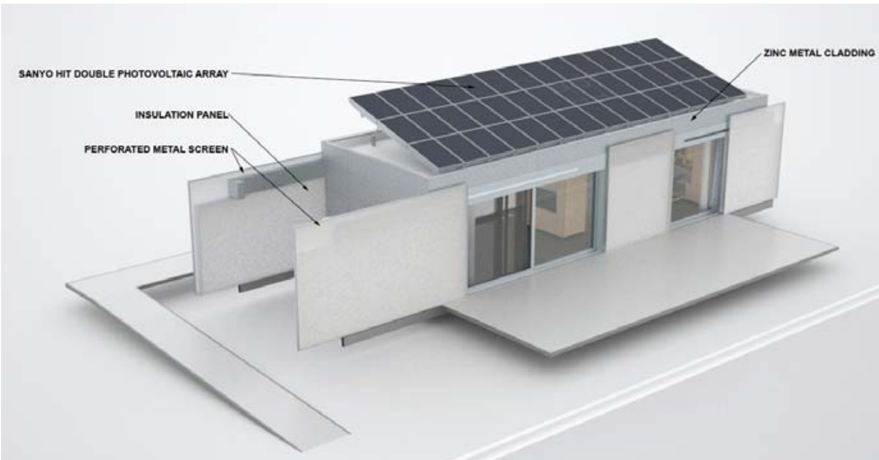
Conservation is an undersubscribed activity. The tendency to leave lights on when they are not needed wastes a considerable amount of energy. The patterns of daily life often result in lights burning when no one is in the room. LUMENHAUS addresses this issue by incorporating Lutron's innovative *Ecosystem* lighting program. It is a commercial lighting control system that is comprised of dimmable electronic dimming ballasts for fluorescents, led controls, remote switching and environmental sensors. These components combine to provide energy savings from 40 – 70%, increases space flexibility, increased comfort and control and low maintenance costs. The system goes beyond vacancy sensors. Daylight harvesting automatically adjusts the electric lighting levels based on the amount of daylight in the space utilizing lutron's daylight sensors. 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, but most importantly is integrated with the Siemens Apogee building controls software to allow autonomous operation. The system also provides information on energy use to the home touchscreen or the i-phone. Giving the homeowner access to energy use should result in better energy management.

The overall ambient lighting needed to illuminate the entire interior house at night consumes less than 331 watts, less than the power needed to light five 75w incandescent bulbs. Much more energy is saved when you factor in the programmable operations and motion, occupancy and daylight sensors, of course that is when artificial light is even necessary in the Lumenhaus.

## Lumenhaus Lighting

| | | |
|---|---|---|
| Fluorescent Ceiling Ambient | **208 watts** | Ambient |
| Elliptipar F303 8' fixture with (2) F28T5 4' bulbs | | |
| (8) Eco 10 low energy dimmable ballasts by Lutron | | |
| 28 watt 4' bulb 7 watts/ft 2900 lumens 104 lumens/watt | | |
| 64 linear feet @ 7 watts per foot at full power | | |
| 416 watts full - Programmed to 1/2 dim | | |
| Low Volt LED Track Lighting | 78.4 watts | |
| Tech Lighting Helios Led Fixtures with MR 16 LED bulb | | |
| 3000 k 4.9 watt 327 lumens 67 lumens/watt | | |
| 30,000 hours | | |
| Bathroom Skylight | 45 watts | |
| Philips EW cove powercore LED | | |
| 4.5 watts/foot 135 lumens 30 lumens/watt 2800 k | | |
| 10 fixtures | | |
| Kitchen task lighting | 50 watts | |
| Philips EW Profile LED | | |
| 19" fixtures 10 watt 275 lumens 25.5 lumens/watt | | |
| 5 fixtures | | |
| Bedroom Reading lighting | 20 watts | |
| Philips EW Profile LED | | |
| 19" fixtures 10 watt 275 lumens 25.5 lumens/watt | | |
| 2 fixtures | | |
| Dining Pendants | 14.7 watts | |
| Tech Lighting Helios Led Fixtures with MR 16 LED bulb | | |
| 3000 k 4.9 watt 327 lumens 67 lumens/watt | | |
| 30,000 hours | | |
| 3 fixtures @ 4.9 watts | | |
| **Interior Lights** | **416 watts** | Extreme case |
| Insulation Panels | 576 watts | |
| I-color cove mx powercore | | |
| 12 watts/ft 119 lumens eff 9.9 lumens/watt | | |
| 48 fixtures | | |
| Philips EW cove powercore LED | 216 watts | |
| 4.5 watts/foot 135 lumens 30 lumens/watt 2800 k | | |
| 48 fixtures | | |
| **Exterior Light** | **792 watts** | occasional use only |

## Engineering Narrative – Virginia Tech Lumenhaus




**General Statement of Engineered Systems Design:**
An overview of the lumenHAUS engineered systems approach can be best described as an adaptable enclosure system combined with passive environmental conditioning strategies supplemented with a highly efficient and flexible geothermal exchange, dual heat pump system. An all-electric power generation and grid-tie strategy, provides an overall approach which simplifies control systems and eliminates the need for active solar thermal collection strategies. A flexible control system with an iPhone as the human computer interface (HCI), provides the occupant with either a “hands-off” approach or a completely autonomous mode of operation. This same HCI relays critical information about the status of the house to the occupant so informed decisions can be made.

**Responsive Architecture**
lumenHAUS possess a highly efficient building envelope in which layers can be deployed based on preset comfort conditions or immediate occupant preference. The enclosure system consists of four discrete moveable layers that can be manipulated to alter the energy balance of the building, to optimize for either human thermal comfort, or economy of operation, or a balance of the two. These discreet layers, moving from outside to inside, include, a moveable perforated stainless steel sunscreen, a moveable aerogel filled translucent insulated panel system with a perimeter air-seal, a series of large moveable sliding glass doors, and motorized moveable curtain system providing additional solar control and privacy. All motion control of the exterior panels is accomplished with eight precision servo motor control units under software control. This allows the panels to be placed in their appropriate location based on the Building Control System (BCS) logic.  There are two servo motors per corner of the building allowing placement of the sunscreens and insulated panels, for a total of eight independently placed panels.

This flexibility of control found in the enclosure system for lumneHAUS not only allows the building to be optimized on a daily basis, it also allows lumenHAUS to be adaptable  to a wide range of climatic zones. Low-energy passive solar design strategies are employed first to satisfy the thermal requirements before more energy consumptive systems are employed. During under-heated periods of the year, solar heat gain is encouraged by providing an uninterrupted aperture between the southern sky and the thermal mass floor, acting as a direct gain passive solar system. Thermal heat flux sensors detect the flow of energy into the space and activate the insulated panel system when the energy flow reverses, i.e., when more heat starts to be lost from the interior space than what's being gained. When outdoor conditions are close to the human thermal comfort zone, the moveable glass doors can be opened, as well as the insulated panel and the perforated metal sunscreen put in place providing shading and allowing an unobstructed path for natural ventilation. If outdoor conditions are so far removed from human thermal comfort conditions, the moveable enclosure system can be redeployed and mechanical conditioning implemented.

Outdoor ambient conditions are sensed by a tower-mounted weather station employing no moving parts. A sensor head consisting of temperature, humidity, wind speed and wind direction delivers information to the BCS and can influence deployment of the moveable panel systems. The sensor head is used to determine outdoor conditions and their relationship to the human thermal comfort zone, plus detect weather extremes, which necessitates moving the panels to a protected state. In addition to the weather station, a pyranometer is placed in the plane of the PV array to measure solar radiation falling on the array.

**Figure 1:** 520 WeatherHawk Wireless Weather Station

At any point, the automated portion of the BCS can be overridden by occupant preference using

a standard iPhone interface. The iPhone provides the human computer interface (HCI) between the BCS and the occupant. This provides critical information regarding energy usage, and indoor and outdoor environmental conditions. Automatic control can be returned back to the BCS by occupant command, or at a predetermined point in time, or when certain environmental conditions are reached. HCI simplicity has been stressed making it intuitive for the occupant to operate.

Another item under control by the BCS is the energy recovery ventilator (ERV). Mechanical ventilation can be provided using a heat recovery ventilator to ensure an adequate supply of outside air to guarantee good indoor air quality and not pay high costs associated with the thermal conditioning of that air.

**PV Power Description**

The power production capability of lumenHAUS is provided with 42 double-sided photovoltaic panels. The bifacial panels were selected to take advantage of their back-side production capability. For competition purposes, this additional power generating capacity will be essential to help increase the power generating density per unit area. To effectively compete, power density becomes very important because of the 800 ft2 (74.32 m2) house footprint limitation. The efficiency and power achieved is based on how effective the reflective surface behind the panels is. A white, diffuse reflector (white roofing membrane) was selected as the reflective surface. This diffuse reflector was chosen for ease of installation, and ease of maintenance. Studies were done on different tracking strategies for the array and their cost benefit. A seasonal adjustment strategy was decided upon because of its simplicity and return on investment. This seasonal positioning is accomplished utilizing six linear actuators to raise the array in three separate banks. Inclination is controlled through the BCS and can also be manually adjusted.

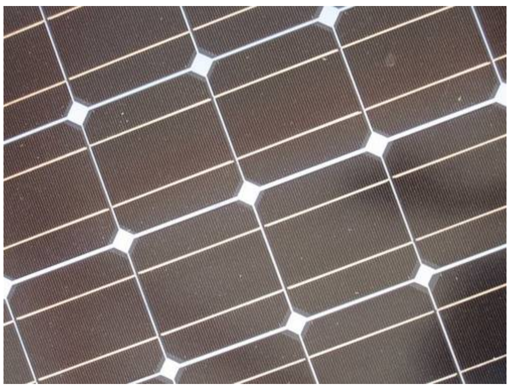


**Figure 2:** Sanyo Hit Double photovoltaic panels

**Integrated Environmental Conditioning and Domestic Hot Water Supply**
A dual heat pump system consisting of a water-to-water and a separate water-to-air heat pump were selected to provide a thermal strategy that optimizes both for comfort and economy

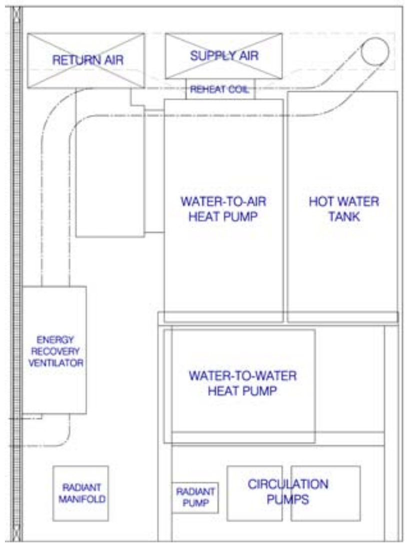



**Figure 3:** Mechanical closet diagram

Domestic hot water is provided through the geothermal heat pumps which allows waste heat to be recaptured and utilized when the water-to-air heat pump is in a cooling mode.

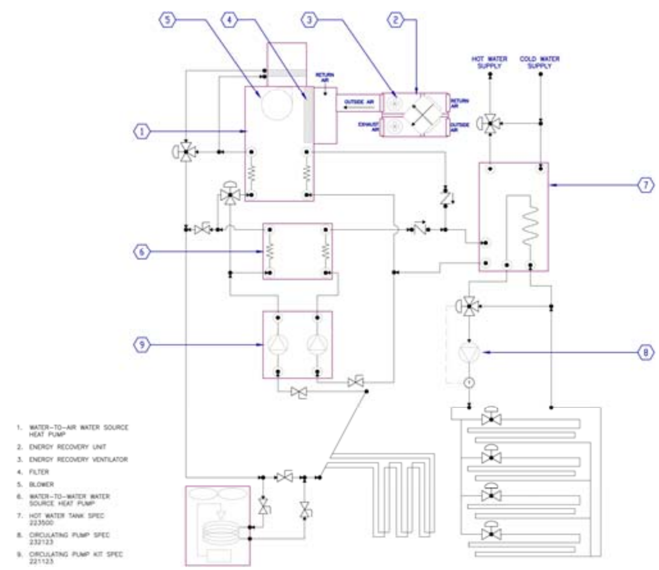



**Figure 4:** Mechanical systems diagram

This essentially provides free heat to supply domestic hot water during the summer months. By utilizing a solar-powered heat pump to produce both domestic hot water needs and space conditioning, this allows the control system to be simplified and standardized rather than a separate solar thermal strategy requiring additional control components. In addition, the need to provide freeze-prevention is eliminated. Should there be additional energy after the building's loads are satisfied, excess electrical power can be fed back into the utility network. In the situation of a solar hot water system, should there be a surplus of hot water, there are limited opportunities to benefit from Btus stored in water as opposed to the usefulness of electricity and the ability to sell it back to the electric provider.

Dual heat pumps allow for optimal thermal control and operating efficiencies. A three-zone water-to-water heat pump is connected to the radiant floor distribution system to provide heating during the winter months. To insure the time-lag constant of the radiant slab doesn't become a liability during the period of time in which heating and cooling is required during a twenty-four hour period. The radiant slab is not activated until later in the heating season, rather, the water-to-air heat pump is used to deliver either heating or cooling to the space by forced air. The linear diffusers located in the ceiling soffits are bimetallicly actuated to direct the air stream either towards the exterior glass surfaces in a heating mode or directed to the center of the space when in it is in the cooling mode. The radiant slab is able to thermally condition the space more efficiently because of the large radiant exchange area requiring lower temperatures than the forced-air distribution system. The lumenHAUs has the flexibility to balance between occupant comfort and economy of operation.

**Building Control System**

The building controls system is centered around a Siemens control panel. The control panel is the hub for all the sensors throughoutthe house - this includes interior temperature/humidity/CO2 sensors, aweather station, electricity usage, etc. While there is a system in place for the control panel to automatically regulate various aspects of the house, there is a desire to provide the occupants with a certain level of manual control over the system. For this, we've created an iPhone application. Our iPhone app provides a friendly, intuitive interface with which occupants may control the house – turn on/off lights, open/close the sun screens, check energy usage, etc. The interface itself makes heavy use of common iPhone gestures – for example, to turn on a light, you simply swipe to the right.

The software for the iPhone app is broken down into two components: one is the iPhone app itself, while the other is a middleware component that resides on a server in the mechanical closet. The iPhone app is merely an interface which does not have any specific logic with respect to communicating with the Siemens control panel. This work is delegated to the middleware component. This piece of software talks directly with the control panel and exposes, via wireless, a specific set of functions to that allow third party components (namely, the iPhone app) to control components in the house. Organizing the system in this manner gives us a great level of control, flexibility, and security. The iPhone can technically have access to any component of the house the control panel has, but we will limit that availability through our middleware software. This
gives occupants with the iPhone the ability to turn on/off lights, control the sun shades, monitor temperature conditions, and in general, be fully aware of the state of the house at any point in time.

**Lighting**

Flexible lighting controls allow adequate lighting levels to be maintained that take advantage of natural daylighting supplemented with artificial lighting.  Overall ambient light is provided through dimmable fluorescent lighting and LED lamps, in combination with natural daylight.  The ratio of artificial light to daylight can be adjusted by means of several space daylight sensors adjusting the illumination levels of the fluorescent and LEDs fixtures. A flexible lighting control system allows the occupant to choose from a series of preset lighting scenarios.  These presets can be chosen to reflect occupant preference, comfort, economy of operation or a combination of all three.

**Water**
A tapered roof insulation system allows all rainwater to be collected from one central location on the roof.  Water from this catchment area is led from the roof by way of a scupper to storage tanks located beneath the house decks.  This water can be used to supplement grey-water supplies in the house for flushing purposes or the stored water can be used to replenish water lost to evaporation for outside water pools.  The outside water features of the house serve several functions.  These constructed hydroponic wetlands

**Figure 5:** Image of water pool

form part of a grey-water filtration system plus serve as landscaping elements for the house. The thermal mass contained in the water can also be used in conjunction with the geothermal heat pump systems, either becoming heat sources, or heat sinks and can be evaporatively cooled.

**Smart-grid ready house**
The Smart Grid brings distributed intelligence to electric utility grids.  This provides a more reliable, more efficient, and safer electric grid, and can reduce costs for both consumers and utilities.  It further encourages the adoption of renewable energy and makes better use of the

existing generation resources we have today.  Adoption of Smart Grid technologies is an ongoing and developing process, involving utilities, consumers, government agencies, research institutions, standards bodies, and other groups.  The European Solar Decathlon is a natural vehicle for promotion of Smart Grid technologies and concepts, as it encompasses renewable energy, energy efficiency, and intelligent homes connected to the grid

The Virginia Tech International Solar Decathlon team recognizes the need for Smart Grid awareness and readiness and plans to incorporate Smart Grid technology in its 2010 entry to the competition.  By serving as a prime example of how a consumer's home can be enabled for the Smart Grid, the Virginia Tech house will help to educate consumers while demonstrating cutting edge Smart Grid technology.

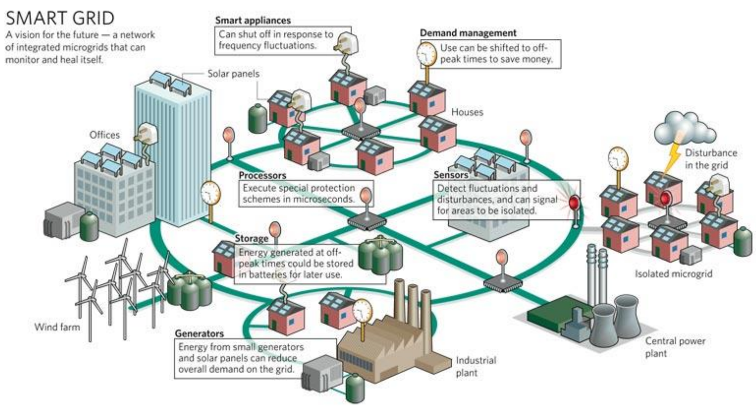



**Figure 6:** Smart Grid diagram

# DETAILED ENGINEERING REPORT

**1. Mechanical System**

***HVAC and Plumbing***

### ~~1216:0:.1216:0:~~1.1 Contest Background

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The LumenHAUS' HVAC and plumbing systems must provide the necessary cooling, heating, and water drawing capacities during the 2010 Solar Decathlon Europe (SD Europe) competition. 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 23ºC to 25ºC (73.4ºF a 77ºC)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 50 liters (13.2 gal) of water at an average temperature of 109.4°F (43$^{o}$C) be delivered within 10 minutes to any plumbing fixture located inside the house. These criteria will be evaluated 16 different times throughout the contest week.

### ~~1216:0:.1432:0:~~1.2 Mechanical System Implementation

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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 heating and 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. 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$^{o}$C) and an entering air temperature of 75°F (23.89$^{o}$C) dry bulb and 63°F (17.2$^{o}$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 to 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$^{o}$C) dry bulb and 63°F (17.2$^{o}$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 vary its power input and load capacity, although, it will usually have 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 exchangesystem is essentially a series of water storage bladders in which a large quantity of water 3,200 Gallons (12,113 liters) can provide either a thermal sink or source to the heat pumps. The bladder water storage system is used to mimic a lake or the ground, which stay at a relatively

constant temperature year round. The geothermal simulation system uses polyethylene piping for the geothermal loop.
The hot water tank is a BoilerMate (Model WH-7DW) 41-gallon capacity, 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 radiant floor heating. The hot water tank receives hot water from the water-to-water heat pump.

The radiant floor heating runs through the concrete slab to four different zones in the house. The radiant system makes use of RAUPEX™ O2 Barrier Piping, which is a highly flexible pipe with enhanced thermal energy transfer capability and an oxygen barrier. The hot water tank supplies hot water to the radiant floor piping, which flows in a closed loop system. The floor heating is accomplished through a distribution header, supplying 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 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. A circulating pump supplies hot water from the hot water tank to the radiant floor system and is only activated when heating is required. The Building Control System algorithm activates the pump when the space temperature sensors detects a need for heat.

Figure 1shows the entire HVAC system.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.

### ~~1216:0:.1648:0:~~1.3 Mechanical Closet

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The mechanical closet is located on the east side of the house, with direct access provided from the outside of the house. The closet is subdivided into two discrete zones, one houses all the mechanical equipment for environmental space conditioning and domestic hot water supply. The other zone houses the power conditioning for the PV system and the Building Control Sytstem. The mechanical equipment zone accomodates (heat pumps, hot water tanks, and, 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 The height and width of the mechanical closet is 163.36 in (W) x 107 in (H) x 32 in (D) (4.15 m x 2.72 m x .81 m).

The ERV unit is an indoor-to-outdoor heat exchanger, which delivers fresh outdoor air to the house. The heat exchanger recovers energy from the already conditioned interior air and delivers it to the incoming air.

Two SMA 5000 inverters with DC disconnect/combiners are used to convert the DC from the solar panels to AC power. These inverters also provide the grid intertie function allowing excess power generated by the house to be placed into the local utility grid. These inverters also provide line isolation should there be a failure in the power grid. Because the inverters may generate a large amount of heat when the power load is high (~11 kW) they need to be cooled. This is accomplished through a passive 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 necessary.From these design specifications, a mechanical closet layout was developed. Figure 2 shows the side view of the mechanical closet plan adopted for implementation.

As shown in this figure, the hot water tank and circulating pump are located on the rightside of the mechanical closet. Both the water-to-air and the air-to-air heat pumps are located in the center alcove. The placement 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 themechanical closet due to the division of the main distribution trunk to the separate branches. The trunk is the main duct exiting the top of the heat pump, whereas the branches are the ductwork 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. Originally, the water-to-air heat pump was turned towards the center wall so  the return duct could have easy access through the wall to the interior space

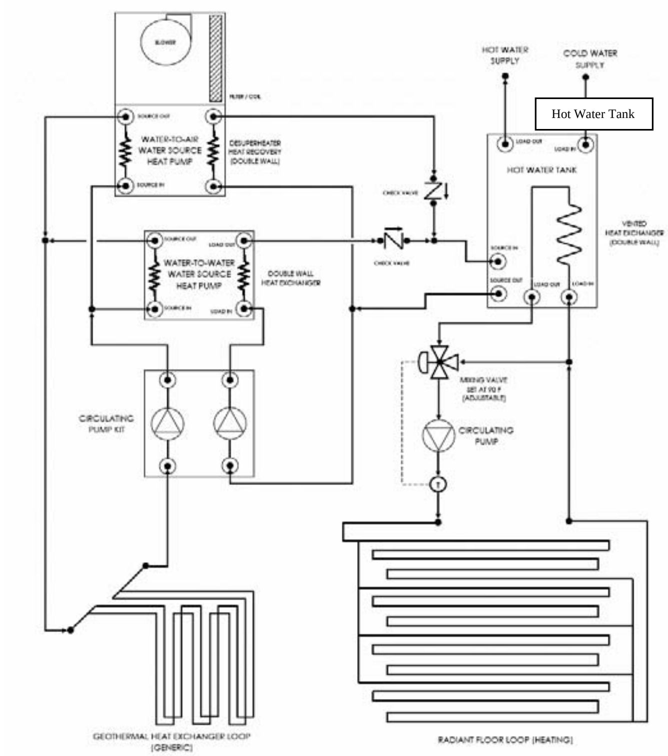
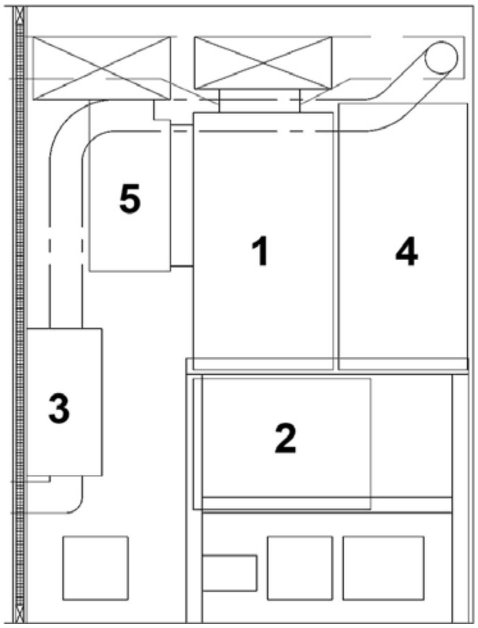



**Figure 1.**HVAC Schematic with added pumps and valves.




**Component Legend:**

1. Water-to-Air Heat Pump
2. Water-to-Water Heat Pump
3. Energy Recovery Ventilator (ERV)
4. How Water Tank
5. Exhaust Air

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**Figure 2.** Mechanical closet AutoCAD design (note the mechanical component labels).

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.

This mechanical closet concept provides a preliminary layout of the largest mechanical components. However, the addition of some components was required to complete the design. A return duct was designed and implemented to return air back into the water-to-air heat pump. The return vent was placed behind the bed, located on the other side of the wall, facing the bed, in the house. The return duct connects to the inlet with the use of an “S-turn” style duct piece. Other minor components that were added to the mechanical closet included the deliveries and returns of the piping system.

### ~~1216:0:.1864:0:~~1.4 HVAC System

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As per the contest rules, the HVAC system must keep the house conditioned to 73.4-77°F (23°C-25°C) and 40-55% relative humidity at all times (Gobierno de España, 2010). 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.

The heat pump is an Aquarius II AP Series Two Stage R-410A, which runs nominally at 750 CFM (21.2 $m^3$/min). Figure 3 shows 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.

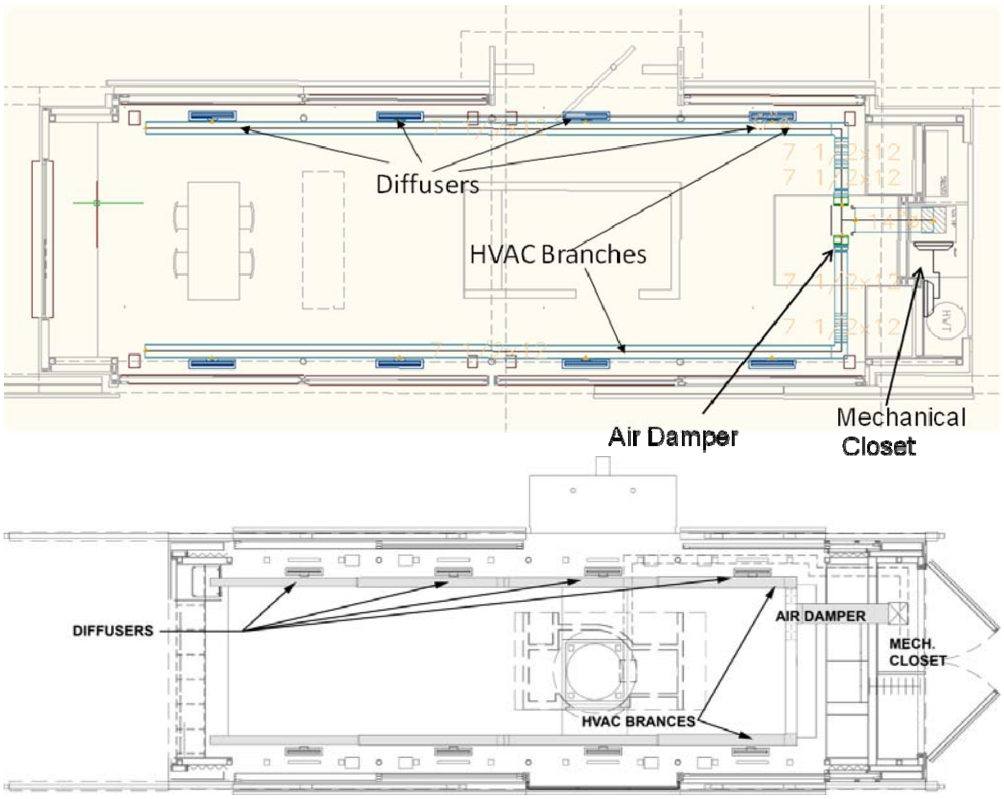


**Figure 3.** Drawing of the ductwork layout in the house for the water-to-air heat pump. The rectangles on the sides of the branches indicate linear slot diffusers.

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 in mind the noise factor. Based on the standards for a residential system, the air velocity through the ductsshould 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 thesespecifications, the velocity divides the known volumetric flow rate. This is given by the relationship

$$A = \frac{Q}{V} \qquad (1)$$

where A is the cross-sectional duct area under consideration, Q is the volumetric flow rate, and V is the flow rate velocity. As the water-to-air heat pump is locked out of the second stage in order to reduce power consumption, the flow rate is known to be 750 CFM (21.2 $m^3$/min) at its maximum. Since there is anabundance of space available in the mechanical closet for the main trunk, a velocity of 900 ft/min(274.32 m/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, the diameter for the circular duct is 15.14 in (0.38 m).A schematic of the cross section of this air space is shown in Figure 4.A short section of this design is shown of the mechanical closet. The branch sections that circulate the air throughout the house are located in the air space above the ceiling.

In order to determine the size of the ducts half of the main trunk's flow rate is used, i.e., 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 fits just inside the space, as long as no other obstructions are added to the area.

As energy efficiency is a primary goal of the air distribution system, the loss of energy through the duct walls must be avoided. An important issue with the insulation is the limited space abovethe ceiling. To solve this problem, spray foam insulation is used for much of the house and forsome of the ductwork. Some areas of the mechanical closet ducts require fiberglass insulationdue to space and system access requirements. This insulation keeps the conditioned air at desired levels before the air enters the space.

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 are used forthe outlets because this is the most effective system for the perimeter-intensive application that exists in the house. The diffusers are 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 used to project air vertically downward, parallel to the window. This creates a buffer zone between the exterior and the center of thehouse to stifle heat transfer either in or out of the house, depending on the season.Figure 5 shows the airflow pattern utilized by the linear diffuser system. Using linear diffusers in this

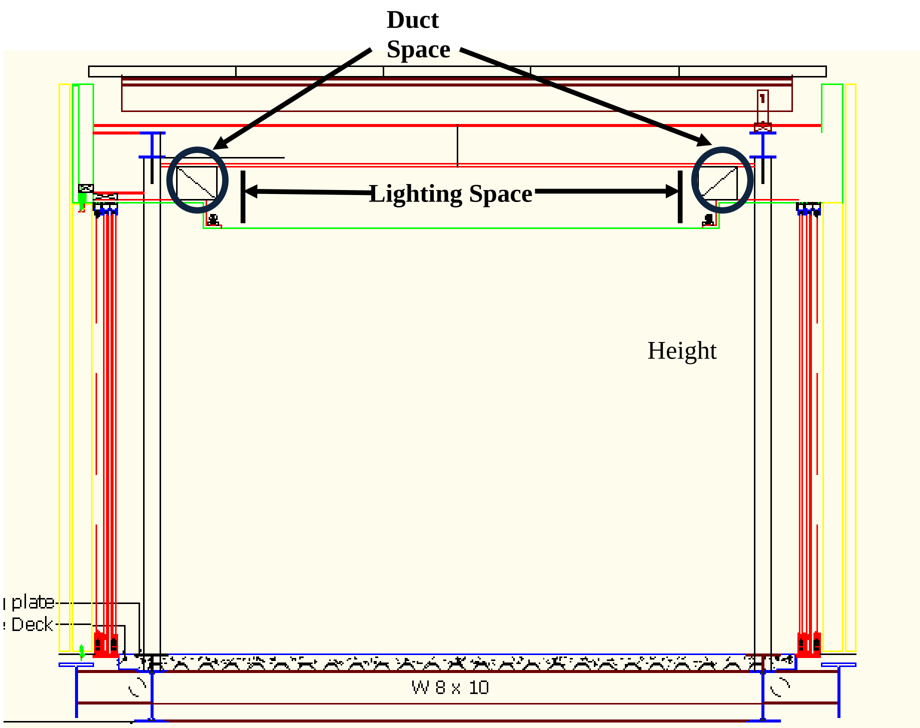


**Figure 4.** Cross sectional view of the mechanical closet.

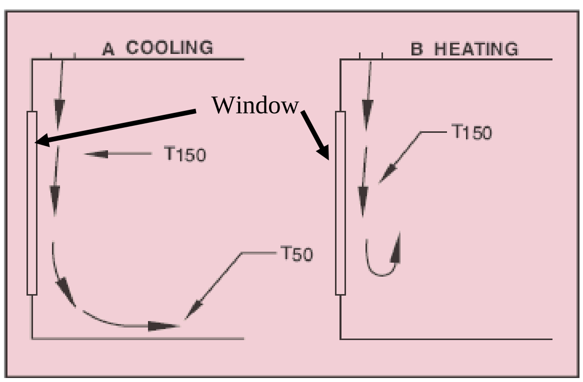


**Figure 5.** The vertical projection of hot and cold air parallel to a window (note: $T_{150}$ and $T_{50}$ refer to throw velocities of 150 and 50 FPM, respectively).

fashion, creates a buffer zone at the window.This figureillustrates the resulting natural air circulation.Since linear diffusers are 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.

However, air interfacing with the window before it reaches the floor will alter the air pattern and temperature. As a consequence, stratification throughout the height of the room could occur.

Also of concern 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 both the branch duct and the diffuser. The flexibility of the flex duct allows machining errors to be overcome but the flex duct is inherently noisy due to its thin material properties.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.

Figure 6 shows the Titus™ DynaFuser linear slot diffuser used in the LumenHAUS. This model meets the listed criteria for the house design. The Titus DynaFuser is an auto-changeover plenum slot diffuser for use in perimeter applications that require both heating and cooling. Powered by the temperature of the supply air, the diffuser automatically adjusts the air pattern for the proper setting in the heating or cooling mode.

Utilizing shaped metal alloy technology, the internal actuator senses the supply air temperature and automatically adjusts the air pattern for horizontal airflow (cooling mode) or vertical airflow (heating mode).

In addition to the DynaFuser increasing the comfort level by correctly discharging supply air in both heating and cooling modes, it does so without the use of an internal or external power source which translates to energy savings. When 100% of the supply air is utilized, the room temperature reaches the set-point faster requiring the HVAC system to run for a shorter duration of time, saving energy.

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'soccupants experience respiratory and other health problems as well as comfort issues.

Chemicals and pollutants mostly from within the house due to adhesives, carpeting, upholstery, and cleaning agents usually cause these ailments. Also, if stagnant water builds up in ducts, thatcan be a breeding ground for mold, bacteria, or viruses, which can end up in the living space (EPA, 2008).

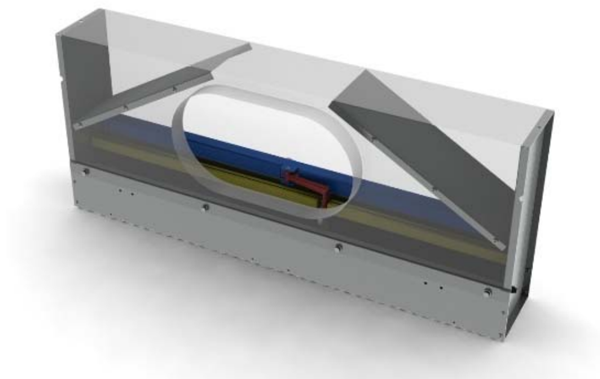

**Figure 6.** Titus™ Linear Slot Diffuser (Model ML-37).

The concern for SBS is heightened in the solar house, as the design dictates minimal infiltration andexpulsion from the interior or exterior of the house, respectively. 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 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

$$\dot{V}_{min} = \dot{N}_{ac} V_{tot} \tag{2}$$

where $\dot{V}_{min}$ is the volumetric flow rate, $\dot{N}_{ac}$ is the rate of the air changes, and $V_{tot}$ 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 is some factor of safety to make sure that the flow rate is always greater than the minimum.

### ~~1216:0:.1080:0:~~1.5 Plumbing System.

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The Solar Decathlon House features a plumbing system to supply cold and hot water throughout the house. The contest rules state that 10 gallons of water at a temperature of 109.4°F (43°C) must be supplied for 10 minutes. This must occur 16 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 PVC or copper piping which both need to be pre-sized before installation. The flexible nature of the piping allows it to also expand laterally such as in freezing 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.

### ~~1216:0:.13296:0:~~1.6 Controls Sequencing

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The ME design team has worked with Siemens AG to design control mechanisms for the mechanical systems in the house. The Siemens APOGEE™ Building Automation system is used in the solar house to tie the controls into a central personal computer for maintenance and manual control.
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 recorded. 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, 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 becauseit 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.

### ~~1216:0:.10512:0:~~1.7 Motion Systems

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A key component to executing a concept of responsive architecture is the incorporation of dynamic building components. Lumenhaus' identity is very much crafted around its ability to have the north and south facades actively and instantly engage conditional changes to optimize climatic performance, energy efficiency, and user preferences. The Eclipses Shade system incorporates a prototype motion control component system using existing motion control industry components repurposed for testing and exhibition. Using Danaher Motion's servo controllers coupled to high efficiency position feedback motors mounted to linear motion tracks, the house's Building Control System can send specific position data to each movable panel based on data compiled from sensoring (internal and external) and the occupant's personal desires. This level of control delivers a dynamic space whose changing identity offers insight to the house's approach to efficient climate control and energy conservation through a mixing of passive and active systems.

Insulation Panel Design

### ~~1216:0:.17728:0:~~1.8 History

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The 2010 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 2010 solar house. One of the returning elements that was and is again vital to the success of the house is a translucent insulated panel system. The panels are composed of a composite of materials and products that work together to produce an efficient and operable insulation wall solution.

### ~~1216:0:.14944:0:~~1.9 Mobility

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A principal difference 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 an “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. Danaher-Motion controllers were chosen to provide mobility to the panels. The Danaher RapidTrak™ rail bears the weight of the panels through use of a single-saddle assembly (ME Final Report, 2009). This mechanism allows the panels to be moved by the Building Control System or by occupant preference..

### ~~1216:0:.12160:0:~~1.10 Main Dimensional Criteria

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The entire length of the glazed façade is approximately 38 ft long. This length is divided into four equal width “bays” (approximately 9 ft per bay) and is shown in Figure 7.Separating the west (1 and 2) and east (4) bays is a single bay (bay 3) which houses a utility space and the main entrance. Bay 3 has permanent insulation and bays 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 in their stored state, (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

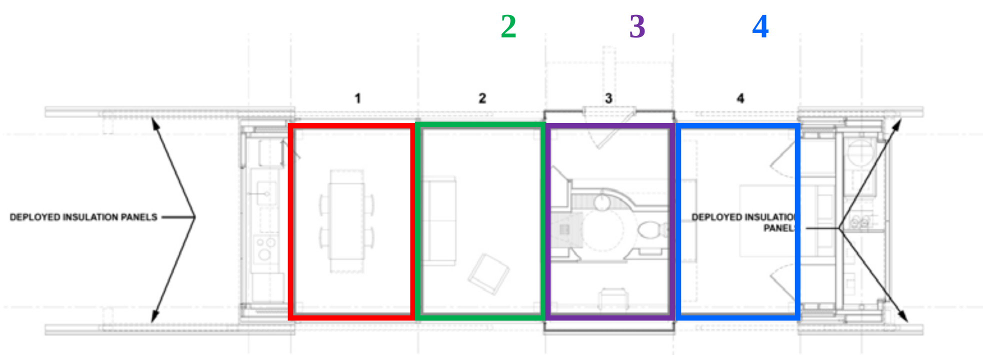


**Figure 7.** The overall layout of the house, indicating the positions of the deployed insulation. panels. Bays 1-4 have their respective sections identified.

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.

### ~~1216:0:.19376:0:~~1.11 Components

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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, airspace, and an outer wall. The airspace contains the frame of the panels, LED accent light strips, , a gasket seal, and any wiring needed to power/control any of the aforementioned components.

### ~~1216:0:.19376:0:.1216:0:~~1.11.1 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 the polycarbonate panel is 60 mm (2.36 in) and is 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.

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### ~~1216:0:.19376:0:.1432:0:~~1.11.2 Danaher Motion – AC Servo drive (S300 series)

**Danaher Motion's servo drives provide the exact position control and energy use optimization for processing commands sent from the house's Building control System. Packaged programing software allows the system to be tuned for each motor and operating circumstance. The drive accepts a multitude of input and output signals, both digital and analog, for creating custom control scenarious and thrid party control devices.**

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### ~~1216:0:.19376:0:.1648:0:~~1.11.3 Kollmorgan – Brushless servo motors (AKM series)

**The brushless servo motors offer a low-maintainence, high-torque, high precision motion control with feedback resolvers for motion optimization. In-line planetary gear housings increase torque 10:1 and further increase efficiency while ensuring safe operational speeds. As a bolt-on component using NEMA standards, a motor can be readily removed and replaced if needed.**

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### ~~1216:0:.19376:0:.1864:0:~~1.11.4 Thompson Linear Motion Systems – TG (Rapidtrak series)

Thomson's Rapidtrak Series of linear rodless actuator slides provide guided linear motion through a belt drive and a saddle that rides along the actuator to carry the load. The self-adjusting, Cover Band Stretcher extends the life of the cover band, which protects belt and guide from contaminants. The insulation panels hang from the over-head inverted tracks and resist lateral sway using a pin-slot system set into the deck-house threshold.

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### ~~1216:0:.19376:0:.1080:0:~~1.11.5 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:

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- 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 the most important factor in the success of thiswall 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.

### ~~1216:0:.19376:0:.13296:0:~~1.11.6 Color Kinetics Inc. – iW Cove Powercore™

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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.

The existing installation consists of a cable that attaches to the bottom side of the panel and acts as an umbilical cord supplying electricity to the lights. When the panel moves, the cord moves with it, giving it a continuous source of power for illumination. The cable simply rolls up on itself when retracted. The data enabler is located underneath the house and has a wired connection to the iPlayer, which controls the color schemes of the panel lights.

### ~~1216:0:.16592:0:~~1.12 Sealing Systems

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A sealing system is a required element 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. If used, the pneumatically controlled gasket would 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 could be attached to both. Two sealing options were considered. The product that was chosen is called 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. Since ease of replacement is a priority, the bristle is slid into a holder making removal very simple. The simplicity of this system and minimal space usage are advantages. Sealeze produces this product specifically for large industrial size door. 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.

The second option was 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 minimizing friction preserves the efficiencies of the panel track system, the gasket wears less quickly, and a seal can be made accurately at any location that the panel is placed.

***Moving Sunshade Screen Design***

### ~~1216:0:.13808:0:~~1.13 Introduction

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The purpose of the shading panels used on the solar house facades is for solar control and privacy, 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 under control by the Building Control System. Deployment of the screens is based on the outside conditions and the energy requirements of the house. 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.

### ~~1216:0:.11024:0:~~1.14 Mission and Objectives

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The mechanical engineering team in charge of the moving sun-shading screens 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.

### 1.15 Scope and Assumptions of the Solution Procedure

The shading screen system is designed for use in a single bedroom house that requires all utilities to be extremely energy efficient. Due to the overall efficiency requirements for the house, energy efficiency is the number one design requirement for the screen system. This requirement has been the breaking point for many possible solutions for the screen system, as seen in later sections of this report. Another design limitation of the screen system is that it must have minimal noise, since the screens will be sliding back and forth all day and must not be bothersome for the homeowner. The panels that make up the shading screen are 11 ft (3.35 m) high, covering the façade from the floor to the bottom of the parapet. Each screen is 18 ft (4.49 m) wide spanning half of the house. The weight of the shading screens is another design consideration as they are made of steel and weigh approximately 2000 lbs (907.2 kg) total for the four screens. The system holding the shading panels must be structurally rigid with an appropriately sized frame keeping the panels in place. The final design requirement for the system is that the system should be compact and clean so that it does not detract from the elevation of the building.

### 1.16 Approach and Methods Used in the Design Process

#### 1.16.1 Shading Panel Structure

Progress on the design of the structure and mobility system was delayed since the architecture department's design of the shading panels changed considerably during the design process. As a result the needs of the system changed as well. The final design of the shading panels that make up the screens has now been set so that the design concept generation phase of the structure and mobility system have been finalized as well. Given below are characteristics of the shading panels that the structure and mobility system needs to meld with effectively in order for them to function efficiently.

The shading panels are 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. Zahner is capable of cutting sheet metal and forming operations in three dimensions. One of the core competencies of the company is creating shading systems composed of custom patterns. This skill precisely matches the needs of 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 screens. The paneling system of the Zahner Company must be precisely matched to the structure and mobility system of the shading screens to ensure that the aesthetic, performance, and structural requirements are met.

The shading panels developed by the architecture department uses a pattern to define perforations in the panel that control the amount of light entering the interior spaces. The pattern design also incorporates the seams between panels that make up the entire shading screen. The support frame gives structure to the whole façade. The idea is simple. However adapting these ideas to the structure is somewhat more difficult. 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.

The main fastening/construction system that was used as construction method is a skinned frame system. In this system, a tubular metal frame that follows the panel seams serves as an attachment point to any of the various Zahner panels. Here, the frame serves as the main structural component. The design was dependent upon how strong the individual panels that make up the screen are and how capable this construction was able to support its own weight as well as any other loads and stresses put on the system.

### 1.16.2 Shading Panel Mobility System

The structure and mobility system that supports the screens 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 screen supports the entire load of the screen and guides it into position. Another track, mounted to the parapet supports the screen to avoid any side-to-side movement.

Since these screens are operable and automatic, a drive mechanism needed to be implemented so that active control is possible. Figure 8 shows the LumenHAUS' track system, which is directly bolted to the house frame. This acts as the stabilizer for the top of the screen. The track on the bottom of the door shown in Figure 9 supports the entire load of the door and guides it into position. The entire panel is actuated by means of a RapidTrak™ rail provided by Danaher-Motion.

Specifics for components have been articulated in these previous sections of this report:

- 1.11.2 AC servo drive
- 1.11.3 servo motor
- 1.11.4 linear track

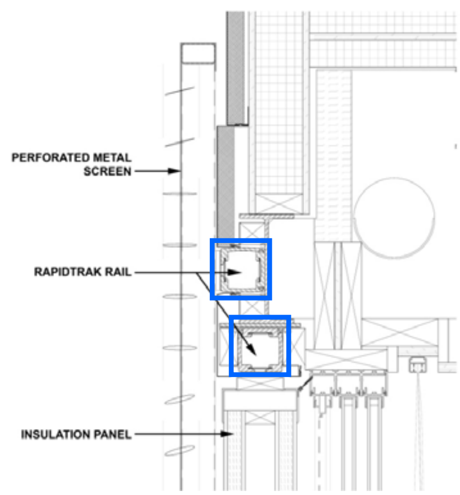


**Figure 8.** Side section view of the shading panel top. **The RapidTrak™ rail locations are outlined in blue.**

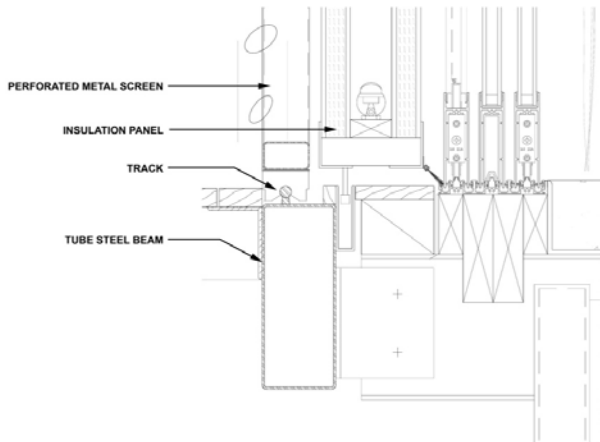


**Figure 9.** A section of the bottom details of the shading panel and its relation to the insulation panel.

***PV Tracking Analysis and Design***

### ~~1216:0:.12672:0:~~1.17 Photovoltaic Panels

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The array consists of 42, Sanyo HIT Double190 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 house power requirements above the output of the solar array will be supplied by a grid-tie interface. Conversely, any surplus power produced by the 2009 house will be relayed to the power grid and recorded.

Due to the new trend of selling excess power, the array design criteria has shifted from neutral energy balance to net energy production. Recent calculations have demonstrated that the 2010 array will be capable of generating twice as much power to satisy base loads in the building. A major effort is also being placed in minimizing losses in the electrical system and energy transfer due to heating and cooling. 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 also is expected to be inclined at an optimal angle seasonally adjusted for maximum light absorption within the constraints of the solar envelope. Also, due to the bifacial nature of the Sanyo HIT Double panels, non-specular 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 42 to be placed on the roof of the house, producing an estimated 8.0 kW 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. According to manufacturers information, this yields up to 30% more power generation compared to the nominal value. Because there is no standardized testing procedures at this time for bifacial panels, the STC rating does not reflect this ventral contribution. Up to an additional 2.4kW could be expected from our array configuration. 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.

The Sanyo HIT Double panels are an excellent candidate in all criteria. To maximize the area occupied by the PV array, 42 individual PV panels will cover the entire roof. The PV arraywill be positioned at angle of inclination of 21° during the competition. This will yield the most favorable solar energy capture within the constraints of the competition solar envelope requirement. A low cost, yet efficient, PV array design is realized by this design. 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.

### 1.19 Solar Tracking System

#### 1.19.1 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 results 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 were 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 was 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.

#### 1.19.2 Solar and Panel Angle of Incidence

After traveling $1.495 \times 10^{11}$ meters, the light striking the Earth can be modeled as parallel light rays. However, because of the Earth's tilt of 23.45° 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 10 illustrates one way of determining the angles with the Earth's Sun. Besides the three angles shown in this surface of the Earth at that location.

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.

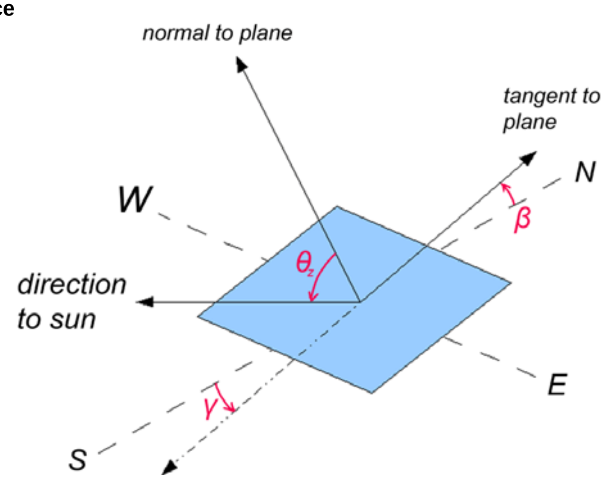


**Figure 10**

Figure 10 illustrates the solar angle of incidence with a plane where $\theta_z$ is the angle of incidence with the sun, $\gamma$ is the angle the plane makes with the southern meridian, and $\beta$ is the angle of the plane. With the figure, the solar hour,latitude, longitude, and Julian day are needed.

Using the Julian day it is possible to calculate the declination angle, δ, which is the angle, plus or minus 23.45$^{o}$, 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 (δ) given by

$$\delta = 23.45 \sin\left(360 \times \frac{(284 + J_{day})}{365}\right) \tag{3}$$

where $J_{day}$ is the Julian day and $\delta$ is in degrees (Duffie, 1980). Once the declination is known, the angle of incidence ($\theta_z$) is given by

$$\theta_z = \sin\delta \sin\phi \cos\beta - \sin\delta \sin\phi \sin\beta \cos\gamma + \cos\delta \cos\phi \cos\beta \cos\omega + \cos\delta \sin\phi \sin\beta \cos\gamma \cos\omega + \cos\delta \sin\phi \sin\beta \sin\gamma \sin\omega \tag{4}$$

where $\Phi$ is the latitude, $\beta$ is the angle the plane makes with a surface tangent to the Earth's surface, $\gamma$ the departure from due south that the plane is facing, and $\omega$ the solar hour in degrees (Duffie, 1980).

Tracking the Sun to optimize solar radiation collection can be accomplished by one of five basic methods:

~~1216:0:)~~1) Lay the panels horizontally packed as close as possible to minimize the footprint. **Formatted:** Bullets and Numbering

~~1432:0:)~~2) Pivot the panels on an axis running east and west and change the inclination based on the season or time of day. **Formatted:** Bullets and Numbering

~~1648:0:)~~3) Pivot the panels on an axis running north and south and change the inclination based on
the solar hour. **Formatted:** Bullets and Numbering

~~1864:0:)~~4) Pivot on a single-axis east and west plus pivot about the surface normal. **Formatted:** Bullets and Numbering

~~1080:0:)~~5) Use dual-axis tracking of solar insolation throughout the day's course. **Formatted:** Bullets and Numbering

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 11 shows a side view of a single plane of panels at 14.5 to 22.1$^{o}$ angles of inclination.This maximum inclination position allows the LumenHAUS to meet the 2010 SD Europe competition height requirements. 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.

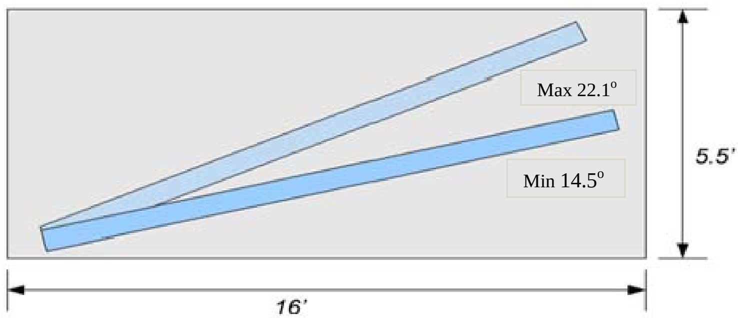


**Figure 11.**Single plane fixed or with partial tracking.

Figure 12 shows a side view of a dual-plane of panels that reach the optimal winter angle of 62° 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°. Because the 2010 SD Europe competition is in the summer, the optimal angle of the panels is much lower than what was found for Washington, D.C.

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 13 illustrates concept four. Specifically, this shows another specialized version of single-axis tracking. In an attempt to put more panels on the roof, the maximum tracking angle has been limited to 40 degrees, with a corresponding total number of panels around 43 to 45. A 40 degree angle of inclination for the PV array wouldallow the three rows of PV panels to be positioned

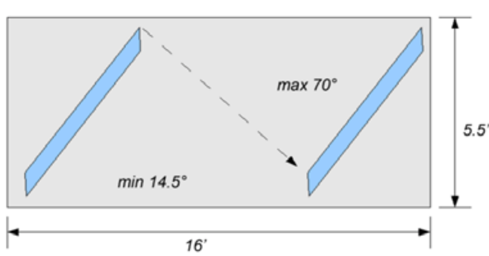


**Figure 12.**Dual plane single-axis tracking.

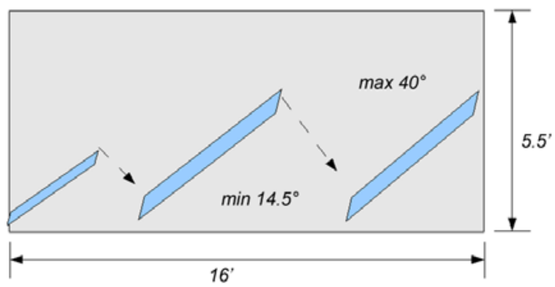


**Figure 13.** Single-axis tracking with a limited elevation angle. This will allow more PV panels on the roof to fit in the very short row.

closer to one anotherwithout shading each other. Like the dual-row tracking system, two of the rows will have to translate as well as rotate to eliminate the shading problem.

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 $5^{o}$ of elevation towards the sun.

Concepts one and four are simulated using equation (4) with sums based on calculations of the angle of incidence, $\theta_z$, 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. Concept three assumes both a continuous elevation adjustment, and that an analytical equation can be used. The angle of incidence for this case is determined by

$$\theta_z = \sqrt{\sin^2\delta + \cos^2\delta \cdot \cos^2\omega} \qquad (5)$$

(Duffie, 1980). This equation is used to model the performance of concept two. A similar analytical equation for a one-time panel adjustment isgiven by

$$\theta_z = \sqrt{1 - \cos^2\delta \cdot \sin^2\omega} \qquad (6)$$

(Duffie, 1980). This equation 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 (5) and (6) are variants of 4, although Duffie does not go into great depth on their derivation.

The task of selecting the designs that are competitive given the contest limitations requires 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.

### ~~1216:0:.14320:0:~~1.20 Solar Light Reflective Losses

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Figure 14 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, $\theta_2$, depends on the ratio of the coefficients of refraction and the angle of the incident light, $\theta_1$, such that

$$\theta_2 = \sin^{-1}\left[\sin\theta_1 \frac{n_1}{n_2}\right] \tag{7}$$

where $n_1$ and $n_2$are the indices of refraction for the medium of the incoming incident light and the medium contacted, respectively (Duffie, 1980).

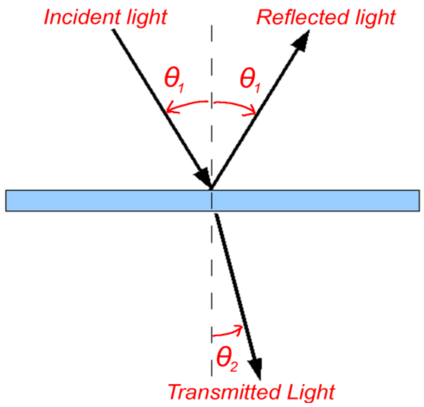


**Figure 14.** Reflection and transmission angles for the incident light.

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 ratio of the reflected light can be expressed by given by

$$r(\theta_1,\theta_2) = \frac{1}{2}\left[\frac{\sin^2(\theta_2-\theta_1)}{\sin^2(\theta_2+\theta_1)} + \frac{\tan^2(\theta_2-\theta_1)}{\tan^2(\theta_2+\theta_1)}\right] \tag{8}$$

where $\theta_1$ and $\theta_2$ are not equal. For the special case where they are equal, the relationship

$$r(\theta_1,\theta_2) = \left[\frac{(n_2-n_1)}{(n_2+n_1)}\right]^2. \tag{9}$$

determines the ratio of the reflected light between the two angles of incidence. Solar panels use either PMMA (Polymethylmetacrylate) 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 a loss of 9.3 percent.

### ~~1216:0:.11536:0:~~1.21 Solar Constant, Air Mass, and Available Solar Energy

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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). Figure 15 shows the energy flux versus wavelength for AM0, AM1.5g and AM1.5d.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).

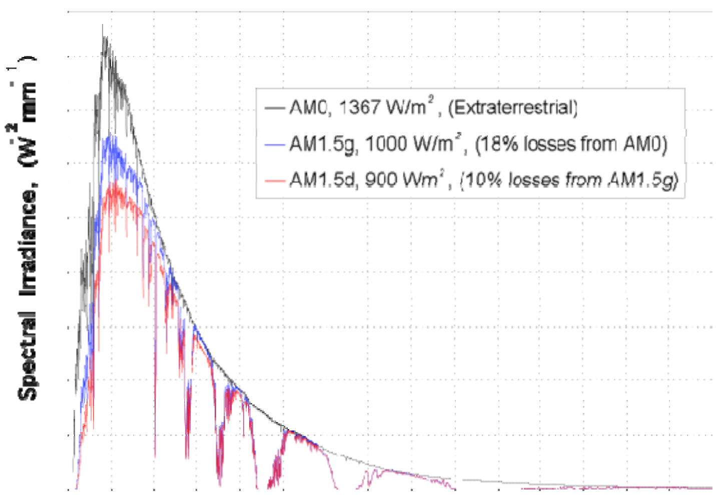


**Figure 15.** ASTM G173-03 Reference Spectra for AM0, AM1.5g **(direct and diffuse), and AM1.5d** (direct) (US DOE, 2008a).

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 by

$$AM = \frac{1}{\cos(\theta_{el})} \tag{10}$$

where $\theta_{el}$ is the solar angle of elevation. Corrections for angles greater than 60 degrees are not made with this equation (Duffie, 1980): Please note, however, that the linear relationship used in the model is only an approximation. One figure in *An Atmospheric Solar Irradiance Model* (Farrell, 2002) shows radiation

[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.

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.

The final value of solar radiation per unit area striking the panels is the insolation (*I*).This is the product of the air mass, the proportionality constant for losses per air-mass, and the solar constant, as given by equation (11) below.

$$I = AM\ L_{am}\ G_{sc} \tag{11}$$

### ~~1216:0:.18752:0:~~1.22 Design Performance for the Solar Radiation Model

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Figure 16 shows the results obtained when using the solar angle of incidence computed for each hour of daylight. Also shown are the losses due to light passing though the atmosphere and reflection losses for each of the five designs under consideration. The best solution for optimizing solar energy capture is the single plane of 60 plus PV panels angled from 0 to 22.1° (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.

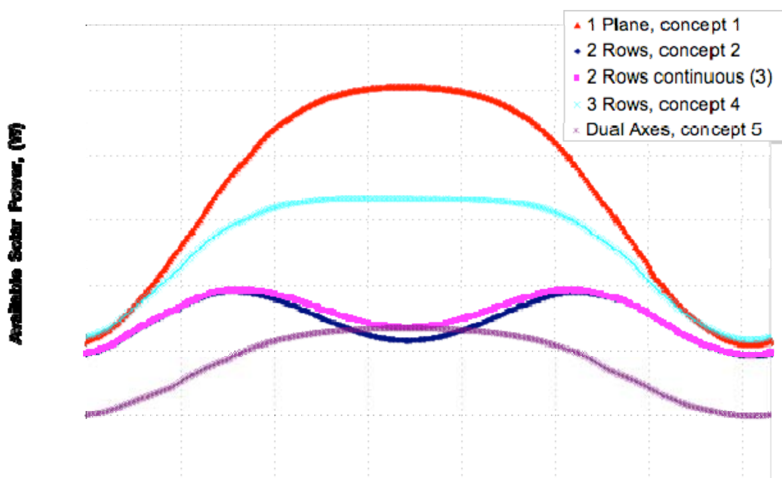


**Figure 16.**Comparison of available solar power and energy for each design concept.

### ~~1216:0:.15968:0:~~1.23 Photovoltaic Performance for the Concept Selected

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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 42.

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 17 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%.

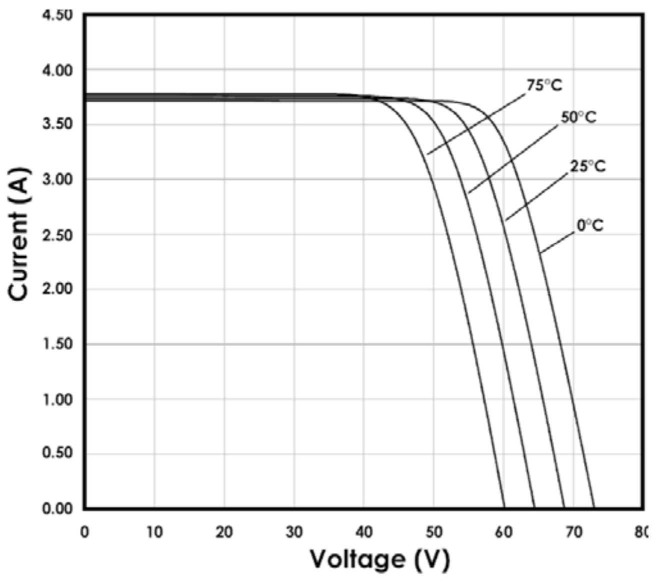


**Figure 17.**Sanyo double-sided current-voltage characteristics for different temperatures (Sanyo, 2008).

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.

### ~~1216:0:.13184:0:~~1.24 Mid-term Sturctual Design Constraints

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The physical contraints listed below are based on the new Solar Decathlon rules from Madrid, Spain. Figure 18 shows the points where support beams are located on a basic diagram of the house. The constraints, as the M.E. team understand to be based on the solar decathlon rules (Gobierno de España, 2010), are:

~~1216:0:.~~1. There is up to 42 in (106.7 cm) of bridge clearance while stowed during transportation to the site.
~~1432:0:.~~2. The structure is 50 ft (15.24 m) wide.
~~1648:0:.~~3. The structure is 16 ft (4.88 m) deep.

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~~1864:0:.~~4. The weight of the PV support structure must be distributed among the house's fourteen support columns.

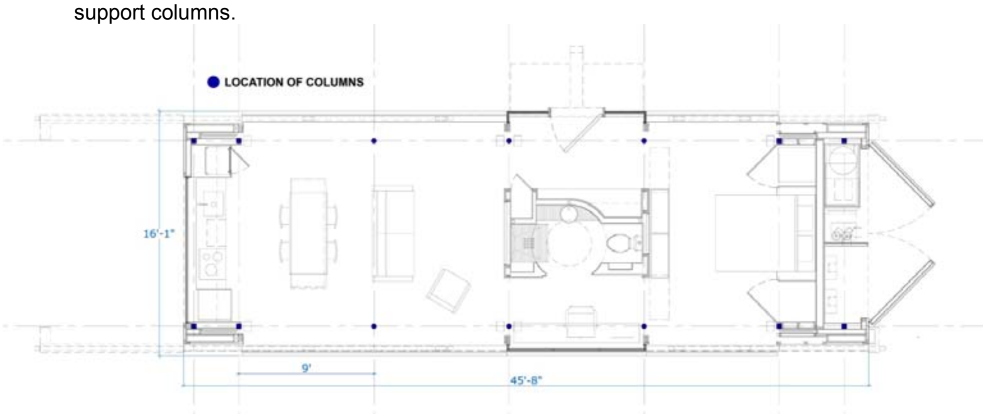


**Figure 18.** Top view of house with constraints indicated.

### 1.25 Concepts for the PV Panel Elevation Support Structure

#### 1.25.1 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. Figure 19 illustrates concept one. In the stowed position, the highest point is the top plane of the PV panels about 42 in (3.3 feet) (106.7 cm) above the roof.

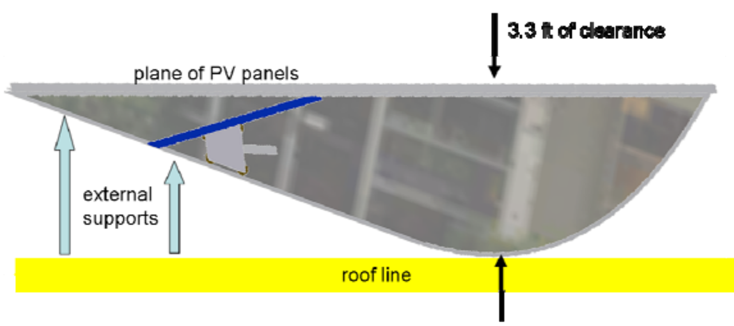


**Figure 19.** Side-view of concept 1 in the stowed position and ready for transport position.

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 to 14.5$^{o}$, as shown in Figure 20. Some concepts to push the wedge include a WZ60 linear rod drive from Danaher Motion; however a representative for Siemens suggests using multiple torque motors ganged together into a single unit instead of the linear rod drives.

The curved profile in this concept requiresthe work to lift the leading edge of the panel to be a function of the pivot point location, which should be as close to the center of gravity as possible. 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.

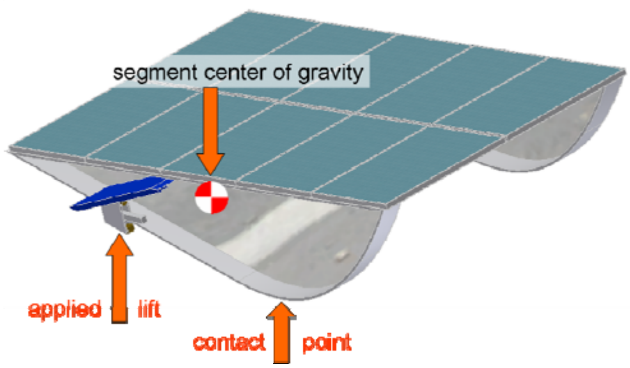


**Figure 20.**Orthographic-view of concept 1 in the deployed position.

#### 1.25.2 Concept 2

Figure 21 shows an orthographic model of concept 2. This is a trimmer version of concept 1, requiring 24 in (60.96 cm) above the roof line for bridge clearance compared to 42 in (106.68 cm) for concept 1. This designs 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 are installed.The teamwould have to complete this task once the house was 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.

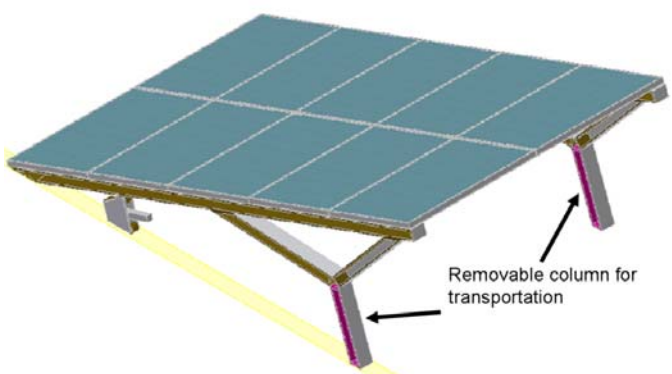


**Figure 21.** Orthographic-view of concept 2, the magenta support is removable for transport.

### 1.26 Elevation-Control Lift Concept Selection

Five different concepts are considered for lifting the front edge of the panel support structure. Table 1 below 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 for lifting the panels. Interfacing just requires wiring the motor to the Siemens controller, but the cam requires manufacture.

**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 maintain position* | 2 | 0 | 0.000 | 1 | 0.143 | 1 | 0.143 | 1 | 0.143 | 1 | 0.143 |
| *Little (if any) noise emissions* | 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 close tothe PV panels' center of gravity* | 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** | |

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 weight is based on 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).

Lift mechanism concepts D and E were originally selected for implementation. The primary selection, E, involves using the cam with the Siemens toque motor. However, the cam size needed to achieve a 16 in (40.64 cm) of vertical lift requires too great a torque for only one torque motor. For example, cams with 30 degree contact surfaces are smaller,yet generate larger normal forces and still require a large amount of torque near the end of their rotation.Cams with a 10 degree contact surface are rather large. They, too, produce very large torques throughout their rotation.The large cams require too many torque motors to justify their use.

A simplified diagram of the roller and wedge design is shown in Figure 22. The blue text block identifies where the motor and power screw used to push and pull the elevation control device are mounted. A linear resistor in the form of a piston-cylinder is mounted between a fixed point on the roof and the main support beam. To simplify interfacing, the selected model is compatible with the Siemens controller. However, this and the cam torque motor concepts cannot be implemented, as discussed in the following sections.

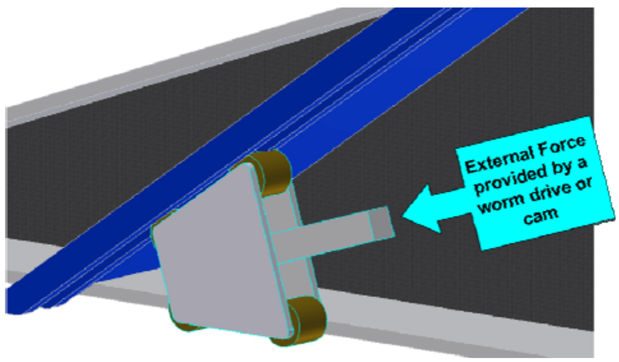


**Figure 22.** Design for the roller and wedge PV support solution.

### 1.27 Updated Structual Contraints

An undimensioned drawing of the house frame in Inventor™ DWG format has been created by the architectural group. After using Inventor™ to compute the LumenHAUS' maximum height, the bridge clearance had changed from 42 in (106.7 cm) to 12.5 in (31.75 cm). Last year, the PV panel cross-sectional area 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).This areal reduction allowed a greater number of panels to be placed on the LumenHAUS' roof. Figure 23 below shows where support beams and columnal access are provided. The current dimensional constraints of the LumenHAUS are:

~~1216:0:.~~1. The structure is 15 ft (4.57 m) deep.
~~1432:0:.~~2. The weight of the PV support structure must be evenly distributed among the LumenHAUS' fourteen support columns.
~~1648:0:.~~3. There is access to support beams and columns to mount the PV supports.
~~1864:0:.~~4. The PV panel support structure is a monolitic plane.

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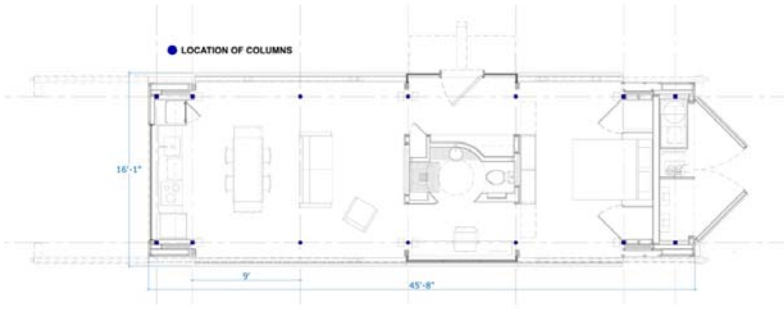



**Figure 23.** Updated design constraints for the PV structural support.

### 1.28 Elevation-Control Lift Design Concept Selected

Figure 24 shows an orthographic view of one of four PV support structure sections in the fully elevated position (22.1$^{o}$). 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 PV panels. Also shown inFigure 24are the spanning beams, which provide support, and attachment points where the PV panels (illustrated in sea green) meet at the gray seams. The totalweight of the six spanning beams is 438 lbs. An individual main supportbeam is approximately 300 lbs, including welded joints. Beyondthe four mainsegments, there are two wings using six spanning beams and two main beams. It is estimated that the weight of the entire support structure is approximately 9,000 lb.

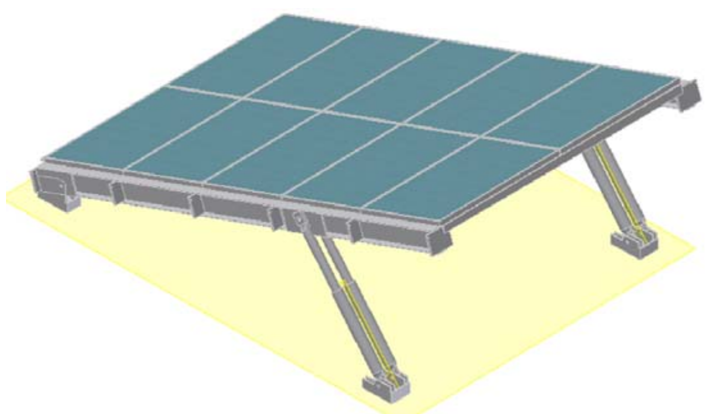


**Figure 24.** Orthographic view of one segment (house bay) of the final PV support structure solution.

Figure 25 shows a top view of one support segment. The main beam (callout balloon 3) is built around a standard S8x18.4 I-beam. To attach the spanning beams (callout balloon 5), plates designed to fit inside the web are welded into their appropriate positions. This allows the spanning beams to be either bolted or welded to the main beam. The front of the house and the front bracket are shown to the far left of the figure. At this location, two plates are welded to the main beam (across the web), thereby providing additional support against shear forces caused by the pivot pins. Approximately two-thirds distance from the rear panel mounting brackets along the main beams are similar plates to protect against shear stress from the linear actuators.

Figure 26 shows a side-view of the proposed PV support structure to be used in the competition. This more clearly illustrates where the web plates are welded inside the main beam web. Callout balloon 1 locates the front bracket, which has a pivot point 4.75 in (12.065 cm) off of the main roof beams. This is built from welded pieces of ½ in (1.27 cm) angle iron and ½ in (1.27 cm) plate. This plate thickness is subject to change, as the hydraulic support performance parameters are unknown at this time. Callout balloon 2 identifies the rear bracket that is constructed of the same materials. To allow for the best possible leverage, the pivot point for the hydraulic cylinder is positioned as close to the roof as possible.

Two linear actuators (identified by callout balloon 4 in Figure 25) of 3 in (7.62 cm) diameter support the horizontal sides of the PV panels.These enable each main beam to lift the entire PV panel structure. Using the main beam and rear bracket pivot heights, and assuming a 40 in (101.473 cm) cylinder length, the angle of the applied force is approximately 17.6o. Knowing this, each actuator must supply up to 4000
lbf for the initial lift.To prevent twisting, there aretwo actuators for each main beam for a total of fourteen

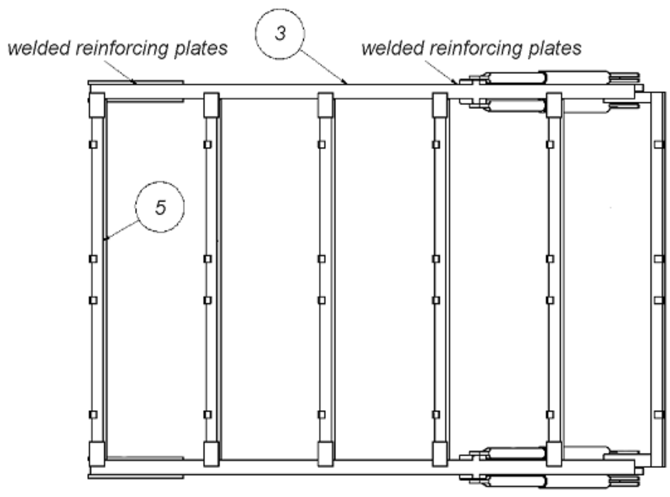



**Figure 25.** Top-view of PV support structure. Callout balloons 3 and 5 identify the main beams (S8-18.4 I-beams with weldments) and the spanning beams (L3.5x3.5x3/8 with weldments), respectively**.**

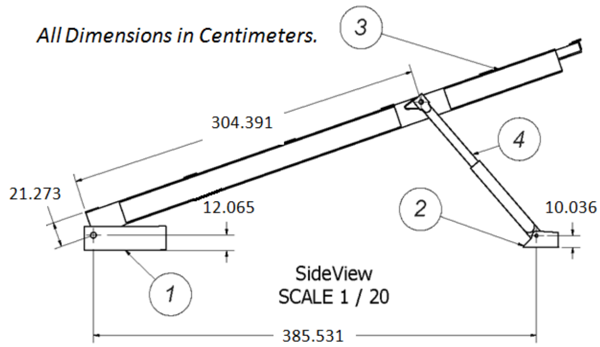



**Figure 26.** Side-view of the PV panel support structure. Callout balloons 1-4 identify the locations of the **front brackets, rear brackets**, main beams, and linear actuators, respectively. The spanning beams are not visiblein this figure.

actuators. Additionally, the linear actuators must stay synchronized. The architectural group will supply a vendor to accommodate this.

### 1.29 PV Support Structure and Current and Future Work

#### 1.29.1 Measurements and Control

The linear actuators selected interface with the Siemens controller system. Therefore, a Siemens Apogee™ controller has been developed to control the rotational motion of the PV panels. The controller receives a desired angle command from its user, and converts this into an output voltage (or current) value. This is then delivered to the PV array support system, which adjust the linear actuators accordingly. The program then measures the voltage or current reading from the roof sensor. The measurement and control is complete when the controller receives this detailed position feedback.

#### 1.29.2 Testing and Validation Plan

The support beams and angle iron selected must meet a safety factor of at least 2. The engineering firm responsible for approving the support beam plans has already signed these. In addition, calculated deflections cannot 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).

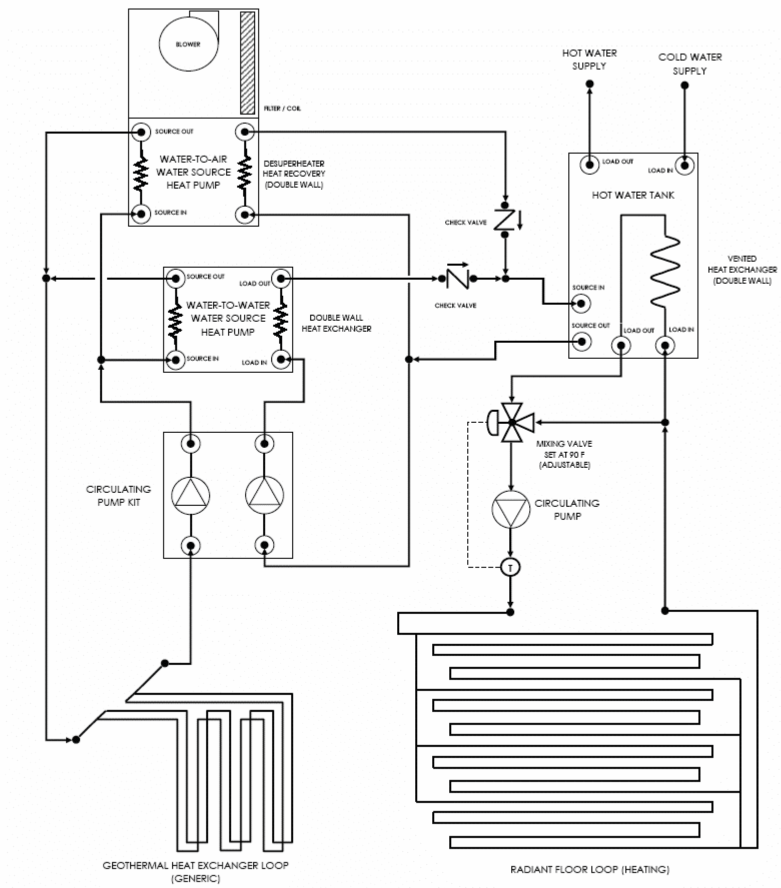
Stress concentrations around holes will be computed, and adjustments for safety factors will be made. No load testing has been performedof the front and rear brackets, and linear actuators will be used to support the PV panels' weight. If stress concentration calculations yield safety factors are greater than 3 or 4, then Finite Element Analysis (FEA) should be unnecessary. However, some FEA testing with a coarse mesh is the most effective way todouble-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. A professional engineer must approve the PV support structure plans for validation purposes.

### 1.30 Photovoltaic Panels

A single plane of PV panels with variable inclination has been selected for implementation. The LumenHAUS' Sanyo bi-facial PV panels exceed the performance of their closest competitor by 19 percent. Forty-six (42) of these PV panels are mounted atop the LumenHAUS roof at a maximum angle of $21^{o}$. Each PV panel is not only able to produce a maximum of 190 Watts of power on its front side, but also collect approximately 15-20% of this power on its' rear side as diffuse light. This equates to an additional 28.5 to 38 Watts (1.31 to 1.75 kW collectively) of photovoltaic power per PV panel at peak production.

## SOLAR THERMAL SYSTEM

In the 2002 Solar Decathlon, Virginia Tech experimented with ways to integrate solar thermal panels into the façade of the house. Based on that experience, a conscious effort was made to eliminate them from the Virginia Tech's 2005 Solar Decathlon entry. Problems with over-heating in the summer, and freeze prevention in the winter, plus an overall rapid deterioration of the solar thermal components directed us towards finding another solution. The concept of dual geothermal heat pumps with the ability to capture waste heat from environmental conditioning and redirecting in to domestic hot water heating was selected as the alternative solution. Based on our positive experience with the 2005 system, we decided to pursue a refined version of the dual heat pump system for our 2010 entry.




The hot water system was designed to meet the requirements for hot water while minimizing system cost and complexity and maximizing the benefit from the sunlit surfaces of the house. The team chose to use a water-to-water heat pump (WWHP) connected to a simulated earth-coupled heat exchanger to provide water heating. This system provides not only domestic hot water but also space heating through a radiant floor heating system. With one system serving two purposes, the cost, complexity and maintenance are reduced.

The use of PV provided electricity through an earth coupled heat pump to produce domestic hot water also makes more effective use of the sunlit surfaces of the house. Using an earth coupled heat pump system, the 30 gallons of hot water required per day can be heated with a winter COP of;,,3 thus requiring only 1500 Wh of energy per day. During the month of December, the PV modules average 3 equivalent rated hours per day. Thus, the hot water needs can be met with only 500 W-rated of additional PV modules. At a PV cost of $3/W-rated and a power conditioning cost of $1/W, this translates to $2,000 to provide additional PV modules and power conditioning to accomplish water heating using the WWHP system. In the summer months, when the solar irradiation is more intense and more sustained, the excess power from the additional PV modules can be used for other purposes such a feeding back into the grid or powering an electric vehicle. If the house is grid-connected, the excess power not required for water heating can be sold back to the utility providing a economic benefit to the owner and displacing power that would otherwise be generated primarily by coal. In contrast, a solar thermal system would have to be sized to meet the winter heating need but would not have a use for the excess energy available during the summer months.

The hot water system is closely integrated with the space conditioning system and the building controls system. As noted, the hot water and radiant floor heating system both use the WWHP as the source of heat. In addition, the hot water system uses thermal energy rejected from the air conditioning system desuperheater to provide "free" heating for the hot water during the air conditioning season. This recovered heat is predicted to supply 30% of the hot water requirement during the air conditioning season, freeing PV power for other applications. The energy used for water heating is also minimized through the operation of the control system. The control system dispatches the WWHP to provide heat to either the radiant floor system or water heating system. During unoccupied hours, the control system can prevent operation of the WWHP for water heating, allowing the tank temperature to drop and reducing storage losses. In the summer, the control system can delay operation of the WWHP to allow additional time for the desuperheater to heat the water.

Careful integration of the hot water system with the space conditioning system and the control system reduces the initial cost of the hot water system; provides free heating through the operation of the desuperheater; allows the use of a very high COP earth coupled heat pump; and provides for scheduled operation of the hot water system. Moreover, since PV power is the energy source for the system, excess energy arising from these energy saving measures and from the increased irradiation during summer months can be used for other (non-thermal) purposes such as powering an electric vehicle or returning energy to the grid in net-metered grid connected applications.

## PHOTOVOLTAIC SYSTEM

The 7.98 kW array on the roof of the Virginia Tech LumenHaus is quite unique. The design process was focused on generating a Net Energy Zero home without taking away from the aesthetic appearance of the house. The panels themselves are more visually pleasing because they do not have a solid block of solar cells. Rather, they are spaced slightly to allow some natural light to pass through. This light that passes through can then be collected on the backside of the solar array which can boost production up to 30%. This can quickly turn the 7.98 kW array into a 10.37 kW array. While a 30% boost may be a generous estimate, we can still expect to get more energy out of our panels than our rated power output. The array is also entirely contained on the roof of the house, out of sight and out of mind. It has motors that put it into optimal position throughout the year to ensure the consumer is getting the most out of the array.

The photovoltaic generators used for the array are the 190 Watt Sanyo HIT Doubles. These panels are strung together in groups of six panels. The seven strings total up to 42 panels. Each panel has a maximum power voltage of 55.3, giving each series-strung group a voltage of 331.8 volts. The maximum power current for each panel is 3.44 amps, with a series fuse rating of 15 amps. Open circuit voltage maximum per panel is at 68.1 volts, with a short circuit current maximum of 3.7 amps. The maximum system voltage is listed as 600 volts. Cell efficiency is at 18.8 % with a module efficiency of 15.7 %, resulting in 14.6 watts of power per square foot. The technology of the bifacial solar cells on the panel is exclusive to SANYO, each cell being a hybrid of single crystalline silicon surrounded by ultra-thin amorphous silicon layers. The back face of HIT Double solar panels takes reflected light off surrounding surfaces to generate electricity, which is combined with power generated from the panel's front face. As temperatures rise, the panels produce are able to generate more electricity than conventional solar panels at the same temperature, allowing for higher performance in high temperature locations.

The two inverters used for the array are Sunny Boy 5000US. One inverter is used with three strings of six panels, while the other is used with four strings of six panels. The recommended maximum PV power is 6250 watts. DC maximum voltage is 600 volts, while DC maximum input current is 21 amps. The peak power tracking voltage for the inverter is 250-480 volts. The AC nominal power is listed at 5000 watts, which is the same as the AC maximum output power. AC maximum output current at 208 volts, 240 volts, and 277 volts is 24 amps, 21 amps, and 18 amps, respectively. The AC frequency range is 59.3-60.5 Hz, with a nominal frequency of 60 Hz. The nominal power factor is 0.99. The peak inverter efficiency is 96.8 %. The inverter can operate at an ambient temperature range of −13 to 113 °F, and only consumes 0.1 watt of power at night.

The solar panels come with MC3 connectors at the ends of AWG 12 pigtails. In order to maximize the efficiency of the connections between panels these connectors, in most places, were removed and the pigtails were crimped and soldered together. This reduces the lengths of the cables and gives a more solid connection between panels. The only exception to this is that there is one connection in each string made with the MC3 connectors for trouble shooting processes. The cabling between the ends of strings and the inverters was done with AWG 12 cabling rated for out door use.

The PV array is grounded using #6 bare copper which is strung from panel frame to panel frame and lugged to the panel using #10-32 thread-forming screws and tin-plated copper lugs. This bare copper is also lugged to the rails that support the PV array. This bare copper is then run to the 8 foot grounding rod driven into the ground near the inverters. The inverters are grounded in the same fashion, using #6 bare copper wires and lugged to the grounding rod. The two ground wires are mechanically crimped together in the load center.

The output from the inverters is tied to the load center using two 30 amp breakers at the opposite end of the load center from where the utility is connected. The utility's service is fed into a meter-disconnect combo. From the disconnect cables run under the utility closet and are landed in the bottom of the load center

The PV array itself is very low maintenance. The panels should be cleaned once a month with any regular glass cleaner to allow maximum light to get to the panels. The motors lift the array into the correct position on a weekly basis so it is not necessary to adjust them at all. After about ten years it is recommended that the panels be wired into a configuration with 6 strings of 7 panels each to account for the reduction in voltage over that period of time.

## PHOTOVOLTAIC SYSTEM DESIGN SUMMARY TABLE

**Type of Distribution:**
120/240 Center tapped feed (See drawing EL 101/EL 804)

**Type of Earthing:**
None of the live conductors on the DC side is earthed (See SS 201)

**Protection for Safety**:
All wiring done in compliance with NEC 2005 (See EL 804)

**Protection against electric shock**:
All wiring done in compliance with NEC 2005 (See EL 804)

**Protection against contact:**
All wiring done in compliance with NEC 2005 (See EL 804)

**Fault Protection:**
Lightning arrestors on DC side and Circuit Breakers on AC side (See EL 801)

**Protection against overload on DC side:** (See EL 804)

**Protection against short circuit currents:**
Individual panels have a blocking diode to prevent short circuits (See Inverter Information packet)

**Protection against EM interference in buildings:**
Lightning Arrestors

**Selection and Erection of equipment:**
Calculations based on energy needs for a year used to select equipment(See EL 804)

**Compliance:**
All parts used are UL listed or equivalent

**Operational**: See EL 804

**Accessibility:** See SS-100

**Wiring:** See EL 804

**External Influence:** See EL 804

**Isolation**:
AC/DC Disconnect located on inverters (See SS 201)

**Earthing:** Not Applicable

**SMA Solar Technology AG**
Sonnenallee 1
34266 Niestetal
Tel.: +49 561 9522-0
Fax: +49 561 9522-100
E-Mail: info@SMA.de
Internet: www.SMA.de

**SMA Solar Technology AG** · Sonnenallee 1 · 34266 Niestetal

Contact Person Joanna Marienhagen

Direct dial
+49 561 9522- 3127

Telefax
+49 561 9522- 3129

E-Mail Joanna.Marienhagen@SMA.de

Date 29.01.2009

# Manufacturer's Declaration / Country of Origin

SMA Solar Technology AG hereby certifies that all SMA inverters type "Sunny Boy" SB 700U, SB 3000US, SB 4000US, SB 5000US, SB 6000US, SB 7000US are developed and manufactured by SMA Solar Technology at Niestetal in Germany.

**SMA** Solar Technology AG

i.V. T. Henne
Director Product Management

i.A. J. Marienhagen
Product Management

IDCO_SBUS_ZUS090510

## TECHNICAL NOTE

### TOPIC: DC Disconnect UL Listing Update

### SUMMARY

The UL Listing for the SMA DC disconnect used with SMA Sunny Boy inverters has recently been updated. Effective April 21st, 2009, the new maximum fuse rating will be 20 $A_{DC}$. The SMA DC disconnect will continue to be shipped with 15 $A_{DC}$, 600 $V_{DC}$ rated fuses as standard.

UL required no redesign for this update. Therefore, units that were manufactured prior to the effective date will bear the original ratings label. Please use this document if needed of proof of this change until such time as new units with updated labels are available.

### STRING FUSE SIZING REVIEW

In any electrical system, fuses are used to protect wiring and equipment from excessive currents that can cause damage, heating or in extreme cases even fire. If the fuse rating is too small it could open during normal operation. If the fuse rating is too large, it cannot provide the needed protection. In PV systems, the minimum and maximum size of the series fuse is determined by the electrical ratings of the PV module as well as by UL and National Electrical Code (NEC) requirements. Be sure to consult with your PV module manufacturer for appropriate PV string fuse ratings.

The minimum size of fuses and wiring are calculated using the Short Circuit Current Rating ($I_{SC}$) of the PV module. The NEC requires that all fuses and wiring be sized for a minimum of 1.56 times the Isc of the PV module used in the system. The proper size PV string fuse is determined by calculating 1.56 x $I_{SC}$ (of the PV module) and then rounding up to the next standard fuse size.

If there are additional questions or if further clarification is needed, please refer to the inverter manual or contact technical support at SMA America, Inc.

SMA America, Inc.
4031 Alvis Court
Rocklin, CA 95677
+1 916 625 0870
Service@SMA-America.com

TECHNOTE20AHUS091712

## RETAIL PHOTOVOLTAIC PANEL PRICE QUOTE

Virginia Tech purchased (42) photovoltaic panels (190 W Sanyo HIT Double bifacial) from Sanyo for $3/watt. The retail price that would be charged by a local dealer is $3.90/watt, in addition to the dealer's mark-up amount of 15%. For small orders this would amount to a total retail cost of $4.25 per watt.

## LIST OF APPLIANCES AND EQUIPMENT SPECIFICATIONS

A. Cooktop

Diva 24" 3 Burner Electromagnetic Induction Cooktop. Model #DDP-3.

Features:

- Energy Star Compliant
- Over-Heat Safety and Over-Flow Safety Sensors
- Efficiency: 90% of heat transferred to cooking utensil; compared to 50% for gas and 60% for other electric technologies.

B. Microwave/Oven

120V Advantium 27" Wall Oven with four oven modes: Speercook, True European Convection, Warming/Proofing and Sensor Microwave. Model #PSB1001NSS

Features:

- Speedcook technology: Delivers oven-quality food up to four times fasten than a conventional oven.
- Sensor Microwave Oven: 975-watt sensor microwave oven mode automatically delivers exceptional cooking results.
- Warming Oven: Keeps prepared foods warm and fresh, and retains superb moistness and crispness.
- Glass Touch Controls: Features a smooth glass design that is easy to operate and easy to clean.
- Multi-Level Cooking: Removable pedestal rack allows cooking of multiple dishes at once.

C. Refrigerator/Freezer

Liebherr 24" Fully Integrated Refrigerator Freezer. Model #HC-1011 Right hinge Without Ice Maker.

Features:

- Finish: Custom Paneled
- System: Dual Refrigeration featuring SoftClose
- Energy Star Compliant
- LED lighting systems

D. Dishwasher

Fisher and Paykel Single Integrated Dish Drawer Dishwasher. Model #DD24S16.

Features:

- Finish: Custom Paneled
- Capacity: 6 Plate settings for plates as large as 12" and long stemmed wine glasses.
- Energy Star Compliant featuring 'Eco Option' wash program using as little as 1.95 gallons of water per use.
- Flow through detergent dispenser.
- Load sensors for optimum performance.

E. Espresso Machine

Nespresso Essenza on-counter residential espresso machine with pre-packaged capsule brewing system. Model #D100 GS.

Features:

- Compact Brewing Unit technology using Thermoblock heating element and 19 Bar pressure pump.
- Capsule container for up to 14 used capsules.
- Automatic and programmable coffee quality with backlit buttons.

F. Laundry Machine

LG Full-size all-in-one SteamWasher™ and dryer combination, Model #WM3988HWA.

Features:

- Largest capacity front load combo (4.2 cu. ft. IEC) with NeveRust™ stainless steel drum.
- Direct Drive Motor for the ultimate in durability and reliability.
- TilTub™ is designed with a 10° tilt for easy reach of clothing in the rear of the drum.
- 1320 RPM powerful spin for efficient water extraction.
- SteamWash™ system for better washing performance and higher water and energy efficiency.
- Allergiene™ cycle.
- SteamFresh™ cycle for reducing wrinkles and refreshing clothes.
- TrueSteam™ generator.
- Vent-less condensing drying system.
- SenseClean™ & sensor dry system for intelligent fabric care, water and energy efficiency.
- RollerJets™ & forced water circulation.

lumenHAUS
a brighter way. everyday.

# COMMUNICATIONS PLAN

## Executive Summary

The vision of the Virginia Tech 2010 Solar Decathlon Europe Solar Decathlon team is to brighten the day, literally and figuratively, of everyone who comes into contact with us or our house. This plan summarizes the ways we seek to embody this vision in our communication tactics, our fundraising activities and our media outreach. LUMENHAUS is the name of Virginia Tech's 2010 Solar Decathlon Europe home. Lumen literally means the "power of light" while haus, a German word meaning house and home, is a playful reference to the Bauhaus movement's inspiration on our house's architecture. Just like the actual house, the LUMENHAUS brand is light and open, with a sunny, happy disposition. We will try to uplift anyone who comes into contact with us – whether they are a journalist, a homeowner or a potential donor – through the provision of illuminating information and a bright, lively in-house experience.

We have identified three targets for our communications activities: progressive homeowners, local residents and green-building-industry professionals. These have been prioritized to maximize use of scarce communication resources. Our two primary communication vehicles for all three audiences are exhibitions of the house (either scale models, working parts or the full house) and our website, www.lumenhaus.com. Through the use of cheerful, light colors, a straightforward presentation of information and enlightening interactive tools, the website aims to translate the physically bright feeling in the house itself into a compelling digital experience. At both the real and the cyber locations, the umbrella idea that LUMENHAUS, Virginia Tech's entry into the Solar Decathlon Europe Solar Decathlon, delivers a "brighter way" to think about solar energy and sustainability will be promoted. Beneath this, tailored messages differing in technical specificity have been developed to best appeal to the different needs of the three communications targets.

Online and offline promotional tactics have been developed to drive people to both our website and to one or more of the exhibitions featuring LUMENHAUS. A comprehensive digital media strategy encompassing search engine optimization tools, email outreach campaign, blog campaign, twitter campaign and a Facebook campaign will primarily drive visitors to the website. More traditional media outlets, such as local radio and newspaper advertisements, will announce exhibitions. In a reciprocal manner, the website will also announce events and exhibitions of the house will also promote the website.

Our fundraising activities are progressing well, with over fifty companies donating cash, in-kind goods or services, putting us within reach of our goals. Donors seem excited about the potential to brighten their day, and their company's image, by associating with Virginia Tech in this prestigious competition. Media outreach has also begun and will intensify in the coming months as we enact a comprehensive online and offline press release campaign highlighting the many different ways LUMENHAUS can brighten the day of each target media audiences.

This remainder of the report is laid out as follows: the overarching vision and mission of LUMENHAUS are first discussed as well as a brief overview of the LUMENHAUS product and brand. Then follows separate sections detailing the specific plans for communications, fund raising and media outreach. A brief discussion of the process we undertook to arrive at these plans concludes, showcasing the flexibility of the team and how we communicated with each other. A detailed budget and a timeline are also included.

lumenHAUS

a brighter way. everyday.

Team Vision, Mission and Goals.

The Virginia Tech 2010 Solar Decathlon team's vision is to **brighten the day** of everyone who comes into contact with us, or our house. We will strive to do this both literally, through the light living experience of our house, and figuratively, through the provision of enlightening information about energy efficiency.

To accomplish this vision, we aim to develop and promote **brighter ways** of thinking about energy (particularly solar) and sustainability among all our stakeholders and audiences – from student team members to donors, from architects to homeowners by:

- Illustrating how solar energy can improve quality of life through increased energy and access to natural light in residential building.
- Clarifying how energy is used in our daily lives and illustrating the energy consumption of daily activities.
- Demonstrating market-ready technologies that can meet the energy requirements of our daily activities by tapping into the sun's power.
- Revealing how 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.

LUMENHAUS

LUMENHAUS: The Name

LUMENHAUS is the name of Virginia Tech's 2010 Solar Decathlon home. The original working name of the house was "Eclipsis." However, extensive research among team members, architecture students, local residents and homeowners suggested this was not the correct name for us. Most worryingly, Eclipsis suggested darkness – as in, a solar eclipse of the sun – which is the exact opposite of the image of brightness and light we wanted to create. We thus embarked on an extensive brand name search. Using students from both marketing and architecture classes, we first developed a master list of over 50 potential names. These were reduced to a more manageable set of 30 names through desk research (online and dictionary searches to check for alternative meanings). Then, in an iterative, 3-stage process, over 200 staff, students, local residents, VT alumni and homeowners rated these names according to two criteria: how well the name captured the essence of "brighter days" and how much they liked the name in general. There was also an opportunity for open-ended feedback after each name and to suggest variations on the name or completely new names. After each stage, the top performing names were revised according to the feedback and submitted to the next stage.

In the final stage, the name Lumen was the top choice for the majority of respondents. Lumen literally means the "power of light" and over 80 percent agreed this name best communicated the idea of "brightness." Lumen on its own was perceived to be too abstract. There was some debate, however, as to whether the full name should be Lumen Home or Lumen House. In our focus group research, consumers always spoke about their living quarters as their *home*, not their house. However, architects and builders involved in the project talked primarily about *house* design, not home, a word they felt was too soft. We finally settled on the word Haus. Haus is a German word meaning both home and house. The word is also a play on the term Bauhaus. Early founders of the College of Architecture and Urban Studies at Virginia Tech were aligned with the educational institutions of the Bauhaus movement and that inheritance is present today throughout the school. Moreover, the inspiration for the pavilion design of our 2010 Solar Decathlon house comes from the Farnsworth house, designed by Bauhaus architect Mies Van Der Rohe. Furthermore, important themes associated with the Bauhaus, such as the idea that mass production can be reconciled with individual artistic spirit, are captured in LUMENHAUS, which can be mass produced off site, but be specified to site and owner requirements with individually tailored screens. Finally, some research respondents noted that, said quickly, LUMENHAUS sounds like "luminous" which is precisely the image we wished to communicate!

There was concern, however, about dropping the name Eclipsis completely, since the name had some positive brand equity (goodwill) that we did not want to lose. While we had not done any extensive communication activities at this point, Eclipsis was the name on the existing website and it had appeared on promotional materials at an event held in 2008. It had also been the primary name used when recruiting donors. During the research process, therefore, we also tested the idea of naming the screen system Eclipsis. This was received extremely well by the team and so the Eclipsis System is used to describe the two independently sliding layers that help to maximize the home's energy performance. In fact, the original meaning of the name Eclipsis, design elements that serve as eclipses of light, view, environment and privacy, was actually perfect for the screen system. It is this system that permits LUMENHAUS to have full north and south walls of glass. The Eclipsis name was truly taken to heart by the team designing the shutter screens. They updated the pattern so that it now looks like lots of mini solar eclipses – a circular geometry of laser-cut holes and folded tabs.

LUMENHAUS: The Brand and House

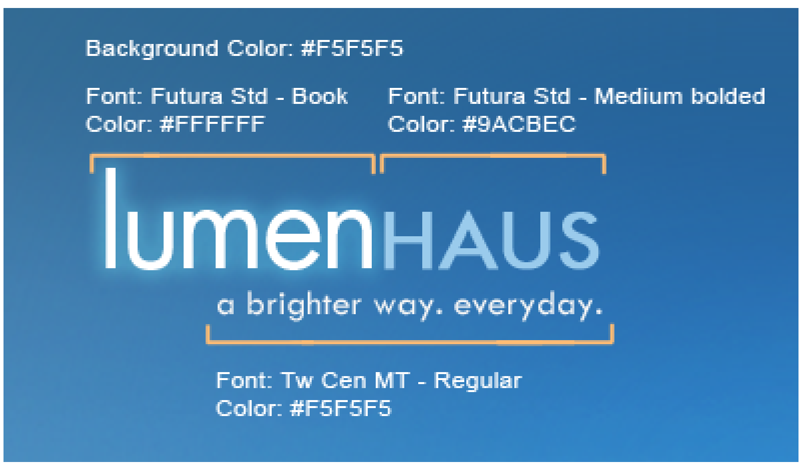
LUMENHAUS aims to epitomize the word "bright" literally and figuratively, in the house itself, through the team, and through its communication materials. The brand's personality is light and open, with a sunny, happy disposition. It will try to illuminate and uplift anyone who comes into contact with it. It will strive to NEVER be dark, dreary or dull.

Visitors to the home itself will directly experience this brightness, from the expanse of natural sunlight that enters the north and south glass walls during the day to the adjustable white LED lights at night. These properties literally address one of the most common requirements of homebuyers: lots of light. LUMENHAUS also improves a potential homebuyer's daily living experience by delivering two additional common home priorities: an open layout and location. Where most energy conscious houses are closed with strategic openings to resist heat transfer, LUMENHAUS has open, flowing spaces linking occupants to each other within the house and to nature outside, making it feel much larger than its actual size. And because LUMENHAUS can be tailored to meet specific location needs, it can be positioned in most any location a homebuyer chooses.

LUMENHAUS aims to brighten a potential homeowner's life in other figurative ways too. By responding *automatically* to environmental changes to balance energy efficiency with user comfort, LUMENHAUS simplifies the owner's day. With an array of PV panels covering the roof, LUMENHAUS is able to produce more energy than it needs, potentially eliminating energy bills. Living in LUMENHAUS will minimize the owner's environmental footprint in other ways too, from the use of passive energy systems, to the radiant floor heating and grey water systems to the use of renewable and/or recyclable building materials. Since the home is fabricated completely offsite, the environmental costs associated with on-site construction are also minimized. All these decisions were made to try and demonstrate that sustainability requires no compromise in design and beauty, which is truly a bright proposition. (More details on the design features of LUMENHAUS that deliver the end benefit of a brighter day can be found in the Architecture Design Narrative in the Project Manual.)

In communication materials, such as the website, in-line activities and on-site exhibition materials, LUMENHAUS' bright personality will be expressed through the provision of enlightening information, presented in a fun, interactive manner using vivid, clean and modern imagery and language.

The LUMENHAUS logo will always appear in upper case in text documents. When using the logo proper, in materials with a colored background (such as brochures, posters, the website) the logo will appear as below, with a glow around the word "lumen" to emphasize the sparkling personality of the home.




On white backgrounds, this glow will be omitted and the logo will be reproduced as below:


All team members will (and currently do!) also reflect the brand's personality through the positive upbeat energy and passion each brings in seeing this home to completion.

Communications

Target Audience and Message Overview

Our market research highlighted several groups of people that would be interested in learning about LUMENHAUS itself as well as solar energy and sustainability issues more generally. As we have limited resources, we prioritized these audiences in order of importance to our goals, and those of the Solar Decathlon Europe Solar Decathlon; our ability to find and reach the target; and the likelihood they would visit either the house or the website. A demographic and psychographic description of our target audiences follows below.

Our communications goal is to engage with these audiences at either our revised website (www.lumenhaus.com) or in the house when it is on display in Madrid during the competition or another location (measurable objectives are described in detail later). With regards to the message, a hierarchy of information was established, in accordance with our audience prioritization. All communication materials will promote the overarching idea that LUMENHAUS, Virginia Tech's entry into the Solar Decathlon Europe, delivers a "brighter way" to think about solar energy and sustainability. Beneath this umbrella message, however, there will be layers of information, differing in technical specificity and highlighting different supporting features, to best appeal to the different needs of the three communications targets. Some examples of specific messages are described after each target below.

Primary Target and Message

Our primary target is a group we call the Progressives. Progressives are most likely to be in a steady relationship and have a moderate income. Age-wise they are diverse, ranging from young professional couples to older empty nesters. Aside from age, however, they have much in common. They share a love of modern art and architecture and regularly visit local museums and art galleries. Though they are very active online and follow their favorite blogs daily, they still pick up the local newspaper or the free alterative press for weekend event listings. Their car radio is tuned to NPR though they try to walk or bike whenever possible.

Progressives are environmentally conscious and interested in social issues for the greater good. For example, they make regular trips to their local recycling center with their glass, cans and paper and they have installed energy saving light bulbs throughout their current home. However, their green behavior stops short of being willing to completely trade off other things – such as looks, comfort or price. For example, when they bought their new car, considerations of fuel economy were near the top of their list and they test drove a Toyota Prius. However, they decided in the end it was too expensive and not roomy enough and chose a different car that still had good fuel economy.

They are currently either looking to purchase a new home (either their first home, or perhaps a vacation home, depending on their age) or are looking for ways to improve the current home they own. When it comes to their ideal home, their top priorities are: location, light and layout. Fulfilling these three "L's" is critical and they are willing to trade off other things, such as number of bedrooms or bathrooms, to achieve them. In particular, rooms with lots of natural daylight make them extremely happy and are the rooms they spend the most time in. On sunny days they wake up feeling happier and healthier, more ready to take on the world. In fact, they never draw their curtains at night, preferring to wake with the sunrise.

In the long term, we envision LUMENHAUS as a home Progressives might actually purchase. So, while it is not currently commercially available to them, we believe this target will be extremely interested in all the features and technologies used in the home. Communication messages aimed at this primary target will highlight the many ways LUMENHAUS could brighten up their future home, while providing inspiration for living in a more sustainable manner today. They can use the information to help make improvements to their current home or to understand what to look for in designing or purchasing a new home. To that end, we will communicate:

- The five "living experiences" that LUMENHAUS provides:
  - ✓ Smart Living – How LUMENHAUS uses technology to balance energy efficiency with user comfort and illustrate the energy consumption of daily activities.
  - ✓ Responsive Living – How LUMENHAUS responds automatically to its environment to maximize energy efficiency.
  - ✓ Green Living – The many sustainable features and systems in LUMENHAUS that work together to reduce environmental impact.
  - ✓ Comfortable Living – How LUMENHAUS can be quickly and easily controlled, both at home and remotely, to maximize living comfort.
  - ✓ Pavilion Living – How the open floor plan and fully opening north and south glass walls connect the owner to others in the house and to nature outside.
- The market ready technologies that exist now to minimize energy usage. For example, off the shelf solar panels; radiant flooring systems; high efficiency insulation; energy efficient lighting solutions; energy efficient appliances.
- The energy used in a home to improve awareness of daily environmental footprint and the notion of zero energy homes and how to improve energy efficiency.
- The broader benefits of solar power and the Solar Decathlon Europe
- The broader benefits of natural day light and LED electric light.

<u>Secondary Target and Message:</u>

Virginia Tech students, faculty, staff and alumni as well as surrounding community residents who have regular interactions with Virginia Tech ("Locals") form the second target. The participation of Virginia Tech in the Solar Decathlon Europe is a source of pride to this target and they want to know how the house is developing and performing as the competition progresses.

Many in this target will overlap with the primary target. To this end, many messages aimed at the primary target will be tailored to a local level to appeal to this audience. Furthermore, more detailed messages highlighting Virginia Tech's past and current role in the Solar Decathlon will be promoted. For example, we will highlight

- Information about Virginia state energy conservation initiatives and Virginia Tech sustainability efforts.
- The Virginia Tech team members, particularly the students, and their involvement in the construction progress.
- Local events showcasing the home, for example Secretary of Natural Resources Preston Bryant's tour of the home and the display at a local museum.

Third Target and Message:

Anyone interested more generally in energy efficient architecture and construction and pre-fabricated housing. These are differentiated from the primary target in that they are more likely to be *professionally* involved in the industry (e.g. architects, designers, builders) with a particular interest in green practices. For this audience, more detailed information about the construction and operating systems and the plans and technologies behind the house will be communicated. In particular, we will focus on those features that we consider to be unique to LUMENHAUS, including:

- The Eclipsis System, without which a pavilion style home with two walls of glass would be virtually impossible in a fully solar powered home. The system comprises two independent sliding layers:
  - ✓ A metal shutter screen, similar to the mashrabiya, a delicate screen found in the Middle East, it provides a simultaneous sense of protection and openness
  - ✓ An insulating panel, filled with an areogel with high insulating values that also delivers a beautiful translucent natural light from sunrise to sunset
- The iPhone application that the Virginia Tech computer science department developed to enable house systems to be operated remotely
- How LUMENHAUS aims to transform the vision of *pre*-fab homes to *pro*-fab, which stands for:
  - ✓ *Prof*essional Fabrication: No flimsy siding and laminate floors here! LUMENHAUS is solid and durable, from the polished gray concrete floor to the solid steel beams and columns that make up the structural system.
  - ✓ *Pro*gressive Fabrication: An innovative transportation system allows the house to be transported easily without expensive permitting and very little on-site construction or assembly.
  - ✓ *Pro*creative Fabrication: The modular design of LUMENHAUS allows it to grow with your family. PROgrammable fabrication: The design of the Eclipsis System will be tailored to embrace the sunlight dispersion and privacy conditions unique to each location.

Objectives and Measurement

Our communications goal is to engage with our target audiences at either our website, www.lumenhaus.com or in the house when it is on display in Madrid during the competition or another location. Engagement encompasses two primary objectives: getting our target to visit the site in the first place and then keeping them there, interacting with the site. Specific objectives related to this broad goal are outlined below, together with details of how we will measure the success:

| WEBSITE OBJECTIVES | MEASURE (From Google Analytics) |
|---|---|
| Increase visits to www.lumenhaus.com from 85 unique visitors per month (October 2008) to 600 unique visitors per month on average and 800 unique visitors per month when the house is on display. | *"absolute unique visitors."* |
| Double the average amount of time spent on www.lumenhaus.com from 1:40 minutes (October 2008) to three minutes or more. | *"average time spent on site"* |
| Increase the number of average pageviews for all visitors on www.lumenhaus.com from 4 to 8 pageviews | *"average pageviews for all visitors"* |
| Increase use of the brand name "LUMENHAUS" as a keyword search engine term from 0 percent to 20 percent* | *"keywords" used in search engine searches* |

| | |
|---|---|
| Increase the percentage of visitors from our primary target from 15% to 30%* | *"top traffic sources:" direct traffic & referrals from targeted sites (e.g. www.dwell.com )* |
| Increase the percentage of visitors from our secondary target from 10% to 20%* | *"top traffic sources:" referrals from vt.edu and local news media (e.g. www.wsls.com )* |
| Increase the percentage of visitors from our third target from 1% to 5%* | *"top traffic sources:" referrals from targeted sites (e.g. www.designanlyze.com )* |

*PLEASE NOTE: Due to budget constraints, this is a proxy measure for true market research assessing unprompted awareness or reach among the three target audiences. These measures explicitly exclude traffic referred to from www.solardecathlon.org or www.sdeurope.org since visitors to these sites may not have come about from Virginia Tech / LUMENHAUS promotional activities.

| HOUSE VISITOR OBJECTIVES | MEASURE (In house Counter) |
|---|---|
| Generate 500 visitors per week to the house when it is on display in Blacksburg Square in Blacksburg | Total / weeks on display |
| Generate 8,000 visitors a day to the house when it is on display in Madrid | Total / days on display |

Communication Strategy and Tactics

Our two primary communication vehicles for all three audiences are the website, www.lumenhaus.com, launched June 5th 2009, and exhibitions of the house itself. At both the real and the cyber locations, the overarching idea that LUMENHAUS, Virginia Tech's entry into the Solar Decathlon Europe, delivers a "brighter way" to think about solar energy and sustainability will be promoted. Beneath this will be layers of information, differing in technical specificity and highlighting different supporting features, to best appeal to the different needs of the three communications targets. These two communication vehicles are now described in more detail, together with the proposed tactics to get the three different targets to actually visit them.

(1) www.lumenhaus.com and Interactive Media Strategy

The first two iterations of the website were developed by a very small team of students with very little web expertise or background. Aside from the house itself, the website is our most powerful communication tool and the only media through which many people will be able to view LUMENHAUS. To do the house justice, therefore, we sought expert help and advice to develop version 3 (v.3) in the form of local digital services agency Modea as well as architectural rendering and 3D animation company Spine 3D. Both companies are highly experienced in their fields and have international client bases of well-known and respected companies and brands. Both companies donated all their services while working closely with students and faculty to share the workload and provide an invaluable educational experience. The new site (www.lumenhaus.com) went live on 5th June.[1] Visitors to the old

[1] The new website will be tested to ensure it complies with the Minimum Web Site Coding and Accessibility Standards provided in the Solar Decathlon Europe rules.

website address will be automatically forwarded to this site.

The site aims to be an online experience that "brightens up" the visitor's day, exactly as the house aims to do for its owner. Consistent with the LUMENHAUS personality, the website's look and feel is bright and light, achieved through the use of a selective color palette (blue, orange, white and gray). It is simple to navigate and provides key information in a friendly manner that non experts can understand confidently. There are plenty of photos to visually illustrate the complicated technologies used in the house. And there are numerous interactive features and videos to keep the visitor engaged and on the site longer. The central focus is on the home itself, which "shines" on the home page. Central navigation links at the top also "shine" to indicate where the user is on the website.

Conceptually, www.lumenhaus.com is divided into two sections, "The Experience." and "The Project." The home page will encourage all users to "experience the house." This will take users to an interactive video[2] which will highlight the five primary living experiences LUMENHAUS provides to deliver a brighter day: Smart Living, Responsive Living, Green Living, Comfortable Living and Pavilion Living. This interactive experience will demonstrate the benefits of living in LUMENHAUS to all target audiences, though it is particularly aimed at the Progressives described earlier. Of interest to this audience too, will be a section providing links to more information about solar energy, energy efficiency, materials and products used in the home, the power of light, as well as links to fun, happy websites or news stories related to solar power that will brighten the user's day and reinforce LUMENHAUS' brand positioning. All members of the Virginia Tech solar decathlon team are alert for such inspiring information in their daily activities and forward them to the webmaster for posting as and when they find them.

The rest of the website provides many more details about the project itself which are likely to be of more interest to the secondary and third audiences. These include a documentary about the process of building the house; details on past Virginia Tech houses and the Solar Decathlon Europe competition; technical specifications of the home, including information on the sustainable aspects of LUMENHAUS, diagrams, plans and the technologies used; details of the team and the donors and events LUMENHAUS will be participating in. There will also be a prominent invitation to "fan" LUMENHAUS on Facebook. Our Facebook page is focused more on the LUMENHAUS team, rather than the house itself and includes regular updates on progress as well as information about informal gatherings. It is the "face" behind the house and hopefully showcases what a bright, happy team we are! We also have a You Tube account http://www.youtube.com/lumenhaus where we will post videos produced by the team constructing the house.

Having a great website is not sufficient on its own however to meet our objectives. It will help with the second part of engagement (keeping visitors on the site) but we need to get people there in the first place! This will be accomplished via an online social campaign aimed at creating conversations and sharing information related to our house with various online communities, blogs and forums. The digital campaign will combine five tactics and will begin in earnest once the new website goes live on June 5th. Please note that because the ultimate objective of each of these tactics is to get people to engage with www.lumenhaus.com, we have not set specific objectives for each tactic, focusing instead of the overall website objectives listed earlier. However, we will be monitoring website referrals daily (using Google

[2] Equivalent alternatives will be provided for all multimedia pages.

analytics), which will enable us to adapt and optimize our strategies as we progress. For example, if we see that a design blog is generating a lot of leads we will follow up with more design blogs. Similarly, if we see a surge in website activity on a day when a new tweet went out with no other communication, we may increase our twitter activity. The five tactics of the digital campaign are:

(1) **Search engine optimization.** The name LUMENHAUS is not clearly associated with Virginia Tech! A key emphasis of this tactic therefore is to ensure that anyone who searches for something like "Virginia Tech Solar Decathlon" understands that www.lumenhaus.com is the Virginia Tech website. The description of the website that search engines will find and display is "*LUMENHAUS is Virginia Tech's 2010 entry to the Department of Energy Solar Decathlon competition. LUMENHAUS delivers a brighter way, everyday, literally and figuratively*." We have also embedded several Meta-tag keywords including Virginia Tech, VT, Hokies, College of Architecture and Urban Studies as well as more general words such as solar energy, modern home and pre-fab home to increase the likelihood that www.lumenhaus.com will be found among people searching those terms.

(2) **Email outreach**. Each team member sens an email to all friends, family and colleagues announcing the launch of the website and requested that they pass the message on further. They also sent a message to listserves they have appropriate permission to use. We will further send emails to targeted VT alumni listserves that we have permission to use.

(3) **Blogs.** To reach our three targets, we intend to reach out to home building and interior design websites and blogs (e.g. www.designspongeonline.com); green websites and blogs (e.g. www.treehugger.com) and local websites and blogs (e.g. newriverjournal.blogspot.com). The blogs will be monitored by two decathletes on a daily basis for postings to which we might be able to intelligently contribute – for example, by providing information regarding a particular kind of insulation that we chose to use if someone inquired about effective insulation. While we will always be upfront about the fact that we are posting as part of the LUMENHAUS team, we will not necessarily be trying to "sell" LUMENHAUS. Instead, we want to become a valued resource for bloggers posting on design and environmental issues. Later, as part of the media outreach strategy, we will send more traditional press releases to these websites and blogs.

(4) **Tweets.** We have set up a twitter account http://twitter.com/lumenhaus. Using Twellow (Directory) and Twitter Search we will find and build relationships with twitterers interested in Virginia Tech, Blacksburg, solar energy, modern architecture or modular housing. We are currently drawing up an extensive list of potential tweets that we will release on a regular basis once the site goes live. While it is not possible to target the tweets to particular audiences, we plan to rotate a variety of tweets that will be of interest to all three targets to maintain interest. Approximately one in every four tweets will directly mention LUMENHAUS; the remaining will be less promotional. For example, a promotional tweet aimed educating the primary target may be: "LUMENHAUS uses net metering. If the house produces more energy through the PV panels than it uses, there will be a net energy gain. Visit www.lumenhaus.com" A less promotional tweet of more interest to local residents might be: "Roanoke Times discusses greener future at Virginia Tech here http://www.roanoke.com/news/nrv/wb/205817." And a less promotional tweet aimed at educating on the benefits of day-lighting may read: "Daylighting improves student performance in schools says NREL sponsored report http://www.nrel.gov/docs/fy00osti/28049.pdf."

(5) **Facebook**: A LUMENHAUS Facebook page has been created to post more regular updates and photos about construction progress and upcoming events at: http://www.facebook.com/home.php#/pages/Blacksburg-VA/lumenhaus/73617811767?ref=ts

Links to our Facebook page will be made by all team members, who will encourage their friends to put a link on their pages too. We will also work with relevant organizations who have a Facebook presence (such as the Downtown Merchants of Blacksburg) to place reciprocal links and we will connect with other architecture groups, green groups and Virginia Tech groups on Facebook. We will also announce events on Facebook.

In a reciprocal manner, events that we participate in will also publicize the www.lumenhaus.com website address through promotional materials such as business cards, posters and leaflets.

(2) Exhibitions

Exhibitions of either the full scale model of the house, specific sections of the house (e.g. the screens), or the actual house itself form the second part of our communications campaign. Some of these exhibitions have been planned for many months. Others occur at short notice, as we learn of local events that it makes sense for LUMENHAUS to be a part of. The flexibility and passion of the team is demonstrated in particular at these events, which require quick action on the part of the team to participate. Promotion of our presence at these events will take many forms, including:

- Details at www.lumenhaus.com as well as the LUMENHAUS Facebook page.
- Print advertisements in mainstream local newspapers (e.g. The Roanoke Times or The Washington Post) and local alternative newspapers (e.g. 16 Blocks)
- Radio announcements on local stations (e.g. NPR and VTech Radio)
- Utilizing local listserves (with permission), such as the New River Valley Green Builders listserve and Virginia Tech community listserves.

Some key exhibitions that LUMENHAUS has already participated in, or will participate in the future:

- **Architecture Exchange East**, Richmond, VA, November 2008. A lecture and exhibition featuring sustainable aspects of the house were presented at the statewide convention of the American Institute of Architects. This event primarily reached our third target.
- **3rd New River Valley Green Building Tour and EXPO**, Blacksburg, VA, April 2009. Solar decathletes were on hand with a scale model of LUMENHAUS to answer questions about the home and energy efficient technologies and, in lieu of paying to participate, helped to clean up afterwards. This event reached our primary and secondary targets.
- **International Contemporary Furniture Fair (ICFF)**, New York, NY, May 2010. Introduction of the Eclipsis System prototype in conjunction with an exhibition on industrialized furniture. This event reached our first and third targets.
- **The Taubman Museum of Art**, Roanoke, VA, June 2009. The museum will house an exhibit of the Eclipsis System and how it functions as part of a broader environmental initiative. As our primary target is interested in art, this event will help drive awareness among them locally, as well as reaching our secondary target.
- **Summer Solstice**, Blacksburg, VA June 2009. A day long festival with thousands of local visitors celebrating the sun – what could be more perfect for a solar powered home?! Solar decathletes will display the model and test out some ideas for in-line communication materials and activities. Reaches local primary target and the secondary target.
- **National Building Museum** Green Communities Exhibit, Washington DC, September 2009. This exhibition that focuses on the way communities are investing in new technologies to create greener approaches to modern life will allow us to showcase LUMENHAUS to all our target

audiences and also discuss in more detail the modular growth and community potential of the house.
- o **Solar Decathlon Europe Solar Decathlon,** The Mall, Washington DC, October 2009. The competition itself! An opportunity to reach all our target audiences.
- o **Solar Decathlon Europe,** Madrid, Spain, June 2010. Virginia Tech is one of only two U.S. teams invited to compete in the European Solar Decathlon. Opportunity to reach our primary target in Europe.

(3) Public Tours (Referenced from CD sheets PT-101 and PT-201; More details in “Public Tours” sections of Project Manual)
Past events have always featured members of the LUMENHAUS team to explain the models and materials on display. We have also had business cards to hand out with details of the website. Going forward, we have a team specifically tasked with developing exhibition materials for the various future events that we will be displaying the house, model, or components at, including the competition in Madrid. For the public tours of LUMENHAUS in Madrid, where long lines are expected in the hot sun, we will be providing “in-line” activities to keep visitors happy and enlightened, by offering information though signage on the South of the house about the process of creating LUMENHAUS as well as highlights on the sustainable aspects of the house, providing material samples for those waiting in line to observe and examine. In order to combat the potential hot sun, we will be handing out “LUMENellas” at the start of the line to keep our guests comfortable as they read our signage and wait to tour the house.

While on site in Madrid, the LUMENHAUS team will be hosting tours of the house in a station-based style in order to keep the lines moving and to move as many people through the house as possible. The basic layout of the stations is based on the Experience LUMENHAUS section of the website and can be found on the House Tour Floor Plan on sheet PT-101 of the construction documents. Five of the six stations will be labeled in concurrence with each of the five sections found under the Experience LUMENHAUS section of the site. A sixth station will be located outside of the mechanical closet where one can see and learn more about the equipment and systems that run the house. Each tour station will feature a knowledgeable LUMENHAUS team member giving out short, concise bits of information dealing with their respective area and answering any additional questions visitors might have. Detailed information on the focus of each tour station is located directly below.

Station #1, Green Living

- LUMENHAUS is a zero energy home – it produces all the energy it consumes from the sun. A vast array of solar panels automatically responds to external conditions to best capture the sun’s energy.
- Opening the sliding doors in LUMENHAUS naturally cools and ventilates the home.

- Using the roof as a catch basin, rainwater is collected and purified for reuse in the house, reducing the need for municipal water and reducing strain on storm water management systems.
- Coupled with a geothermal heat pump to extract heat from the ground, a radiant floor system pumps water through pipes in the concrete floor, using far less energy than a typical heat pump.
- Wherever possible, LUMENHAUS uses recycled or long-lasting renewable materials to help preserve the earth's valuable natural resources.  For example, the wooden deck and cabinets come from sustainable forests. Various material samples are located in this station for those in line to inspect.

Station #2, Responsive Living

- A weather station on the roof provides LUMENHAUS with live weather updates. Numerous house systems use and adapt to this information to run as efficiently as possible.
- The Eclipsis Shutter Shade is a modern interpretation of the centuries-old shutter. Automatically responding to sunlight conditions to maximize energy efficiency, it also provides privacy without blocking external views.
- Without the Eclipsis Insulation Panels, glass walls would be impossible in a zero-energy home. These highly insulated translucent panels allow light to penetrate without letting heat escape.
- LUMENHAUS breathes with variations in natural light, mediated by different combinations of the Eclipsis System.

Station #3, Pavilion Living


- Making use of an open floor plan, LUMENHAUS features the most flexible space possible ready to accommodate any of the inhabitants needs.
- The lack of interior walls and widespread use of glass in the house create a visual and physical connection to the surrounding environment, making LUMENHAUS feel much larger than its small footprint really is.

Station #4, Smart Living (Highlights the "Smart" aspects of LUMENHAUS)


- LUMENHAUS monitors the weather forecast and automatically adjusts house systems to prepare for oncoming weather condition, maximizing energy efficiency.
- LUMENHAUS allows one to easily and efficiently collect information about current inside and outside comfort conditions from any viewable screen in the house.
- LUMENHAUS continually tells the owner how much energy it is producing, where energy is being consumed in the home, and, if there is excess energy, how much it is selling back to the utility grid.

Station #5, Comfortable Living


- LUMENHAUS uses a smartphone like the iPhone to create an intuitive house control system. From music to movies, from lighting to shading, one can relax in comfort with a simple touch of a screen. In addition to the phone application, multiple touch screen displays can be found in the house, displaying information about the house energy use and production and also allowing full control of house systems just like the phone.

Station #6, Mechanical and Electrical Closet

- LUMENHAUS utilizes many types of equipment. In the mechanical closet, one can see the "brain" of the house and learn more information about the energy efficient systems that heat, cool and power the house.

(4) Other Communication Activities

We remain vigilant to other opportunities that might arise to promote LUMENHAUS. For example, Virginia Tech mailed out a series of postcards to 20,000 alumni each month over the summer of 2009 as part of their university wide Annual Fund campaign. These postcards highlight innovative activities that Virginia Tech students participate in to encourage alumni to donate to the flexible Annual Fund. The U.S.

Deparment of Energy's Solar Decathlon was featured on one of those postcard mailings in the beginning of July, 2009. The postcard included a website link to direct visitors to www.lumenhaus.com. The draft postcard can be seen in the Proofs Appendix. We hope to once again be involved in the summer 2010 mailings to advertise for the Solar Decathlon Europe and the LUMENHAUS.

## FUNDRAISING

Virginia Tech has leveraged its experience in two previous Solar Decathlon Europe competitions (2002 and 2005) to build a knowledge base for development and fundraising. Two related fundraising objectives are central to the design and construction of a house that can compete on an international level in this fourth Solar Decathlon. The first involves expanding the network of "grass roots" donations that has been built in the past – generally small in-kind support of materials and small cash donations; the second involves major corporate sponsors. For 2010 we have been successful regarding both initiatives. Our base of support continues to grow through the notoriety of our previous work. The companies that supported the 2005 project have grown in significant number to match the increased complexity and needs of the ongoing effort. There are currently over 50 companies donating either cash or in-kind services and products to the project.

The development officer of the College of Architecture and Urban Studies has been given a specific charge to solicit support for this project. This aligns well with the university's recently announced Capital Campaign to raise $1B over the next few years. The Solar Decathlon Europe House is a line item in the College of Architecture and Urban Studies prospectus for development and, as such, it is positioned as a focal point in discussions with alumni and other supporters. In addition, the four principal professors on the project are well-skilled in approaching suppliers, fabricators and corporations. The critical element is to provide a two-way exchange of ideas and experience so contributors become thoughtfully vested in the enterprise. Over the past seven years, Virginia Tech's Solar Decathlon program has earned the trust of corporations, design professionals and manufacturers who have pledged to help with LUMENHAUS.

We strive for our contributors to feel comfortable in their decision to support our project – we want them to feel that contributing brightens their (and their company's) day too! We can achieve this by drawing the public into our house through good design, fabrication and craftsmanship. Products that have been contributed are visible to the visiting public (in accordance with Solar Decathlon Europe rules). Contributors can also align their companies with green research and design; one such company is an oil company that is interested in furthering sustainable research. More detailed progress is reported below. All donations (in kind with an estimated value and cash) are tracked and recorded in a central spreadsheet by a faculty advisor.

| Target 1 | Monetary Corporate Donors |
|---|---|
| Example | Energy companies and materials companies |
| Goal | $600,000 by summer 2010 |
| Tactic | A team of professors contacts corporations to garner support. |
| Incentive | Improved public image through association with a project that embodies the ideals of environmental sustainability. Contribution recognized on website according to one of four levels of support. |
| Progress | Conoco Phillips has agreed to donate $350,000 and five other corporations have agreed to donate between $10,000 and $25,000 in cash each. |

| Target 2 | In-Kind Corporate Donors |
|---|---|
| Example | Manpower and expertise from architecture and design firms and online media agencies; material & equipment from materials suppliers such as solar panels and glass; machine time and personnel from fabricators |
| Goal | No financial number – as much material, services and labor donated free of charge or at cost as possible |
| Tactic | Professors and members of the team have attended various conferences, expositions and fairs to solicit support and donations for the project, including GreenBuild, Boston, MA; Light Fair, Las Vegas, NV; International Builders Show, Orlando, FL; Architecture Exchange East, Richmond, VA; American Institute of Architects National Convention, San Francisco, CA; Society of Environmental Journalists, Roanoke, VA. |
| Incentive | Donated products will be on display in the house (according to Solar Decathlon rules) not only in the Washington DC competition, but also the Solar Decathlon Europe in Madrid 2010 competition and other regional events. Contribution recognized on website. |
| Progress | Over $200,000 of in-kind donations or discounted materials, from the construction of the frame to the donation of fabrication facilities, windows, PVs and other materials and services. |
| **Target 3** | **Individual Monetary Donors** |
| Example | Virginia Tech staff, students, faculty and alumni and local residents with an interest in solar energy and environmental issues |
| Goal | Raise $10,000 |
| Tactic | Raffle held to gain support from the community and to spread knowledge of the project, during 2008-2010 academic year. Tickets were printed in-house to minimize cost and were sold by students from all disciplines of the team, as well as professors, faculty and alumni of the school. Tickets were sold at $10 a piece, with the aim of selling 1000. |
| Incentive | The prize was the GEM (Global Electric Motorcars) a 2-seat vehicle, donated by the Department of Energy the 2005 Solar Decathlon. The GEM requires no gasoline in a time marked by increasing fuel prices and a growing sense of environmental responsibility. Support Virginia Tech in an international competition. |
| Progress | Sold 989 tickets, resulting in $9,890 cash for the competition. Winning ticket was drawn by Virginia's Secretary of Natural Resources Preston Bryant at the School of Architecture and Design's Ferrari Symposium and generated local publicity. |

## Media Outreach

The Media Outreach team is a subset of the overall Communication team and in addition to students and faculty from the Communications school, the Pamplin College of Business and the College of Architecture and Urban Studies, the team also includes the Communications Manager for the College of Architecture and Urban Studies. The primary aim is to reach and obtain coverage in those media outlets that are consumed by our three target audiences. A list of target media have been identified that meet these criteria and they form our primary focus. The first step was identifying media coverage reaching a broad range of audiences, while simultaneously implementing the most effective message to shape audience impressions. A checklist was created to determine previous coverage in the 2005 U.S. event. Using Google and Amazon, we then identified magazines and websites that were similar to highlight future potential opportunities. By analyzing what mediums have worked in the past and potential media to incorporate in the future, we have a baseline for measuring our outreach success. Press releases will be tailored with each outlet's specific needs in mind and will draw on the communication messages outlined earlier. For the online targets, the approach will be a combination of traditional press releases but also less traditional grass roots activities, where we participate in blog discussions to add value, as discussed earlier. In addition, the personal relationships established by the College's Communication Manager will be leveraged so that we work to provide the information a particular media wants for their story angle.

**Media outlets of interest to primary target (Progressives):**
Outlets from 2005: PBS; This Old House; ABC Extreme Makeover, Home Edition; HGTV "I Want That"; Los Angeles Times; Miami Herald; Washington Post; Knight Ridder News Service; Dwell magazine; CNN.com; DIY Network.
New for 2010: Metropolis magazine; www.inhabitat.com; www.popularmechanics.com; www.livemodern.com; www.mocoloco.com; Domino magazine; New York Times Art and Design section; www.livemodern.com; www.padstyle.com; thelazyenvironmentalist.blogspot.com/; Wired magazine; The New Yorker; Vanity Fair; SEED magazine; www.slate.com; Ideal Living magazine; Wallpaper; Monocle; Home Energy; Organic Style magazine; Patio magazine.

**Media outlets of interest to secondary target (Virginia Tech affiliated and local residents):**
Outlets from 2005: Blue Ridge Business Journal; Richmond Times-Dispatch; Roanoke Times; http://www.wsls.com/; CBS local affiliate; NBC local affiliate.
New for 2010: FOX local affiliate; local newspapers and TV news affiliates in hometown of each student decathlete; The Roanoker magazine; City Magazine, Roanoke; NRV magazine; 16 Blocks magazine. WVTF (local NPR affiliate).

**Media outlets of interest to third target (Industry professionals):**
Outlets from 2005 Popular Mechanics magazine; Construction; Contractor; Prism; Virginia Construction Journal; Solar Today; TheTartanOnline; www.highbeam.com; http://www.newswise.com/; http://sunpowercorp.com/;www.backyardnature.com.
New for 2010: Architect magazine; www.fabprefab.com; www.arcspace.com; www.treehugger.com; www.ecotoolbox.com/blog; www.groxie.com; greenbiz.com; www.dezeen.com; E The Environmental Magazine; Step Inside Design; Artichoke; Greensource magazine; Natural home magazine; Mother Earth News magazine.

We have been and currently are writing press releases documenting the progress of the LUMENHAUS construction and team activities. For example, press releases went out to local media announcing the electric car raffle and the raffle drawing by Virginia's Secretary of Natural Resources Preston Bryant. Below is a list of press releases issued to date regarding the 2010 Solar Decathlon Europe(most recent first). These stories are also available on www.lumenhaus.com.

http://www.vtnews.vt.edu/story.php?relyear=2010&itemno=22
http://www.vtnews.vt.edu/story.php?relyear=2010&itemno=54
http://www.vtnews.vt.edu/story.php?relyear=2009&itemno=648
http://www.vtnews.vt.edu/story.php?relyear=2009&itemno=638
http://www.vtnews.vt.edu/story.php?relyear=2009&itemno=585
http://www.vtnews.vt.edu/story.php?relyear=2010&itemno=439
http://www.vtnews.vt.edu/story.php?relyear=2010&itemno=426
http://www.vtnews.vt.edu/story.php?relyear=2010&itemno=280

http://www.vtnews.vt.edu/story.php?relyear=2010&itemno=201
http://www.vtnews.vt.edu/story.php?relyear=2010&itemno=3
http://www.vtnews.vt.edu/story.php?relyear=2008&itemno=52
http://www.vtnews.vt.edu/story.php?relyear=2008&itemno=743

Further press releases are planned on the following topics. More will be added as the competition progresses. While these bullets represent the broad topic areas, the message in them will be tailored to the specific needs of each media outlet's audience and will be followed up with phone calls.

- Major website updates
- Local student involvement (aimed at hometown newspapers of decathletes)
- Daily press releases and student blog during competition week

Media hits are tracked through the University, which is standard operating procedure. In regards to the budget for the Public Relations aspect of the competition, all expenses - a professional communications manager, a staff of university relations professionals and the materials and resources we use, are built into the operating budget of the college and the university.

The list below illustrates the media hits so far in 2009 and 2010:

- Good Morning America on ABC News: Get Green by Going Solar
- WDBJ-TV, CHANNEL 7 (CBS): Virginia Tech students compete in energy decathlon
- WDBJ-TV, CHANNEL 7 (CBS): In October, Virginia Tech will enter a house that is completely run by solar energy in the Department of Energy's Solar Decathlon.
- WSLS-TV CHANNEL 10 (NBC): Virginia Tech is one of 20 schools competing in a solar house competition
- WSLS-TV CHANNEL 10 (NBC): Virginia Tech sells tickets for electric car raffle
- WSLS 10: Virginia Tech to compete in 2010 solar decathlon
- www.designalyze.com: Grasshopper workshop with Virginia Tech's solar decathlon team

In addition, we participated in the Society of Environmental Journalists Conference that was held in Roanoke, VA from October 16$^{th}$-October 18$^{th}$, 2009. We created custom made gum wrappers in house to cover packets of gum as a promotional giveaway to hand out to the journalists. The gum wrappers included the design of the Eclipsis System with the original name, Eclipsis (see Proofs Appendix). We also provided the students and faculty participating in the conference with some basic media training and instructed them to collect contact details for follow up later.

## BUDGET

To save money, most projects completed by the communications team have been completed in-house wherever possible. We have been very successful in soliciting in-kind support from communication experts, such as Modea and Spine 3D, or support at subsidized cost. For example, the gum in the packages that we distributed at the SEJ conference was supplied at a 75% discount from local grocer Food Lion, while the packets were designed and printed by graphic design students at the School of Architecture. Similarly, all the raffle tickets and flyers promoting the electric car raffle were design and printed by architecture students. Otherwise, we have been fortunate to work with dedicated students, faculty and sponsors that have volunteered their time and services to the project at no cost. A detailed overview of current and planned expenses, together with a timeline, is overleaf.

lumenHAUS
a brighter way. everyday.

FOC = Free of Charge to VT Solar Decathlon Team

2008: Oct, Nov, Dec — 2009: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sept, Oct, Nov

| | |
|---|---|
| **GRAND TOTAL** | $ 34,150 |
| **Branding** | $ - |
| *Name research* | FOC |
| *Logo development* | FOC |
| **Communication** | $ 29,600 |
| **Website construction** | $ 10,000 |
| *Design & production & updating of site* | FOC |
| *Design & production of interactive video* | FOC |
| *Documentary video of process* | $ 10,000 |
| **Online communication campaign** | $ - |
| *Search engine optimization* | FOC |
| *Email campaign* | |
| *Blog monitoring and outreach* | FOC |
| *Twitter campaign* | FOC |
| *Facebook campaign* | FOC |
| **Exhibitions** | $ 19,600 |
| *Exhibition Costs (including relocation)* | $ 10,000 |
| *Supporting Advertising* | $ 2,100 |
| *In line activities* | $ 2,500 |
| *Brochures* | $ 4,000 |
| *In house posters and displays* | $ 500 |
| *Team uniforms* | $ 500 |
| **Other Communication Activities** | |
| *Postcard to VT Alumni* | FOC |
| **Fundraising** | $ 2,200 |
| **Raffle for Electric Car** | $ - |
| *Print tickets, promotional flyers* | FOC |
| **Monetary & in kind donor outreach** | $ 2,200 |
| *Conference attendence to solicit donors* | $ 2,200 |
| **Media Outreach** | $ 2,350 |
| **SEJ Conference** | $ 1,350 |
| *Promotional materials (gum)* | $ 350 |
| *In house printing* | FOC |
| *Booth rental* | $ 1,000 |
| **Media packs / press releases** | $ 1,000 |

Process

After the feedback from the preliminary communication plan, it became clear we needed to involve faculty, students and staff with more experience in communication. To that end, we persuaded a marketing faculty member to advise us and also invited graphic and web design students to join the team. Many students participating in the Solar Decathlon Europe Communications team are receiving independent study credit from professors in their respective fields. This academic motivation allows the team to be dedicated to the tasks at hand at all times. A core communication team began meeting weekly from October 2008. Clear roles and responsibilities were assigned, leading to four "sub-teams" within the overall team. One group is responsible for fundraising, in particular, the electric car raffle. Another is responsible for media outreach activities, both online and offline. Another subgroup is responsible for other communication activities, such as website development. The final subgroup is responsible for the on-site communication activities.

The weekly meetings provide an opportunity for everyone to get updated on the whole team's activities and to ensure that all activities are staying "on message." During each meeting we allocate tasks, distribute research and discuss past assignments. One of the members types minutes at each meeting and those are sent to all of the communication team members each week. Furthermore, as activities wax and wane within each sub area, labor and talent from each of the other subgroups can be re-directed temporarily as necessary. For example, there was a two week period when everyone stopped their primary activities to help sell raffle tickets at Virginia Tech football game tailgate parties. Primary faculty on the team were responsible for selling a majority of raffle tickets, laboring though freezing temperatures and recalcitrant football fans! More recently, most team members have been focused on the website development and expansion as we come closer to the competition in June.

Each subgroup has members from various disciplines, including architecture, to allow the communication experts to work seamlessly with the architects and communicate accurately the features and benefits of LUMENHAUS. The primary method of communication for our team outside of the weekly meetings is email. Also, the team is connected to the Virginia Tech Solar Decathlon listserve so we are able to find out what is going on with the broader team. We also use other methods to stay in touch – from the old fashioned (all faculty involved have an "open door" policy and any students are welcome to drop in at anytime) to the modern (we monitor and approve website developments using a password protected extranet and share and approve press releases and tweets using Google Sites).

The group as a whole is also very flexible: as we realize we need more expertise in certain areas, new team members, or even outside experts, are solicited. This is how Modea was brought on board for example. Furthermore, we identify ahead of time the key stakeholders (usually Joe Wheeler and Robert Dunay, the two architecture faculty that head up the project and Heather Riley Chadwick, the architecture school Communications Manager) that will need to sign off on our proposed communication activities. Not only do we build in time for them to review material, but, perhaps even more importantly, we seek their involvement early in the idea generation phase of processes, meaning they are more likely to "buy in" later. For example, we had a full day of brainstorming with Modea to generate ideas for the content and look and feel of the website with most of the architecture and engineering students and key faculty advisors. Interestingly, the website development process and many of the idea generation phases closely mimic the way the architectural team came up with and agreed on the design of the house. Small subgroups work together generating schematic designs (for the house, for the website, for the raffle ticket). Those designs are presented to the other subgroups and agreement is reached as to which one should be progressed further. This similarity has no doubt helped to make the approval process for the website and other communication materials flow smoothly.

Clients/Stakeholders: Internally Architecture Professors Joseph Wheeler and Robert Dunay must approve all communication materials before they go live. Also consulted are Heather Riley Chadwick, the Communications Manager for the College of Architecture and Urban Studies. At their discretion, further approval may be sought from Jack Davs, Dean of the College of Architecture and Urban Studies, Robert Schubert, Vice Dean and Scott Poole, Director, School of Architecture and Design. We also seek guidance as necessary from University Development, University Relations and University Legal Counsel. External to Virginia Tech, stakeholders and clients whose needs and requirements we taken into consideration include the Solar Decathlon Europe and those of our donors. The involvement of these clients/stakeholders in media outreach is by obtaining releases from the professors and/or deans as necessary before issuing communications, adhering to University Relations practices and requirements for external communications, advising/seeking advice from University Development, sharing and seeking information as needed with counterparts in other colleges and offices on campus and striving to adhere to the Solar Decathlon Europe's communications requirements pertaining to the competition.

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Thank you for reading this report!

We look forward to meeting you soon in Madrid.

We will try our best to brighten up your– and all the other visitors' – day!

lumenHAUS
a brighter way. everyday.

Proofs Appendix 1: Image published of house and three team members in Times Square on front page of Virginia Tech Website.

lumenHAUS

a brighter way. everyday.

Proofs Appendix 2: Postcard mailed to 20,000 Virginia Tech alumni.
Front View


Proofs Appendix 3: Postcard mailed to 20,000 Virginia Tech alumni.
Back View

## Group projects help students build skills and show teamwork.

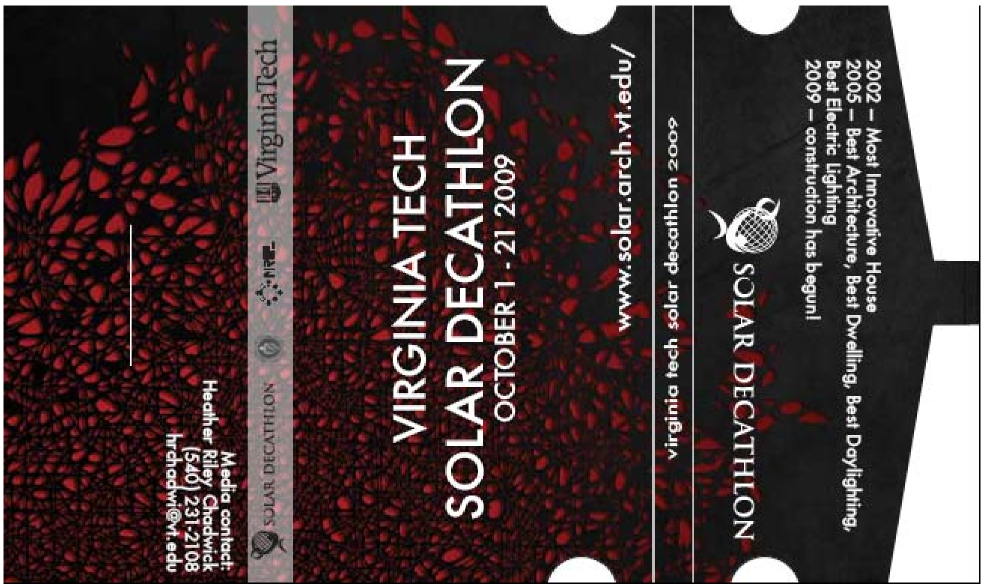
But the Virginia Tech students who are competing in the U.S. Department of Energy Solar Decathlon 2009 are building a lot more than that. They're building an 800-square-foot residence — named LumenHaus — to showcase cutting-edge technology and design. Students Alden Haley, Corey McCalla, Kevin Smith, and Danny Slover (left to right, with model) took lead roles designing a house that includes a computerized system to automatically maximize energy efficiency and user comfort.

Virginia Tech's Solar Decathlon team is among 20 chosen to display their houses on the National Mall in Washington, D.C., as part of the competition. Contests like the Solar Decathlon are the type of extraordinary student experiences that are supported by the Virginia Tech Annual Fund, which provides flexible money to our colleges and programs.

Visit *www.campaign.vt.edu/unlimited* to learn more about the Solar Decathlon, and how your gift to Virginia Tech Annual Fund can create unlimited opportunities.

VirginiaTech
Office of University Development
University Gateway Center (0336)
Blacksburg, VA 24061

Proofs Appendix 4: Gum packet used as giveaway at Society of Environmental Journalist Conference.



# INDUSTRIALIZATION AND MARKET VIABILITY NARRATIVE

## Introduction

The Architecture, Engineering and Construction (AEC) industry has long been under pressure to maintain design excellence, improve productivity and safety, reduce cost and improve quality of work. With more recent and increasing demand for affordable housing, growing production costs, and energy concerns, AEC stakeholders are re-examining historic criteria that defined local markets and delivery strategies therein. This trend, paired with global access to markets, has resulted in an emphasis on prefabricated (prefab) building systems. Prefab contains the opportunity to pair control on a local level with global access.

As a result, the Virginia Tech Solar Team (VTST) bases much of its industrialization and market viability within the realm of prefabricated building systems. VTST further places major emphasis on a **duality** of prefabricated building systems through the context of architecture; meaning, many industrialized processes and, therefore, structures sacrifice **quality** of design for **marketability**, **affordability** or **sustainability**. Homebuyers should not have to make this sacrifice. Our home of the future integrates design with industrial process as response to market and environmental challenges in the built environment. Our work is one of "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 architectural context through prefabrication (industrialization) success that responds to the following current, critical parameters: industrialization and assembly processes, marketability, public appeal and affordability of total product. Further, industrialization success requires appropriate prefabrication solutions through: innovative transportation techniques, flexible designs, multiple design models, intelligent facilities and building assemblies' automation. Our solutions through prefab are designed to increase marketability through access to broad markets and demographics, while also promoting solar power as a viable option for today's home.

## Concepts to be Evaluated

Based on "Rule 23" of the "SD Europe Rules and regulations," there exist three objective and three subjective sets of points awarded for this portion of the competition. The following concepts are included herein for objective/subjective evaluation: S1) Degree of Industrialization, S2) Possibilities of Grouping and S3) Assembly Process. The following concepts are further included herein for objective evaluation: O1) Objective Marketability of the Product, O2) House Appeal and O3) Technical Economic Feasibility.

### S1) Degree of Industrialization

[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.

lumenHAUS achieves a high degree if industrialization through a solid core structure that provides flexibility to all supplementary building system attachments. As a foundation to our industrial process, an innovative transportation system allows the house to be moved easily without expensive permitting and very little on-site construction or assembly. The system, which is inspired by and integrated into the double drop lowboy trailer (Image 1), is made up of removable components (axle/wheel assembly on the back and hitch hookup on the front) allowing for simple truck transport, flexible suspension, and higher height clearances than conventional modular transportation methods. Affordability, ease and efficiency of transportation, is a critical component to the industrialization of construction processes and the future of prefab, modular construction. Later sections of our plan illustrate ease of mobility for this system.

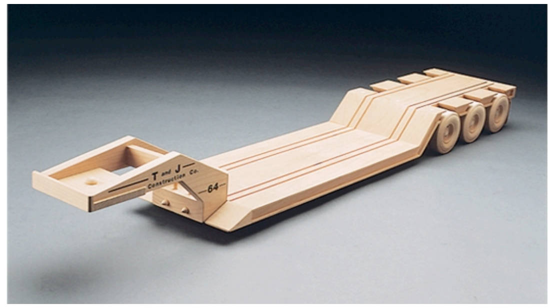


Image 0: Lowboy Trailer Concept

We begin this industrialization and market viability plan with our transportation system and then highlight the many possibilities of grouping such structures. We then discuss advantages of prefab, factory built assemblies including: higher quality control, lower construction cost and less construction waste. Further, manufacturing technologies present economic opportunity through, local workforce development (both skilled and unskilled) and sustainable productivity solutions.

**Innovative Transportation System:**

Image 2 contrasts that of Image 1, showing a fully built integration of the home on the lowboy trailer. The house incorporates the 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). Unlike many other homes, no cranes are needed.

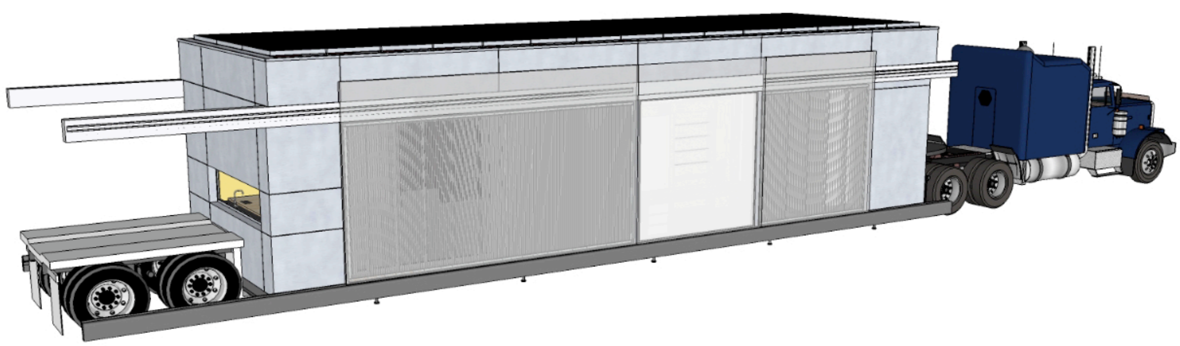


Image 2: Transportation System

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.

**S2) Possibilities of Grouping**

Due to the ease of mobility, lumenHAUS's design further provides for community and lifecycle solutions through multiple units that connect or stack.  A series of additional components, such as plug-in stairs and entryways, make a holistic system and viable product for variable and changing markets.  A sustainable community, an extension of the lumenHAUS concept called lumenCITY (Image 3), has been developed by the team which models different affordable housing schemes and envisions neighborhood growth through a trading of modules to one another, accommodating growth or the modern aspect of shrinking community. lumenHAUS ultimately positions housing solutions at the epicenter of modern, local economies through the promotion of a responsive, technical product and workforce development.

Image 3: lumenoCITY- Streetscape

lumenHAUS will be available in different models, as seen in the (Image 4) configurations below, with varying materials and sizes, appealing to a broad market.  Configurations include side-by-side and stacking schemes that allow for increased openness of the house, depending on the orientation and ability to use passive parameters.  The house presented in Madrid 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.  The 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 efficient, versatile and adaptable.

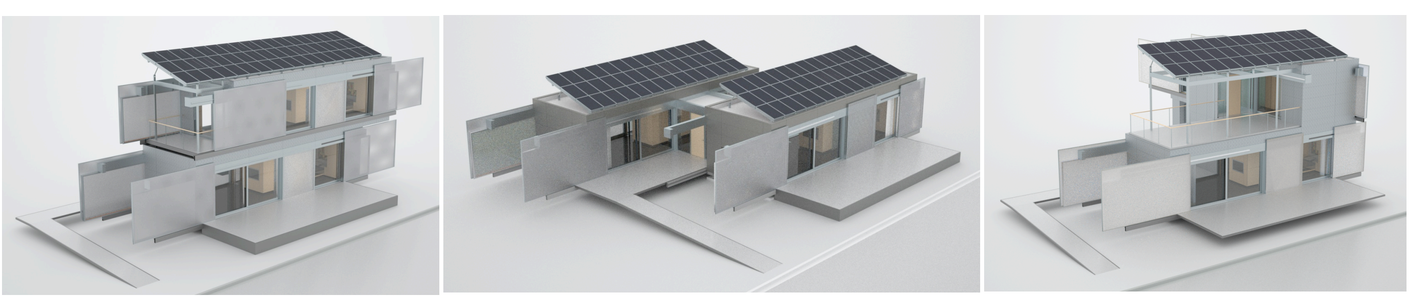


Image 4: lumenHAUS Configurations- Up Close

In grouping the home for multiple markets and possible configurations, the Virginia Tech house is designed to provide affordable and innovative building automation techniques for all markets as well. The automated systems are controlled with an Apple iPhone which has a proven market for its ease of use for all ages and reliable consumer product history, costing approximately $300 and decreasing in cost with advances in technology. 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.

**S3) Assembly Process**

While the home is easily moved and configured, our simply refined system allows for multiple assemblies on the same structural frame (Image 5). The core of the house is a steel frame that supports all of the industrial systems included in our design, while also an open system for other customized configurations, if desired. Further, the exact nature of the steel frame allows for ease of supplementary system designs that can be drawn and manufactured to a high degree of tolerance and control. For the purposes of this report, we will discuss the assemblies designed, prefabricated, then installed on lumenHAUS.

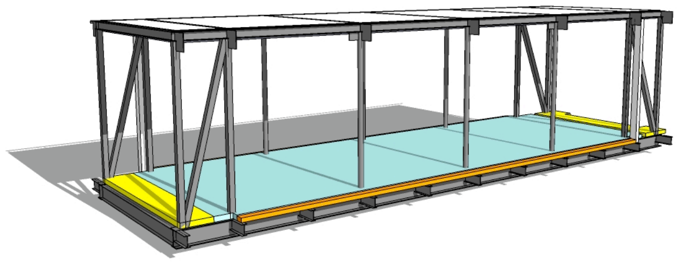


Image 5: lumenHAUS Steel Skeleton

Following the manufacturing of the steel skeleton, the Structural Insulated Panel system (SIPs) was built off-site, delivered to the prototype construction site and attached. Once attached, the SIPs combined high energy efficiency with an appropriate sub-surface for all subsequent materials created through industrial processes. Initially, multiple glazing systems were produced off-site and delivered, all fitting properly according to the designed tolerances. Next, VTST designed and installed a zinc-plated metal siding system from Robert A. Zahner Company (known for Frank O. Gehry buildings). During the same period of time, an innovative modular roofing system (termed V2T vent) was detailed, pre-fabricated and installed onto the SIPs sub-roofing (http://sites.google.com/site/v2tventurivent/) and behind the parapet wall. VTST also placed a cast-in-place concrete floor on top of radiant PEX tubing, allowing for solar heat gain and structural rigidity of the frame. Next VTST implemented its automated systems, attached to the exterior of the house, designed to respond to the environment by controlling thermal conductance, radiation or light transmittal. Due to the exactness of the frame and subsequent systems, the many innovative home components fit properly, limiting air infiltration, thermal conduction, material waste, and labor scope creep, as will be expanded upon later.

The house's exterior also incorporates major kits of parts, such as shown in Image 6 below, which require remote assembly and can easily be attached to the home's main structure. Each additional item attached to the home is therefore customizable for the locality, environment or desires of the homeowner. To begin, a series of insulation panels move along the exterior of the home. These panels were built off-site to the limits of common polycarbonate dimensions and then connected to automated tracks along the exterior. Depending on whether energy needs to be trapped, released or insulated against, the panels move across the main façade of the building (directly in front of the expanses of glass windows).

The concrete floor easily gains thermal mass from sunlight, so this surface requires shading. Outside of the insulation panels are laser-cut screens that therefore interact with the local environment to shade and protect the home and its inhabitants, or offer full access. The inhabitants might also desire occasionally obstructed views into the home, depending on the space. Light is reflected through the screening, improving the quality of light at specific times of the day. All of these considerations were incorporated into the prefab design of the screens that attach onto the same automated tracks as the panels behind. Image 6 also shows the photovoltaic panels that rest on top of the house (prefabricated and attached). The basic structural system used in the house allows for this heavy load to move atop the house for optimal inclination.

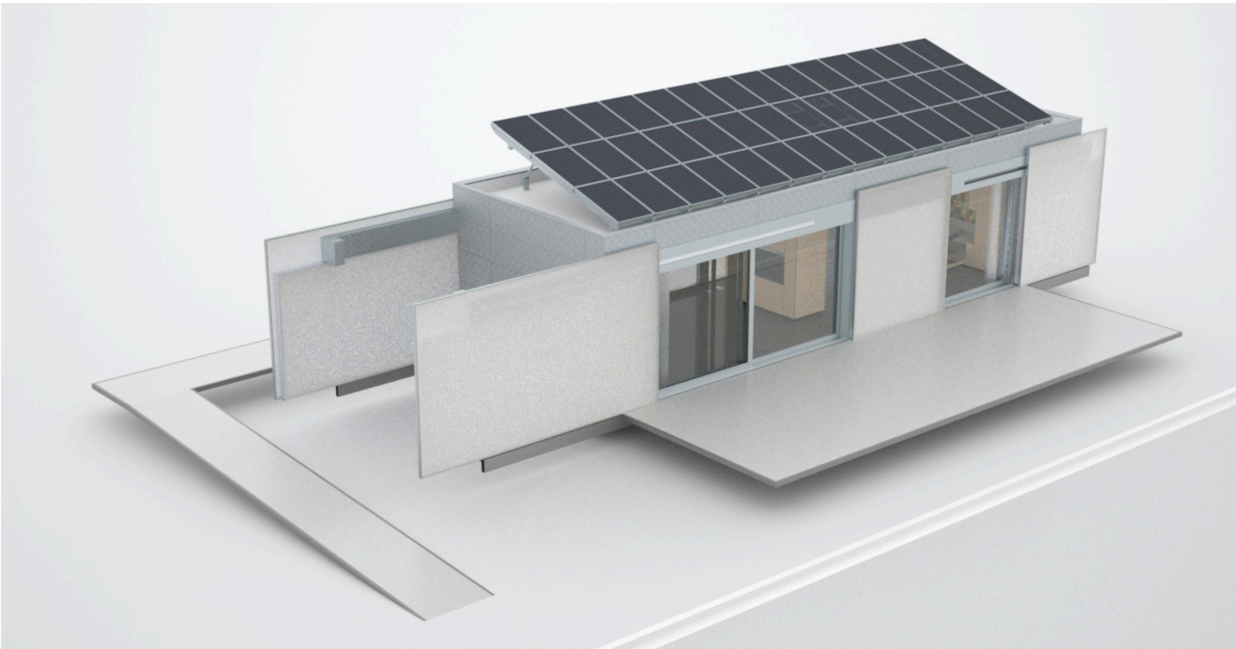


Image 6: Assembly Kit of Parts

Among other elements, the image above illustrates the decking system, a prefabricated modular system that adapts to multiple settings and also combines water features necessary for many of these settings. Each section of the decking is a modular design that simply attaches at the wooden structure (joists). The decks rest upon simple columns that adjust up and down, depending on the grade elevation, or to the side, depending on the slope. The decking modules can also be removed to allow for landscaping elements on between or to adapt to pre-existing conditions such as a tree. Now that the many subjective merits of lumenHAUS have been explained, we will move on to the objective portion of our market viability plan.

**O1) Objective Market Viability of the Product**

In an effort for accuracy of study, VT Solar Decathletes define the following terms for use in our market viability:

- *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) Buyer-Related Analysis**

The VTST bases much of its marketability analysis of previous housing and supporting structure examples, in the US and Europe, 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) | Buyer Market | Successful Features |
|---|---|---|---|---|---|---|
| Glidehouse | Michelle Kaufmann | Oakland, CA | 2210 sf | $163.00 | Single Family | 1. Multiple Configurations<br>2. Flexible Designs |
| Flatpack | Lazor | Minneapolis, MN | Varies | $300.00 | Varies | 1. Flexible Designs<br>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<br>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<br>2. Multiple Configurations |
| P.L.U.G. | Lutz & VT Students | Maha Mountains | N/A | N/A | Research/Single Family | 1. Transportation<br>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<br>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<br>2. Transportation |

**Table 1: US & European 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.

**O2) House Appeal**

**Livability**

lumenHAUS has been designed to provide a client (Family, couple or individual) with a beautiful, resource-limited, 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 for the 2009 Solar Decathlon competition, which are still pertinent to this context, and the solutions implemented in the design of the home.

The most important livability consideration of our home is 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 quality of surrounding 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 most 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 a software application on the homeowner's portable communication device.

lumenHAUS considers "liveability" as central to house appeal. The 2009 Solar Decathlon competition specified all of the "Livability Considerations," except for the row category "Prefabrication" at the bottom, addressed in Table 2. We feel these considerations remain pertinent to any discussion of house appeal. VTST further includes 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 | Questions of Livability | lumenHAUS 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. |
| | 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. |

| Livability Considerations | Questions of Livability | lumenHAUS Livability Considerations |
|---|---|---|
| | 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. |
| | 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. |

| Livability Considerations | Questions of Livability | lumenHAUS Livability Considerations |
|---|---|---|
| | 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. |
| 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 |

| Livability Considerations | Questions of Livability | lumenHAUS Livability Considerations |
|---|---|---|
| | | 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. |

## O3) Technical Economic Feasibility

### O3.1 Production Viability

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.

In response to the requirements of the SD Europe competition, VTST posits the following scenarios for lumenHAUS production values. Table 3 reports production values in terms of each scenario's value calculations and profit per year. Value calculations are based on initial investment, expenses, interest, depreciation, tax implications (US tax code), building profit and basic return. Profit calculations are based on cash flow, appreciation, tax savings, total return and return on equity. Recovery time is considered, for our work, as the number of years for the total investment return per year (line 19) to reach the initial investment amount. These costs are delineated for the market based on Low production level (2 houses/year), Medium production level (100 houses/year) and High production level (1000 houses/year). According to home builders interviewed, low production costs contain no discount from efficiency or bulk values, Medium contains 25% reduction in building costs and High contains approximately 40% reduction in initial costs of building. These reduced costs are accounted for in line 2 (Loans) below. All values are in US dollars for comparison (currently a 1.43 multiplier to Euros).

**Table 3: Value Calculations & Profit Reporting**

| | | Scenario | | | | | |
|---|---|---|---|---|---|---|---|
| | **Value Calculations** | **Low (2 each)** | | **Medium (100 each)** | | **High (1000 each)** | |
| | | Amounts: | Totals: | Amounts: | Totals: | Amounts: | Totals: |
| **1** | Property Value | 75,000 | $ 150,000.00 | 7,500,000 | $ 7,500,000.00 | 75,000,000 | $ 75,000,000.00 |
| **2** | Loans | 860,000 | $ 860,000.00 | 32,250,000 | $ 32,250,000.00 | 258,000,000 | $ 258,000,000.00 |
| **3** | Equity (10% down) | 10% | $ 86,000.00 | 10% | $ 3,225,000.00 | 10% | $ 25,800,000.00 |
| **4** | Yearly Gross Income: Amt./mo. x 12= | 5435.78 | $ 65,229.36 | $271,789.00 | $ 3,261,468.00 | $ 2,717,890.00 | $ 32,614,680.00 |
| **5** | Yearly Expenses: Amt./mo. x 12= (25% of gross income) | | $ 16,307.34 | | $ 815,367.00 | | $ 8,153,670.00 |
| **6** | Loan Payments: Amt./ mo. x12= | $4,939.07 | $ 59,268.84 | $194,384.33 | $ 2,332,611.96 | $1,628,427.19 | $ 19,541,126.28 |
| **7** | Interest: loan amount x 4.2%= | | $ 42,420.00 | | $ 1,669,500.00 | | $ 13,986,000.00 |
| **8** | Loan Payoff (Line 6 – Line 7)= | | $ 16,848.84 | | $ 663,111.96 | | $ 5,555,126.28 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **9** | Cash Flow (Line 4- Line 5 – Loan 6)= | | $ (10,346.82) | | $ 113,489.04 | | $ 4,919,883.72 |
| **10** | Depreciation: (Guess based on 5000 w/ $220,000 home) | | $ 19,545.00 | | $ 732,954.55 | | $ 5,863,636.36 |
| **11** | Tax Shelter (Line 10 – Line 9 – Line 8)= | | $ 13,042.98 | | $ (43,646.45) | | $ (4,611,373.64) |
| **12** | Tax Savings (tax bracket: 28% x line 11)= | | $ 3,652.03 | | $ (12,221.01) | | $ (1,291,184.62) |
| **13** | Building Profit (line 8 + Line 9 + Line 12)= | | $ 10,154.05 | | $ 764,379.99 | | $ 9,183,825.38 |
| **14** | Basic Return (Line 12/Line 3)= | | 35.97% | | -1.60% | | -14.06% |

| | | Scenario | | | | | |
|---|---|---|---|---|---|---|---|
| | **Profit Calculations** | **Low (2 each)** | | **Medium (100 each)** | | **High (1000 each)** | |
| | | Amounts: | Totals: | Amounts: | Totals: | Amounts: | Totals: |
| **15** | Cash Flow (line9) | | $ (10,346.82) | | $ 113,489.04 | | $ 4,919,883.72 |
| **16** | Loan Payoff (line8) | | $ 16,848.84 | | $ 663,111.96 | | $ 5,555,126.28 |
| **17** | Tax Savings (line12) | | $ 3,652.03 | | $ (12,221.01) | | $ (1,291,184.62) |
| **18** | Appreciation: 1.5% (inflation)x Line 1 | | $ 2,250.00 | | $ 112,500.00 | | $ 1,125,000.00 |
| **19** | Total Investment Return (Line 15 + 16 + 17 + 18) | | $ 12,404.05 | | $ 876,879.99 | | $ 10,308,825.38 |
| **20** | R.O.E. (line 18/line 3) | | 2.62% | | 3.49% | | 4.36% |

Based on the numbers proposed above, the sum of lines 1&2 (total initial investment) divided by total investment return per year (line 19) should yield the total number of years for a return on investment (recovery) on lumenHAUS. For the Low Production scenario, this would be a period of 81.4 years. For the Medium Production scenario, this would be a period of 45.33 years. For the High Production scenario, this would be a period of 32.3 years. These numbers suggest that the VTST housing system, through its industrial processes, would have a much better recovery period through high production; high production factors being a 40% reduction from low production return periods.

### O3.2 Target Markets

Marketing is made most efficient through identifying a product's target markets. VTST submits the following target market parameters as a basis for our work:

- Locations: European metropolitan areas
- Housing type: Single family detached house
- # of occupants: Two adults
- Occupant demographic: 25 -30 year olds OR<br>55 – 70 year olds
- Homeowner annual income: 150K US Dollars (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 4 identifies a range of possible target markets for lumenHAUS. Tables 5 and 6 further apply affordability constraints to our home through income level and geographic location likely for our market's homeowner.

**Table 4: Target Markets**

| Market I.D. Parameter | 1 | 2 | 3 |
|---|---|---|---|
| Location of Permanent Site | Germany | Spain | United Kingdom |
| 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 | $95,000 | $70,000 | $87,000 |
| # of Bedrooms | One | One | One |

### Market 1- Germany

The average household size in Germany is 125 square meters. While household income in Germany is higher than any other market, the cost of housing is high. We decided to use an average housing cost value of DM4840 ($3,436.40) and a building land average value of DM80.5 per square meter ($57.16) for a total of $3493.56 per square meter. This equals approximately $388.17 per square foot which comes close to the cost of our home, making lumenHAUS affordable in the German market.

### Market 2

The average household size in Spain is 97 square meters. According to BBC news, the average housing price in Spain was 240,000 Euros ($328,560) last year. While household income in Spain is on the low end of our chart, the housing costs are also high. At 873 square feet average household size and $328,560 average household cost, that results in a cost of $376.36 per square for average housing, making lumenHAUS close to affordable in the Spanish market.

### Market 3

The average household size in the UK is 76 square meters. According to BBC news, the average housing price in the UK was 224,064 pounds ($352,900) last year. While household income in the UK is in the middle of our chart, the housing costs are also high. At 684 square feet average household size and $352,900 average household cost, that results in a cost of $515.93 per square for average housing, making lumenHAUS affordable in the UK market.

**Table 5: Affordability: Qualifying Income Approach**

| Year | Cost of Single Family Home (average) | Qualifying Income | Home Affordability Ratio (Cost/Income) |
|---|---|---|---|
| 2008 | $361,536.78 | $87,965.15 | 4.11 |
| 2009 | $372,718.33 | $87,287.67 | 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 (US) was developed to identify a family's necessary income to purchase lumenHAUS. Data from the US 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, which we are comparing to those in Europe. These averages were noted for 2007 and 2008 (based on US affordability indexes) 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. Recent 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 4 & 5, 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 6: Geographic Costs of Housing**

| Location | $/Sq. Ft. | Avg. Sq. Ft. of Single Family Home | Cost of Average Single Family Home |
|---|---|---|---|
| U.S. | $92.51 | 2479 | $229,332 |
| Germany | $388.17 | 1125 | $436,691 |
| Spain | $376.36 | 873 | $328,562 |
| United Kingdom | $515.93 | 684 | $352,896 |
| VT Lumenhaus | $510 | 810 | $430,000 |

**Cost of Housing in Germany, Spain and UK is 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 Europe. The cost per square foot of homebuilding in each location and the average square footage of a single family home were taken from various websites. These two numbers were then multiplied to establish an estimated cost of a single family home for each location. Germany is more affordable per square foot than lumenHAUS, but not when looking at the average household cost. The UK is comparable to lumenHAUS in price per square foot, while not close to the average household price. lumenHAUS seems the least appropriate for the Spanish market, based on our numbers. lumenHAUS remains affordable in almost all markets, though, according to these parameters.

## 4) Conclusions

As a research project, lumenHAUS proposes to concentrate on issues of innovative systems for buildability, affordability in sustainable home construction and a competitive price in the European market through the use of prefab technologies. Table 7 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 7: 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.

Our data show that the cost of the house in place in Madrid 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 25% less for medium production and approximately 40% for high production. 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 European living, as it is transportable, and the affordability would currently match many local household incomes.

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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lumenHAUS

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Virginia Tech

# SUSTAINABILITY REPORT

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## I. Concept of Sustainability

Energy consumption in residential and commercial buildings accounts for 39 percent of our nation's energy budget. Buildings typically operate at less than 50 percent overall efficiency. With the nation's energy security and future in mind we must challenge the status quo and re-invent the way energy is used in residential building. This requires bold gestures that will increase awareness and spur action.

The best way to have sustainable building is to use as little energy as possible. To this end and throughout our design we have implemented a dual approach of technological innovation and common sense decisions. Computer monitoring and controls, sensors and servomotors linked as a centralized system, and moveable building components that are adjusted on an hourly, daily, or seasonal basis comprise an integrated system that optimizes building performance. Left to individual action, most people do not have habits that conserve energy – consider the lights left on in a vacant room, or the shades that are rarely moved. The automated systems of LUMENHAUS are designed to maximize the conservation of energy.

Correspondingly, the pavilion type architecture allows for an immediate and open connection to the outside. The natural cross-ventilation extends the comfort range at least five degrees and reduces the need for air conditioning. Passive heating gathers sunlight on the dark floor and radiates heat back to the room at night. The concrete floor

This project aims to conceive, design, and build a house that is bigger than itself—to create a place so tied to its surroundings, it literally opens up to them. With the goal of enriching patterns of daily life, the Virginia Tech "LUMANHAUS" celebrates energy awareness and resource conservation by bringing the outside to the inside. As much in the tradition of "pavilion," as "house," the interior space flows uninterrupted to a porch and landscape design that is integtated to the interior spaces. While our position is that a well-conceived, well-detailed, and well-built house is necessary to the concept of sustainability, it is by no means sufficient. Rather, we reject the idea that a building with both beauty and performance is anathema, and to that end, embrace quantitative analysis, empirical rigor, and innovation.

Central to the pavilion experiences is the method by which the house opens. Ours is a responsive architecture (to the regional climate, the daily weather, and the user's whim). The north and south walls contain  layers that can be deployed based on preset conditions or immediate occupant preference. The enclosure system consists of four discrete movable layers that can be manipulated to alter the energy balance of the building, to optimize for human thermal comfort or to adjust the economy of operation. These individual layers, moving from outside to inside, include a movable perforated stainless steel sunscreen, a movable aerogel filled translucent insulated panel with a perimeter air seal, a series of very large movable sliding glass doors, and a motorized movable curtain system providing additional solar control and privacy. These layered membranes move automatically by motor to optimize based on occupancy and weather, but at any point the automation can be overridden by occupant preference using a standard i-Phone interface. While we embrace materials reuse, water conservation, healthy indoor air, low-embodied energy materials, and the other tenets of sustainable building, ours is an "energy-first," approach with a secondary emphasis on daylighting. We focus on energy-use because it is a major metric for overall sustainability; we focus on daylight because of its contribution to a low-energy strategy and because of its impact on human performance, livability, and health. When the weather is right our pavilion approach allows us to replace low-energy concepts with no-energy concepts. These are executed through direct solar gain, solar shading, and cross ventilation.

Reinforcing these passive heating and cooling whole-building concepts are a series of well-established green building strategies. All our energy is provided by grid-tied, photovoltaics. Our home is heated by high-efficiency dual heat pumps (a water-to-water heated floor slab system for the steady state thermal condition of colder months and a water-to-air system for the periodic heat flow regime of warm and temperate months and air conditioning in the summer). Waste heat from the heat pump in the summer is recovered for domestic hot water and a heat exchanger recaptures the heat of exhaust air and transfers it to intake air. LED and high-efficiency florescent light fixtures automatically dim in response to daylight and occupancy sensors; our house is built with an eye for air-tightness and high thermal resistance (R-Value); we use vegitation to filter our Greywater before reusing it; our appliances and fixtures perform at (and typically well-above) Energy Star standards for energy and water use; we've designed and built with low VOC finishes; and finally, we've taken advantage of the reuse of materials inherent to the modular building process.

While many of these strategies have gained wide use, especially in recent years, we embrace innovation and look forward to "what's next." As a multi-disciplinary project, and as one that will likely be visited by hundreds of thousands of people, it is the innovative that we wish to research and promote. Aside for our i-Phone interface, we utilize movable insulation panels and automatically tinting eclectrochromatic glass, bifacial seasonally-tracking photovoltaics and a high albedo roof membrane from which to bounce light, smart-grid-ready technology and high-efficiency inverters, and finally, linear air diffusers with actuators that redirect the air to optimize for thermal comfort as it relates to the season. To be clear, it is not novelty that we seek, but rather an exploration into, and a showcase for, promising technologies.

Open floor plan and efficient design reduce building materials and allow for a "larger home feel" while maintaining a smaller footprint. LUMENHAUS utilizes responsive architecture to respond to climate and site conditions, as well as the needs of the inhabitant. The house works with the weather, rather than against it, utilizing good weather through pavilion design. Use of the deck area can double the square footage of the house to accommodate guests. Unobstructed sight lines expand interior spaces. Whole building design construction approach includes the use of recycled or recyclable materials, which decreases initial environmental impact and end-of-life waste. Space saving storage hardware is used throughout the house. Building orientation and site planning allow for optimal passive strategies and active solar and water collection. Use of technology educates the homeowner as to the amount of energy each appliance is using which can reduce overall energy use. Automated processes ensure user-friendly energy savings. Photovoltaic panels and geothermal loop produce energy, making LUMENHAUS net positive. Use of light powers the home, requires less artificial light, and brightens the life of the homeowner. Studies show that natural daylight increases personal health. Finally, the steel frame of the house serves as the transportation carriage and minimizes site assembly. Because of the prefabricated process used to build the house, construction waste is minimized and efficiency of building is increased.

## II. Bioclimatic Strategies

For envelope-dominated buildings such as residential buildings, the outside conditions on the site can highly influence building indoor comfort. For a hypothetical site located in Madrid, Spain, there are 536 hours in 8,760 hours per year that fall within the ASHRAE Standard 55 and 2005 California Residential Energy Code comfort zone. During these comfort hours, 6% of the year, neither heating nor cooling is required to maintain the interior conditions, saving energy.  We are not nostalgic for a time when passive means (and fire) were our only means of thermal comfort. Rather our goal involves using passive strategies to effectively *stretch* the comfort zone, to include more hours, then supplement as needed with active means.

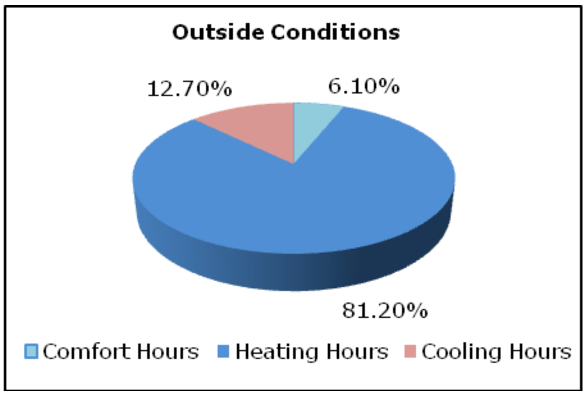


**FIGURE 1 - OUTSIDE CONDITIONS**

The program Climate Consultant v.4 was used to research and analyze the climatic conditions and propose design strategies to increase comfort levels. This program generates charts detailing the temperature range and relative humidity for the given site, shown in the figure, below. Note that the temperature-humidity combination only sits in the comfort zone for a small percentage of the year.

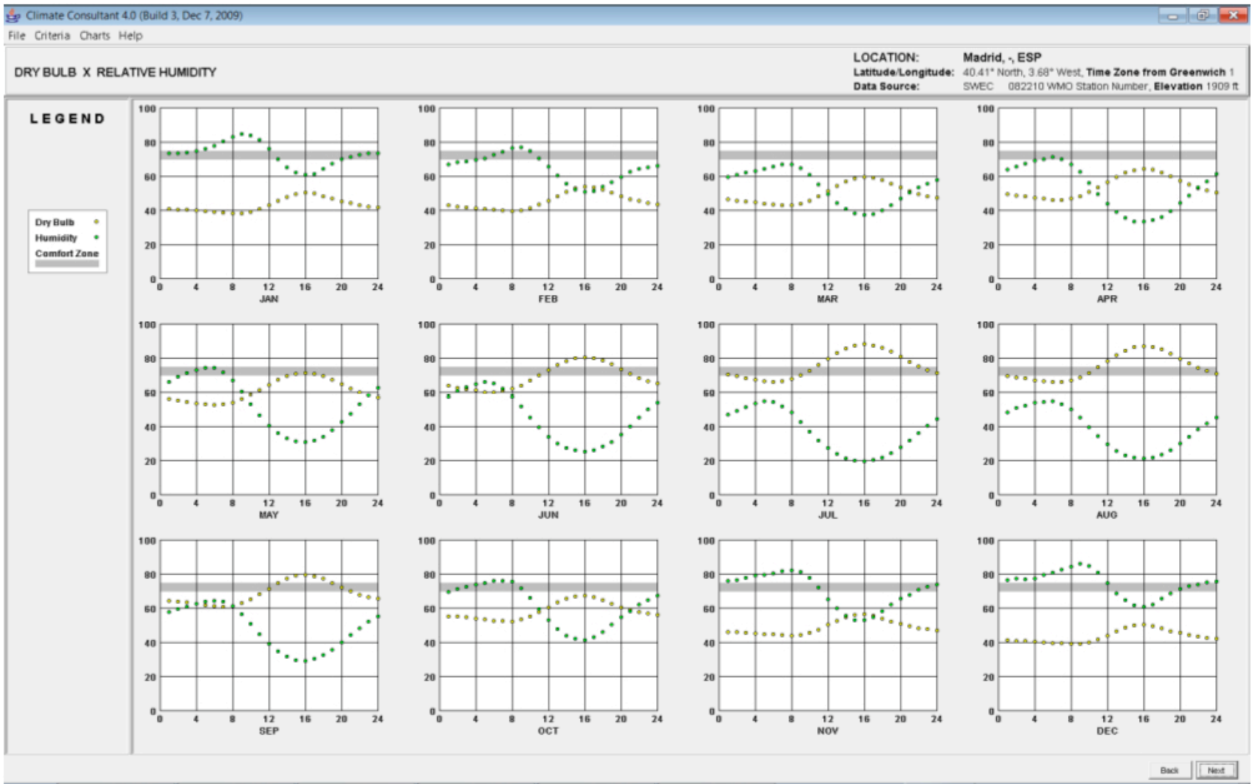


**FIGURE 9 - DRY BULB TEMPERATURE VS. RELATIVE HUMIDITY**

**FIGURE 2 – DRY BULB TEMPERATURE VS. RELATIVE HUMIDITY**

Specifically, our passive heating and cooling goals are as follows: (1) reducing the indoor comfort temperature at night to reduce heating energy consumption, (2) keeping the building well insulated to take advantage of heat gain from equipment, lights, occupants, and thermal mass, (3) minimizing infiltration and unwanted ventilation during heating days with air locks, (4) locating the heat source centrally to reduce traveling loss, (5) reducing the building footprint, (6) employing south facing windows for heating the thermal mass, (7) utilizing ventilation on cooling days to lower the comfort zone at least 5 degrees, (8) placing exterior wind shields on the site to protect from winter winds, (9) providing extra insulation to keep indoor temperatures more uniform, and (10) reducing night time heat loss with insulating members.
The effects of proposed passive heating and cooling design strategies are shown in the psychometric chart in the figure, below.

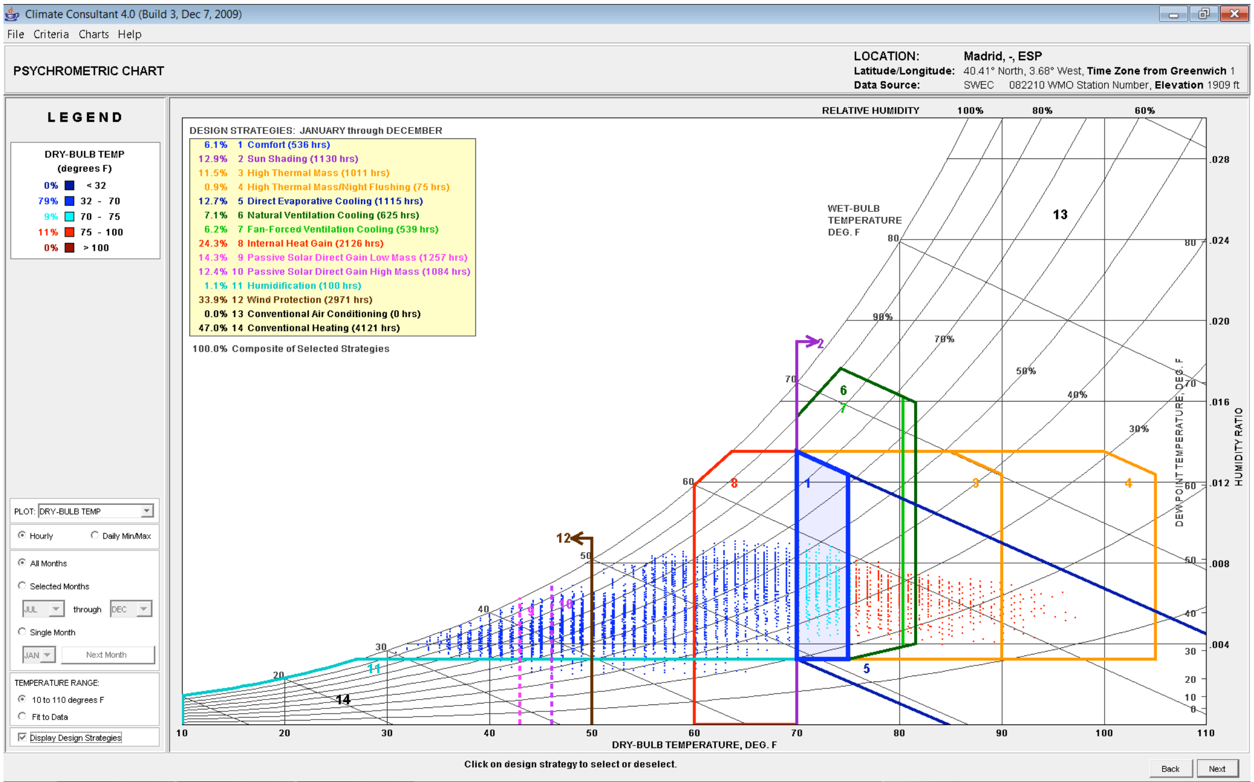


**Figure 3 - Psychrometric Chart (All Months) with Possible Design Strategies**

This chart shows the annual exterior dry bulb temperatures outside of the comfort zone and how the employed design strategies adjust the conditions to maintain the comfort zone despite time of year or day. The inertia that is part of human habit often dictates the relationship of a building to its environment. For instance, one might close a window immediately when cold, then wait days to open it again, long after exterior temperatures moderate. When glare enters a building, shades are deployed, only to stay down long after glare is gone in anticipation of tomorrow's glare. By contrast, LUMENHAUS sports solar shading, insulation panels, apertures for breezes, lights, and mechanical systems that are automated, allowing the house to automatically adapt without the need for (but always with the option of) user control.

We believe that the majority of our space cooling need can be met by sun shading (with night ventilation/thermal mass) and ventilation. Our analysis suggests that space cooling is required for 13% of the year; but per that analysis, sun shading can effectively cool the space for the same portion of the year. (Experience, of course, suggests that mechanical cooling will still be needed at times, regardless of the software output.)  Importantly, the geometry of our solar shading screen protects the house from direct sun between June and September from 10:00am to 6:00pm and provides privacy all day, yet it allows for simultaneous cross ventilation.

Sun path diagrams can serve as tools for determining the optimum position of the sliding panels. The figure, below, illustrates the path of the sun throughout a given day in the year from June 21 to December 21.

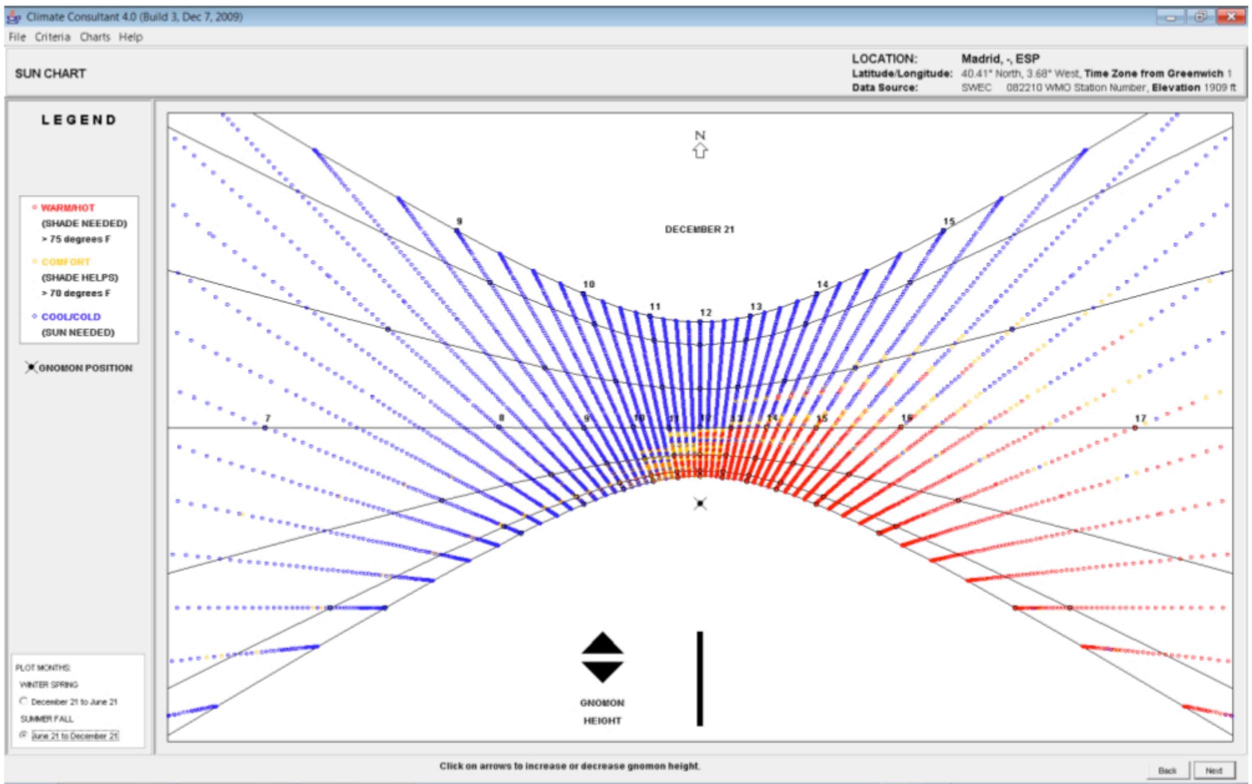


FIGURE 11 - SUN CHART (JUNE 21 TO DECEMBER 21)

**FIGURE 4 – SUN CHART (JUNE 21 TO DECEMBER 21)**

The red indicates when shade is needed while the blue indicates when sun is needed. Using this data, the panels will be programmed to open and close and provide interior comfort based on solar geometry and temperature.

By contrast, the analysis indicates that passive heating strategies alone cannot sufficiently heat the house without mechanical system assistance. For this, our strategy begins with a foundation of high insulative values and low infiltration levels. The direct solar gains facilitated by the south facing glass and thermal mass are doubly beneficial when coupled with the nighttime insulation provided by the deployable polycarbonate-aerogel panels, which not only keep in the solar thermal gains acquired during the daytime, but also trap internal nighttime thermal gains.

### III. Water

Water strategies for LUMENHAUS center on water conservation through efficient interior appliances and fixtures, as well as a landscape system that integrates the exterior and interior environments inclusive of rainwater harvesting system and constructed wetlands. The goals of the landscape plan are as follows:

- 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

The water budget for LUMENHAUS is as follows:

| % | Water (gallons) | Use |
|---|---|---|
| 11% | 300 | Potable water tank |
| 4% | 100 | Reservoir for charging the sun |
| 74% | 2000 | Geothermal pool |
| 11% | 300 | Rainwater harvesting tanks |
| | 2700 | Total |

**A. Strategies for the reduction of consumption**

Efficient appliances and low-flow faucet technology help us use less water. The dishwasher and washer were selected to be water efficient. The Saile brand toilet with Dual Flush technology has the option of a 1.6 gallon per flush water consumption or an eco-friendly 0.8-gallon flush. The Saile toilet can save as much as 22,200 gallons of water annually compared to a 3.5-gallon toilet. It also meets the EPA's (Environmental Protection Agency) strict WaterSense flushing performance guidelines that stipulate toilets use at least 20% less water than standard 1.6-gallon toilets.

**B. Recycling, reuse**

Rainwater is harvested, stored, and purified in order to create a self-sufficient water supply for LUMENHAUS. The system has been designed to utilize both treated and untreated rainwater. The untreated rainwater can supplement the grey water system in maintaining the health of biological system, while the rainwater treated with a chlorine injection allows for a potable use such drinking or washing.

Grey water is water that has been used in processes within the house, excluding the water closet and kitchen sink. This water represents approximately 60% of the household wastewater. Our system intends to reuse this water, therefore offering a significant savings in the need for potable water. In order to reduce concerns that have been raised regarding the use of grey water, our system engages natural and ultraviolet decontamination processes to ensure its safety. The grey water system uses nature to purify water for additional uses; 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 the construction, management, and setup of the system. The hydroponic wetland provides high performance levels for Biological Oxygen Demand (BOD), and a reduction of Total Suspended Solids (TSS). The grey water treatment system will take discharge from the bathroom sink, shower, washing machine, and dishwasher and pass it through a three-stage system for purification and subsequent reuse. The first stage of treatment involves a sand, soil, and membrane filter which removes particulates. The water then moves through the second stage which involves a series of progressive hydroponic pools where aquatic plants utilize and remove phosphorous, nitrogen, potassium, and other trace elements. Finally, in the third stage, the grey water is passed through a UV filter and may then be used to irrigate the planting beds and other terrestrial plants, used to supplement black water to sustain the health of the anaerobic septic system, or used as a water source for the toilet (W.C.). The hydroponic pools are interconnected in a positive, single-direction flow to facilitate the entire process. The grey water is circulated through the system using a single, low-pressure, low-volume, low-energy pump.
The second stage of grey water treatment involves the use of hydroponic plants, or plants that pull their nutrients from water rather than soil. These plants use biological processes to treat waste water, prevent the growth of algae in order to keep the basins clean naturally, and repel insects to prevent infestation. The water hyacinth, or eichhornia crassipes, is often used in wastewater treatment for its ability to grow quickly, tolerate high levels of pollution, uptake heavy metals, and enhance nitrification. The plant can be utilized for the biocleaning of industrial wastewater though its high capacity to uptake metals such as Cd, Cr, Co, Ni, Pb and Hg, and even cyanide. Water hyacinth is also observed to enhance nitrification in waste water treatment because their root zones are excellent micro-sites for bacterial communities. Due to its abundant nitrogen content, it can also be used as a substrate for biogas production and the sludge obtaind from the biogas. Bronze Canna (*Canna australis*) and Pickerel Weed (*Pontederia cordata*) also extract many undesirable pollutants in this wetland environment as they too have a high tolerance for contaminants.

Dwarf Umbrella Palm, or cyperus alternifolius 'Gracillis', is more of a special interest plant. It has received attention for being a larger, fast growing species that could be used in the production of paper and even biofuels. This plant is also used as food for the larvae of some Lepidoptera species. The seeds and tubers are an important food for many small birds and mammals. Common Rush (*Juncus patens* 'Carmen's Grey') is also used as a food plant by the larvae of Lepidoptera species. These plants begin a food chain and can sustain the needs of other animals. Japanese Aster (*Kalimeris incise* 'Variegata') can attract butterflies, adding to the overall atmosphere created by the water basins.
Water Cabbage, or *Pistia stratoites*, prevents the growth of algae within the basins by outcompeting it for nutrients within the water. The submerged portions of this aquatic plant provides habitats for micro and macro invertebrates, which in turn can be used as food for fish and other wildlife species. It creates an environment that is welcoming to a food chain.

Pitcher Plant (*Sarracenia*) leaves are a necessity to the aquatic life as they prevent the growth of insects within the water. Their leaves have evolved into a funnel that traps insects and is able to digest them using prteases and other natural enzymes. In addition, the variegated Society garlic (*Tulbaghia violacea* ‘variegata’) leaves not only can be used in salads for human consumption, but have a garlic odor that is said to repel insects.

In addition to the hydroponic plant life, there is a surface landscape ground cover system. This system is designed to absorb carbon dioxide 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 has a dense and course texture, thereby increasing the leaf surface area for the sequestration of carbon dioxide. The use of varieties of sedum as the principal plant material ensures increased carbon dioxide sequestration. The large 'sedum lawn' is built on a special water-holding, soil foundation that aids in on-site percolation of the run-off from the decks, the ramps, and other impervious surfaces surrounding the house. It is important to note that this system resembles the setup of a conventional green roof system, but by permanently setting it into the earth a runoff detention system is formed.

### C. Treatment of wastewater

The water from the toilets, or blackwater, is treated through a conventional, gravity-fed septic system. The septic field drain is located over the geothermal heat exchanger, thereby improving the geothermal heat exchanger's efficiency.

## IV. Solid Waste

### A. Assessment Plan

Because the concept of LUMENHAUS involved substantial pre-fabrication, many of the materials were made to size, therefore eliminating any waste from production. By the very nature of the business models associated with manufacturing (as opposed to on-site building) the first choice is to procure only what you need, the second choice is to reuse what you didn’t use on the next project, and the third choice is to recycle. Specifically, the chasis, metal screens, and steel structure were entirely fabricated in factory conditions. For the on-site construction, efforts were made to size materials in the building to align with their dimensions in their raw state, further reducing waste. By choosing long materials associated with long life and durable products we aim to save both the money and energy required when replacing something. In the charts, below, the house has been separated into categories, each containing materials or products and their first and second disposal options during construction and for post use.

*Site Construction*

The decking is ordered to size limiting waste generation. Ipe deck is naturally resistant to rot & decay with high fire resistance rating with a life span of 50-70 years.

| | **Construction**<br>Option 1 | Option 2 | **Post use**<br>Option 1 | Option 2 |
|---|---|---|---|---|
| Decking | | | reuse | incinerate |
| Deck plants | compost | | compost | |
| Tarps | | | reuse | |

*Concrete*

Concrete was chosen as a floor because of its thermal mass and its durability. In addition, the weight and mass of the concrete floor is important in establishing a sense of permanence and security commensurate with a sense of dwelling and home. During construction and post use, any extra concrete is disposed of in a construction material landfill or down-cycled to be crushed and used as aggregate.

| | **Construction** Option 1 | Option 2 | **Post use** Option 1 | Option 2 |
|---|---|---|---|---|
| Plywood | reuse | downgrade | down-cycle | incinerate |
| Plastic Pads | recycle | | recycle | |
| Concrete | landfill | down-cycle | landfill | down-cycle |
| Concrete Stain | reuse | landfill | reuse | landfill |

*Metals*

During construction, any scrap metal is recycled while extra paint and de-ruster is saved for reuse. For post-use, all metal that cannot be re-used is to be recycled.

| | **Construction** Option 1 | Option 2 | **Post use** Option 1 | Option 2 |
|---|---|---|---|---|
| Metal | recycle | | recycle | |
| De-ruster | reuse | | reuse | |
| Paint | reuse | | reuse | |

*Wood & Plastics*

Polycarbonate was chosen for its thermal and light qualities rather than its material properties.

| | **Construction** Option 1 | Option 2 | **Post use** Option 1 | Option 2 |
|---|---|---|---|---|
| Wood | reuse | incinerate | reuse | down-cycle/incinerate |
| MDF | down-cycle | incinerate | reuse | down-cycle/incinerate |
| Polycarbonate | recycled | incinerate | recycle | incinerate |

*Thermal & Moisture Protection*

The Cabot Nanogel Company has been known to be re-use its aerogel waste as a pollution cleanup tool for oil spills due to its moisture resistant and absorbent qualities. PVC roof membranes and structural insulated panels (SIP) are made to size, minimizing waste.

| | **Construction** Option 1 | Option 2 | **Post use** Option 1 | Option 2 |
|---|---|---|---|---|
| Insulation | Reuse | recycle | recycle | |
| Housewrap | Reuse | recycle | recycle | |
| Aerogel | Reuse | recycle | recycle | |
| PVC | | | recycle | |
| SIP’s | | | landfill | |

*Doors & Windows*

During construction, extra aerogel is recycled. The doors and skylight are made to size. Aluminum frame sliding glass doors last decades longer than wood and vinyl.

| | Construction<br>Option 1 | Option 2 | Post use<br>Option 1 | Option 2 |
|---|---|---|---|---|
| Aerogel | reuse | recycle | recycle | |
| Doors | | | reuse | incinerate |
| Sliding doors | | | reuse | recycle |
| Skylight | | | reuse | recycle |
| Weatherstripping | landfill | | landfill | |

*Finishes*

| | Construction<br>Option 1 | Option 2 | Post use<br>Option 1 | Option 2 |
|---|---|---|---|---|
| Greenboard | reuse | landfill | reuse | landfill |
| Spackling | reuse | down-cycle | landfill | |
| Tile | reuse | recycle | reuse | recycle |
| Grout | reuse | landfill | landfill | |
| Drywall | reuse | landfill | landfill | |
| Paint | reuse | | reuse | |

*Specialties*

All kitchen, bedroom, and living components are to be re-used.

| | Construction<br>Option 1 | Option 2 | Post use<br>Option 1 | Option 2 |
|---|---|---|---|---|
| Curtains | recycle | | recycle | |
| Ceiling Fabric | recycle | | recycle | |

*Mechanical & Plumbing*

Raupex, the barrier pipe used, has a lifetime of over 50 years. For post-use, any mechanical and plumbing elements are to be reused if still able.

| | Construction<br>Option 1 | Option 2 | Post use<br>Option 1 | Option 2 |
|---|---|---|---|---|
| PVC | recycle | | recycle | landfill |
| Raupex | recycle | | recycle | landfill |

*Electrical*

All electrical elements are pre-made reducing onsite waste. For post-use, all electrical elements are to be re-used if possible.

| | Construction<br>Option 1 | Option 2 | Post use<br>Option 1 | Option 2 |
|---|---|---|---|---|
| Romex | recycle | | recycle | |

## B. Management of Domestic Waste

## V. Materials

### A. Character of the enclosure

Most of the interior finishes within the house are maple-veneered plywood from Columbia Forest's line of Pure Bond Non-Toxic Technology. This urea-formeldaye (UF) free plywood uses a Soy-Based Adhesive, which reduces air born toxins in factories, stores, and homes. Columbia Forest Products recycles scrap for fuel in their furnaces, and sells residual material to others who use it for mulch or other products. They also employ a certified team of professional foresters to work with landowners and develop timber plans that assure long-term health of the forested property. It is also cost-Competitive with standard UF construction of most decorative veneer-core hardwood plywood that's made today.

The Fleetwood sliding doors are composed of single pane glass encased in an aluminum frame. The glass comes from vendors who practice waste reduction by recycling remnants and glass scrap for future use. The recycling of glass uses significantly less energy than manufacturing from virgin materials, and also substantially reduces the production of carbon dioxide. In Fleetwood's factories 100% of the aluminum remnants are collected and melted down to make new windows and doors. This severely reduces energy input because aluminum production from scrap uses 95% less energy and limits the waste stream. Because Fleetwood's painted finishes are factory cured at 400 degrees Fahrenheit, VOCs are safely removed. All windows and doors eventually must be replaced but aluminum windows and doors last decades longer than wood and vinyl.

R-Control Structural Insulated Panels (SIPs) were used on the West and East walls as well as the roof. A SIP is a panel construction system consisting of Foam-Control® EPS (expanded polystyrene) insulation laminated between sheets of a structural sheathing such as plywood. Because they are custom manufactured to specified sizes, they reduce assembly waste and are up to 50% faster to install than stick framing. They provide superior insulation as well as structural strength. The EPS is composed of small plastic beads that are fused together to create a rigid foam insulation separating the two pieces of plywood. EPS does not contain Chlorofluorocarbons (CFCs), HFCs, HCFC's. Although it has an energy intensive manufacturing process, it takes less than one year for 100% energy payback through the substantial energy savings due to state-of-the-art energy efficiency and insulation.

Shade screens provide shade protection during harsh summer months. Operation of both insulation and shade screens allows effective passive solar heating strategies in combination with the concrete thermal mass floor. The dark colored concrete floor acts as a thermal storage mass which can retain heat absorbed from the sun, but also from the radiant floor heating which is embedding in the slab. Concrete is composed of four basic ingredients: aggregate, cement, water, and air that will be ground and polished.

The glass window at kitchen has a radiation shielding film which blocks unwanted west light when activated.

Sherwin Williams' green line paint was used on the interior and exterior of LUMENHAUS. One of the interior paints used was Duration Home Interior Latex Coating which is packaged in recycled plastic containers and has soy-printed labels containing 75% recovered fiber and 25% post-consumer waste. Another inter paint used was PrepRite ProBlock Interior/Exterior Latex Primer/Sealer. Pro Industrial Pro-Cryl Universal Acrylic Primer was used on the exterior to apply an anticorrosive metal primer to the exposed steel. All of these paints have a VOC Content of <100g/L; <0.83 lb/gal.

FSC Certified (Forest Stewardship Council) Ipe wood is used for the exterior decking and in the bathroom. The wood is constructed from select cut Brazilian Woods, which have been harvested in an environmentally responsible method and designed to preserve and enhance the economic viability of rain forest hardwoods. Ipe is a very hard wood – approximately three times harder than Red Oak. Because of this, it is very durable, and may be left untreated without negative weathering effects. Ipe is naturally resistant to rot and decay and has a high fire resistance rating. It also has a life span of 50 to 70 years. Glass walls at entry and office are insulated glass units filled with Aerogel insulation, giving them an r 6.0 and allowing transmittance on natural daylight. Cabot Nanogel (a trade name for Aerogel) is used as loose-fill insulation in the polycarbonate panels on the north and south walls of the house. Aerogel is the lightest weight solid and one of the best thermal insulators in the world. It is made from silica, salt and limestone – three of the most abundant minerals in the world. Aerogel is an ideal insulator because of the following properties: a high light transmission of 75% per cm, low thermal conductivity with an R-value of 8 per inch, sound attenuation which reduces transmitted noise, and its resistance to color change, mold and mildew, and performance degradation.

The roof SIPs panels are covered with a white Acrylife Roofing Membrane. This weatherproof, highly insulating, and lightweight material protects the roof from harsh weather conditions. The membrane's white surface reflects light, therefore decreasing the amount of heat from sunlight that is absorbed through the building envelope, in turn lowering the amount of energy needed to cool the interior. Gallina Polycarbonate Panels act as the main form of insulation. They include Sealeze weather-stripping and allow an R 24 insulation cover over all major window openings. During production, 20% of the polycarbonate regrind material is stored and re-used. Gallina does not emit any harmful toxins into the environment during production and uses sealed water cooling system to filter used water repeatedly for reuse. Polycarbonate panels can let in up to 80% of daylight into the house, allowing the house to use less electric energy during the day. Its hollow-core structure uses 80% less material than an equal thickness of solid glazing, and weighs 1/6 as much as glass and 1/3 as much as acrylic. Polycarbonate panels are 100% recyclable at end of life.

Polyisocyanade spray foam insulation was sprayed beneath the corrugated floor decking and along the seams of the steel frame. This insulation expands to 100 times its original volume to create an air tight seal. After installation, all scraps can be trimmed and ground into fill for use in batt insulation or as fill in attics.

RAUPEX O2 Barrier Pipe is REHAU's trade name for its specially formulated cross linked polyethylene pipe. This is a durable, highly flexible pipe with enhanced temperature and pressure capability and long-term strength. The pipe is 4 times lighter than copper pipe and is freeze break resistant, as it expands when frozen. Its smooth interior wall is resistant to scaling and corrosion.

**B. Maintenance Plan**

One of the most beautiful characteristics of day-to-day living in LUMENHAUS is the low level of maintenance required. Hard surfaces such as the concrete floor, the glass walls, and the maple panels and cabinets are easily cleaned of household dust, dirt, and spills.

**C. Incorporated Energy**

Incorporated energy, otherwise known as embodied energy, is defined as the amount of energy required to extract, manufacture, and transport a material to its location of use, in our case, Blacksburg, Virginia. This number is based on how many mega joules it takes to produce one kilogram of a given material. Using a database for incorporated energy, mega joules required to produce one kilogram of each material are estimated taking into account recycled content if applicable. The amount in kilograms of thirteen chosen materials in the house is then measured and multiplied by the estimated incorporated energy found in the database. The total incorporated energy for the house is calculated by adding up the mega joules required to produce the total amount in kilograms of all of the materials used in the house. The thirteen materials that contribute to this calculation and their individual incorporated energies are detailed in the chart below. These thirteen materials were included in the calculation because all other materials used are either negligible or unavailable. Appliances, and furniture, and hardware are also excluded from the calculation because these are seen as temporary additions to a permanent structure and may vary greatly based upon the inhabitant.

It is important make a few notes regarding the specifications and assumptions made for individual incorporated energies. The SIPs panel is assumed to be 79% foam and 21% plywood by volume and 20% foam and 80% plywood by weight. An additional 20% wood (exterior deck) volume was added to account for support and railings and 35lb/ft3 was the assumed wood density. The aluminum is known to be 55% virgin material and 45% recycled with incorporated energies of 200MJ/kg and 20MJ/kg, respectively.

| MATERIAL | LB | KG | MJ/kg | Reference | embodied energy (MJ) | % |
|---|---|---|---|---|---|---|
| Structural Steel (frame) | 22012 | 9984 | 32 | 1 | 319,503 | 40% |
| Concrete (floor slab) | 22179 | 10060 | 1.2 | 1 | 12,072 | 2% |
| SIPs (plywood + polystyrene insulation) | 4439 | 2013 | 34 | 1 | 40,210 | 5% |
| Photovoltaics | | | | 2 | 45,360 | 6% |
| Stainless Steel (Eclipses System) | 3100 | 1406 | 80 | 1 | 112,491 | 14% |
| Glass (Sliding Doors) | 4694 | 2129 | 16 | 1 | 34,067 | 4% |
| Zinc (Exterior Cladding) | 1532 | 695 | 70 | 1 | 48,636 | 6% |
| Polyvinylchloride (Roof Membrane) | 400 | 181 | 90 | 1 | 16,329 | 2% |
| Polycarbonate (Insulated Sliding Panels) | 900 | 408 | 110 | 1 | 44,906 | 6% |
| Aluminum (Sliding Glass Door Frame) | | 689.00 | 120 | 1 | 82,680 | 10% |
| Wood (Exterior Deck) | 6300 | 2864 | 8 | 1 | 22,909 | 3% |
| Polyethylene (Radiant Floor Tubing) | 69.2 | 31.46 | 80 | 1 | 2,517 | 0% |
| Plywood (Interior) | 3000 | 1361 | 15 | 1 | 20415 | 3% |

| | | |
|---|---|---|
| | 802,095 | 100% |

*[1]Data estimated from CES Selector Version 4.8.0, Granta Design Limited, 2008.*

*[2]Sanyo Manufacturing Co.*

Based on these calculations, the total incorporated energy for LUMENHAUS is 830,334 MJ. As seen in the chart, the highest yielding energy users are the structural steel frame, the stainless steel sliding panels, and the aluminum sliding glass doors frames, accounting for 40%, 14%, and 10% of the total. By analyzing this chart, the team can establish high energy materials and either justify their use in the house or make a case for excluding them from the construction process.

For example, the use of steel is justified because of the inherent properties of the material and its manufacturing process. Pre-fabrication design minimizes construction energy use and waste as well as design error. Also, the majority of structural steel used in America is recycled, meaning that this durable material can be reused at the house's end-of-life. Stainless steel and aluminum can also be recycled. Although some materials offer benefits at their end of life, SIPs panels, which rank fourth in incorporated energy, provide superior insulation that will save daily energy use. A full life cycle analysis can help in this justification and establish the benefits and detriments of each material over the lifetime of the house. Please see the materials section for more information.

Inherent energy required for transportation was minimized in the decision to use locally harvested and manufactured raw materials. Maple plywood, the predominant interior material, was manufactured within a 100-mile radius, at Columbia Forest Plywood in North Carolina, USA.

**VI. Solar Facilities**

LUMENHAUS's proposed solar system is the main source of energy for all loads requiring electric energy within the house. The solar panel chosen is a Sanyo 195 HIT (Heterojunction with Intrinsic Thin-Layer) Double Bifacial Photovoltaic Module, which is a hybrid of single crystalline silicon surrounded on both sides by ultra-thin layers of amorphous silicon. [1] Forty-two of these panels cover the entire surface of the roof, making up the solar array. This solar array converts solar energy into useable electric energy, serving all appliances, lighting fixtures, and mechanical equipment. The sustainable attributes of the system lie in the bifacial design as well as the innovative manufacturing techniques employed by Sanyo, which combine to achieve an overall efficiency in the process of solar electrical conversion.

Instead of relying solely on the panel face exposed to the sun, the Double HIT's simultaneously absorb sunlight from the back face of the panel while inclined, vertical, or even horizontal, as shown in Figure 15.3 below. A portion of the sunlight passes through the panels which combines with sunlight reflected off the surface below, thus transferring the highest power per square footage to the bifacial solar cells. A light colored surface increases light reflectivity, therefore the white roofing membrane allows the panels

[1] (2008). Bifacial Photovoltaic Module. SANYO - Think Gaia.

perform at maximum capacity. By utilizing both top and bottom surfaces as a means to capture sunlight, the Double HITs can produce up to 30% more electricity than a one sided PV panel.[2]

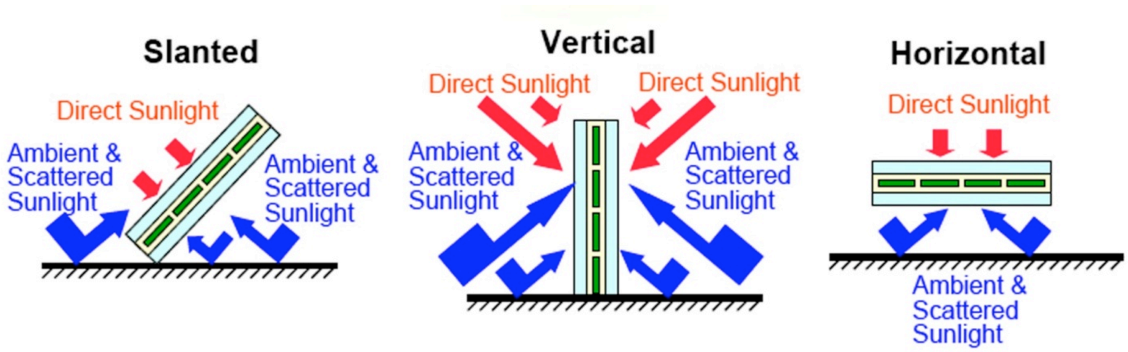


**Figure 15.3** Section cut of Sanyo panel showing inclination options and backside irradiation.

The maximum power output Sanyo estimates for just the front side of the panel under Standard Testing Conditions (STC) is 195 W. The following numbers show the estimated total wattage with the addition of the backside irradiation, as a percentage of the STC (2).

**Table 15.12** Maximum power output in watts under standard testing conditions (STC) with varying backside irradiation percentages.

| | Standard Testing Conditions | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|---|
| Maximum Power (Watts) | 195 | 204 | 213 | 222 | 231 | 240 | 249 |

In order to understand Sanyo's innovative manufacturing techniques, one must first understand the layered composition of the individual solar cell. The innermost layer is the crystalline (c-Si) wafer (shown in gray), which is sandwiched between two intrinsic amorphous (a-Si) layers(shown in pink). Toxic Conducting Oxide (TCO) layers (shown in blue) follow suit, allowing the most solar energy to pass through to the interior layers while still protecting them from sun degradation. [3] As a final layer, the grid electrodes (shown in white) are formed using the screen-printing method.[4] See Figure 15.4. All of these layers combine to create a solar cell, ninety-six of which make up one Double HIT panel.

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[2] (2008). Bifacial Photovoltaic Module. SANYO - Think Gaia.

[3] Material Science and Physics of In-Zn-O based Transparent Thin Film Transistors. Retrieved March, 2009, from http://ei.colorado.edu/pdf/rogers_web_abstract.pdf

[4] Kanno, H., Kinoshita, T., Maruyama, E., Sakata, H., Taguchi, M., & Tanaka, M., et al. (2006) 22% Efficiency HIT Solar Cell. 1 May 2009.

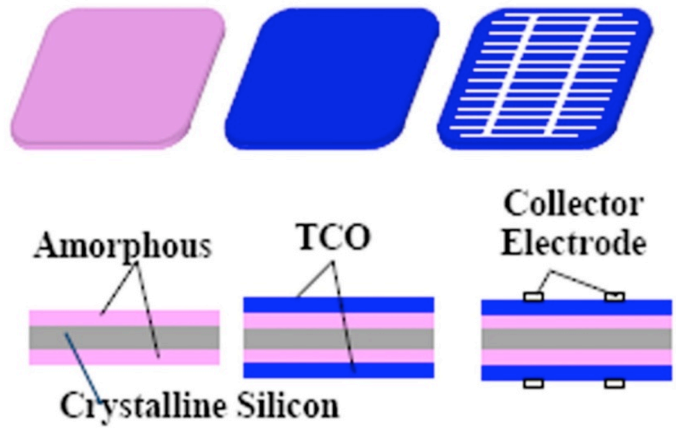


**Figure 15.4** Layering of a-Si, c-Si, TCO, and grid of electrodes.

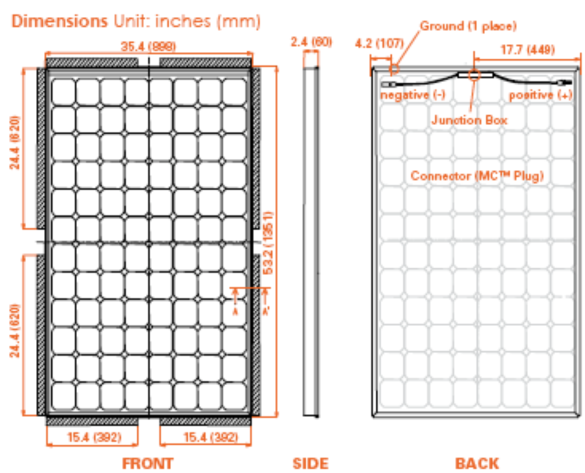


**Figure 15.4** Ninety six solar cells create a Double HIT solar panel.

Through improvements in the manufacturing process Sanyo has achieved a solar cell conversion efficiency of 22.3%. This means that out of the total sunlight beating down on the solar panels, 23.3% of that sunlight is converted into electricity and 76.7% is lost as heat. The areas of technological advancement are dependent upon high Open Current Voltage (Voc), Short Circuit Current (Isc), and Fill Factor (FF) numbers, as shown in Figure 15.3. Voc can be defined as a measurement of electric potential in volts when there is no external load or appliance, connected. ISC is the maximum current, or amount of electrons being charged and converted into electricity. When Voc and Isc are multiplied together they produce the theoretical power output in Watts. Because Sanyo's lower-light absorbing TCO allows more sunlight to pass through to the amorphous silicon layers, more electrons are able to be become electronically charged, therefore increasing the Isc.[5] The FF is a ratio of the theoretical power to

[5] Kanno, H., Kinoshita, T., Maruyama, E., Sakata, H., Taguchi, M., & Tanaka, M., et al. (2006) 22% Efficiency HIT

the actual power output and is presented as a percentage. Therefore, a higher electric potential (Voc) multiplied by a larger amount of electrons (Isc) offers a greater theoretical power output, and thus, a larger percentage of actual power output (Watts).

**Table 15.3** Voc, Isc, and FF affect the Cell Efficiency for a certain surface area.
Note: These numbers do not include backside irradiation

| Cell Efficiency | VOC | ISC | FF | Total Area |
|---|---|---|---|---|
| 22.3% | .725 V | 3.909 A | 79.1% | 100.5cm$^2$ |

The efficiency of the electrical conversion within the solar cells adds to the overall efficiency of the solar system. By studying how sunlight is converted into electricity and travels from the panels, to the inverters, to the light itself one can determine how much energy is produced and wasted at each stage of electricity production. The process begins with sunlight activating electrons within each of the forty-two photovoltaic panels, creating a circuit of Direct Current (DC) Electricity. The forty-two panels are divided into two series, each containing twenty-one photovoltaic panels. Each series is further subdivided into three groups of seven panels and wired together. These arrangements are shown in Figure 15.8. The left side shows the first series in parallel alignment and the right side shows the second series in an irregular configuration, all connected to the transition box by wires.

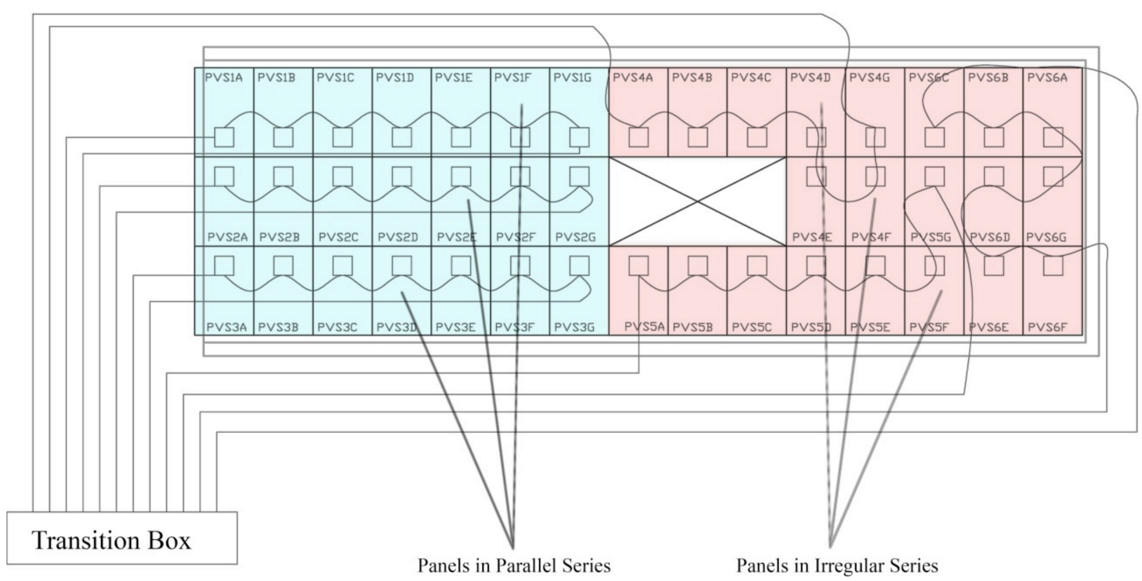


**Figure 15.8** Roof Photovoltaic Plan.

Each series is connected to a SMA Sunny Boy 7000US inverter located within the electrical closet. The path the energy will travel through is shown in figure 15.8. To begin, the DC energy travels through wires to these inverters, where it is promptly converted into Alternating Current (AC) Electricity. These inverters are 95% efficient—compared to the industry average of 85%—and only lose 5% of the energy to heat.

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Solar Cell. 1 May 2009.

When the power load is high (~11 kW) the inverters will need 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 mandatory.  The inverters will automatically split the AC energy between supplying the house appliances directly with energy and selling back the excess energy through the electric grid tie to Pepco Electric Company.[6] Once the energy requirements for the Solar Decathlon House are met by the energy produced by the panels, all of the excess is sold back to the electric company, awarding the homeowner with a monetary payment.  Evaluating this process is necessary to understanding the energy payback time and monetary payback time of the photovoltaic panels.

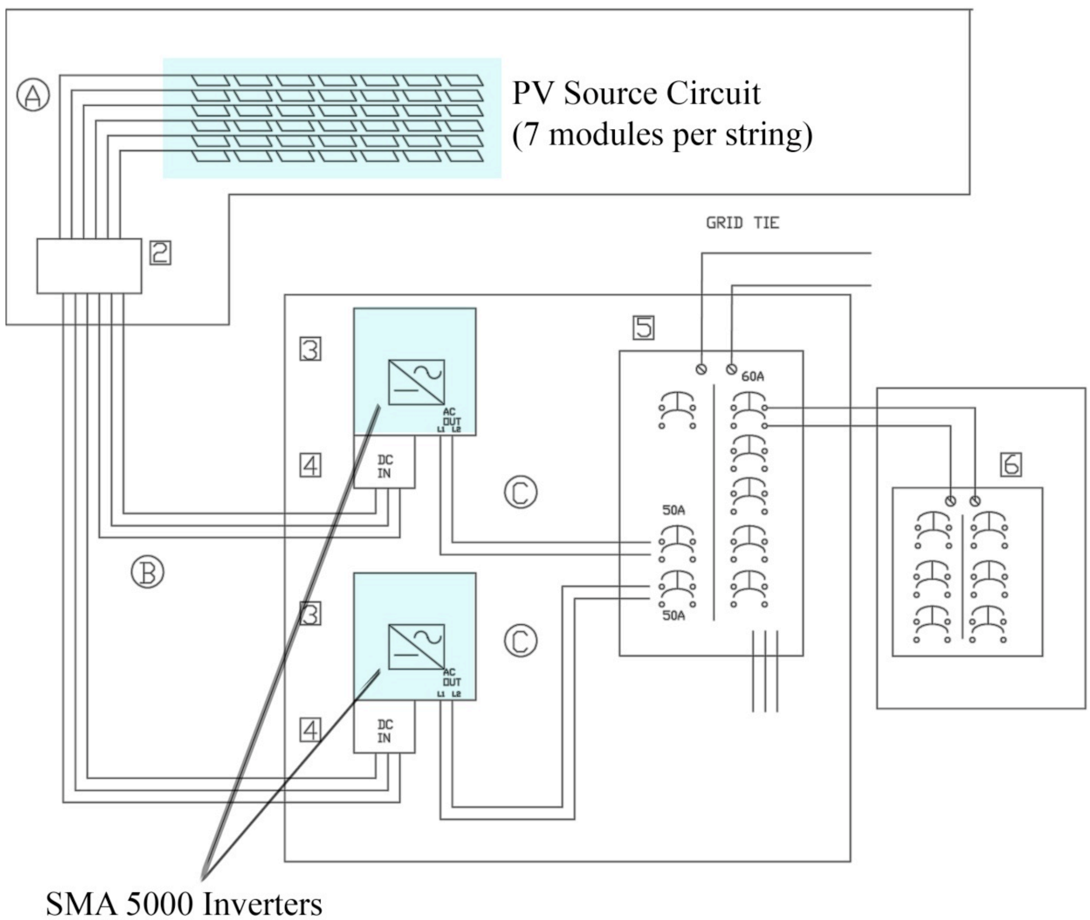


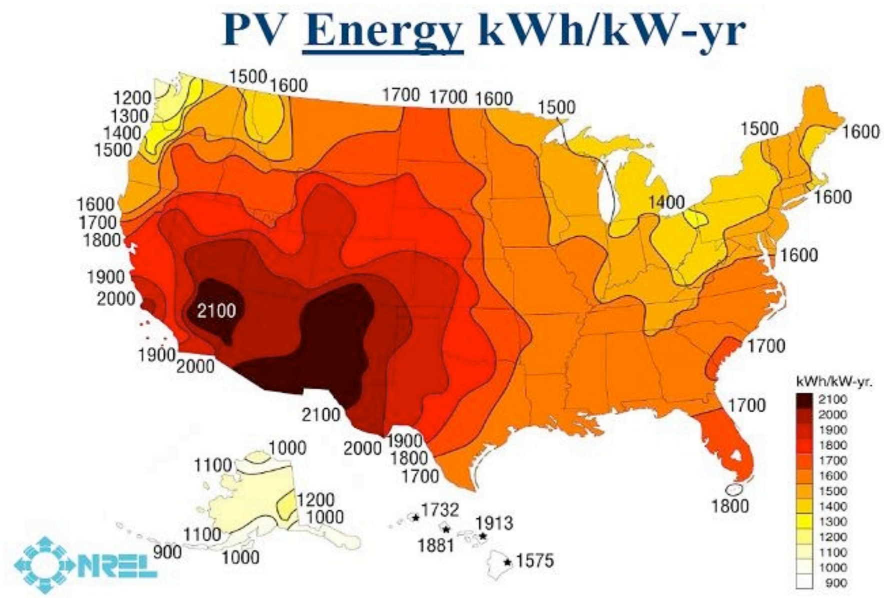

**Figure 15.8** Photovoltaic system from roof panels, to inverters, to grid tie/appliances.

### A. Description of the time calculation of the energy recovery

Energy payback time is defined as the time, in years, required to generate the energy equal to the amount needed for the panels' production.  It takes approximately 1500 kWh of power to produce 1kW of Sanyo's HIT solar panels.  In many parts of the USA, energy payback time is within a year for each kW of

[6] Dehart, Roddy. personal communication, 13 March 2009.

PV panels produced.  See Figure 15.9 to find how many kWh are generated per kW of solar panels according to geographic location within the United States. [7]




Map of how many kWh are generated per kW of solar panels according to geographic location within the U.S. (Zerner, 2009).

To begin the calculation, one must first determine the energy required to manufacture the entire 42-panel array.  It takes 1500 kWh of power to produce 1kW and each panel has an energy output rating minimum of 195 Watts (.195kW) which does not include backside irradiation.

$$\frac{1500kWh}{kWrated} \times \frac{42}{panels} \times \frac{.195kW\ (rated)}{panel} = 12{,}285kWh$$

Next, determine how much energy can be produced by the array per year according to your geographic location.  As seen in the map above, Virginia is in the orange, therefore the panels are capable of producing 1600kWh/kW yr.

$$\frac{1600kWh}{kW\ yr} \times \frac{42}{panels} \times \frac{.195\ kW\ (rated)}{panel} = \frac{13{,}104kWh}{yr}$$

With these results you can determine the number of years it would take to for the energy produced by the array to pay for the energy it took to manufacture them, or the energy payback time.

$$\frac{12{,}285\ kWh}{13{,}104\ kWh/yr} = .9375\ years$$

Based on the processing energy data provided by the manufacturer, it will take less than one year for the energy payback.  The best photovoltaics will have an energy payback time of 1-3 years, but since the

[7] Zerner, Robert . 14 Mar. 2009. Life cycle analysis of double hit PV's for VT solar team. Zerner, Robert. Frisco, TX.

boundaries of this energy analysis were not provided, it is unclear whether the rating of 1500 kWh of power to produce 1kW includes the energy it would take to extract, purify, and process the silicon. Because the energy payback time is quite low, it calls into question the scope of the processing energy data. As a check on Sanyo's data, a baseline annual solar electricity production for a forty-two panel array of .195kW panels was done for comparison.

$$\frac{42}{panels} \times \frac{.195\ kW}{panel} \times \frac{365}{days} \times \frac{24 hours}{day} = \frac{17{,}936.1 kWh}{year}$$

An assumption of 25% capacity factor was made to account for the lack of solar radiation at night and variations of sunlight during the day. Therefore the 24 hours/day is lowered to 6 hours/day.

$$\frac{71{,}744.4 kWh/yr}{4} = \frac{17{,}936.1\ kWh}{year}$$

The baseline annual electricity production of 17,936.1 kWh/yr is relatively close to our calculation based on Sanyo's data of 13,104 kWh/yr, therefore the data provided by the manufacturer is fairly consistent with our baseline calculation.

**B. Calculation of the CO2 emissions savings associated to a year of functioning.**

The electrical energy produced by the solar array will either serve the loads within the house or be fed back into the grid to serve the needs of others. By using solar energy as compared to electricity produced by fossil fuels, the carbon that would be emitted by the burning of non-renewable resources is eliminated. The AEP Western Virginia Electricity rate of pounds of $Co^2$ emitted per kWh of electricity for 2008 is 1.73lbs $Co^2$/kWh.

$$\frac{13{,}104 kWh}{year} \times \frac{1.73\ lbs}{kWh} = \frac{22{,}669.92 lbs\ Co2}{year}$$

$$\frac{22{,}669.92\ lbs\ Co2}{year} \times \frac{.0005 lb}{1\ ton} = \frac{11.3\ tons\ Co2\ saved}{year}$$

In the first year the solar array will prevent 11.3 tons of $Co^2$ from being emitted into the air. Assuming that the rate remains the same, the array will save 11.3 tons of $Co^2$ with each coming year. If specific numbers were provided from Sanyo as to how much $Co^2$ was emitted during the production of their panels, the $Co^2$ payback time in years could be determined. Once the $Co^2$ that was emitted in the production of the array is accounted for by the tons of $Co^2$ saved/year, all of the $Co^2$ saved in the future would be a surplus for the environment.

| | | Units | Comments |
|---|---|---|---|
| Number of Panels | 42 | Panels | |
| Sanyo Panel Power Rating | 195 | WW | |
| Manufacturing Energy | 1500 | kWh/kW | |
| NREL Solar Panel Energy Production | 1600 | kWh/kW yr | |
| | | | |
| Energy Pay Back Time | 0.9375 | yr | |

| | | | |
|---|---|---|---|
| Annual Electricity Production | 13,104 | kWh | |
| Carbon Emissions Factor | 1.73 | lbs C02/kWh | AEP Western Virginia Electricity 2008 |
| Annual CO2 Emissions Reduction | 11.3 | tons | |

**Back of the Envelope Check**

| | | | |
|---|---|---|---|
| Annual Solar Electricity Production | 17,936 | kWh | Assume capacity factor of 25% |
| | | | This suggests analysis above is in the right order of magnitude, but efficiency < 25%. |

**C. Description of the accessibility for the maintenance of the facilities.**

The photovoltaic array uses a low energy rack system to seasonally track the sun, providing maximum power generation throughout the year with a low cost of energy. A Unirac solar array mounting system is paired with Danaher-Motion linear actuators. Aluminum extrusions and specific hardware make installation of this product relatively simple. These systems have been designed in accordance with weather conditions for the specific location of Blacksburg, VA, and designed for seasonal solar-tracking. The linear actuators are placed periodically along the length of the house to provide a stable mounting point for the solar array. During transportation, the house height requires that the array lay totally flat, so that there is adequate clearance under bridges. However, once the house is on-site, the array must be lifted to the optimal angle for solar radiation collection. The solar array is lifted to its position manually, at which point the actuators are engaged to hold the array in place. This mounting system makes seasonal tracking and on-site maintenance very reliable and efficient.

Keeping the photovoltaic panels clean is an important and simple procedure. A walkway on the roof, in front of the PV array, is accessible by ladder. The walkway is easy to navigate as it is flat and unobstructed. A glass cleaner and a squeegee are used to clean the panels. Monthly cleaning would be sufficient in most locations to achieve ideal solar collection.

**VII. Equipment**

The kitchen appliances in LUMENHAUS, having met strict energy efficiency guidelines set by the U.S. Environmental Protection Agency and the U.S. Department of Energy, are Energy Star rated (with the exception of the Washer/Dryer which has not yet gone through the Energy Star process). The refrigerator (Liebherr HC 1011) is compact and integrates LED lighting. The drawer-style dishwasher (Fisher & Paykel DD24SI6) is also compact and saves water as well as electricity relative to baseline models.

An innovative linear slot diffuser was chosen for the house because of the Building Envelope's unique qualities. Since glass covers a large portion of the house's walls, the space adjacent to the North and South windows are areas of concern with respect to radiant heat loss and gain. The house uses Titus Dynafuser diffusers. These are unique because they feature an internal actuator that senses the temperature of the airflow and change the airflow direction for the most efficient effect. During forced-air cooling, the air is directed parallel to the ceiling to circulate through the house. During forced-air heating, when surface temperatures of the glass are likely to rob radiant heat from occupants, the air is directed perpendicular to the ceiling, toward the floor, along the glass. Rather than motors, the actuators use temperature-sensitive springs which expand or contract based on the flow air temperature, to redirect the forced air.

A tablet PC provides a user interface with the systems controller box located in the mechanical closet and remotely monitors and controls house features using an i-Phone.

The lighting was designed to provide both user control and energy efficiency. Dimmable linear T5 fluorescent tubes provide ambient lighting reflected on the stretched fabric ceiling. Dimmable MR16 LED fixtures are suspended on tracks around the perimeter of the living space and over the dining table to provide direct lighting. These fixtures can be repositioned anywhere along the track by the user, per his preference. The task lighting fixtures on both workspaces also use low-energy MR16 LED lamps. When run at full power, the ambient lighting system uses only 208 watts (pre-programmed to 50% capacity), equivalent to less than three traditional incandescent bulbs. Daylight and occupancy sensors reduce wasted energy when lighting is redundant or useless. As detailed elsewhere in this report, daylighting is generous.

A high efficiency geothermal-tied heat pump system assists in heating and cooling the living space. This also provides free hot water in summertime cooling months.

The condenser unit for the water-to-air and water-to-water heat pump runs directly off the water from the geothermal heat exchanger.

Air exchange utilizes an air-tight heat exchanger, minimizing energy loss during extreme weather temperature conditions.

The fully automated control system, using data from the weather station, optimizes for efficiency and user comfort.

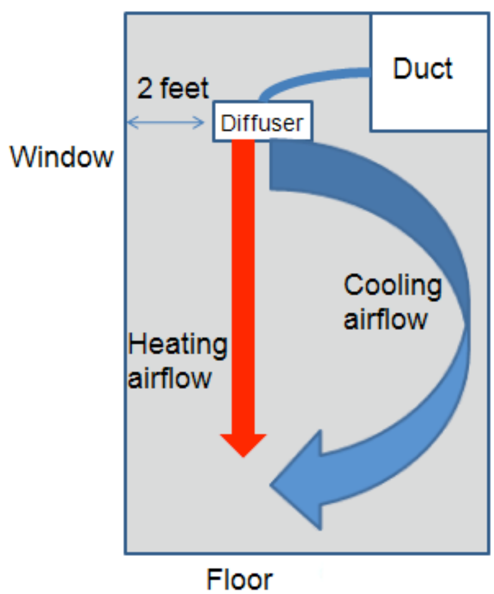



**Figure 5.6.** Airflow patterns from the Dynafus

## PUBLIC TOUR PLAN

While on site in Madrid, the LUMENHAUS team will be hosting tours of the house in a station-based style in order to keep the lines moving and to move as many people through the house as possible. The basic layout of the stations is based on the Experience LUMENHAUS section of the website and can be found on the House Tour Floor Plan on sheet PT-101 of the construction documents. Five of the six stations will be labeled in concurrence with each of the five sections found under the Experience LUMENHAUS section of the site. A sixth station will be located outside of the mechanical closet where one can see and learn more about the equipment and systems that run the house. Each tour station will feature a knowledgeable LUMENHAUS team member giving out short, concise bits of information dealing with their respective area and answering any additional questions visitors might have. While most team members primarily speak English, we will have two students who speak fluent Spanish and one who speaks Japanese helping with the tours.

LUMENHAUS is approached by a walk from the Main Pedestrian Path at the southeast corner of the site. As viewers come to the line to see the house, team members will distribute "LUMENellas" – a bright colored umbrella-like shading device that protects visitors from direct sun. Handouts presenting sustainable and other features about the house will also be distributed so that those in line have something to read as they wait. In order to "break up" or seemingly shorten the long line, visitors will experience our first tour station while they wait in line on the South side of the house. It is here at station one, also know as our Green Living station, that visitors will find a number of signs informing them about the process of how LUMENHAUS came to be as well as a series of sustainable facts about the house featuring several product samples each person can see and feel to better understand what they are and how they function in our house. Station one will serve as a primer to those about the enter the house so they enter with some knowledge of the project in hand, enabling them to better understand and appreciate LUMENHAUS in a more timely fashion, allowing us to move more people through the house on a daily basis and therefore educating as many people about the house as possible.

As space becomes available in the house for more guests, we will be moving groups of 10-15 people from the waiting line to station two. Station two is called Responsive Living and it is here that we will be explaining the overall concept of the house, *Responsive Architecture.* At this station, visitors will learn more basic information about the house and the overall scope of the project. This additional knowledge should prepare our guests even more before entering the house, allowing them to easily understand what it is they are seeing, and move through quickly.

Inside of the house, visitors will be brought into the living/dining area where they will see a large informative display showing a short video about the project including information about team members, the construction of the house, it's journey to get to Spain as well as some night shots of the house so people can get a grasp for what the house is like at night as well as during the day. The interior space of the house features the next three stations in our house tour, each comfortably supporting groups of 10-15 people. Inside the house, our guests will learn about the design of the house in our Pavilion Living station near the kitchen area. Next, in the living area, they will learn about the smart technologies behind LUMENHAUS and get a general overview of the systems controlling the house in our Smart Living station. Finally, our guests will move on to our Comfortable Living station located in the bedroom where they will learn the many reasons living in a smaller footprint can not only be without compromise, it can be very comfortable and luxurious as well. Additional information about and demonstrations of specific objects in the house will be given at several of the stations along the tour.

Once the visitor has gone through the three interior stations, a team member will offer them our handout again to ensure everyone who wanted one got one as they move outside and begin to exit the site. As each person leaves, they will have the option to stop at our last station featuring all of our mechanical, electrical and plumbing systems and equipment or move on if they are ready to see the next house. More details about specific talking points at each of our stations can be found below.

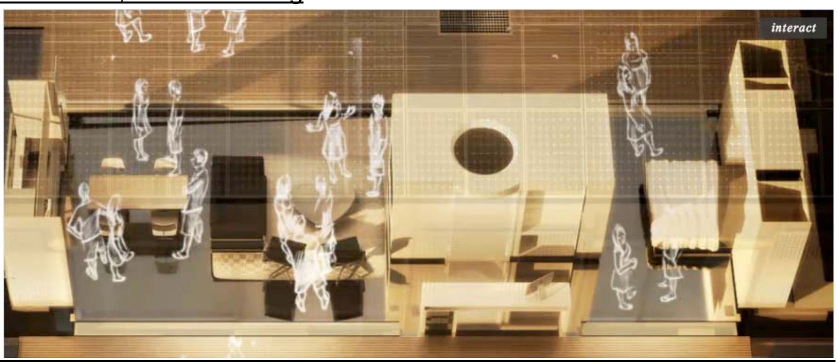
Station #1, Green Living

- LUMENHAUS is a zero energy home – it produces all the energy it consumes from the sun. An array of solar panels automatically responds to external conditions to best capture the sun's energy.
- Opening the sliding doors in LUMENHAUS naturally cools and ventilates the home.
- Using the roof as a catch basin, rainwater is collected and purified for reuse in the house, reducing the need for municipal water and reducing strain on storm water management systems.
- Coupled with a geothermal heat pump to extract heat from the ground, a radiant floor system pumps water through pipes in the concrete floor, using far less energy than a typical heat pump.
- Wherever possible, LUMENHAUS uses recycled or long-lasting renewable materials to help preserve the earth's valuable natural resources. For example, the wooden deck and cabinets come from sustainable forests. Various material samples are located in this station for those in line to inspect.

Station #2, Responsive Living

- A house weather station provides LUMENHAUS with live weather updates. Numerous house systems use and adapt to this information to run as efficiently as possible.
- The Eclipsis Shutter Shade is a modern interpretation of the centuries-old shutter. Automatically responding to sunlight conditions to maximize energy efficiency, it also provides privacy and security without blocking external views.
- Without the Eclipsis Insulation Panels, glass walls would be impossible in a zero-energy home. These highly insulated translucent panels allow light to penetrate without letting heat escape.
- LUMENHAUS breathes with variations in natural light, mediated by different combinations of the Eclipsis System.

<u>Station #3, Pavilion Living</u>




- Making use of an open floor plan, LUMENHAUS features the most flexible space possible ready to accommodate any of the inhabitants needs.
- The lack of interior walls and widespread use of glass in the house create a visual and physical connection to the surrounding environment, making LUMENHAUS feel like much larger space.

<u>Station #4, Smart Living (Highlights the “Smart” aspects of LUMENHAUS)</u>


- LUMENHAUS monitors the weather forecast and automatically adjusts house systems to prepare for oncoming weather condition, maximizing energy efficiency.
- LUMENHAUS allows one to easily and efficiently collect information about current inside and outside comfort conditions from any viewable screen in the house.
- LUMENHAUS continually tells the owner how much energy it is producing, where energy is being consumed in the home, and, if there is excess energy, how much it is selling back to the utility grid.

Station #5, Comfortable Living


- LUMENHAUS uses a smartphone like the iPhone to create an intuitive house control system. From music to movies, from lighting to shading, one can relax in comfort with a simple touch of a screen. In addition to the phone application, multiple touch screen displays can be found in the house, displaying information about the house energy use and production and also allowing full control of house systems just like the phone.

Station #6, Mechanical and Electrical Closet

- LUMENHAUS utilizes many types of equipment. In the mechanical closet, one can see the "brain" of the house and learn more information about the energy efficient systems that heat, cool and power the house.

## DINNER PARTY MENU

Dinner #1

Appetizers:

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

(2) Gambas Abuñueladas (Breaded Shrimp)………………
Shrimp, flour, water and eggs

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

(3) Queso Manchego (Manchego Cheese)…………………
Goat cheese

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

(2) Jamón Ibérico (Cured Ham)……………………………..

Entrees:

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

(4) Tortilla Espanola (Spanish Potato Omelet)…………..
Eggs, potato and onions

(4) Madrileñas de Ternera con Pimientos Asados (Breaded Veal with Pan Seared Red Peppers)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

……………………………………………………………………….

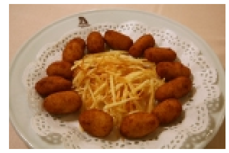
Dessert:

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

(8) Flan Casero (Homestyle Custart)
Eggs, milk, vanilla extract and sugar………………

Dinner #2

Appetizers:



(2) Croquetitas Caseras  (Hush Puppies)…….,………..
Ham, chicken, flour and milk

(2) Mejillones Rellenos (Stuffed muscles)…………………

(3) Ensalada Mixta (Mixed Salad)…………………………. .
Lettuce, onions, carrots, tomatoes, cucumber and asparagus

Entrée:

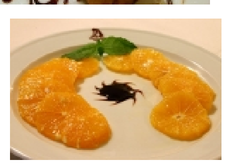
(2) Paella Mixta “La Barraca”…………………………………
Yellow rice, squid, mussels, white fish, lobster and pork

(2) Paella Huertana (vegetarian Paella)…………………….
Yelllow rice, onions, asparagus and spinach

(2) Paella al Horno……………………………………………..….
Yellow rice, chorizo and morzilla (sausages), chic peas, chicken and beef

Dessert:

(8) Buñuelos de “San Isidro” Cream Puff…………………..
Flour, water, eggs and suga



(4) Fruta del Tiempo (Fruit of the season)……………………..

## 1 Precedents and Aim

This Site Operations Plan will serve as an executive document for the exclusive planning and execution of the Virginia Polytechnic and State University entry, hereafter referred to as the Lumenhaus, into the 2010 European Solar Decathlon. The aim of this document is: to guarantee the assembly and disassembly of Lumenhaus with logic, order, and safety; to convey the logic of requests and proposals by the Lumenhaus Team based upon their experience in assembling and disassembling the Lumenhaus exhibit multiple times through varied sites and weather conditions.

It was the intention of the design team to make Lumenhaus an efficient and rapidly deployable prototype for a modern manufactured home that excels in delivering architectural quality integrated with energy efficiency. Therefore, the Lumenhaus exhibit requires minimal heavy machinery in its assembly and disassembly. Much of the exhibit can be safely and efficiently installed through hand labor across a truncated timetable.

## 2 General Data

General data concerning the Site Operations Plan can be referenced in sheet SO-201 of the Lumenhaus Construction Documents and the Lumenhaus Operations Chart. Specifics concerning lengths, weights, and heights of the transport vehicles.

## 3 Site Operations Team Coordinator

The following are personnel listed as primary contacts and project coordinators:

Site Operations Team Coordinator
David Clark (project advisor, recent graduate)
daclark@vt.edu

Lead Project Coordinator
Joseph Wheeler (faculty)
joewheel@vt.edu

Project Coordinators
Robert Dunay (faculty)
dunayr@vt.edu

Robert Schubert (faculty)
silver@vt.edu

# 4 Outside Logistics. Villa Solar

The tight and narrow site of the Villar Solar along the Manzanares river can offer a wonderful pedestrian experience, and the Lumenhaus is situated on its site to offer the maxim experience possible for visitors within the stipulations of the 2010 competition rules. Site access for the delivery of Lumenhaus and its constituent pieces will come exclusively from the east of the its exhibit site. All long term components for the assembly and disassembly processes will be contained within the bounds of the Lumenhaus site, and little to no support machinery will ever step outside of this confine.

The request for an Outside Logistics Plan has been interpreted differently for Lumenhaus to more accurately showcase the self-containment and operating density for assembly and disassembly. Since Lumenhaus requires no heavy machinery (cranes, forklifts, etc.) aside from the transport trucks, it is projected that there will be no interference to the Villa Solar outside the Lumenhaus exhibit site boundaries. Refer to sheet SO-201 in the Lumenhaus Construction Documents for graphics and short narrative illustrating activity outside the site.

The Outside Logistics instead focuses on the exterior assembly and disassembly processes of Lumenhaus within the exhibit site. Refer to sheet SO-001 in the Lumenhaus Construction Documents for graphics and short narrative illustrating activity exterior of Lumenhaus.

## 4.1 Phases Description

Below is the proposed sequence of events for assembly. These events may occur in parallel with corresponding Interior events. The Lumenhaus Team members have developed an efficient choreography, knowing very well the order of operations and phases being implemented simultaneously. Disassembly will generally be the reverse of the narrative below, accept as noted:

The assembly of Lumenhaus begins with site markings for the positioning of the house on the site in accordance with the submitted Construction Documents.

The house arrives by truck and is backed onto the site, positioned within markers.

Foundations are placed under the structure and the house is lowered via its transportation components. Attached hydraulic jacks will then be implemented to raise and level the house.

The delivery truck uncouples and drives off site, leaving the villa solar. NOTE: As soon as the house is positioned on site, the second truck with shipping container can arrive, deploy the container, and leave the Villa Solar. These events can happen nearly parallel in time, though the arrival plan requests the house enter the site first to ensure maximum maneuverability. For disassembly, it is requested that the house leave before the cargo container, so that any delinquent components discovered from a site inspection may be stowed away.

The deck foundation system is laid out in phases and the respective deck components immediately placed. The deck assembly procedure is a concentric layering process. Water tanks are placed within the deck foundations as soon as possible to permit maximum accessibility for making plumbing connections.

The major landscape infrastructure is placed and lined for water retention.  Remaining landscape is constructed as site assembly progresses and space permits.

Box truck delivers landscape plants. It can be accommodated within the confines of the site.

Ramps and stair are placed and handrails attached.  Site Accessibility Inspection is ready.

Photovoltaic array is inclined to competition height, ready for inspection.

Electrical systems are checked over after transport and generator connection is established as soon as permitted until grid connection is allowed.  The house is intended to be electrically ready as soon as it enters the villa, and will be available for inspection, pending all exterior electrical connections are made.

Entry canopy is installed.

Mechanical room doors are installed.

Instrumentation tower is erected.

Plumbing systems are tested, inspected.

Public tour material is installed across tour route.

House is ready for all exterior inspections.

Container Truck returns at the end of the assembly time period to retrieve the container.

DISASSEMBLY IS THE REVERSE, UNLESS NOTED.

### 4.2 Transport

Lumenhaus is a single module, deliverable architecture exhibiting a unique structural transport system.  It requires only one tractor, capable of interfacing with the building's weight and transportation components. A cargo container serves as support space holding all exterior components of the exhibit (decks, landscape, tanks). A box truck will briefly be onsite for the delivery and pickup of landscape plants.  All vehicles can be accommodated onsite for the short durations they are on the Villa Solar during assembly and disassembly.

Refer to sheet SO-201 in the Lumenhaus Construction Documents for graphics and short narrative illustrating activity.

### 4.3 Heavy Vehicles Circulation

Minimal heavy vehicle circulation is anticipated for Lumenhaus. Section 4.2 of this document and reference to sheet SO-201 in the Lumenhaus Construction Documents illustrate what is expected of the Lumenhaus exhibit in assembly and disassembly.

## 5 Inside Logistics. Approximation

The request for an Inside Logistics Plan has been interpreted differently for Lumenhaus to more accurately showcase the self-containment and operating density for assembly and disassembly. Since the Outside Logistics address the exterior assembly and disassembly operations of Lumenhaus, the Inside Logistics address the interior. Refer to sheet SO-101 in the Lumenhaus Construction Documents for graphics and short narrative illustrating activity inside the house.

### 5.1 Phases Description

As already mentioned in section 4 of this document, assembly and disassembly events may occur simultaneously as can be afforded. This helps to facilitate a truncated timetable and effective demonstration of the prototype's capabilities for safe, accelerated deployment. Outlined below are the phases towards full assembly. Unless otherwise noted, Disassembly is generally the reverse:

Interior cross-bracing is removed as soon as the building is sound and level.

Exterior components stowed inside for transport are removed.

Electrical components are inspected and the house is energized pending exterior electrical conditions.

Interior plumbing is inspected and tested. All faucets and fixtures are closed in anticipation for water supply.

Servo panels are energized, positioned. Building Control System is brought online.

Lighting system is checked.

Interior spaces are organized, cleaned, and readied for inspection.

House is ready for public tours, pending inspections.

DISASSEMBLY IS THE REVERSE.

### 5.2 Determining Factors

All afore mentioned sequencing is based upon experiences developed by the Lumenhaus Team through several exhibitions leading up to and after participation in the U.S. Department of Energy's 2009 Solar Decathlon. As of the writing of this document, Lumenhaus has been exhibited in five different locations, each requiring an assembly and disassembly process.

Exhibiting in Madrid, Spain poses a new array of challenges for the project that are being eagerly anticipated by the team.

### 5.3 Infrastructures

Lumenhaus arrives prefabricated and therefore requires a nearly exact support infrastructure which travels closely behind. Little to no construction infrastructure is required, especially no heavy infrastructure outside of the transportation.

### 5.4 Waste Management

Lumenhaus arrives prefabricated and therefore requires little to no onsite construction. There is no construction waste anticipate for Lumenhaus, as all required infrastructure for the exhibit arrives in modular form, ready for assembly or placement.

### 5.5 Load/Unload

The loading and unloading logistics for Lumenhaus are minimal and of short duration. Any loading or unloading event that could potentially disturb Villa Solar activity outside the Lumenhaus site would be extremely brief and of minimal interference. All loading and unloading can be accommodated within the site boundaries if needed. Reference sheet SO-201 in the Lumenhaus Construction Documents for graphics and narrative offering insight to the above statements.

## 6 Assembly/Disassembly

The assembly and disassembly processes have been addressed above in sections 4 and 5 of the Outside and Inside Logistics, respectively. Reference sheets SO-301 and SO-302, Assembly/Disassembly, for graphics and narrative offering more insight to the above sections.

## 7 Timeline

It is possible for Lumenhaus to be assembled in less than hours and fully operational, but this requires a herculean effort unnecessary for the European Solar Decathlon. Instead, it is anticipated that most of the time allotted for assembly will be made use of. The Lumenhaus Team is small by relative comparison to those of 2010 U.S. Solar Decathlon Teams. As safety is the primary focus, it is not anticipated that there will be continuous, 24 hour assembly on the Lumenhaus site. Anticipated times of duration for specific phases of assembly can be referenced in sheet SO-201 of the Lumenhaus Construction Documents and the Lumenhaus Operations Chart.