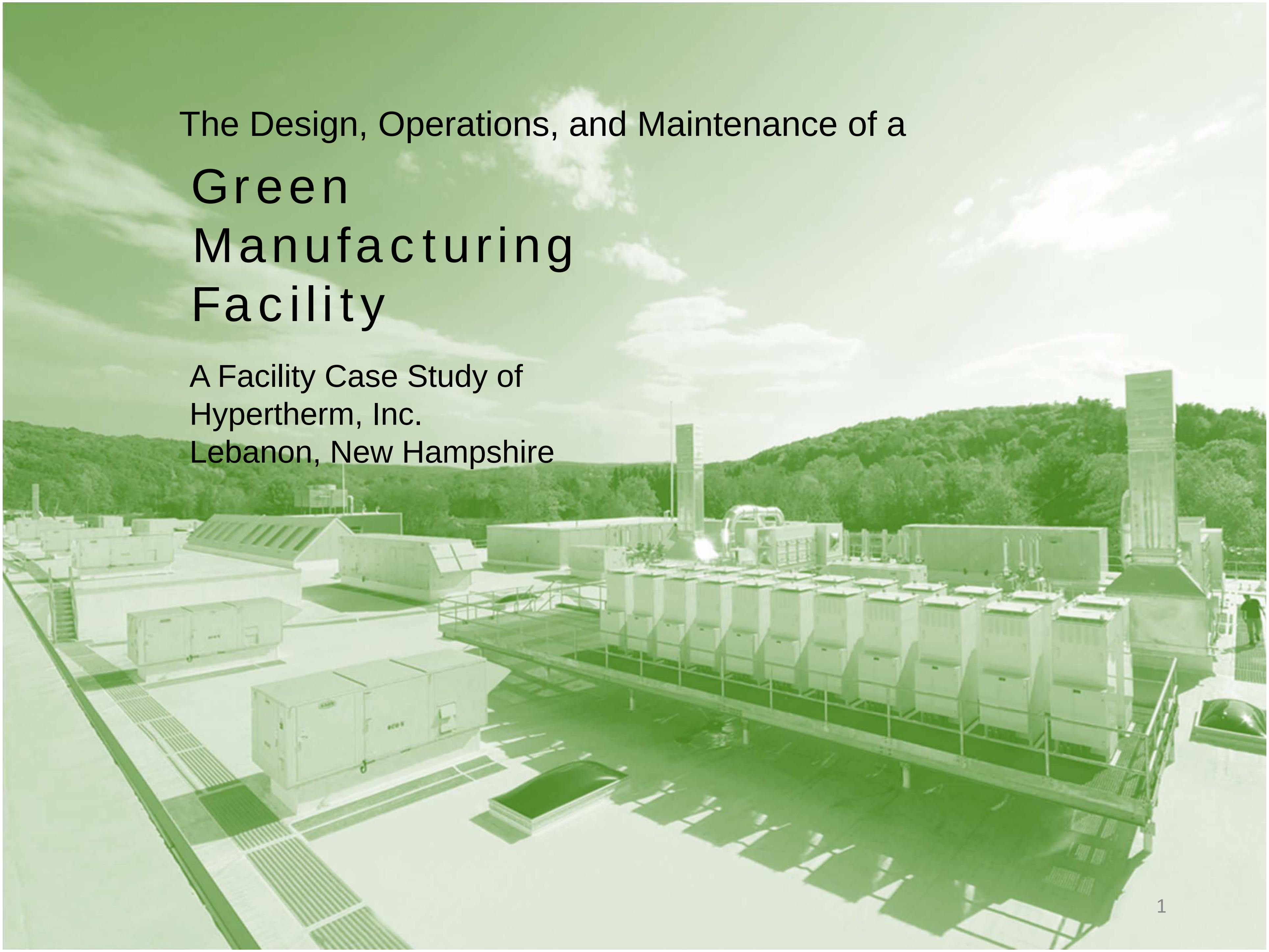
The Design, Operations, and Maintenance of a

Green Manufacturing Facility

A Facility Case Study of
Hypertherm, Inc.
Lebanon, New Hampshire



Learning Objectives

Overall sustainability approach to a large size manufacturing facility

Challenges to building envelope design using standard metal building systems

Challenges in commissioning of a large size manufacturing facility

Approaches to energy efficiency and modeling of a large size manufacturing facility

Presentation of the Hypertherm Heater Road Facility

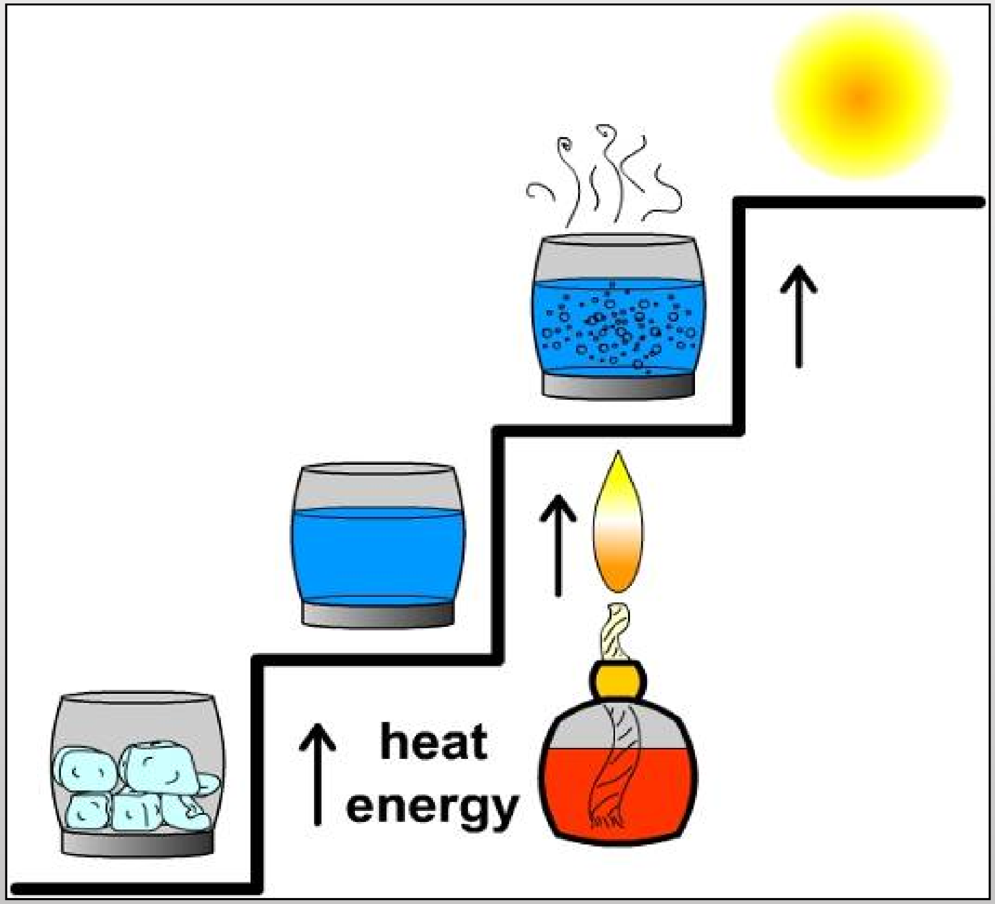
Introduction to Hypertherm and the Owner's Project Goals	**Perry Seale,** Director of Facilities, Hypertherm Inc.
Project Overview and Approach to Sustainable Design	**Jan Becker,** Project Architect, Bread Loaf Corporation
Design of MEP Systems	**John Johnston,** Vice President of MEP Services, Bread Loaf Corporation
Verification and Testing of the Building Systems	**Matthew Napolitan,** Principal, Cx Associates
Project Envelope Commissioning	**Jon Haehnel,** Principal, Zero by Degrees LLC

Introduction to Hypertherm

- World Leader in Plasma Cutting Technology
- Founded in 1968 in Hanover, NH
- Products Made in the Upper Valley
- Shipped Worldwide
- Associate Owned Company
- Technology Driven - 117 Patents
- Voted best Company in NH seven times

What is Plasma?

Plasma is the fourth state of matter: Examples are Sunlight and Lightening



What does Hypertherm Manufacture?

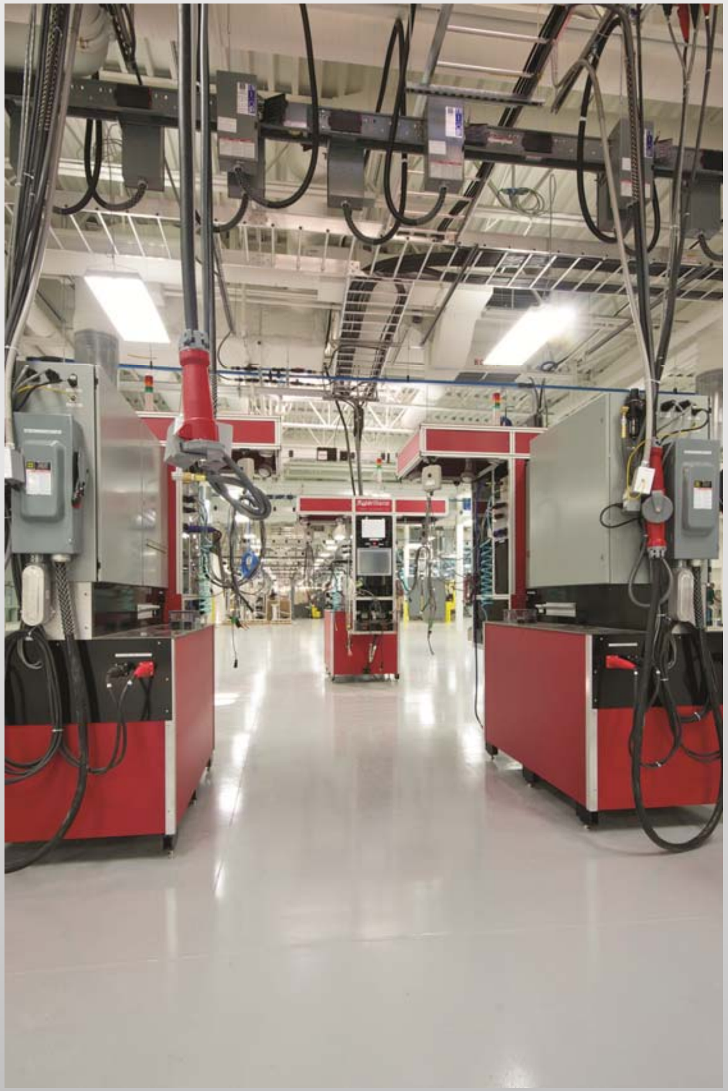
Why Build a Sustainable Manufacturing Facility?

- Hypertherm's environmental impact comes from the following areas, and in this order:
  1. Products in Use,
  2. Supply Chain and Distribution Networks,
  3. Facilities and Operations,
  4. Commuting and Business Travel

- Hypertherm values Associate well-being and positive climate for all Associates
- Hypertherm values Data Driven Decision Making
- Hypertherm desires to do the right thing.

Hypertherm Owner’s Project Requirements

- Team Work Environment: manufacturing, office, lab and research and development
- Open and Transparent Operations
- Fully Flexible Environments
- Uniform Access to Building Systems
- Teaching and Customer Focused
- Measurement and Verification for Continuous Improvement
- Lean Operations
- Redundancy in HVAC and Power Systems for all Manufacturing and Labs where operations run 24/7



Hypertherm's Owner's Thoughts on Process and Outcomes

Process:

1. Select design construction method – Design Build

2. Select correct design/construction partner – Bread Loaf Corporation

3. Create clear definitions of success – Objectives

4. Full Integrated Team with Defined Roles

5. Team process approach toward consensus

6. Problems/Challenges are just opportunities in disguise.

7. Transparency, responsibility and accountability

Hypertherm's Owner's Project Objectives from 2006

- Facilitate/encourage communication/interaction & collaboration
- Sense of community/belonging- Team and Company Identity
- Pleasant aesthetic environment with access to nature
- Corporate Image/Impact on visitors
- Adaptability/Flexibility/ Reconfigurability
- Support effective business operations
- Social Responsibility (Added 2008)

LEED Summary and Status

LEED Gold with 62 Points Achieved

Sustainable Sites: 17 Points
- Construction Activity Pollution Prevention
- Alternative Transportation Public
- Alternative Transportation Bicycle
- Alternative Transportation Alternative Vehicle
- Site Development – Protect Habitat
- Site Development Maximize open Space
- Stormwater Design – Quality and Quantity
- Heat Island Effect, Roof
- Light Pollution Reduction

Water Efficiency: 8 Points
- Water Efficient Landscaping
- Water Use Reduction

Energy & Atmosphere: 17 Points
- Optimize Energy Performance
- Enhanced Commissioning
- Measurement and Verification
- Green Power

Materials and Resources: 5 Points
- Construction Waste Management
- Recycled Content
- Regional Material

Indoor Environment Quality: 9 Points
- Outdoor Air Delivery Monitoring
- Construction IAQ Management Plan
- Low Emitting Materials – Adhesives
- Low Emitting Materials – Paints/Coatings
- Low Emitting Materials – Floor Systems
- Low Emitting Materials – Composite Woods
- Indoor Chemical & Pollutant Source Control
- Thermal Comfort – Design
- Thermal Comfort – Verification

Innovation in Design: 6 Points
- Green Cleaning
- Green Education
- Exemplary Performance Construction Waste Management
- Exemplary Performance Green Power

The Site

23.2 acres - 5.7 acres of preserved wetlands - 416 parking spaces - 160,000 gsf building

The Site

1. Entry Drive
2. Parking
3. Visitors Entrance
4. Associates Entrance
5. Loading Dock
6. Preserved Wetlands
7. Footbridges
8. Associates Exit
9. Basketball Court
10. Bio-retention/ Rain gardens

The Site: Sustainable Strategies

Challenge of a site with wetlands

Opportunity for stormwater management creativity including:

- Raingardens along the building
- Green swales along roadways
- 100,000 gallon holding tank underneath the loading dock
- Roof drains that had to daylight to southwest corner of the building
- Bio-retention pond where water eventually is released off site into the Mascoma River watershed

The Site: Sustainable Strategies

- Native landscaping and trees to shade the parking areas
- Pervious pavement for all parking areas
- White membrane roof with high emmissivity and reflectivity to reduce heat island impacts
- Site lighting 0.5 average footcandles

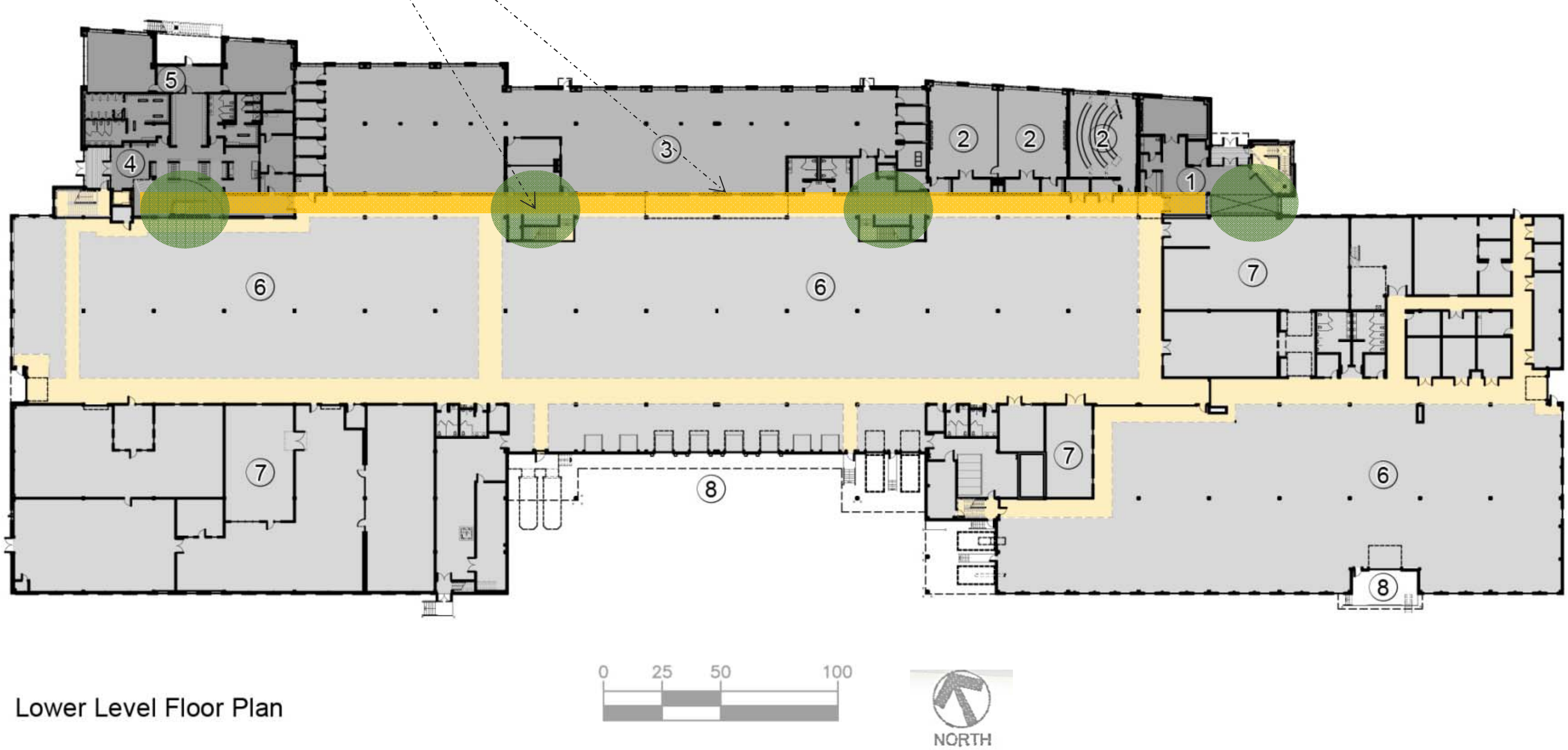
The Site: Sustainable Transportation Strategies

- Preferred parking for fuel efficient vehicles
- Rough-In for future electric vehicle recharge stations
- On-site bus stop
- Bike storage and changing rooms provided for bicycle commuters

The Facility

1. Visitors Lobby
2. Training Rooms
3. Open Office
4. Associates Lobby
5. Fitness Room
6. Manufacturing
7. Research /Training Labs
8. Loading Docks
9. Cafeteria

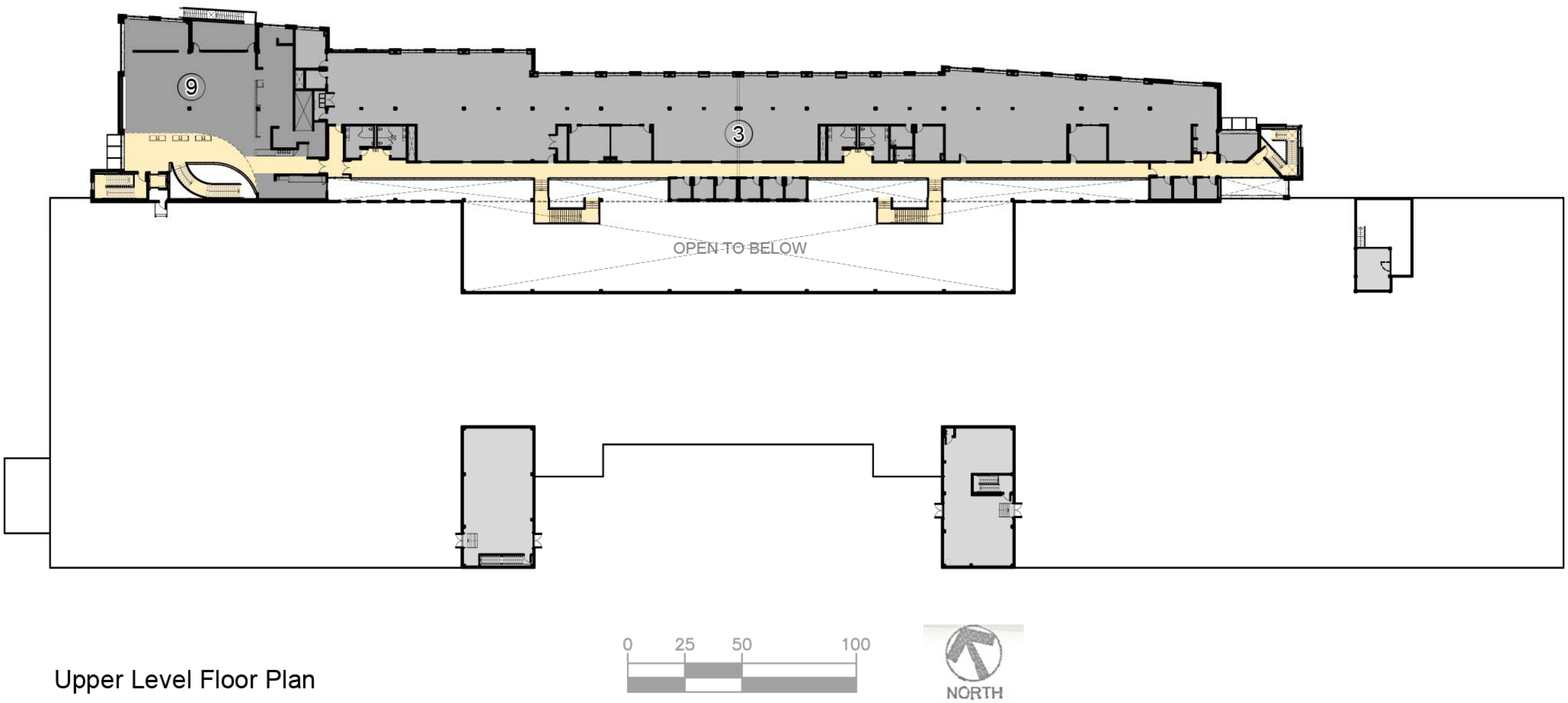
Circulation Spine
Vertical Circulation



Lower Level Floor Plan

The Facility

1. Visitors Lobby
2. Training Rooms
3. Open Office
4. Associates Lobby
5. Fitness Room
6. Manufacturing
7. Research /Training Labs
8. Loading Docks
9. Cafeteria



Upper Level Floor Plan

The Facility: Visitors Entrance

The Facility: Visitors Lobby

The Facility: Visitors Lobby View into Showcase Lab

The Facility: Main Circulation

The Facility: Open Office Environment

The Facility: Manufacturing Floor

The Facility: Day Lighting Strategies

Manufacturing Areas

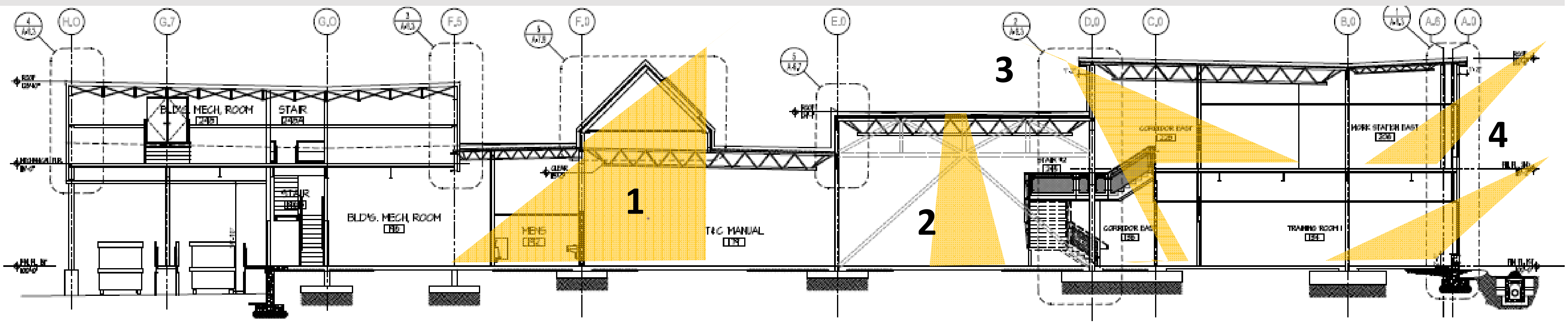
1. A- Frame North facing skylight monitors

2. Skylights

Office Areas

3. South facing clerestory windows along circulation spine

4. Ribbon windows along the north elevation



The Facility: Day Lighting Strategies

The Facility: Day Lighting Strategies

The Facility: Building Materials

Foundation: slab on grade

Walls: Kingspan 6" Insulated Metal Panels *R = 42*

Office Area Windows:
Insulated Fiberglass Windows
Accurate Dorwin Tinted Tri-PPG 2SB60 Argon Gas
U = 0.35, SHGC = 0.42

Manufacturing Area Windows:
Kawneer Trifab Aluminum, Tinted, LowE, *U = 0.41, SHGC = 0.63*

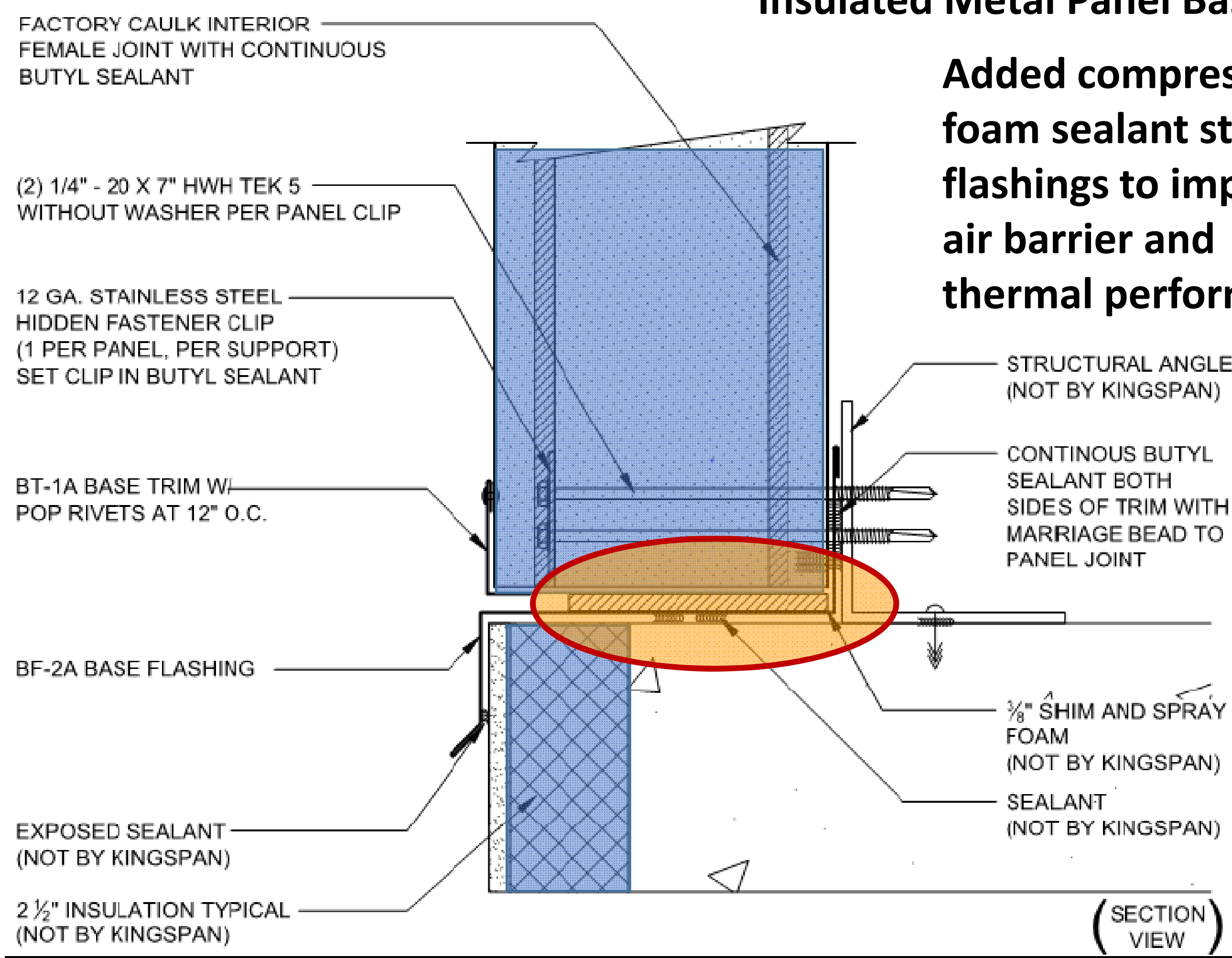
Roof: Firestone .060 TPO Mechanically Fastened Membrane on closed-cell insulation above deck = R42

Building envelope = 11% better than NH Energy Code
Overall building energy cost savings of 25%.

The Facility: Insulated Metal Panel

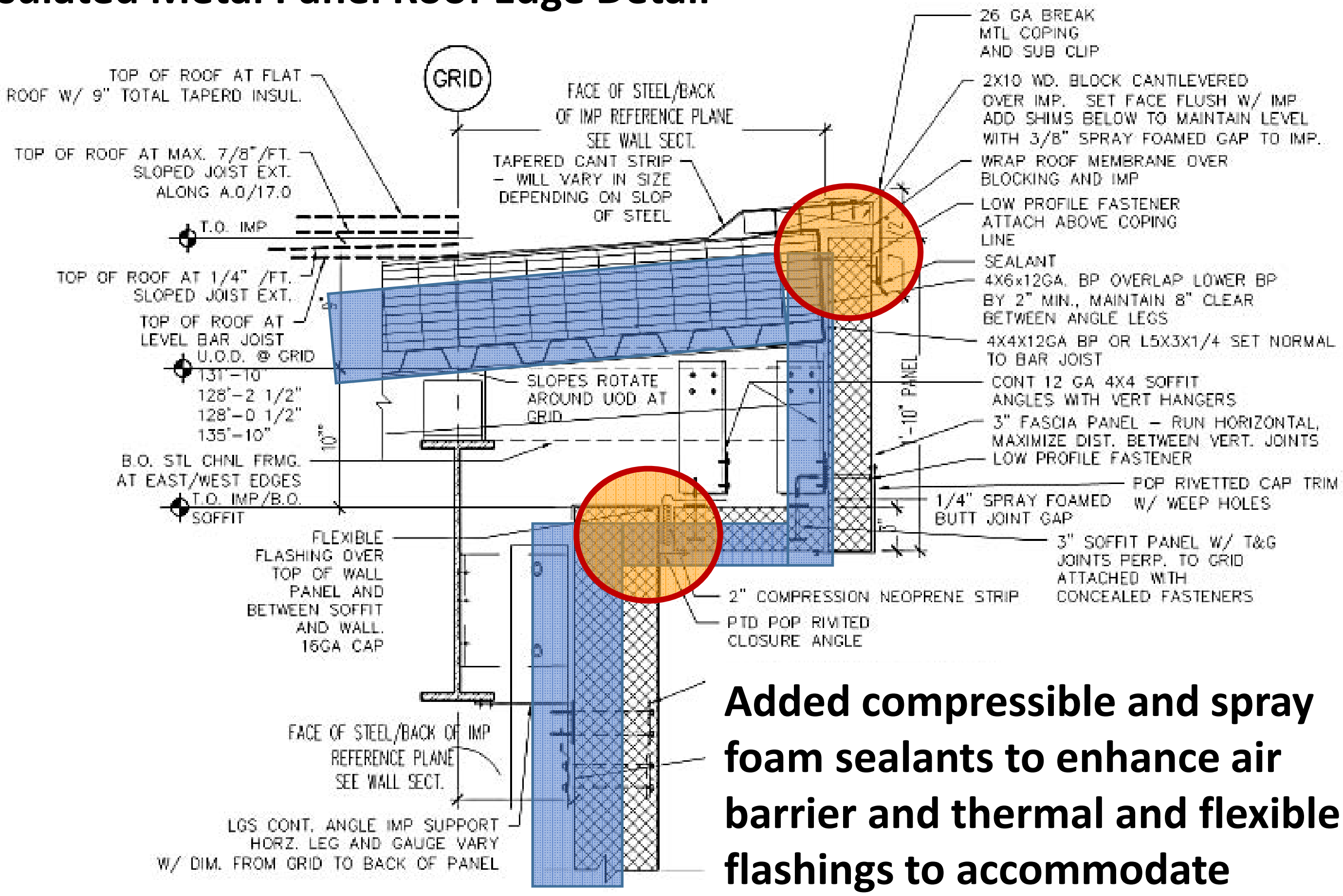
Insulated Metal Panel Base Detail

Added compressible foam sealant strips at flashings to improve air barrier and thermal performance



The Facility: Insulated Metal Panel

Insulated Metal Panel Roof Edge Detail

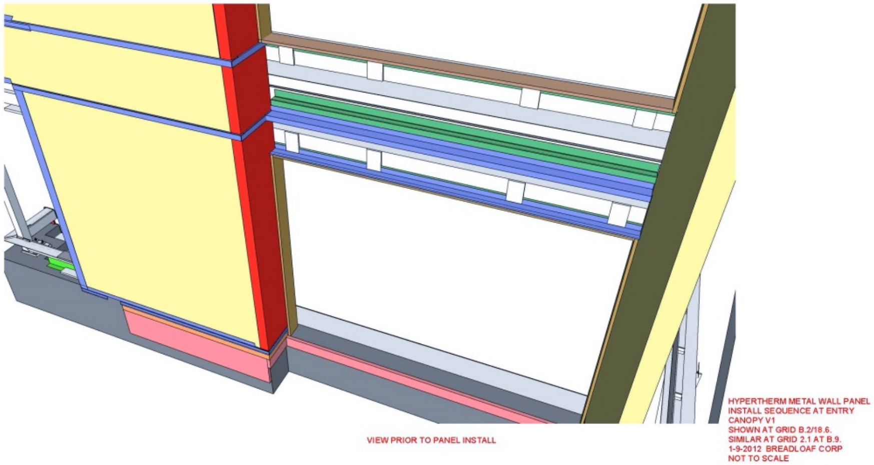


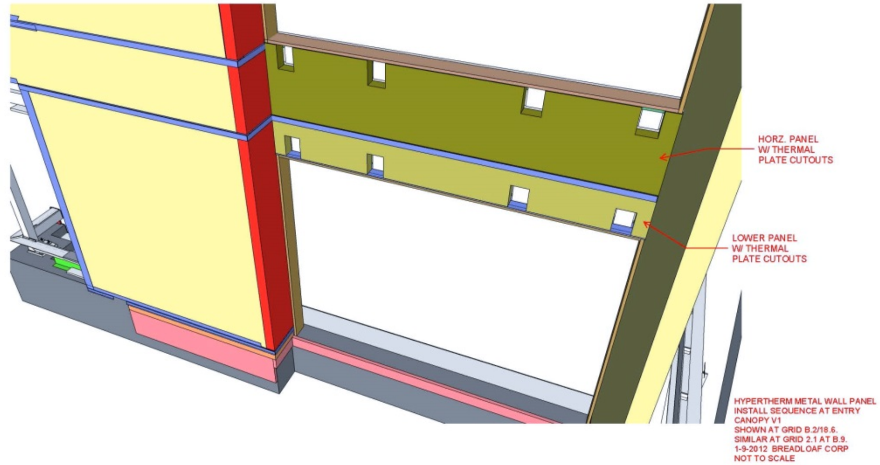
Added compressible and spray foam sealants to enhance air barrier and thermal and flexible flashings to accommodate movement

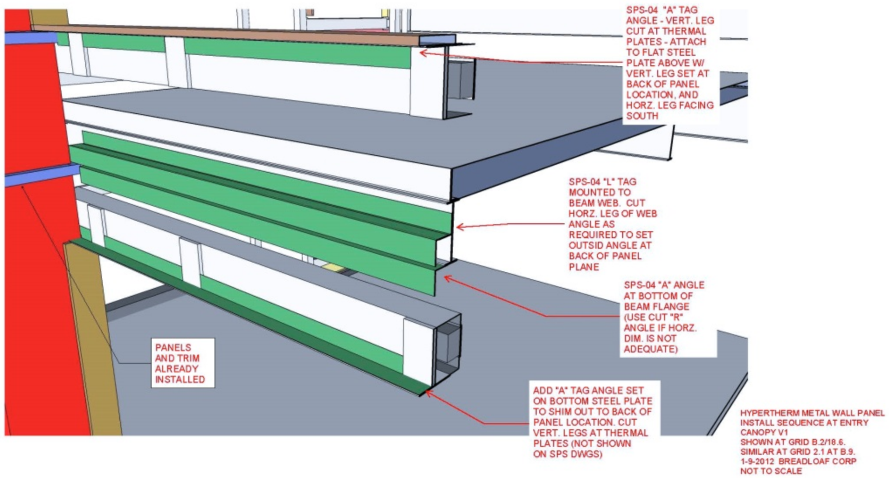
The Facility: Building Materials

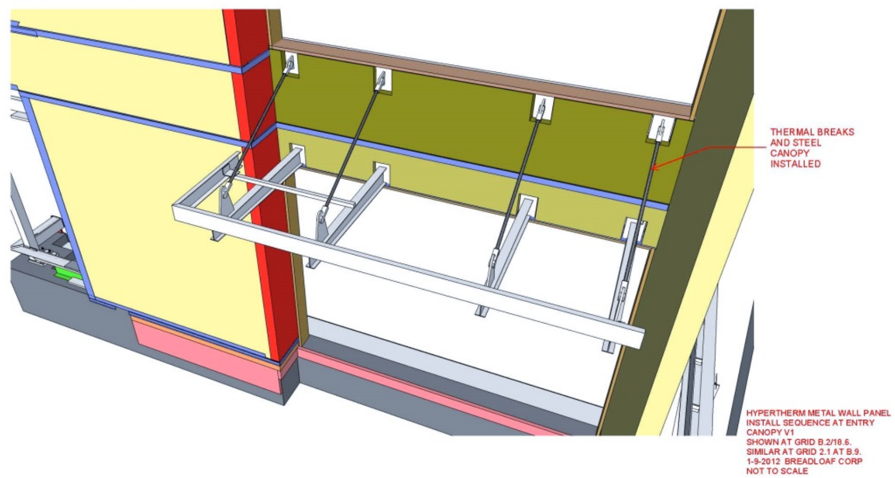
6" Insulated Metal Panel: joint detail with sealant at both tongues

The Facility: Insulated Metal Panel Installation

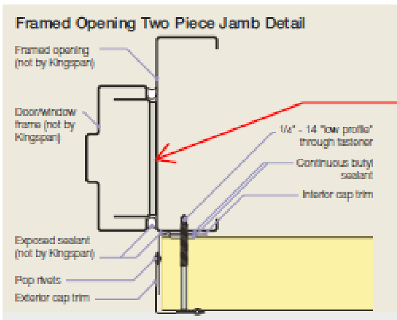






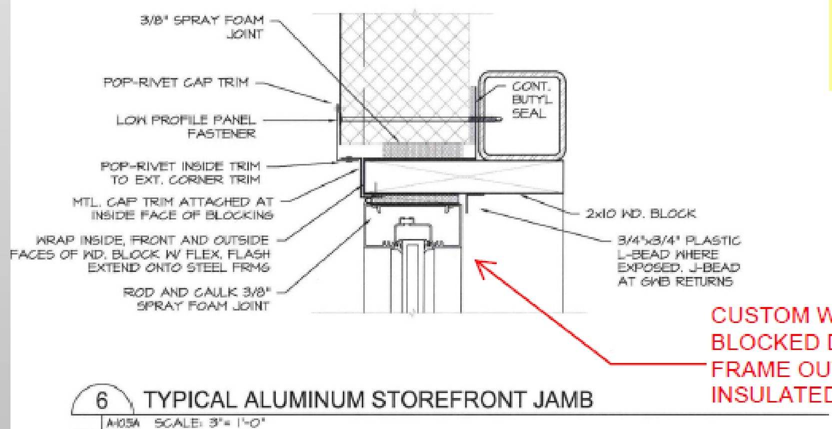


The Facility: Window Details

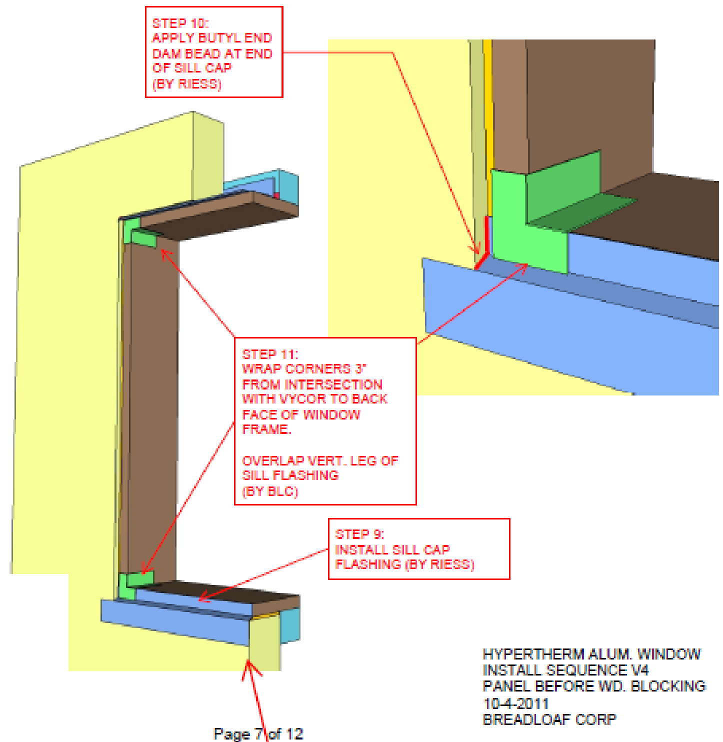


STANDARD MANUF. DETAIL

TYPICAL WINDOW/DOOR FRAME SET AGAINST STEEL FRAMING - NO THERMAL BREAK



CUSTOM WOOD BLOCKED DETAIL MOVES FRAME OUT INTO INSULATED ENVELOPE



3D INSTALL SEQUENCES TO COORDINATE CUSTOM DETAILS.

The Facility: Sustainable Strategies Materials

90% of Construction Waste was diverted from landfills which was rated as exemplary performance by UGBC.

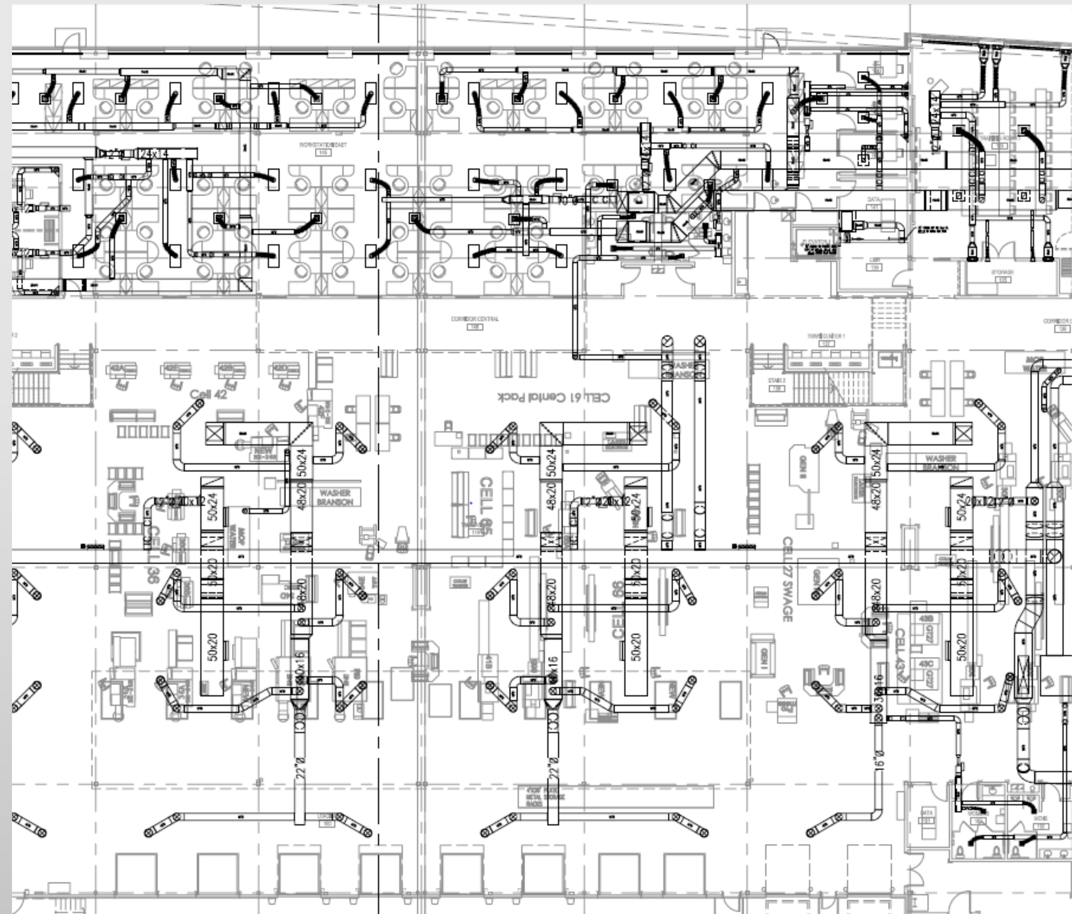
The Building Systems:

The Building Systems: Mechanical

The Building Systems: Mechanical

Design Charges:

- Flexible Systems to allow for multiple manufacturing changes
- Flexibility for future growth in both mechanical and electrical systems
- Energy Efficiency
- Solve existing one pass domestic water process cooling water system using upwards of 70,000 gallons of domestic water per day at existing facility.
- Limit indoor equipment due to difficulty in servicing above manufacturing equipment



The Building Systems: Mechanical

System Capacity:

- 1,000 tons of Building Air Conditioning
- 3,000 GPM Condenser Water Loop
- 90,000 CFM of Process Exhaust
- 400 Ton Process Cooling Load

The Building Systems: Mechanical

Primary Plant Systems

- Packaged Rooftop Water Source Heat Pump (28 RTU's)

- Two 17,500 CFM VAV Water Source Heat Pumps Ventilation Air Energy Recovery Units

- Condenser Water System - heat Pump Loop

- Decoupled or independent cooling tower water system for:
  - Free Cooling for process cooling loop in winter
  - Maintain loop cleanliness

- Optimal sized roof top equipment for first cost

The Building Systems: Mechanical

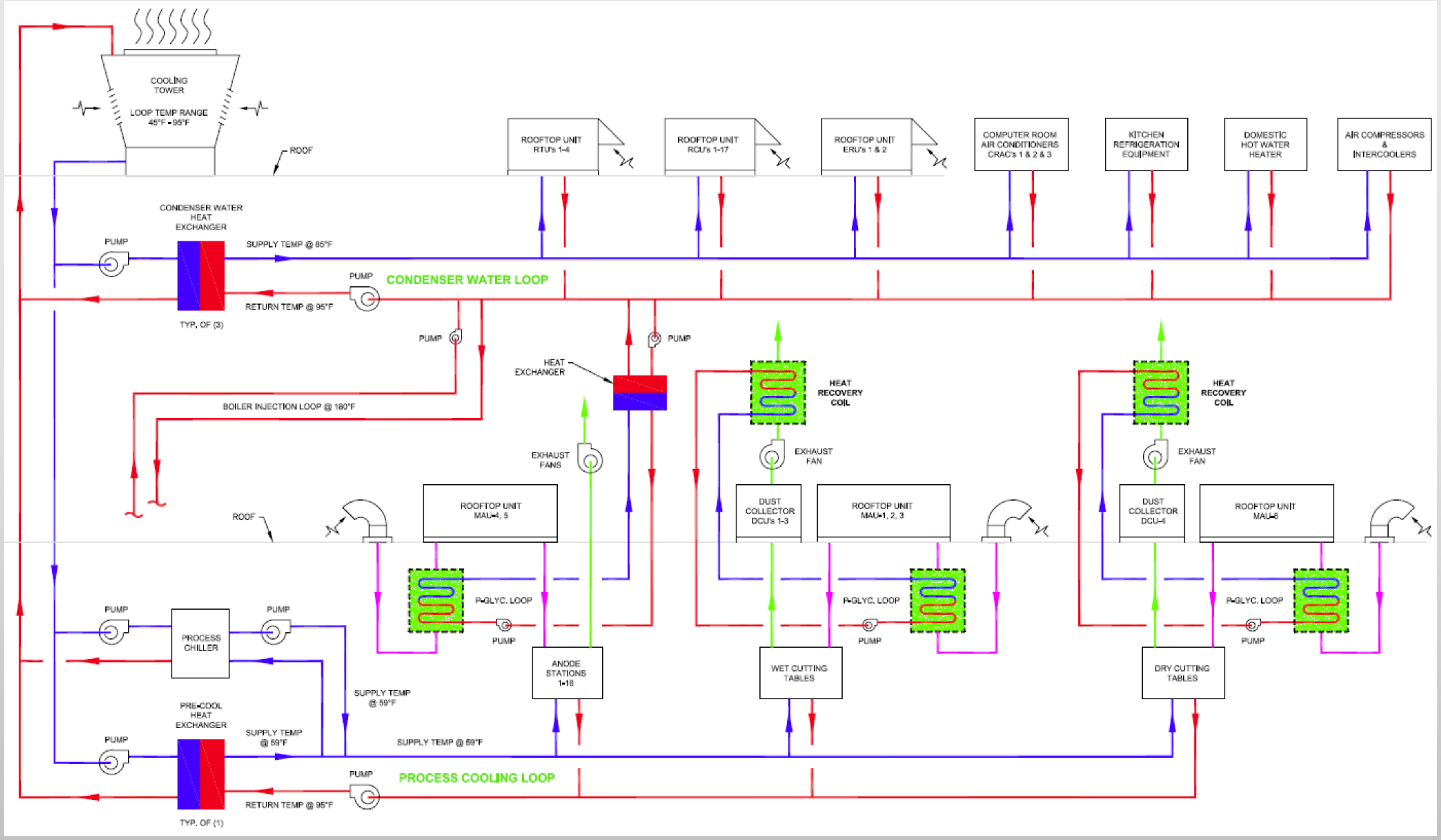
Why:

1. Flexibility for future equipment and numerous facility changes

2. Process Equipment Cooling utilizing condenser water loop
   - Manufacturing parts washers; Three (3) Branson Washers
   - Central oil cooler for CNC machines
   - Manufacturing water cooled variable speed air compressors 2 @ 100 HP each
   - Data Center In-rack cooling units (25 tons)
   - Kitchen Refrigeration Equipment
   - Future Laser Cutting devices
   - Process Cooling Chiller

"The choice for building systems was based on the fact that water source heat pump networked systems would allow for significant heat transfer around the site"

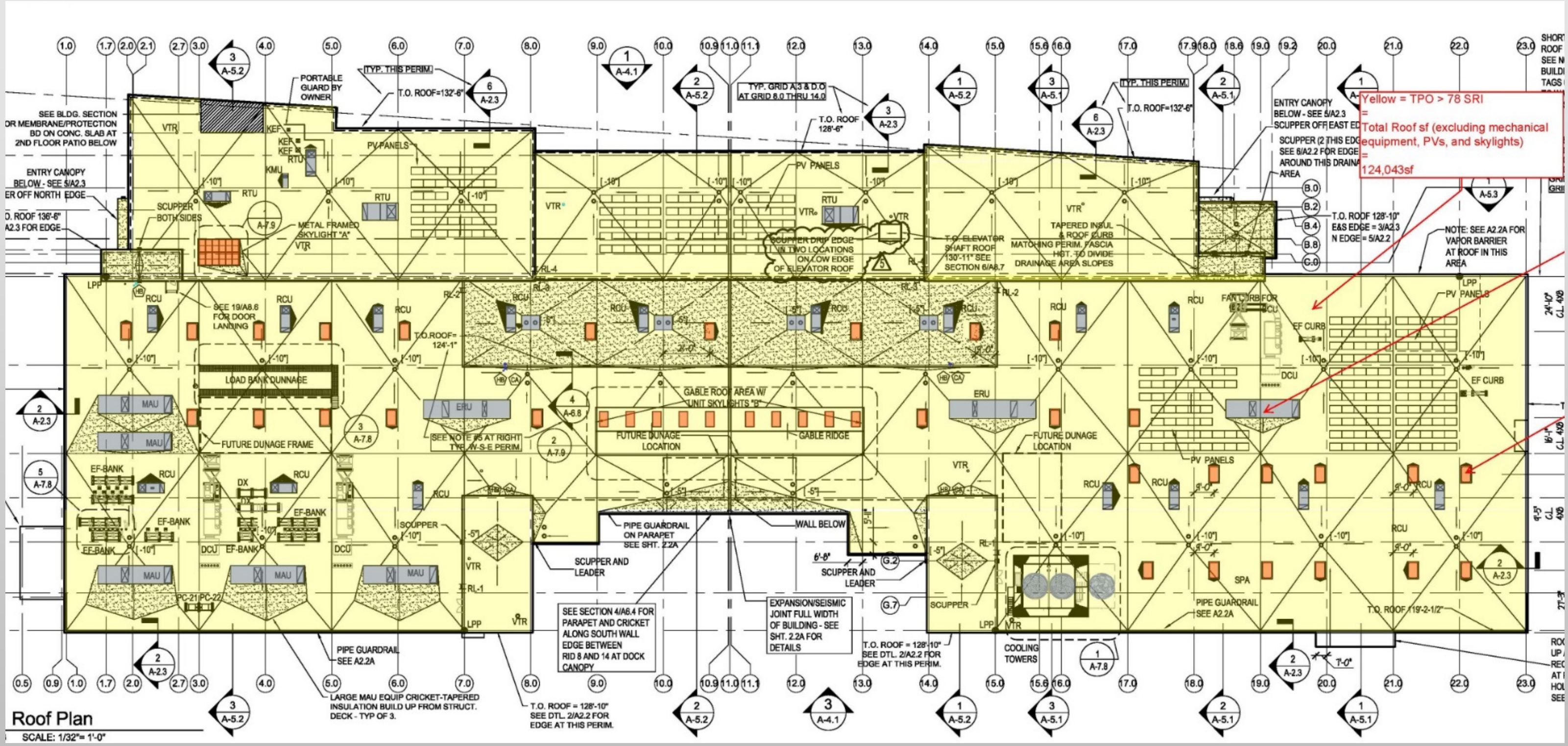
The Building Systems: Mechanical



The Building Systems: Mechanical

Primary Equipment:

- Four (4) Office VAV roof top water source heat pump units
- Twenty (20) manuf. constant volume roof top water source heat pump units
- Two (2) cell 1,500 GPM / cell cooling tower
- 2 Ventilation Energy Recovery Units
- 6 Make up air units
- 8 plate and frame heat exchangers



The Building Systems: Mechanical

Air Side System:

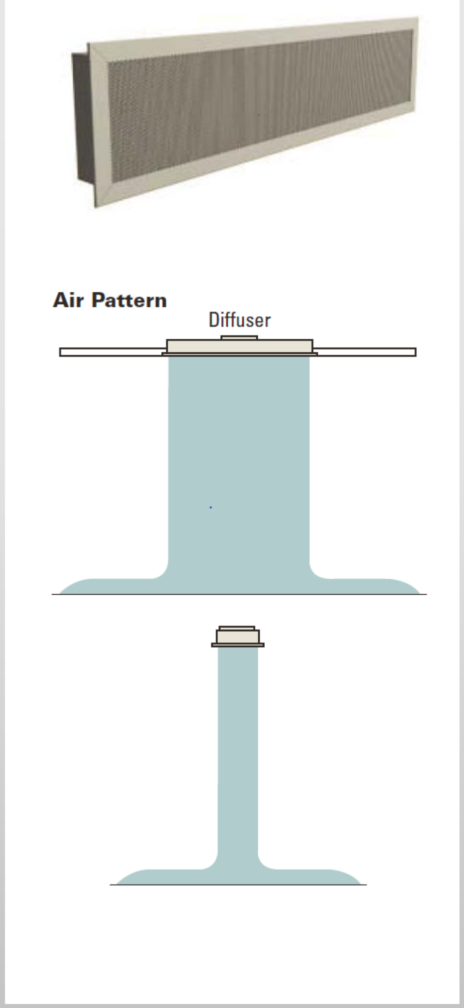
- VAV in office areas with overhead displacement air
- Constant Volume in manufacturing with Overhead displacement air
- Two dedicated outside air heat recovery units serving each roof top unit
- MAU system tied together to serve labs area and provide redundancy, total capacity for connected load

The Building Systems: Mechanical - Energy Efficiency Measures

Displacement Air

Constant Volume in manufacturing with overhead displacement air

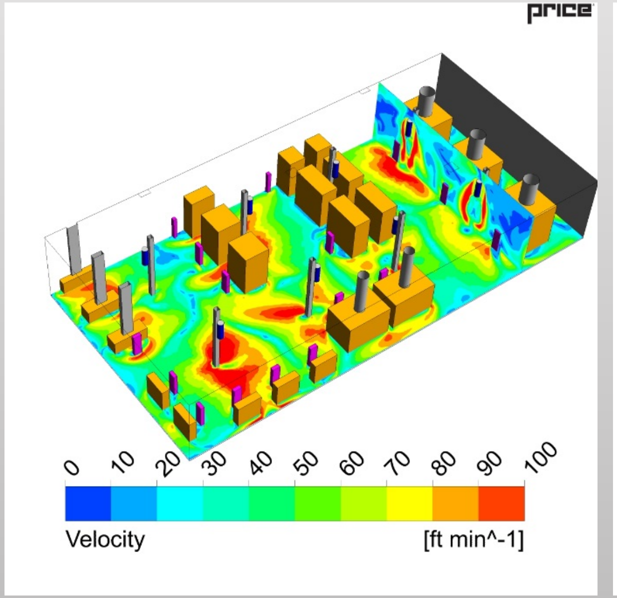
- Office areas with overhead 2’x4’ displacement air Lay in diffusers
- Conference and training rooms – side wall displacement air

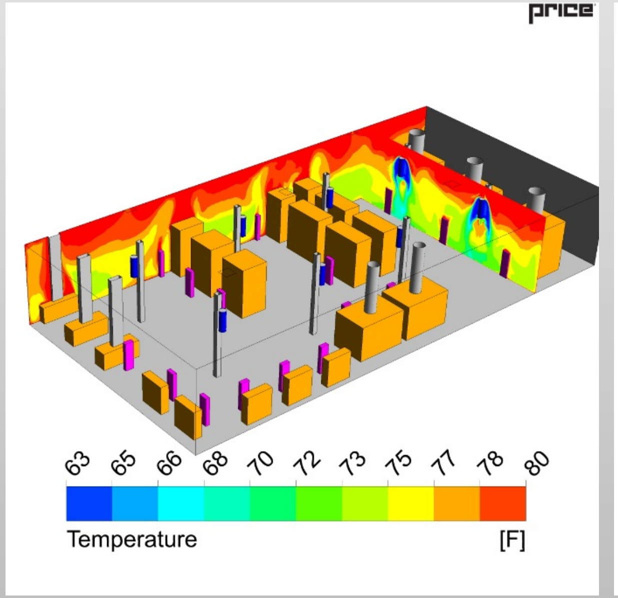


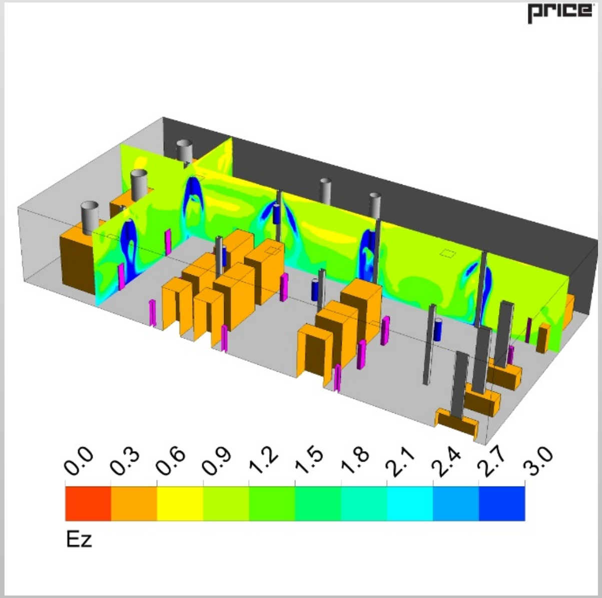
The Building Systems: Mechanical - Energy Efficiency Measures

Displacement Air Manufacturing Modeling Analysis:

- Velocity - Less than 40 FPM except directly below diffuser
- Temperature - Average of 75ºF at 43”
- Zone Ventilation Effectiveness (Ez) - Greater than 1.2 in occ. zone







The Building Systems: Mechanical - Energy Efficiency Measures

- 3 Variable Volume Dust Collection Systems
- 12,000 to 16,000 CFM Ea.
- 6 to 9 cut tables per DCU
- Interlocked with VAV make-up air
- DDC control override for shut down
- Heat recovery run-around loop

The Building Systems: Mechanical - Energy Efficiency Measures

Water Cooled Variable Speed Compressors

- 53% saving over air cooled rotary screw
- Dual pressure distribution (120 psig & 90 psig)
- Auto sequencing for max. compressor Eff.
- Demand Expander for low pressure system
- 1,000 gallon buffer / receiver tank
- 1,500 gallon managed Storage receiver tank
- Low pressure drop filters
- Water cooled cycling air dryers

Description	Air cooled Rotary Screw Modulated Control	Water Cooled Varialbe Speed Screw		VS-70	EBU ST-200
Manufacture	Gardener Denver	Gardener Denver	Power at % Capacity (flow)	KW	KW
Model	Eletra Saver II EBU ST-200 -125 PSIG	VS-70	100%	83.6	163.4
# Units	One w/1 standby	2 in Tandem w/ Optimized Controller; 1 standby	90%	74.2	162.5
PSIG	125	125	80%	66.3	157.5
CFM @ 125 PSIG	875	2 @ 395 cfm	70%	57.5	154.2
Full load kW	182.2	167.2	65%	53.55	151.7
Water Cooled vs Air Cooled	Included	-2.5	60%	49.6	149.2
Water Cooled			50%	41.9	144.2
Filtration	Coalescing Filters; 3-6 PSI loss	Low Pressure Mist Eliminator; .5-1.5 PSI loss	40%	34.5	139.3
Dryer	Non Cyling	Parker SCP1200 - Cycling type	30%	27.7	134.96283

Analysis			
Building Average Usage Load CFM Load:	515		
% load for 2 VS-70's to meet Capacity:	65%		
	Air Cooled Rotary Screw	Water Cooled Varialbe Speed Screw	Savings kW
% Load (ed)	59%	65%	
% Power @ Load	91.00%		
Compressor kW	165.8	107.1	-58.7
Cooling Fan Power (kw)	4.7	-6.45	-11.1
Filtration (.5% per PSI reduction) kW	0	-2.7	-2.7
Dryer (kW)	6.69	3.82	-2.9
Demand Limiter (kW)	0	-7.9	-7.9
Total kW @ 515 CFM Average Load	**177.2**	**93.9**	**-83.3**
Hours / Year	8760.0	8760.0	
Yearly Operating kWH/yr	1,552,202	822,528	
$/kWH	$ 0.14	$ 0.14	
Yearly Cost	$ 217,308	$ 115,154	
Saving	53%		

The Building Systems: Mechanical - Energy Efficiency Measures

Water Cooled Variable Speed Compressors

The Building Systems: Water Use Reduction

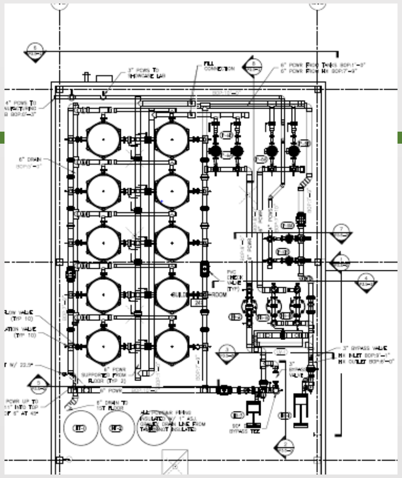
Water use was reduced by 47% including facilities restrooms, locker/shower rooms for Associates and a full service commercial kitchen.

.8 Gal/per flush tank toilets; .125 gal/f valve urinals; .5 GPM Faucets

The Facility: Water Use Reduction

Water use for Process Water was reduced by 100% with the development of a process water recycling system. The system offset over 70,000 gallons per day of domestic water use.

- 3,000 Gallons; Two stage of filtration + UV
- Serves water cut tables and test stations
- Adjustable flow via circuit setter at each work station



The Building Systems: Lighting Strategies

Office

- Day lighting for perimeter zone
- Occupancy sensors for open office areas
- Occupancy sensors for all interior rooms

Manufacturing:

- Twenty two (22) Lighting Zones in Manufacturing for 2nd and third shift control, scheduled via DDC system

Site:

- Lighting of site zoned by parking lot and lot use to allow for 2nd and third shift use of specified lots only. All LED parking and exterior lighting
- Motion sensors for each sidewalk bollard

The Building Systems: Lighting Strategies

Office Areas: Alera Indecon
Indirect fixture, 81.7% Luminaire efficiency;
2 T8: Lighting power density = .51 W/sf

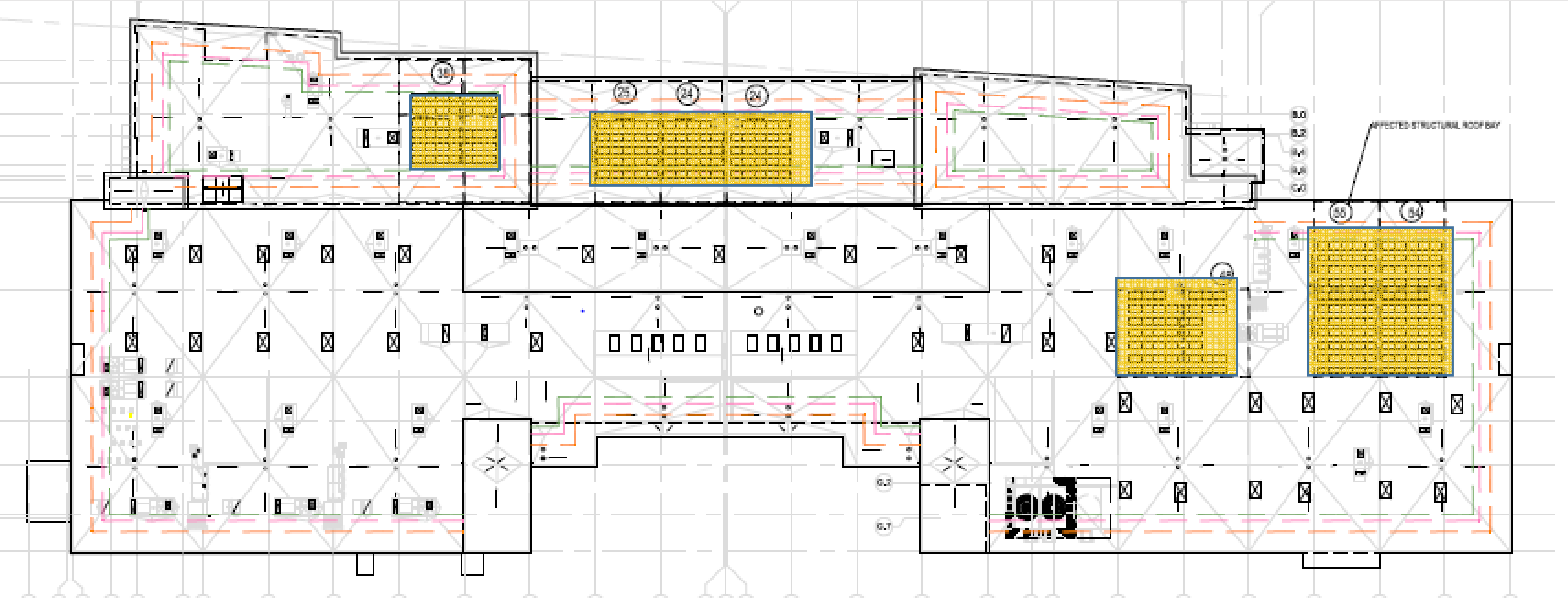
Manufacturing Areas: Columbia Ultra-Efficient Fluorescent High Bay, 4-lamp, T8, 12% Up-light; 92% Luminaire efficiency; Lighting power density = .67 W/sf

The Building Systems: Future Photovoltaic Roof Panels

System Size: 60KW DC

Modules: 268 – 40 inch x 65 inch size modules

Total array foot print = 8,362 sf



The Building Systems: Mechanical - Energy Efficiency Measures

- Additional Energy Saving Measures
- Variable speed compressors in all roof top heat pumps
- Run around heat recovery loops for dust collection exhaust and MAU preheat
- Condenser water pre-cools process water loop
- Low loss aluminum compressed air modular piping distribution system
- Variable Speed Kitchen Hood Ventilation System
- 100 plus Variable Frequency Drives

Modeling a Large Manufacturing Facility for LEED

After initially using Carrier HAP modeling software, it was determined that technical difficulties existed while attempting to model the water-cooled condensers on the rooftop equipment. These rooftop units were also variable air volume systems, thus the basic water source heat pump system would not properly represent these systems. DOE2 was therefore used as the replacement simulation software as it allows for water-cooled condensers on the packaged VAV systems.

"THE ROOFTOP ENERGY RECOVERY UNITS SERVE AS DEDICATED OUTDOOR AIR SYSTEMS (DOAS). DUE TO LIMITATIONS IN THE MODELING PROGRAM, IT WAS NECESSARY TO DISTRIBUTE THE CAPACITY AND POWER OF THIS EQUIPMENT TO THE SERVED SYSTEMS. WE ATTEMPTED TO CREATE A NULL SPACE AND NULL THERMAL ZONE AS RECOMMENDED ON THE ENERGY MODELER'S WEBSITE, BUT BASED ON DISCUSSIONS WITH MR. FOSSBENDER AT ENERGY-MODELERS.COM, OUR COMPLEX SYSTEM IS BETTER MODELED AS A THERMODYNAMICALLY EQUIVALENT SERIES OF HIGHER CAPACITY AIR HANDLERS WITH INTEGRAL WATER-COOLED CONDENSERS AND HEAT RECOVERYCAPABILITIES."

"THERE ARE SEVERAL SPACES THAT ARE SERVED WITH WATER SOURCE HEAT PUMPS BUT THE MODELING SOFTWARE WOULD NOT ACCOMMODATE THEM WHERE THEY ARE A SUBSET OF SYSTEMS TO THE PACKAGED VARIABLE VOLUME SYSTEMS. WE STRUGGLED FOR 4 DAYS TRYING TO GET THESE TO MODEL PROPERLY TO NO AVAIL. FINALLY WE MODELED THEM IDENTICALLY TO THE BASELINE AS VAV ZONES TO THEIR RESPECTIVE SYSTEMS. WE LOOSE THE ENERGY SAVINGS POTENTIAL OF USING THEM AS WASTE HEAT SOURCES AND SINKS."

Several additional features related to process equipment, and not building HVAC equipment, included in the building mechanical scope that are not represented in the model include:

- *Enhanced energy efficient compressed air technology*
- *Heat recovery domestic hot water heaters tied to the condenser water loop*
- *Water side economizer on the process water cooling system*
- *Water-cooled chillers on the process water cooling system*
- *Water-cooled equipment wherever practical*
- *Capacity for future water-cooled equipment*
- *Energy recover and variable flow control on dust collection equipment and dedicated makeup air equipment*

Modeling a Large Manufacturing Facility for LEED

Software Flexibility

Standard Programs HAP, Trace, eQUEST, etc. do not have the flexibility for advanced systems modeling

- I.E. modeling decoupled ventilation air with roof mounted water source VAV heat pump with Heat recovery
- Compressed air system & Process Cooling Loads - Had to be model independently then put loads in as process load
- Modeling of Displacement Air Systems
- Determining and modeling the manufacturing plug loads (12 watts/SF)
- LEED Reviewer – Comprehending and understanding of the model and the numerous building systems and subsets and complexity

The Building Systems: Mechanical - Energy Efficiency Measures

- Additional Energy Saving Measures
- Variable speed compressors in all roof top heat pumps
- Run around heat recovery loops for dust collection exhaust and MAU preheat
- Condenser water pre-cools process water loop
- Low loss aluminum compressed air modular piping distribution system
- Variable Speed Kitchen Hood Ventilation System
- 100 plus Variable Frequency Drives

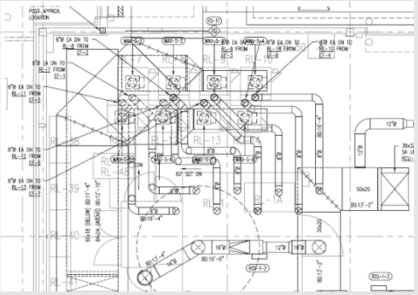
The Building Systems: Interesting Facts after 1 Year of Operations

- Zero need to add heat to condenser water system, loop maintains 75 ºF plus or minus all winter long due to constant heat add due to manufacturing and process loads.
- Zero call for the cooling tower fan operation for first six weeks last winter
- Displacement air has exceeded standard comfort callbacks level based on minimal complaints
- Zurn Siphonic roof drainage system - Largest in North America

Building Commissioning for Hypertherm

What is Commissioning?

- Quality Assurance
- 3rd Party, Independent
- Collaborative
- Hypertherm - Comprehensive Cx
    - Building MEP, Process and Enclosure
    - Design and Construction





The Building Commissioning:

Quality Assurance Process

- **Requires metrics against which to measure success**
- **Metrics and other criteria defined by:**
  - **OPR (Owner's Project Requirements)**
  - **BoD (Basis of Design)**
- **Hypertherm's OPR – Over 44 distinct items in 6 overarching categories.**
- **Design Team's BoD – 15 page, comprehensive outline of the design approach.**
  - **Provided direct feedback on each OPR item.**

The Building Commissioning:

Quality Assurance Process

Examples of OPR items & BoD response

- *OPR – "Consider compressed air efficiency"*
- *BoD – Compressed air will be designed using water cooled, variable speed compressors.*

- *OPR – "Build a Very Good Envelope"*
- *BoD - contained a description of major envelope elements including thermal and air leakage performance.*

Performance Criteria Summary:

Building Envelope Criteria: (updated 3-21-2011)

Assembly R Value for wall below grade = R10 continuous insulation.

Assembly R Value for wall above grade = R46 continuous insulation.

Assembly R Value for Roof = R38 continuous insulation.

Assembly R Value for Slab = Not applicable - continuous insulation at exterior.

Windows: *(updated 3-21-2011 in italics):*

The current BoD provides better performing windows in the office areas than the 2-22-2010 BoD to increase user comfort. The BoD for the office areas will be fiberglass windows based on Serious 925 series with Serious Glass 9H (double glazed with suspended interior film). Fixed picture-Overall U-value 0.14, Overall SHGC 0.42, VT 0.57. Casements & Awnings Overall U-value .17,SHGC 0.33, VT0.45. Window Air Leakage, ASTM E 283: Window air leakage when tested at 1.57 psf (25 mph) shall be 0.05 cfm/ft2 of frame or less.

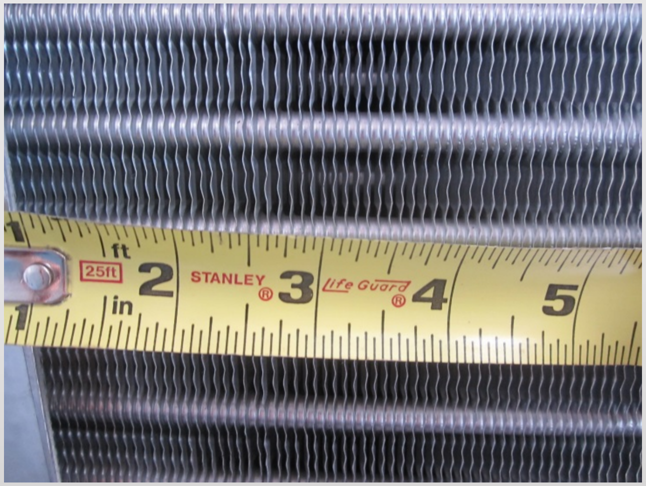
The Building Commissioning:

- **Quality Assurance Process**
  - *Focused Design Review*
    - *Review drawings and specs to ensure conformance with OPR, BoD.*
    - *Identify opportunities for simplified construction, simplified maintenance and energy efficiency improvements.*
    - *CxA & ZbD*
      - *3 Review Milestones*
      - *290 Review Comments*
  - *Design team was receptive and responsive.*

The Building Commissioning:

Quality Assurance Process

- Rigorous Field Work



- Detailed Installation and Testing Documents.
  - Set clear expectations
  - Based on OPR, BoD, Design Docs and Submittals.
- Contractor Participation is KEY.

The Building Commissioning:

Heating Hot Water FPT 10/3

Heating Hot Water Operational Test		Result	CxA Pass Y/N
BOILER LEAD-LAG TEST		(3)	
Boiler scheduled lead-lag.	*Record Lead-Lag switchover day and time:*		
	With system running normally, reset the BMS time clock ahead one week.		
	Lead pump commanded off, lag pump commanded on?		
	Lead boiler commanded off?		
	Lag pump starts properly, status made?		
	Lag boiler commanded on, starts properly and status made?		
	Release all overwrites.		
HWP SPEED CONTROL TEST	*Begin with system running normally, lead HWP speed steady and system dP satisfied.*	✓	
Pump dP reset should be as follows: Setpoint increases (or decreases) 0.5 psi every five minutes when the zone hot water valve with the maximum open position is above 95 percent (or below 90 percent).	*Record system dP setpoint:* 7psi start	✓	
	Record: *dP reset increment* .5 *psi.* *dP reset time delay* 5 *minutes.* *Limits of valve with maximum open position:* *Increase dP if valve is more than* 95 *% open.* *Decrease dP if valve is less than* 90 *% open.*		
	dP reset setpoints match controls submittal?	N	
	Overwrite (increase) the lower limit of maximum valve open percentage to initiate a reset of the pump dP setpoint. ✓		
	dP is reset lower according to reset increment and time delay? Y		
	Lead pump speed ramps down? Y		
	Lead pump does not hunt? Y		
	System dP satisfied? ✓		
	Release overwrite.		
	Overwrite (decrease) the upper limit of maximum valve open percentage to initiate a reset of the pump dP setpoint. ✓		
	dP is reset higher according to reset increment and time delay? Y		
	Lead pump speed ramps up? Y		
	Lead pump does not hunt? Y		
	System dP satisfied?		
	Release overwrite.		
	Repeat test with lag pump.		
	Release all overwrites.		
HWP MINIMUM FLOW BYPASS TEST	*Begin with system running normally, lead HWP speed steady and system dP satisfied.* ✓	X	
	Reduce call for heating by closing hot water coil valves (overwrite space setpoints to above room temperatures). ✓	N	
	Lead pump speed ramps down?		
	Lead pump does not hunt?		
	Pump flow reduces down to 100 GPM? 180		
	At 100 GPM, hot water bypass valve modulates open to maintain 100 GPM of flow? Y		
	System dP satisfied? Y		
	Valve and pump speed do not hunt? Y		
	Increase call for heating by opening hot water coil valves (overwrite space setpoints to below room temperatures). Y		
	Lead pump speed ramps up?		
	Once system flow is above 100 GPM, bypass valve modulates closed? Y		
	Valve and pump speed do not hunt? Y		
	System dP satisfied? Y		
	Release all overwrites.		

NOTE (3) TEST W/ VTV NEXT WEEK

10/3 — NOTE B) — NOTE G) — NOTE (4)

RETEST 10/4 — 7psi

NOTE K — NOTE 6 & 7 & 8

SEE NOTE I) PUMPS DO TRACK → RESET SCH. IS PENDING

RETEST 10/4

NOTE 5 → [NOTE K] [NOTE 7]

NOTE (5) ON SPREADSHEET

2 of 4

Cx Associates LLC

File: FPT 942 Hypertherm Building Systems Cx Htg Hot Water.xls

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1/4

S.S. L.B. 10/3/12

HEATING HOT WATER - FPT NOTES

A) Adjusted OA to 70°F bundle - Manually adjusted to one htg v/v open.

B) FIRST BOTH P1A & P1B COME ON TO MIN = 12HZ & slowly ramp up

C) NEXT BOILER B1 (MASTER) ENERGIZES. THIS BOILER CONTROLS STAGING.

D) 130°F SET POINT TO B1. SLOWLY WARMING FROM COLD START 72°F @ HWST SENSOR & CLIMBING (59°F & RAINING OAT)

E) OVERRIDE HWST SET POINT TO 180°F TO ATTEMPT 2nd boiler B-2 TO ENERGIZE FROM BUDERUS CONTROLS ON B-1

NOTES 1) & 2); REFER TO SPREADSHEET NOTES ON 'JCI Cx & ISSUES LOG'

3.) INTERNAL BUDERUS CONTROLS FOR LEAD/LAG, TEST NEXT WEEK W/ ANDRE M. FROM VTV.

The Building Commissioning:

Quality Assurance Process

- Working Towards Closure
  - Identify, assign and track issues.

CXassociates LLC

942 Hypertherm Heater Road

Revision Date	4/17/2013	Note:	Grey rows are completed
Revision No.	15		Orange rows require Cx verification
			Blur rows are the responsibility of the owner

#	Issue	Date Found	Issue/Effects	Recommendation	Responsible Party	Discussion/ Status	Actions Taken, Date and Party	CxA Sign-off
1.	CAI-1. Dielectric Branch Tee Connection	5-Apr-12	Connections between steel hydronic distribution loop branch-tees and copper branch piping do not appear to have a dielectric fitting.	Verify that all steel/copper connections are equipped with dielectric fittings.	VHV		VHV-7/31: Item fixed. All others checked for compliance.	ACCEPTED
2.	CAI-2. Pipe Hanger System Load Rating	5-Apr-12	Hangers supporting large condenser water steel header piping above the cooling tower sump are suspended by strut-channel. It is not immediately clear what the loading capacity of the channel is.	Recommend verifying load rating of pipe-hanger system, with attention to strut-channel detail.	VHV		vhv 4-23-13: All hanger material and attachments were gone over	ACCEPTED

- *Over 230 issues identified and resolved.*

The Building Commissioning: Measurement and Verification

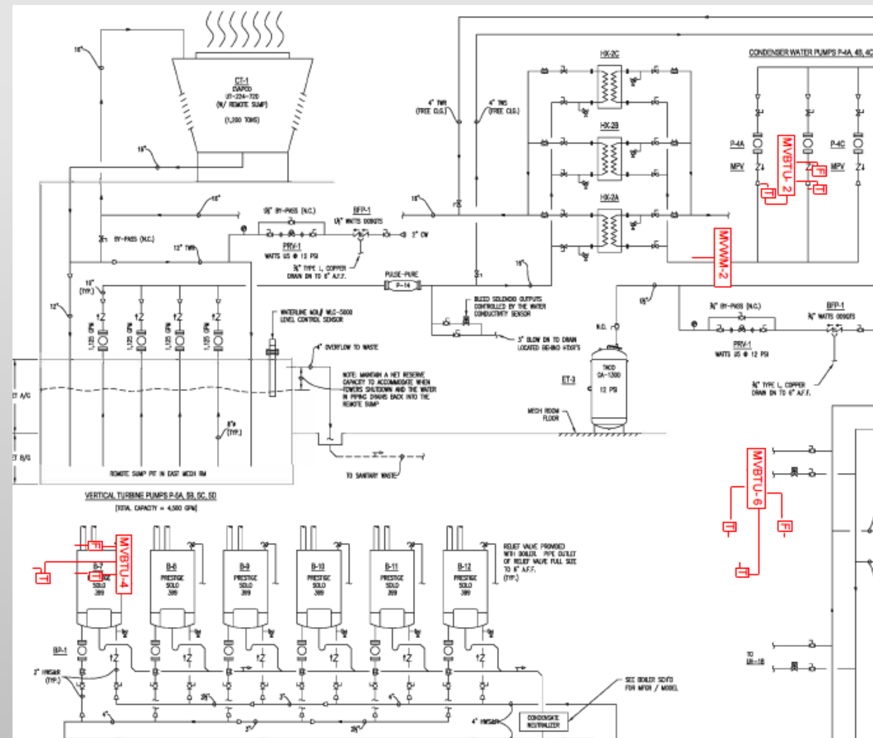
		CT on Panels	CT on Panels	CT on Eq. Feeder	Lp Meter	CT on Bus
MV Zone	**Area**	**Receptacle Power Panels**	**Lighting Power Panels**	**HVAC Eq. Power**	**Lp Gas Consumption Meter**	**Bus Duct Power Metering (120& 480)**
Site	Site	N/A	CT's on feeder from panel	-	Primary Meter at entrance	
Zone A	Second Floor Office	LP-2A; LP-2B LP-2C; LP-2D	E-2	RTU-2; RTU-1	N/A	N/A
Zone B	Training /Auditorium	LP-1D	*E-2	Per Zone A	N/A	N/A
Zone C	1st Floor office	LP-1A, LP- 1B, LP-1C	E-1	Per Zone A	N/A	N/A
Zone D	Cafeteria / Kitchen	K-1, K-2	*E-2	RTU-4; Kitch-MAU; KX	Kitchend cook feed; Kitchen-MAU	N/A
Zone E	Assoc. Entrance/Amenities	LP-FA, LP-FB	*E-1	RTU-3	N/A	N/A
						22- 480 volt bus

Cxassociates LLC

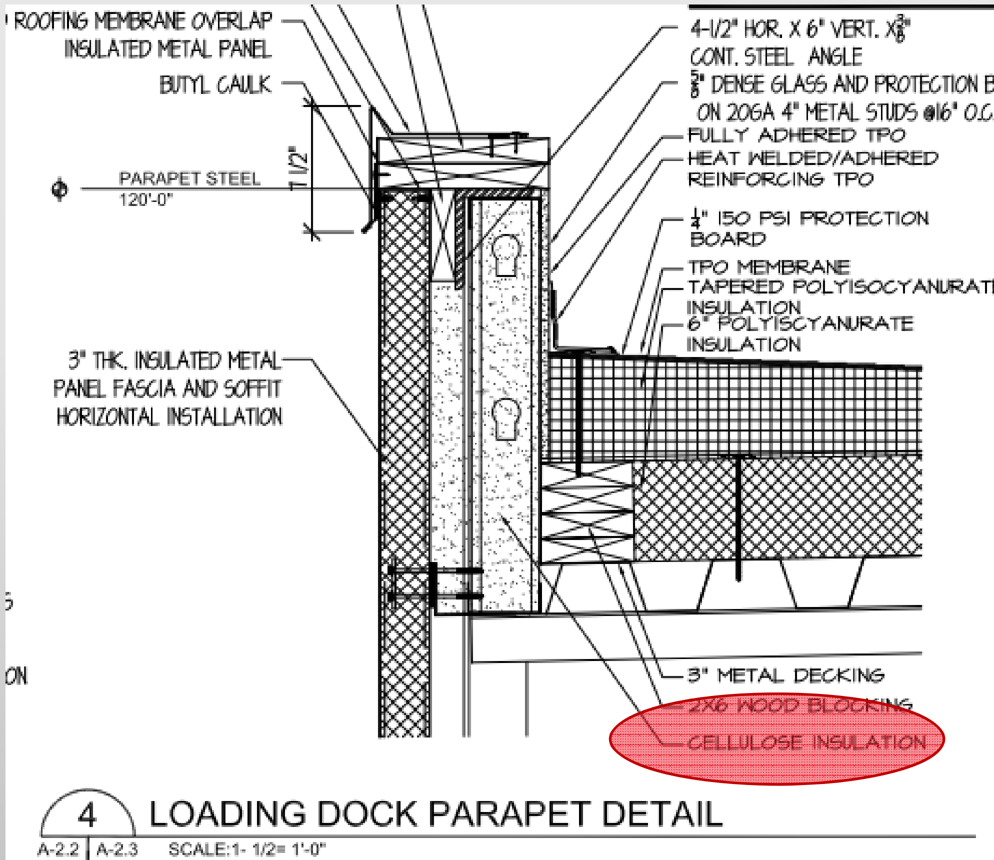
BTU METER SCHEDUL

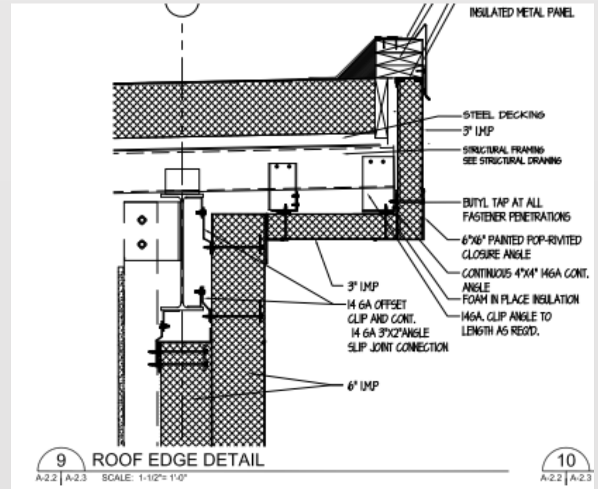
TAG	SERVES	MANUFACTURER	MODEL NO. (NOTE 4)	FLOW METER TYPE	FLOW METER MODEL NO.	TEMPERATURE SENSOR TYPE (NOTE 2)
MVBTU-1	TOWER WATER	ONICON	SYSTEM-10	MAG FLOW METER	F-3500	FACTORY PROVIDED
MVBTU-2	CONDENSER WATER	ONICON	SYSTEM-10	DUAL TURBINE	F-1200	FACTORY PROVIDED
MVBTU-3	PROC COOLING PRECOOL HX 4	ONICON	SYSTEM-10	DUAL TURBINE	F-1200	FACTORY PROVIDED
MMBTU-4	HOT WATER SECONDARY	ONICON	SYSTEM-10	DUAL TURBINE	F-1200	FACTORY PROVIDED
MMBTU-5	CHILLED PROCESS WATER	ONICON	SYSTEM-10	DUAL TURBINE	F-1200	FACTORY PROVIDED
MMBTU-6	HOT WATER TO CONDENSER LOOP	ONICON	SYSTEM-10	DUAL TURBINE	F-1200	FACTORY PROVIDED
MMBTU-7	GLYCOL LOOP	ONICON	SYSTEM-10	DUAL TURBINE	F-1200	FACTORY PROVIDED

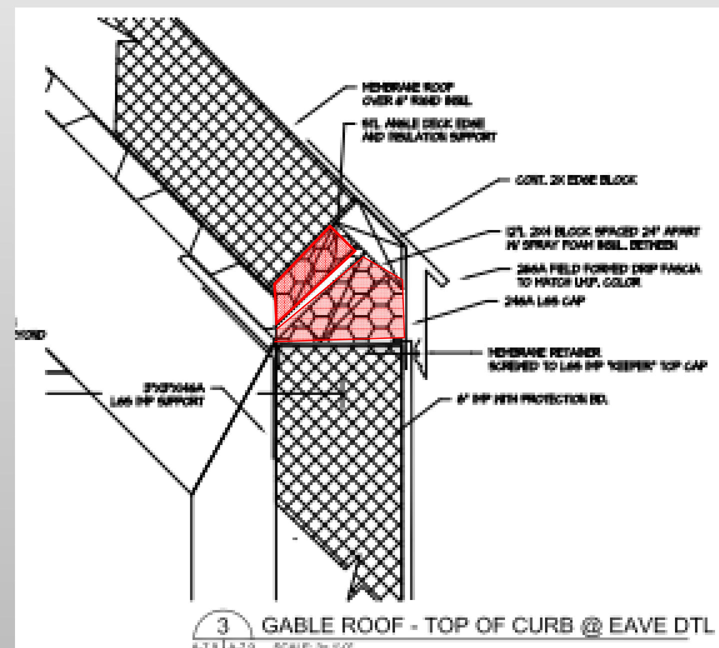
NOTES:
1. COORDINATE PIPE SIZE WITH MOSTCURRENT ENGINEERING DRAWINGS
2. USE DEVICE TEMPERATURE SENSORS IN LIEU OF DDC SENSORS FOR CONTROL AND MONITORING.
3. OPT # IDENTIFIES ONICON OPTION PACKAGE
4. PROVIDE BACNET COMPATIBLE OUTPUT.



The Building Envelope Commissioning







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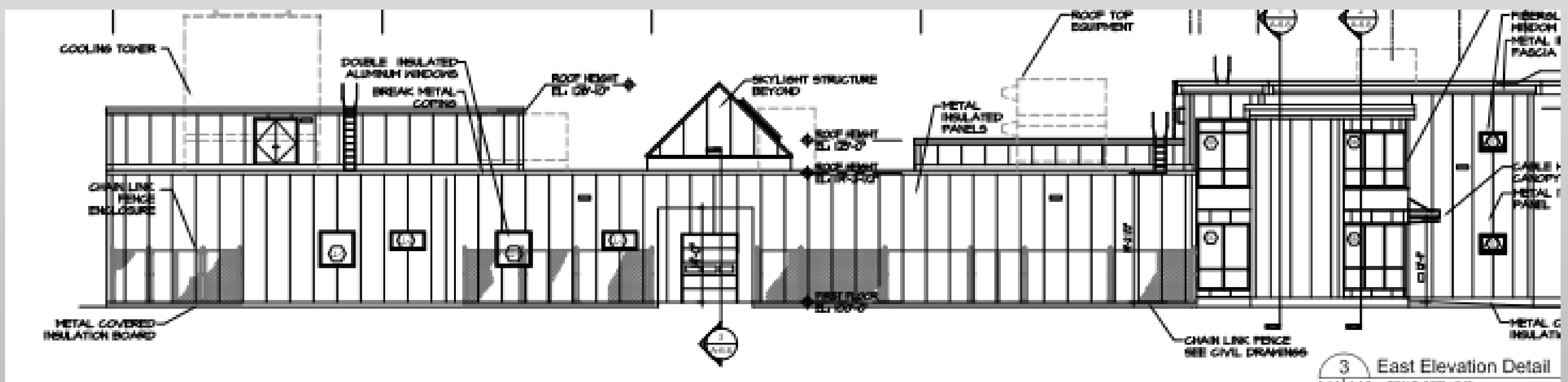

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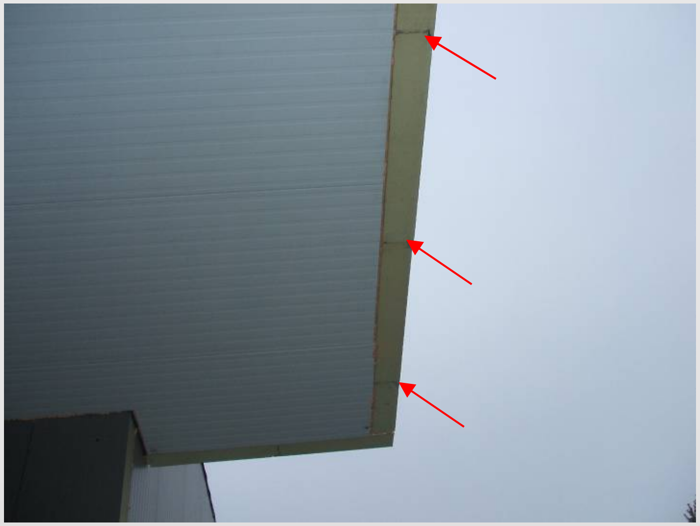

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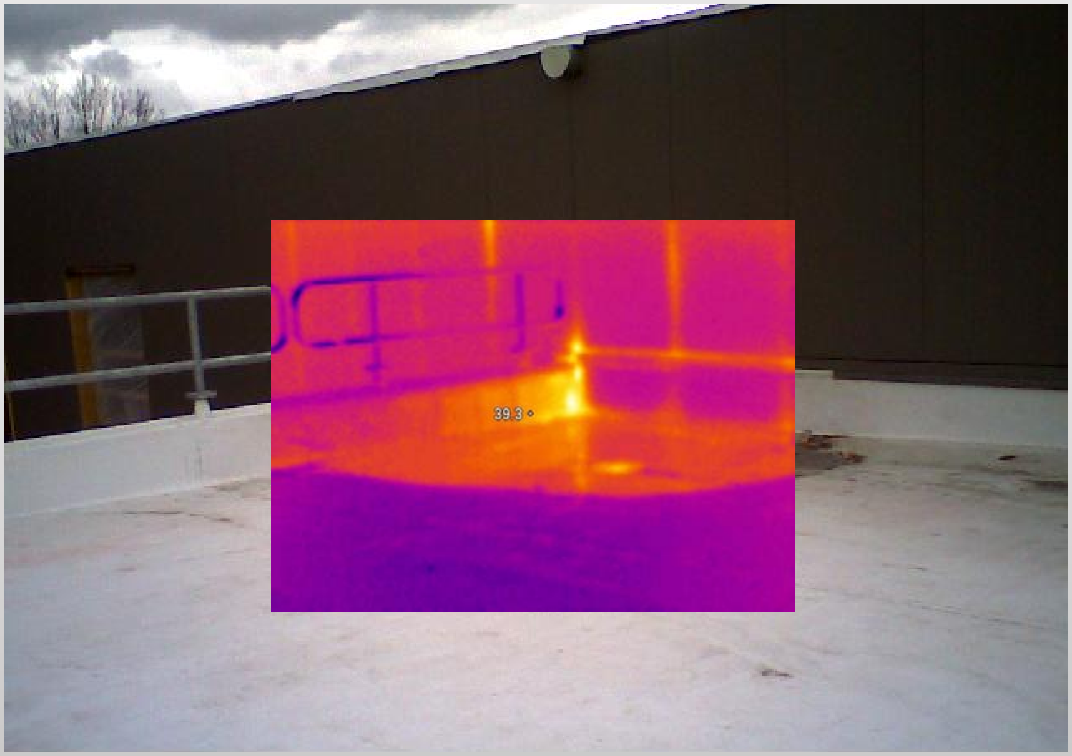
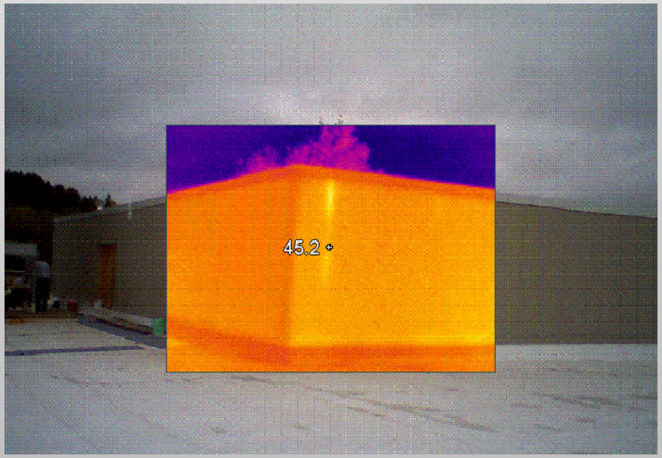
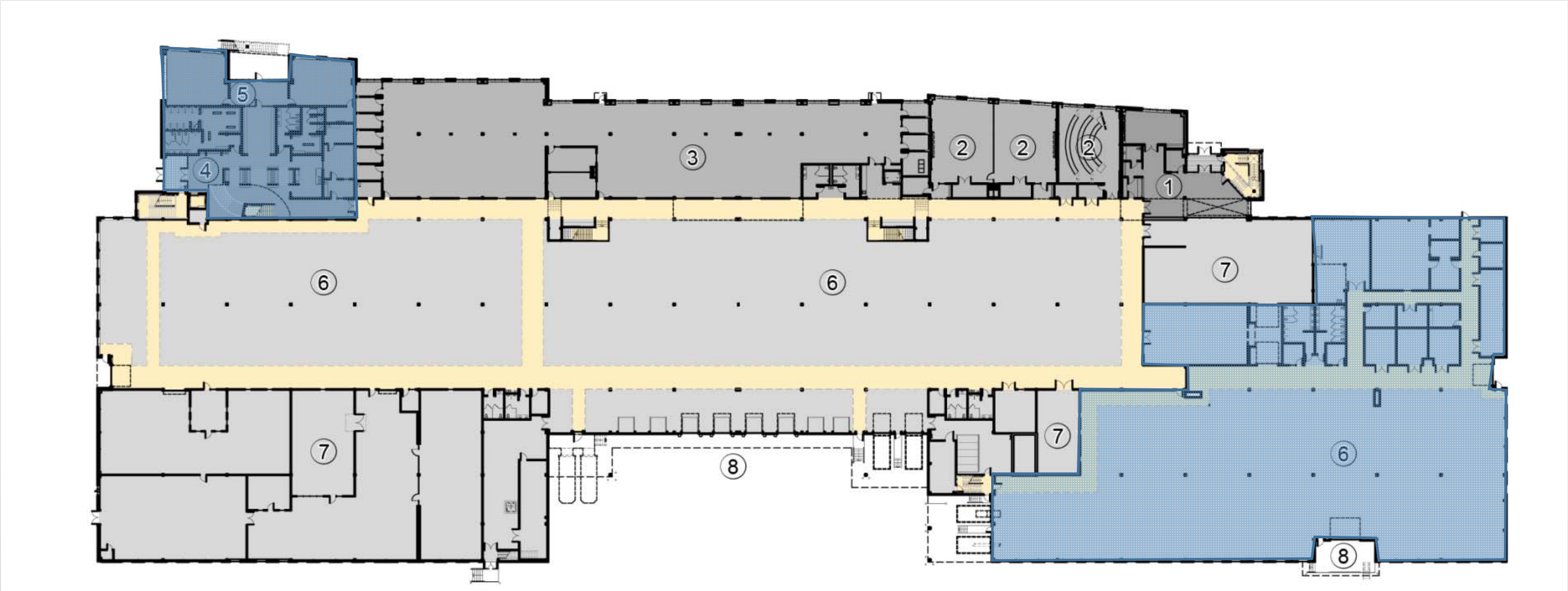




The Building Envelope Commissioning

The Building Envelope Commissioning



The Integrated Design Team

Owner: Hypertherm Inc.

Perry Seale, Ted Dawson, +500 Associates

Architect/Builder: Bread Loaf Corporation

Jan Becker, John Johnston, Bob Eaton, Steve Rooney, Joe Lattucca, Fred Bellucci, Josh Francis

Structural Engineer: Engineering Ventures

Russ Miller-Johnson, Paul Hobbs, Matt Ernst, Bill Nourse

Mechanical, Electrical and Plumbing Engineer: Salem Engineering

Tom Reilly, John Plankey, Joanne Curanceau

Fire Protection Engineer: Chase Engineering

Matthew Chase

Civil Engineer: Pathways Consulting

Rod Finley, Chris Turgeon

Landscape Architect: Saucier + Flynn

Alan Saucier, Chris McGinnis

Leed Consultant and Commissioning Agent: Cx Associates

Matthew Napolitan, Jennifer Chiodo

Building Envelope Commissioning Agent: Zero by Degrees

Jon Haehnel

Thank you.