Villanova University: School of Law

Jason Greer

The Pennsylvania State University

Architectural Engineering

Lighting/Electrical Option

Senior Thesis – Spring 2008

Advisors: Dr. Kevin Houser, Dr. Richard Mistrick & Mr. Ted Dannerth

Name: Villanova University: School of Law

Location: Villanova, PA

Owner: Villanova University

Size: 170,000 SF

Cost: $56,566,661

Building Uses
- Law library
- Classrooms
- Student services
- Faculty/Administrative Offices
- Chapel
- Dining facility

Project Team
- GC: Gilbane
- CM: SmithGroup
- Architect: SmithGroup
- MEP: SmithGroup
- Landscape Arch: ML Baird &Co.
- Civil Engineer: Yerkes Associates, Inc.
- Structural Engineer: O'Donnell & Naccarato, Inc

Lighting Depth
- Entry/Courtyard
- Atrium
- Atrium Daylight Study

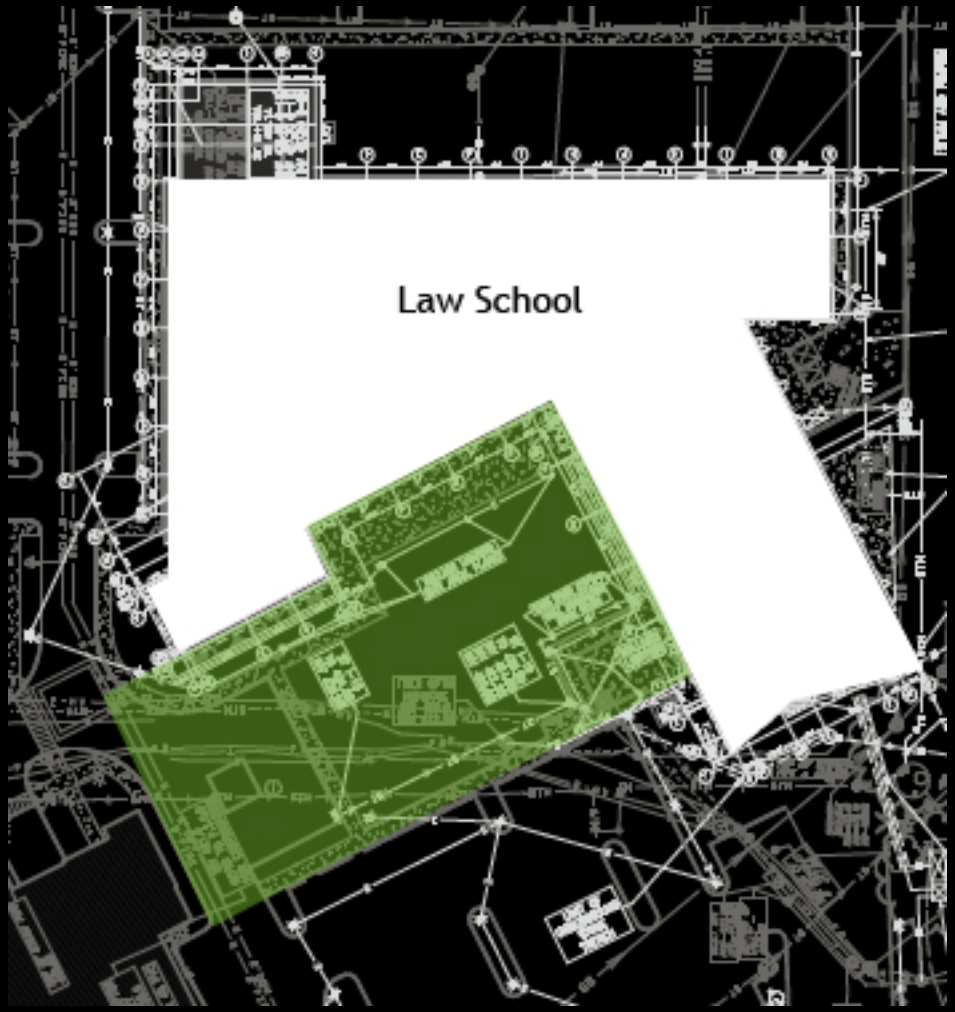
Electrical Depth
- Distribution System Redesign

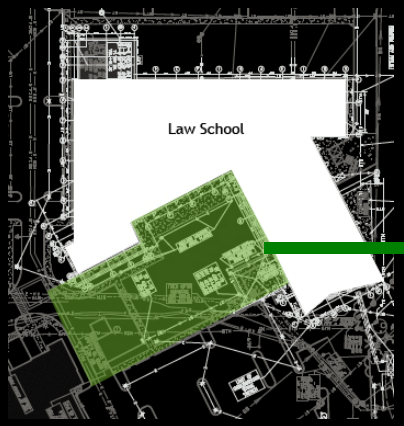
Mechanical Breadth
- Replacement of atrium glazing and the mechanical loading effects

Conclusions

Lighting Depth

Entry/Courtyard


Law School


Law School

Site Plan


Villanova University: School of Law
Villanova University: School of Law

Key Architectural Features

- Open grass area
- Patio against building
- Stone walkway surrounding vegetation
- Great view from parking lot

Space Functions

- Draw attention
- Safe pedestrian passage
- Entry to law school

Design Goals

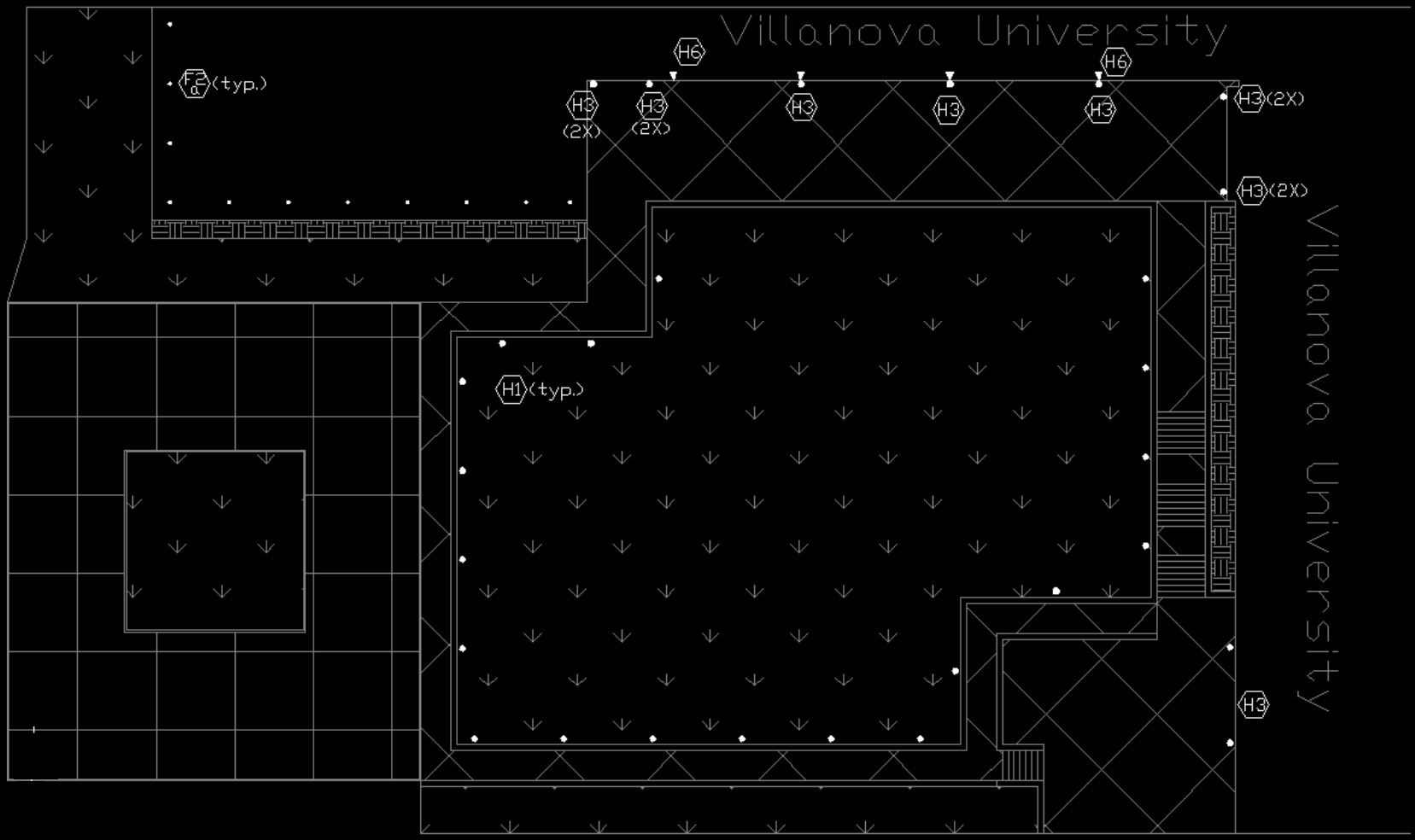
- Provide adequate security lighting
- Illustrate law school's entrance
- Allow the atrium to dominate
- Meet ASHRAE 90.1 power density requirements

Target Illuminance

- 5fc horizontal at entrance
- 1-5fc for walkways

Controls

- Time clock
- Connected to existing control panel

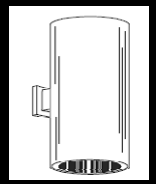


F2a

(2) 26W CFL

H1

(1) 70W MH



H3

(1) 100W MH

H4

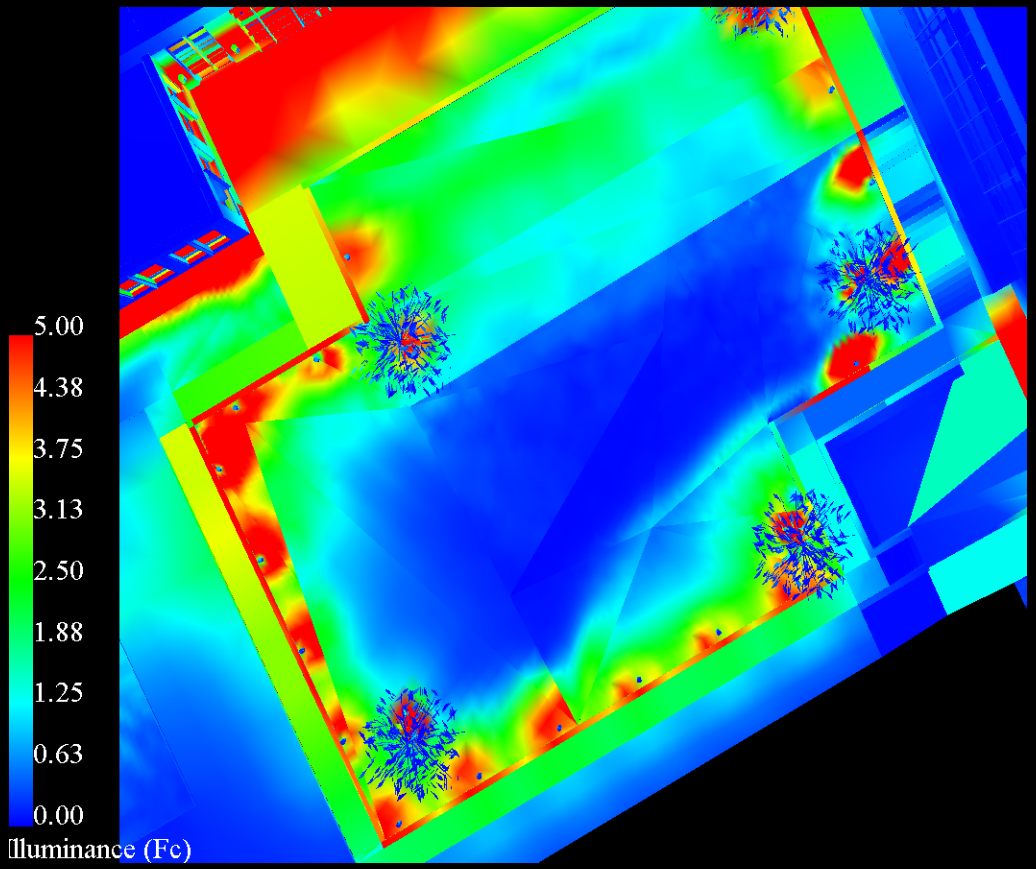
(1) 20W MH

H6

(1) 20W MH

Design Performance

Horizontal Illuminance – Patio: 6.01fc (avg)
Walkways: 2-4fc (avg)



Design Power Density

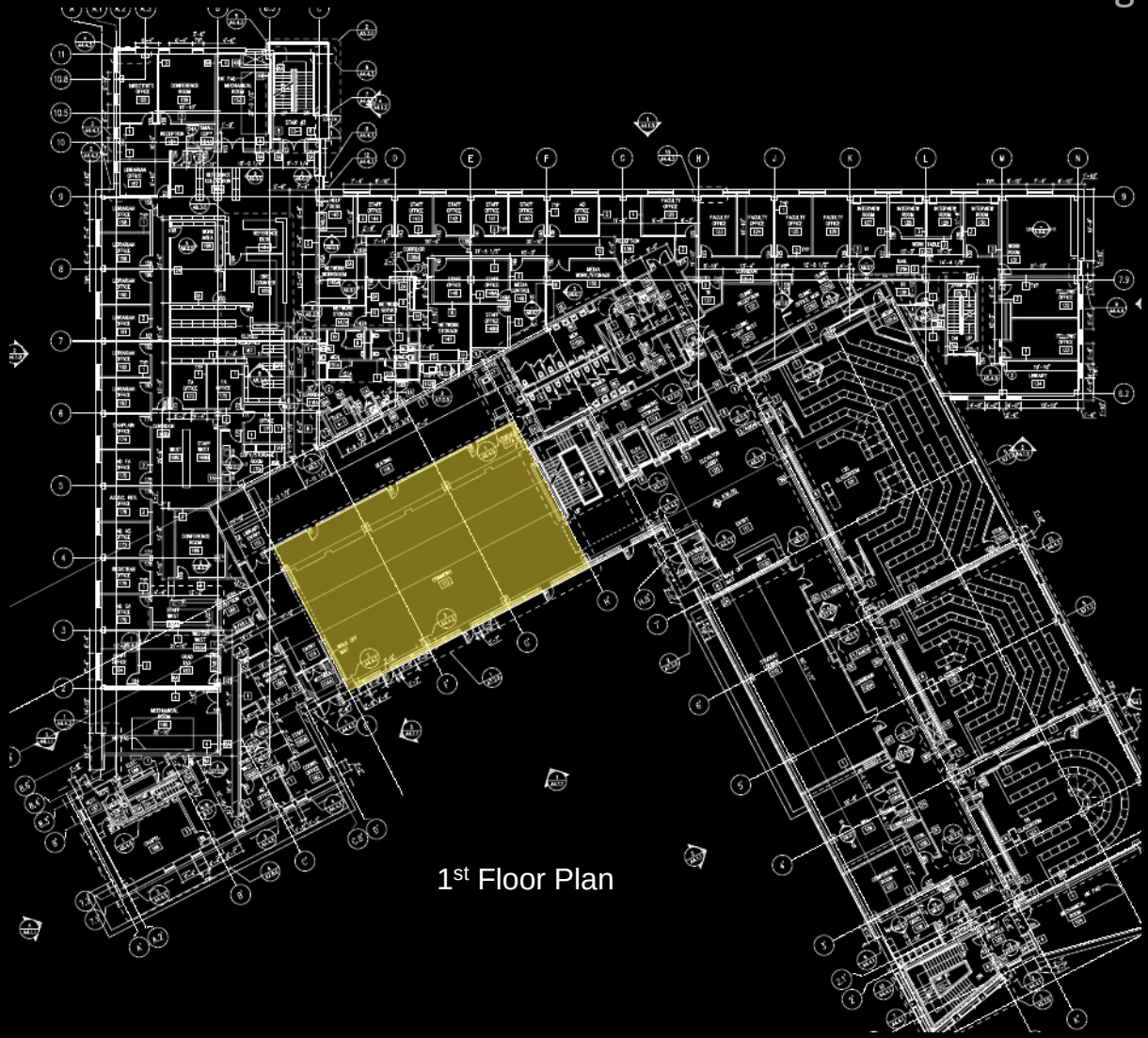
Area: 24,014SF
Allowable PD: 0.2W/SF
Total Watts: 3857W
Design PD: 0.16W/SF

Lighting Depth - Entry/Courtyard

Lighting Depth - Entry/Courtyard

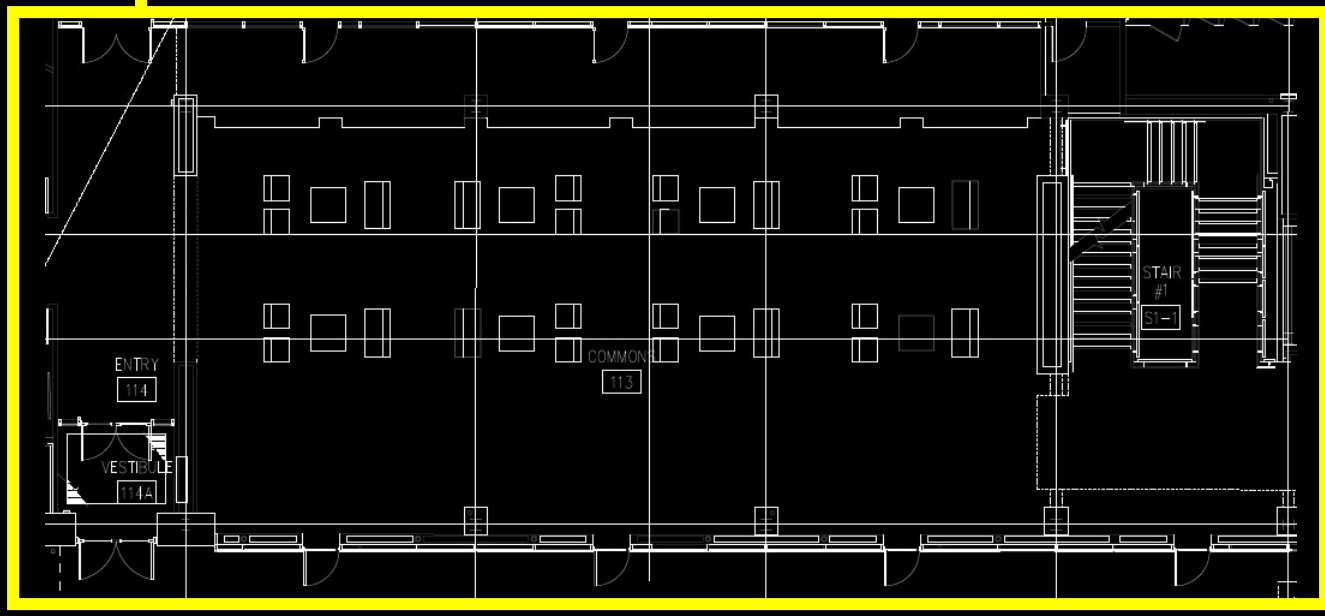
Lighting Depth

Atrium



1st Floor Plan

1st Floor Plan

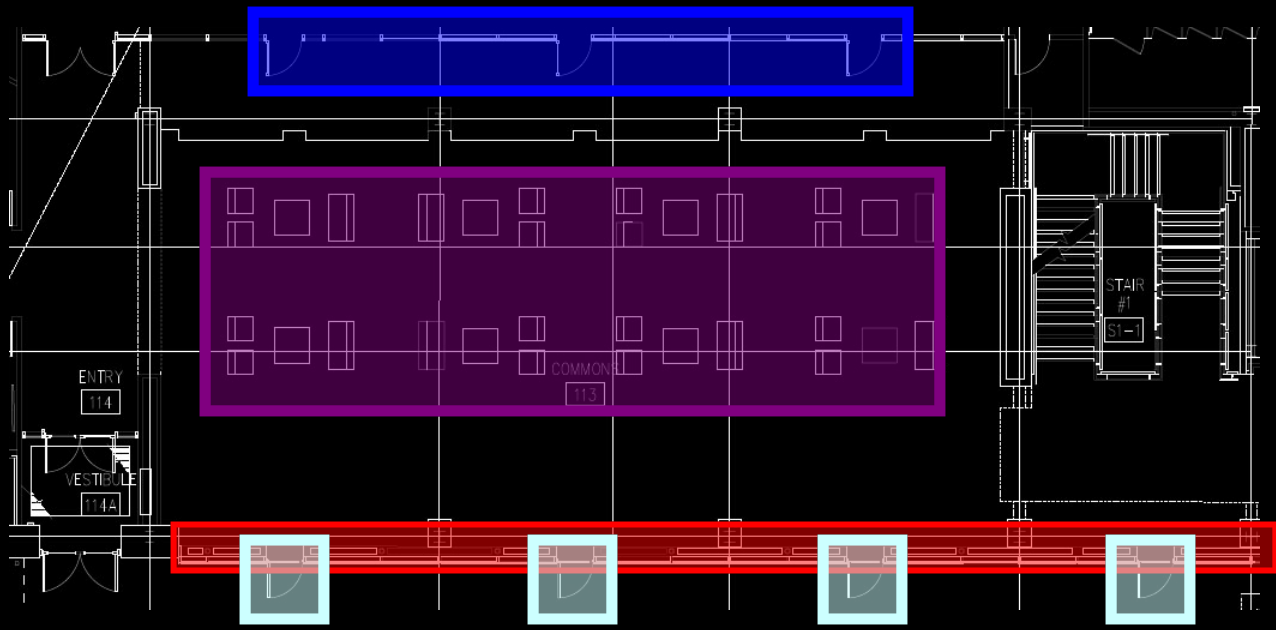


Key Architectural Features

- Glass Façade
- Seating Area
- Entrance to Coffee Bar
- Exits to Courtyard Patio

Space Functions

- Glow from exterior
- Sitting/Gathering
- Passing Through



Design Goals

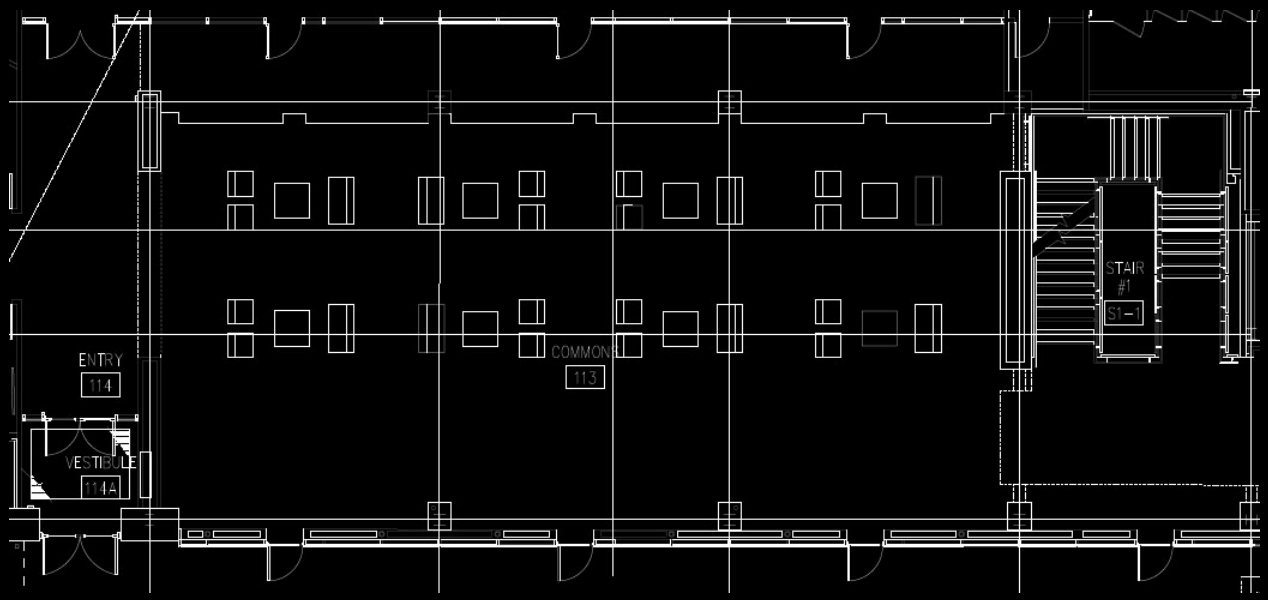
- Attract attention from outside
- Allow smooth transition from wing to wing
- Meet ASHRAE 90.1 power density requirements

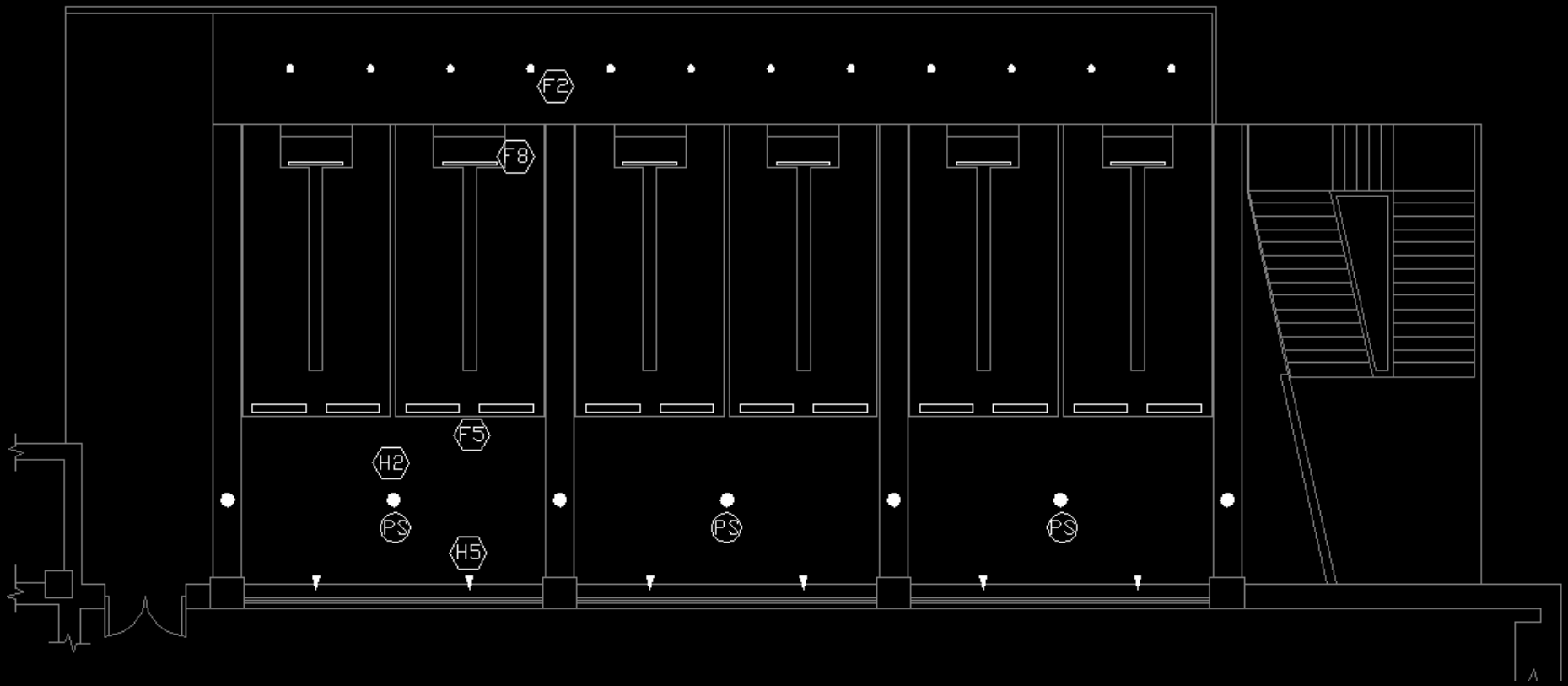
Target Illuminance

- 10fc on floor

Controls

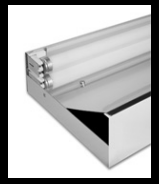
- Dimming controller
- Photo sensors
- Fluorescent dimmed
- HID switched





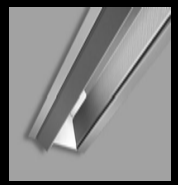
F2

(1) 32W CFL



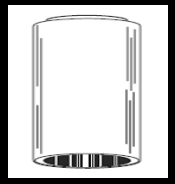
F5

(1) 28W T5



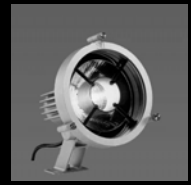
F8

(1) 28W T5



H2

(1) 100W MH

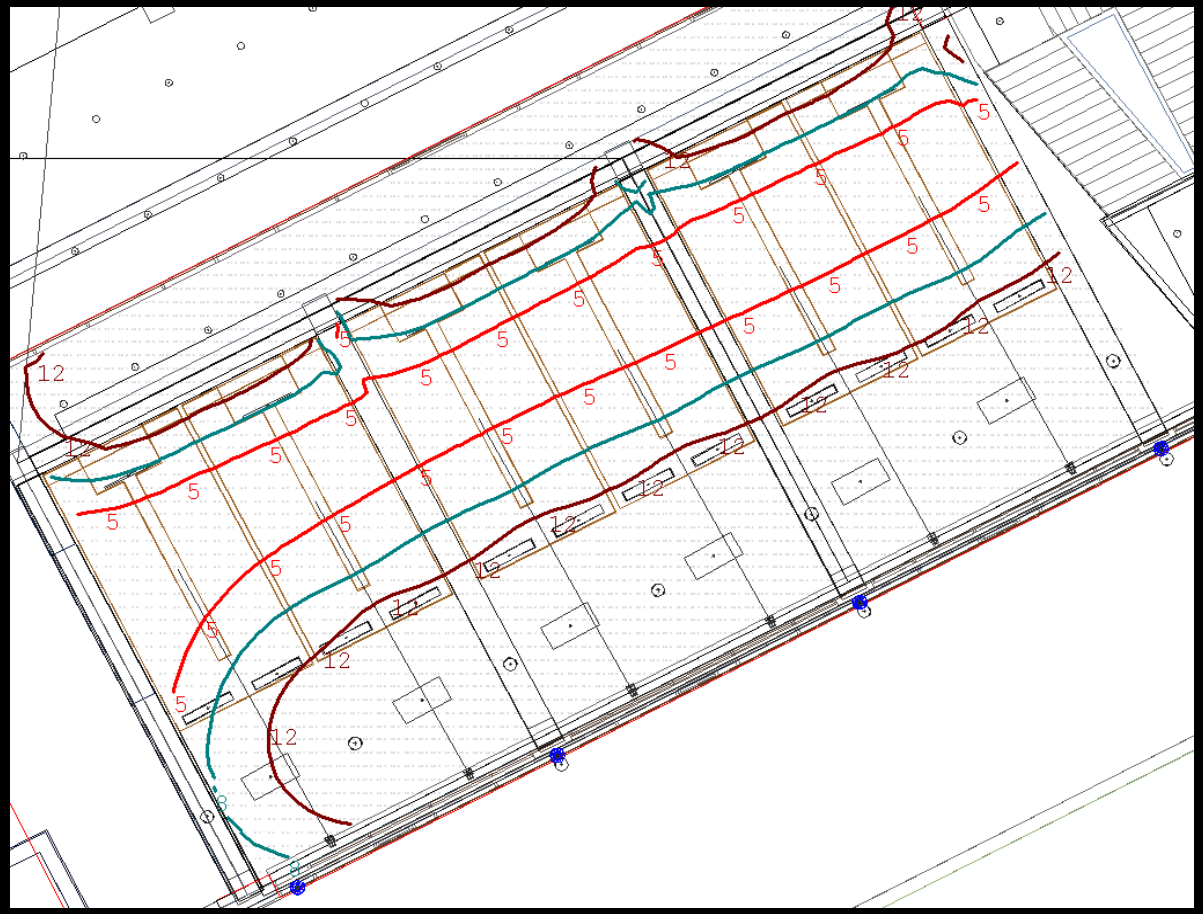


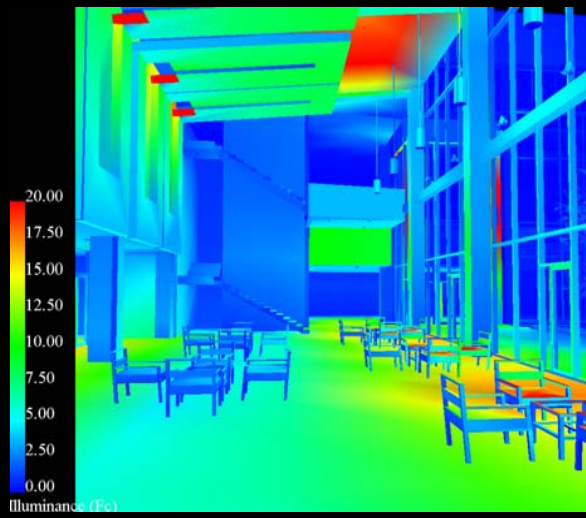
H5

(1) 70W MH

Design Performance

Horizontal Illuminance – Floor: 12.07fc (avg)
4.02 (Avg/Min)





Design Power Density

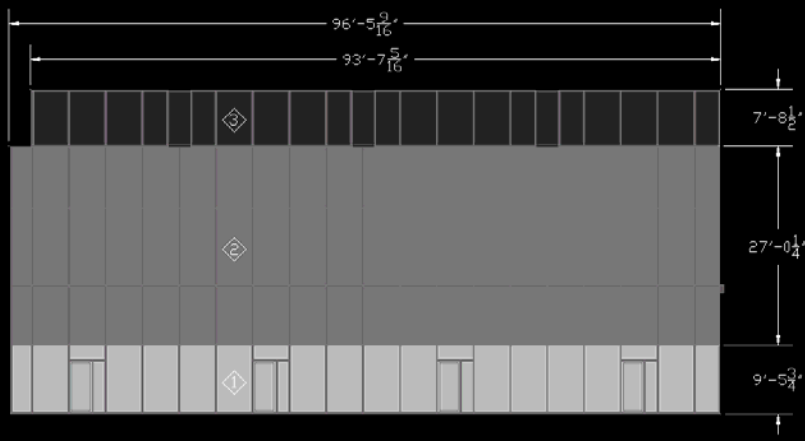
Area: 3274SF
Allowable PD: 1.2W/SF
Total Watts: 2529W
Design PD: 0.77W/SF

Lighting Depth

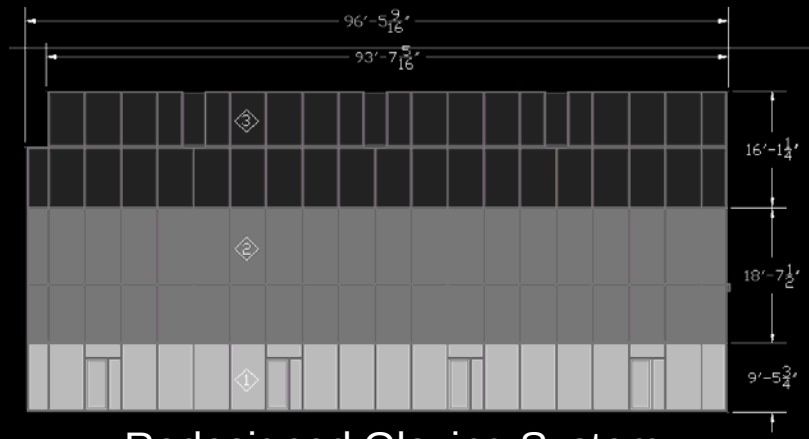
Atrium Daylight Study

Goals

- Compare existing daylight conditions with resulting conditions from change in glazing
- Determine which is preferable (illuminance, glare, penetration)



Original Glazing System



Redesigned Glazing System

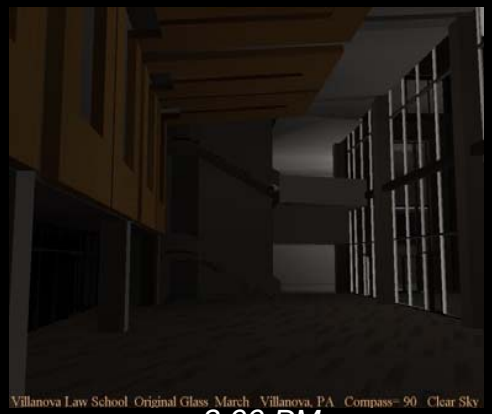
Original Atrium Glazing												
		Transmittance			Reflectance			ASHRAE U-Value				
Viracon No.	Description	Vis. Light	Solar Energy	Ultra-Violet	Vis. Light-Ext.	Vis. Light-Int.	Solar Energy	Winter Night	Summer Day	Shading Coeff.	Relative Heat Gain	Area (SF)
VRE 1-38	Solarscreen (clear)	36%	19%	12%	44%	21%	46%	0.25	0.21	0.26	55	880
VRE 1-38 Frit	Silkscreen (dots)	25%	13%	7%	40%	25%	13%	0.30	0.26	0.21	46	2592
VE 1-2M w/ Metallic Opac	Spandrel	0%	Not Avail.	Not Avail.	Not Avail.	Not Avail.	Not Avail.	0.07	0.07	N/A	Not Avail.	674
New Atrium Glazing												
		Transmittance			Reflectance			ASHRAE U-Value				
Viracon No.	Description	Vis. Light	Solar Energy	Ultra-Violet	Vis. Light-Ext.	Vis. Light-Int.	Solar Energy	Winter Night	Summer Day	Shading Coeff.	Relative Heat Gain	Area (SF)
VRE 7-38	Solarscreen (clear)	28%	11%	9%	28%	21%	14%	0.25	0.21	0.19	41	880
VRE 1-38 Frit	Silkscreen (dots)	19%	8%	5%	26%	24%	13%	0.30	0.26	0.17	37	1795
VE 1-2M w/ Metallic Opac	Spandrel	0%	Not Avail.	Not Avail.	Not Avail.	Not Avail.	Not Avail.	0.07	0.07	N/A	Not Avail.	1471

March 20th

Original Glazing

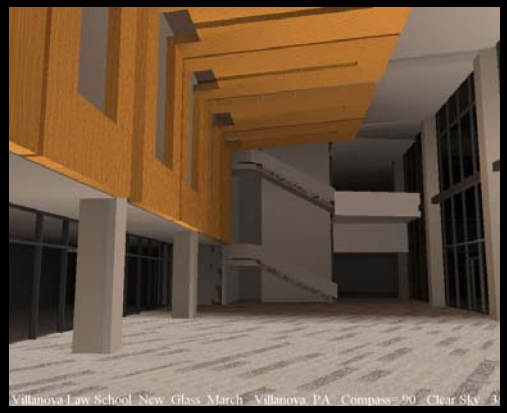
9:00 AM

12:00 PM



3:00 PM

Redesign Glazing



Original Glazing - March 20th Illuminance Data					
0900		1200		1500	
Average	663.73	Average	788.96	Average	36.92
Maximum	1952.00	Maximum	2845.00	Maximum	4639.00
Minimum	8.70	Minimum	8.20	Minimum	0.20
Avg/Min	76.29	Avg/Min	96.21	Avg/Min	184.60
Max/Min	224.32	Max/Min	346.93	Max/Min	23194.00

New Glazing - March 20th Illuminance Data					
0900		1200		1500	
Average	456.24	Average	506.98	Average	26.40
Maximum	1491.00	Maximum	2179.00	Maximum	4625.00
Minimum	6.50	Minimum	3.90	Minimum	0.10
Avg/Min	70.22	Avg/Min	129.99	Avg/Min	264.00
Max/Min	229.38	Max/Min	558.72	Max/Min	46248.00

June 21st

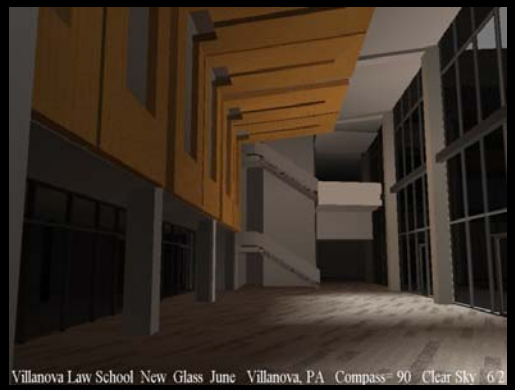
Original Glazing

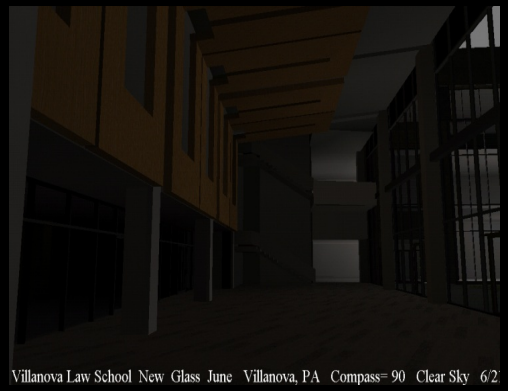
9:00 AM

12:00 PM

3:00 PM

Redesign Glazing





Original Glazing - June 21st Illuminance Data					
0900		1200		1500	
Average	296.00	Average	182.25	Average	30.29
Maximum	2432.00	Maximum	8884.00	Maximum	88.70
Minimum	0.60	Minimum	0.10	Minimum	0.10
Avg/Min	493.33	Avg/Min	1823.00	Avg/Min	302.90
Max/Min	4053.00	Max/Min	88839.00	Max/Min	887.00

New Glazing - June 21st Illuminance Data					
0900		1200		1500	
Average	190.68	Average	105.35	Average	21.61
Maximum	1871.00	Maximum	8871.00	Maximum	68.20
Minimum	0.50	Minimum	0.10	Minimum	0.10
Avg/Min	381.36	Avg/Min	1054.00	Avg/Min	216.10
Max/Min	3743.00	Max/Min	88711.00	Max/Min	682.00

September 21st

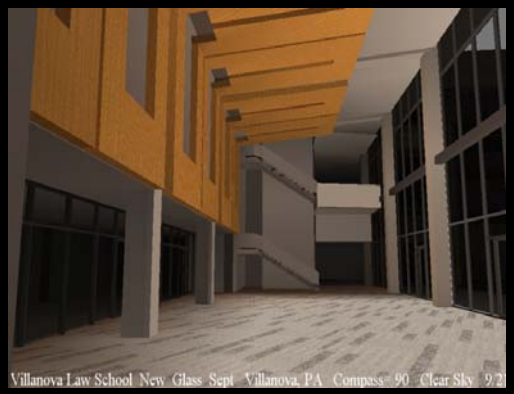
Original Glazing

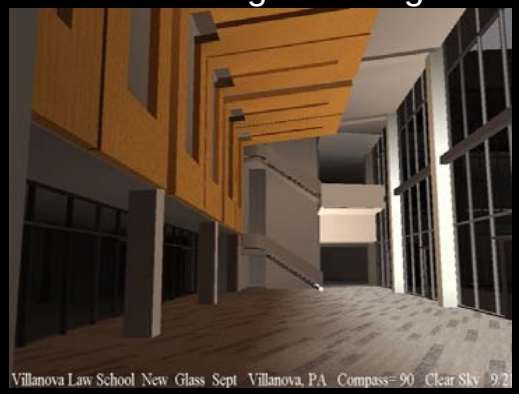
9:00 AM

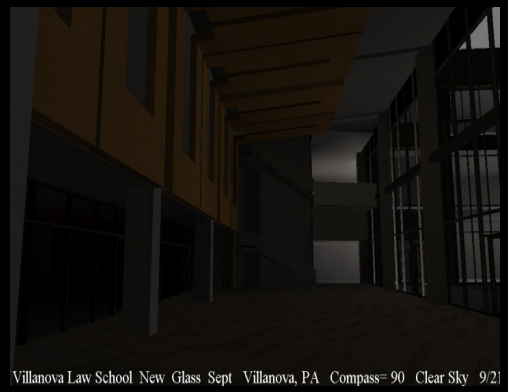
12:00 PM

3:00 PM

Redesign Glazing







Original Glazing - September 21st Illuminance Data					
0900		1200		1500	
Average	794.90	Average	682.48	Average	33.54
Maximum	2052.00	Maximum	2856.00	Maximum	4209.00
Minimum	24.70	Minimum	6.60	Minimum	0.10
Avg/Min	32.18	Avg/Min	103.41	Avg/Min	335.40
Max/Min	83.06	Max/Min	432.67	Max/Min	42085.00

New Glazing - September 21st Illuminance Data					
0900		1200		1500	
Average	526.58	Average	442.46	Average	24.41
Maximum	1562.00	Maximum	2193.00	Maximum	4202.00
Minimum	3.20	Minimum	3.80	Minimum	0.10
Avg/Min	164.56	Avg/Min	116.44	Avg/Min	244.10
Max/Min	488.09	Max/Min	577.05	Max/Min	42022.00

December 21st

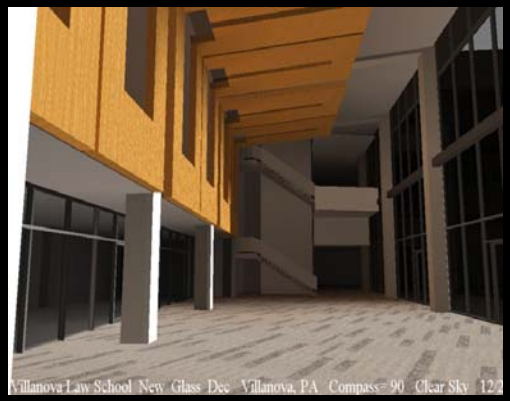
Original Glazing

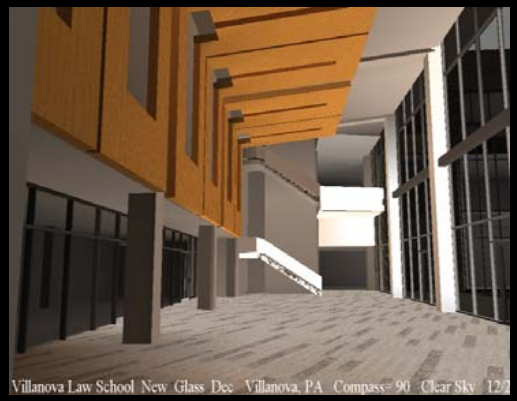
9:00 AM

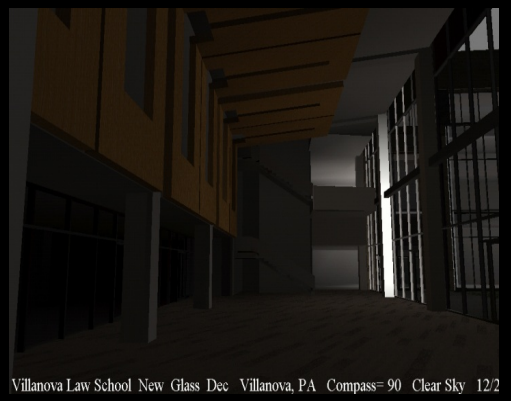
12:00 PM

3:00 PM

Redesign Glazing







Original Glazing - December 21st Illuminance Data					
0900		1200		1500	
Average	382.62	Average	766.31	Average	38.70
Maximum	818.00	Maximum	1725.00	Maximum	506.00
Minimum	10.00	Minimum	25.20	Minimum	0.20
Avg/Min	38.26	Avg/Min	30.41	Avg/Min	193.50
Max/Min	81.76	Max/Min	68.47	Max/Min	2530.00

New Glazing - December 21st Illuminance Data					
0900		1200		1500	
Average	286.23	Average	550.30	Average	27.27
Maximum	618.00	Maximum	1320.00	Maximum	387.00
Minimum	7.50	Minimum	16.00	Minimum	0.20
Avg/Min	38.16	Avg/Min	34.39	Avg/Min	136.20
Max/Min	82.35	Max/Min	82.53	Max/Min	1937.00

Electrical Depth

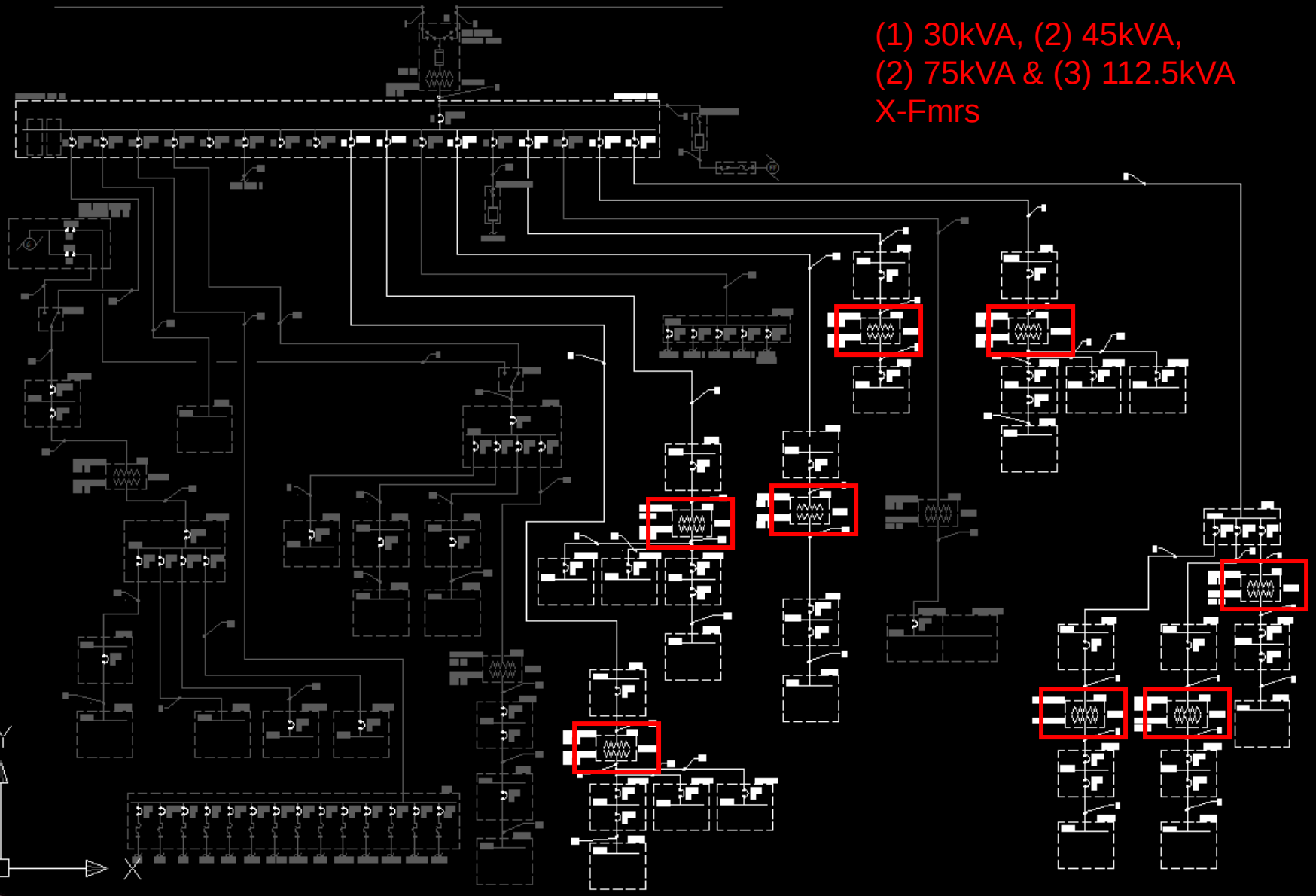
Distribution Panels vs. Standard Lighting Panels

Design Goals

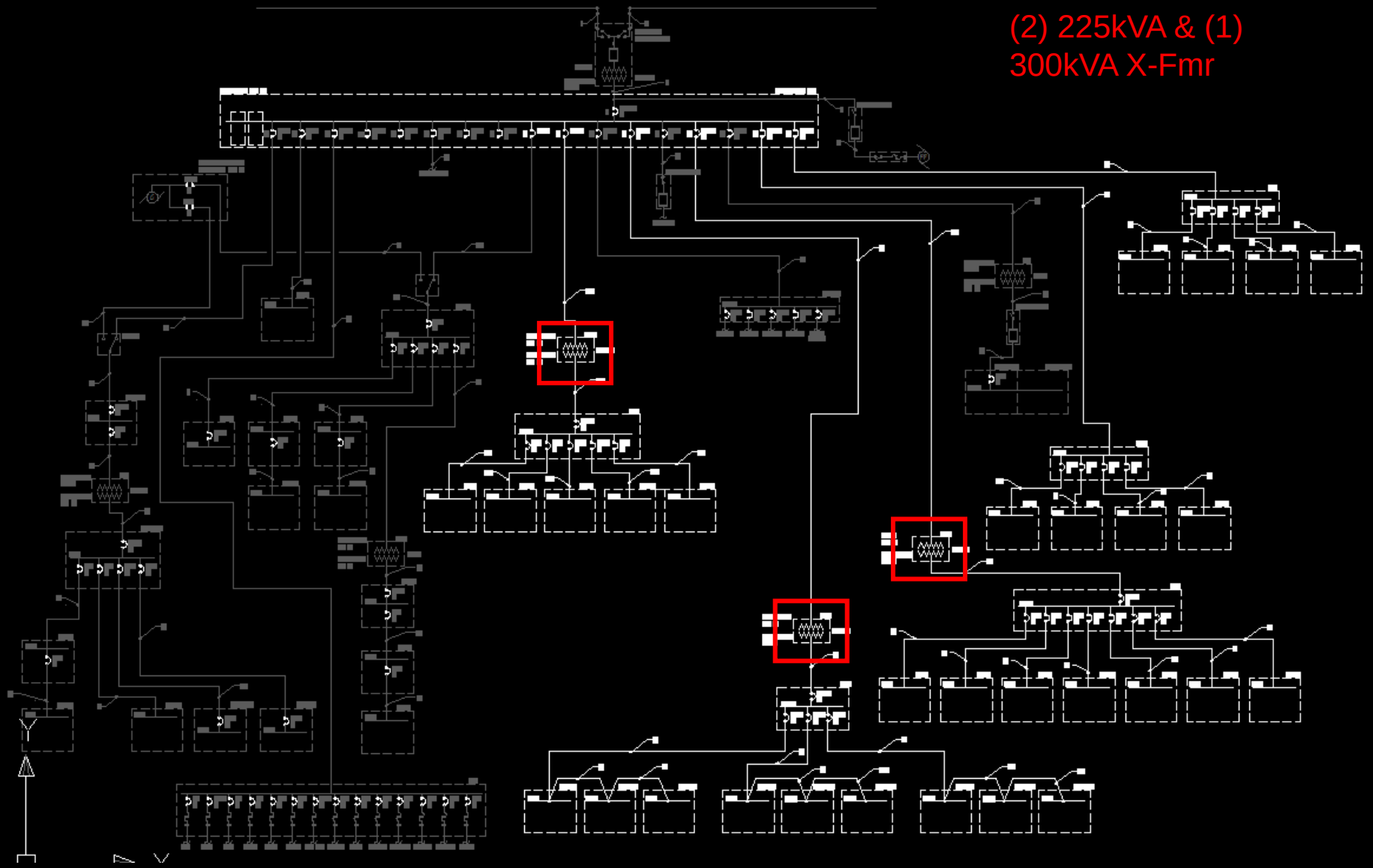
- Use distribution panels instead of standard lighting panels
- Reduce number of transformers
- Reduce size of long run feeders
- Reduce costs

ORIGINAL TRANSFORMER SCHEDULE								
TAG	PRIMARY VOLTAGE	SECONDARY VOLTAGE	SIZE	TYPE	TEMP. RISE	TAPS	MOUNTING	REMARKS
XD-1	13.2kV, 3P, 3W	480Y/277V, 3P, 4W	1500kVA	Silicone-based dielectric filled	55°C	(4) 2.5% Taps (2) Up & (2) Dn	Concrete Pad Mount (outside)	
XS-1	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	75kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-2	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	45kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-3	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	45kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-4	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	112.5kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-5	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	75kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-6	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	30kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-7	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	75kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-8	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	112.5kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-9	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	112.5kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-10	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	45kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	
XS-11	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	112.5kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated	

Original Single Line



REDESIGN TRANSFORMER SCHEDULE							
TAG	PRIMARY VOLTAGE	SECONDARY VOLTAGE	SIZE	TYPE	TEMP. RISE	TAPS	MOUNTING
XD-1	13.2kV, 3P, 3W	480Y/277V, 3P, 4W	1500kVA	Silicone-based dielectric filled	55°C	(4) 2.5% Taps (2) Up & (2) Dn	Concrete Pad Mount (outside)
XS-5	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	75kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated
XS-10	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	45kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated
XS-11	480Y/277V, 3P, 4W	208Y/120V, 3P, 4W	112.5kVA	Dry Type	115°C	(6) 2.5% Taps (2) Up & (4) Dn	Pad mounted, vibration isolated
XS-12	**480Y/277V, 3P, 4W**	**208Y/120V, 3P, 4W**	**225kVA**	**Dry Type**	**115°C**	**(6) 2.5% Taps (2) Up & (4) Dn**	**Pad mounted, vibration isolated**
XS-13	**480Y/277V, 3P, 4W**	**208Y/120V, 3P, 4W**	**300kVA**	**Dry Type**	**115°C**	**(6) 2.5% Taps (2) Up & (4) Dn**	**Pad mounted, vibration isolated**
XS-14	**480Y/277V, 3P, 4W**	**208Y/120V, 3P, 4W**	**225kVA**	**Dry Type**	**115°C**	**(6) 2.5% Taps (2) Up & (4) Dn**	**Pad mounted, vibration isolated**


(2) 225kVA & (1)
300kVA X-Fmr

Goals Met

- Use distribution panels instead of standard lighting panels
- Reduce number of transformers
- Reduce size of long run feeders
- Reduce costs

Distribution System Redesign Cost Analysis			
Original System		Redesigned System	
Panel	Cost	Panel	Cost
LP-1N	$60,079.75	DL-1	$18,549.00
LP-1S	$44,390.00	DL-2	$20,125.00
LP-BN	$16,183.50	DR-1	$66,037.00
LP-BS	$21,650.00	DR-2	$106,168.00
LP-2S	$38,185.00	DR-3	$52,909.25
LP-3S	$39,793.00		
Total Cost	$220,281.25	**Total Cost**	$263,788.25

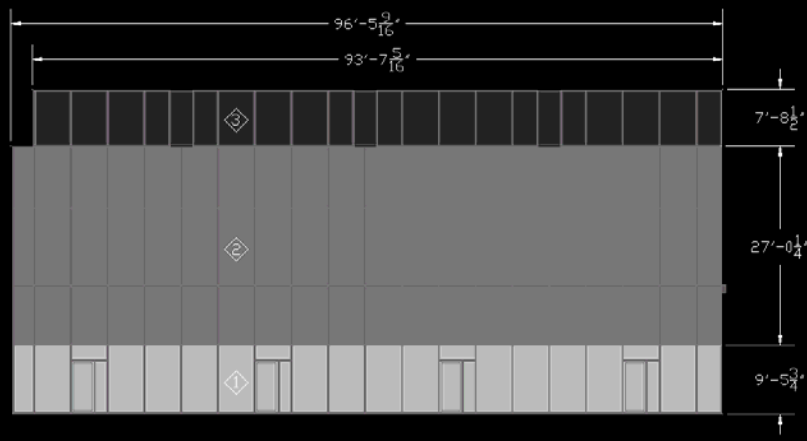
System Not Recommended

Mechanical Breadth

Replacement of atrium glazing and the mechanical loading effects

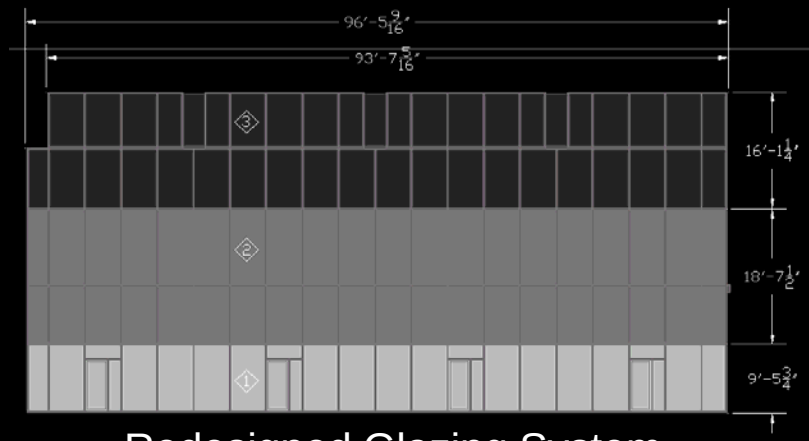
Goals

- Reduce mechanical loading through use of more efficient glazing
- Reduce energy costs



Original Glazing System

Original Atrium Glazing												
		Transmittance			Reflectance			ASHRAE U-Value				
Viracon No.	Description	Vis. Light	Solar Energy	Ultra-Violet	Vis. Light-Ext.	Vis. Light-Int.	Solar Energy	Winter Night	Summer Day	Shading Coeff.	Relative Heat Gain	Area (SF)
VRE 1-38	Solarscreen (clear)	36%	19%	12%	44%	21%	46%	0.25	0.21	0.26	55	880
VRE 1-38 Frit	Silkscreen (dots)	25%	13%	7%	40%	25%	13%	0.30	0.26	0.21	46	2592
VE 1-2M w/ Metallic Opac	Spandrel	0%	Not Avail.	Not Avail.	Not Avail.	Not Avail.	Not Avail.	0.07	0.07	N/A	Not Avail.	674
New Atrium Glazing												
		Transmittance			Reflectance			ASHRAE U-Value				
Viracon No.	Description	Vis. Light	Solar Energy	Ultra-Violet	Vis. Light-Ext.	Vis. Light-Int.	Solar Energy	Winter Night	Summer Day	Shading Coeff.	Relative Heat Gain	Area (SF)
VRE 7-38	Solarscreen (clear)	28%	11%	9%	28%	21%	14%	0.25	0.21	0.19	41	880
VRE 1-38 Frit	Silkscreen (dots)	19%	8%	5%	26%	24%	13%	0.30	0.26	0.17	37	1795
VE 1-2M w/ Metallic Opac	Spandrel	0%	Not Avail.	Not Avail.	Not Avail.	Not Avail.	Not Avail.	0.07	0.07	N/A	Not Avail.	1471



Redesigned Glazing System

AHU-1-R1		
	Original Glazing	Redesigned Glazing
Peak Design Cooling Load	22.7 ton	16.2 ton
Peak Design Heating Load	147 MBh	108 MBh
Outside Airflow	1316 cfm	894 cfm
Cooling Airflow	8873 cfm	6059 cfm
Heating Airflow	8873 cfm	6059 cfm
Return Airflow	8873 cfm	6059 cfm
Exhaust Airflow	8873 cfm	6059 cfm
AHU Fan Size	15 hp	7.5 hp
% of Total Building Energy: Heating	37.20%	37.10%
% of Total Building Energy: Cooling	13.30%	13.40%
Total Building Energy	15172882 kBtu/yr	15058292 kBtu/yr
Total Energy Savings	114590 kBtu/yr	
Total Electricity Cost	$44,064	$43,690
Total Electricity Cost Savings	$374 per year	

VU Atrium Mechanical Cost Analysis

			Viracon No.			Area (SF)		Unit Cost ($/SF)		Initial Cost		
Glass	Tag	Description	Original	Redesign	Add-ons	Original	Redesign	Original	Redesign	Original	Redesign	Cost Diff.
	GL-2	Silkscreen (dots)	VRE 1-38	VRE 7-38	Dots	2539	1742	$18.50	$21.00	$46,971.50	$36,582.00	10,389.50
	GL-3	Spandrel	VE 1-2M	VE 1-2M	Metallic Opac	674	1471	$24.00	$24.00	$16,176.00	$35,304.00	-19,128.00
	GL-4	Solarscreen(clear)	VRE 1-38	VRE 7-38	N/A	880	880	$12.50	$15.00	$11,000.00	$13,200.00	-2,200.00
								Total Glass Cost		**$74,147.50**	**$85,086.00**	**-10,938.50**

			Trane Series			Initial Cost		
AHU	Tag	Description	Original	Redesign	Add-ons	Original	Redesign	Cost Diff.
	AHU-R-1	Rooftop AHU	Trane T-25 (15hp)	Trane T-12 (7.5 hp)	N/A	**$25,990.00**	**$22,190.00**	**$3,800.00**

Construction Cost Difference -$7,138.50

Note: Glazing and AHU pricing was provide by Viracon and Trane representative respectively.

Lighting Depth – Entry/Courtyard

- Meets design goals
- Meets target illuminance levels
- Meets power density requirements

Lighting Depth - Atrium

- Meets design goals
- Meets target illuminance levels
- Meets power density requirements

Lighting Depth – Atrium Daylight Study

- New glazing reduced illuminance levels
- Penetration is less deep due to spandrel glazing
- Glare should be less as a result

Electrical Depth – Distribution System Redesign

- Number of transformers reduced from 8 to 3
- Feeder sizing for long runs reduced
- Cost INCREASED
- System was not recommended

Mechanical Breadth – Reduction in Loading Due to Glazing Change

- Initial construction cost increased by more than $7,000
- Electricity cost savings was less than $400 per year
- System could be recommended based on daylighting improvements

Special Thanks To:

Villanova University
SmithGroup
Trane
Viracon

AE Faculty

Fellow AE Students

Friends & Family

Thank You!

Questions?