Joseph Lookup
Senior Thesis 2005
Wegmans Fairfax

Section 3.0

Mechanical Breadth

3.0 Mechanical Breadth

3.1 Intro

When I redesigned the grocery space to include skylights to improve the lighting and electrical aspects of the building, I had to account for the effects these changes would have on the other disciplines within the building. For example, the addition of daylight can have a negative effect on the mechanical system of the building. A study of just how much additional heat load that would be added to the grocery space and its mechanical equipment was calculated. I used SkyCalc version 2.0 software provided by Energy Design Resources and Carrier's Hourly Analysis Program (HAP) version 4.2 to analyze the potential effects on the mechanical system and then the energy effects that would occur with the addition of skylights into the Wegmans Fairfax design.

SkyCalc was used first to optimize my lighting design. The lighting redesign determined that 1,568 SQ.FT. of additional windows create an optimum amount of light for the space while also decreasing the large amount of electric loads from electric light. An exact skylight was specified, the skylight is 4'x8' with a u-value of 0.35, a shading coefficient of 0.32, a visible light transmission of 0.67, and a solar heat gain coefficient of 0.38.

3.2 HAPS Analysis

**** Note:** Designs Loads represent load produced due to the extra radiant energy entering the room and does not represent the total room load.

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1300 COOLING OA DB / WB 93.2 °F / 75.5 °F OCCUPIED T-STAT 75.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 15.0 °F / 12.2 °F OCCUPIED T-STAT 70.0 °F		
		Sensible	Latent		Sensible	Latent
SPACE LOADS	Details	(BTU/hr)	(BTU/hr)	Details	(BTU/hr)	(BTU/hr)
Window & Skylight Solar Loads	1568 ft²	113711	-	1568 ft²	-	-
Wall Transmission	0 ft²	0	-	0 ft²	0	-
Roof Transmission	38432 ft²	366540	-	38432 ft²	254850	-
Window Transmission	0 ft²	0	-	0 ft²	0	-
Skylight Transmission	1568 ft²	10145	-	1568 ft²	36224	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	0 W	0	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	0 W	0	-	0	0	-
People	0	0	0	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	490396	0	-	291074	0

3.3 Calculations of Additional Load Added

qs = sensible heat from solar loads due to skylight
qc = sensible heat from the skylight transmission
qt = total sensible heat (Btu/hr)

qs = q/A
qs = 68,656 (btu/hr)/ 1568 ft^2
qs = 43.7 btu/hr

qcond = 8454 (btu/hr) / (1568 ft^2)

qcond = 43.7 +5.39 = 49.09 (btu/hr)/ft^2

bth = btu/hr
1 ton = 12,000 bth

qtot = 49.09 bth/ft^2 x 1568 ft^2 = **76,973 bth**
76,973bth x 1/12,000 bth = **6.4 tons**

3.4 Additional Load Summary/Resize/Cost Estimate

In Wegmans existing load capacity, the two rooftop desiccant air handling units (AC-1, AC-2B) which support the grocery space have a total cooling capacity of 3820 MBH. The existing total capacity of the two air-handling units is 318.33 tons. Investigating the possible addition of the cooling loads to the existing air-handling units found that adding 6.4 tons or two percent of the total capacity of the existing two units supplying the grocery space would be out of the design requirements set forth by Wegmans and the mechanical engineer. The current air-handling units were sized using .4% column for the dehumidification design conditions in Chapter 27 ASHRAE (Sterling, VA – 93º F-Dry-bulb temperature, 75º F – MWB). The units were also designed for Sensible cooling credits (Case Credits) which account for the effects refrigeration equipment haves on the mechanical systems inside this building.

Using the additional loads placed on the resized air-handling units and then compiling a cost estimate of the new mechanical equipment was performed to give an estimate of the possible increased costs that are incurred with adding additional capacity to the mechanical system. To perform the cost estimate R.S. Means Mechanical Cost Data was used to find the estimates on the total material costs w/ no overhead and the

total labor costs with no overhead. My mechanical cost estimate breaks down the new air-handling prices into three different scenarios. Each of these scenarios takes into account the increased CFM demand of 2,800CFM and is sized to the next available size that allows for the additional. The first scenario assumes that a whole new separate air-handling unit was bought and provided for this new additional mechanical load. The second Scenario estimates the total cost of increasing the size of AC-1 and increasing its capacity from 25,000CFM to the next available size. The third scenario investigates placing the new mechanical loads on AC-2B and sizing it up from its current 4500CFM capacity to the next available size.

Using this mechanical cost estimate and its possible alternatives, help estimate the new design requirements payback period analysis in section 1.2 (Grocery Space). First, I had to determine the CFM needed for the resized air-handling unit; therefore I used the following equations and the known climate and the total MBH values:

- $Q = (\bullet m)(Cp)\,(\Delta T)$
- $Q = (\bullet m)(Cp)\,(\Delta H)$

Approximately an additional 2800 CFM capacity is needed in the form of a new air-handling unit or resizing existing air-handling unit AC-1 or AC-2B. The following summaries show the additional incurred costs of resizing the mechanical system to meet the new demand loads:

Scenario #1 : Additon of new AHU unit

CFM	$ Material	Labor	Total (M+L)
3000	3900	570	4470

Scenario #2 : Resizing of AC-1			
CFM	**Material**	**Labor**	**Total (M+L)**
4500 (5000)	6500	655	7155
7500	9750	765	10515

Scenario #3 : Resizing of AC-2B			
CFM	**Material**	**Labor**	**Total (M+L)**
25,000 (27,000)	28,100	1825	29925
28,000 (34,000)	35400	2300	37700

Total Price Comparison Between Scenarios	
Scenario	Total (M+L)
1	4,470
2	3360
3	7,775

Scenario 2 was the cheapest solution and therefore was used in the payback period analysis in section 1.2. The prices differed because of the size of the AHU that it is servicing and what it servicing.

3.5 Energy Study & Economic Analysis

A Study to determine the amount of skylights needed in the grocery space was completed earlier in the lighting depth section 1.2 to determine the optimum amount of light for the lighting design and to decrease the electric load. To optimize the new skylight system however, a balance to find the most energy efficient system needed to be studied. There are two positives with the skylight design; first an increase in natural light and then secondly a decrease in electric loads due to a increase of natural light and therefore a decreased demand in electric lighting. The negatives were that with the increased amount of daylight in the space there was going to be increases in the amount of heat and specifically an increase in the amount of radiant heat in the space.

SkyCalc was used to determine the amount of skylights that would create the optimum energy efficient space. The following inputs or assumptions were used in determining the results compile by SkyCalc:

Location: Sterling, Virginia
Average Electric Utility Rate: $0.117/kWh
Heating Fuel Cost: $1.00 therm

Joseph Lookup
Senior Thesis 2005
Wegmans Fairfax

Average Daylight

Effective Aperture = 1.95%, Skylight to Floor Ratio (SFR) = 4.90%

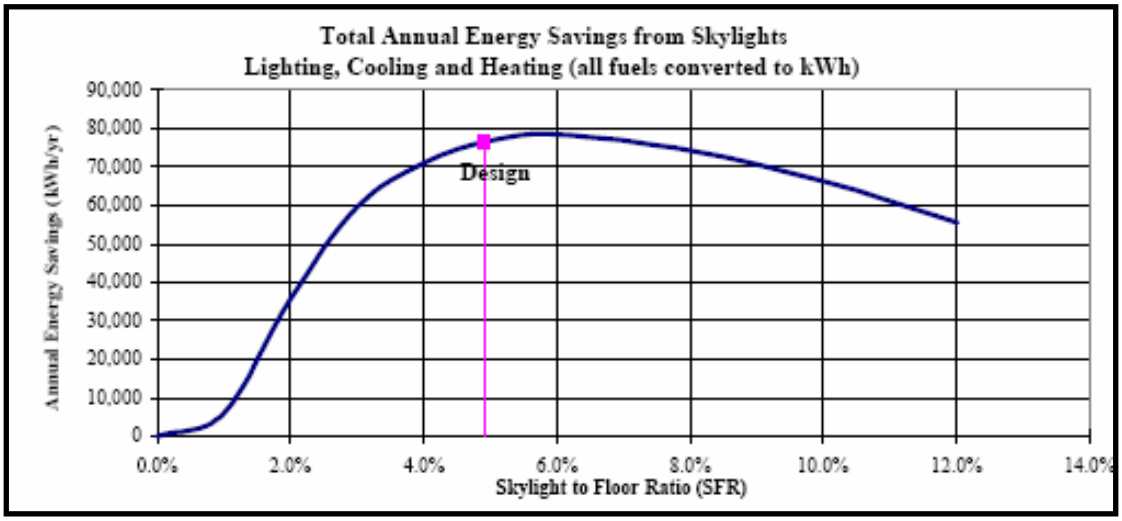
Average daylight footcandles (fc)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	2	9	21	36	45	44	42	32	16	6	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	4	15	33	49	57	63	58	47	28	13	3	0	0	0	0	0	0
Mar	0	0	0	0	0	0	2	11	27	45	65	77	81	77	63	43	22	7	0	0	0	0	0	0
Apr	0	0	0	0	0	0	7	22	44	64	80	89	92	85	80	55	32	13	3	0	0	0	0	0
May	0	0	0	0	0	4	15	33	57	74	90	99	98	87	77	62	40	19	6	0	0	0	0	0
Jun	0	0	0	0	0	6	18	40	65	86	97	105	100	96	87	69	45	24	9	1	0	0	0	0
Jul	0	0	0	0	0	4	15	35	57	77	89	105	106	96	84	67	46	25	8	1	0	0	0	0
Aug	0	0	0	0	0	2	10	26	49	74	94	91	93	95	80	58	38	17	5	0	0	0	0	0
Sep	0	0	0	0	0	0	5	19	41	64	76	87	85	76	65	47	24	8	1	0	0	0	0	0
Oct	0	0	0	0	0	0	3	11	29	51	65	72	67	60	47	27	11	2	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	5	15	28	42	50	50	41	28	14	4	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	1	9	19	29	37	36	33	21	10	2	0	0	0	0	0	0	0

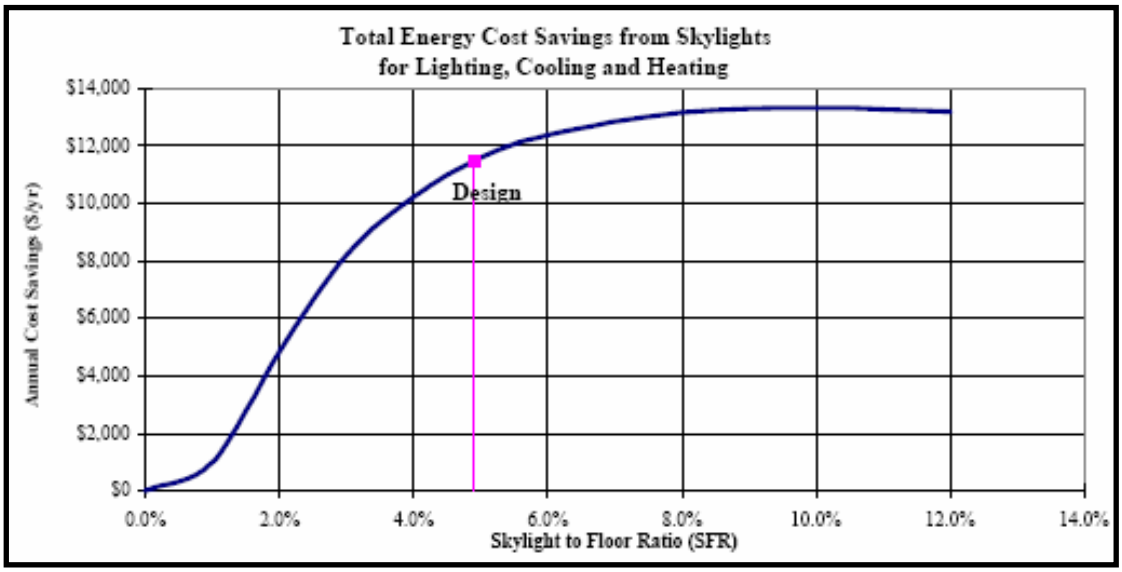
Design Illuminance = 50 fc

< 1 fc; < 25 fc; < 50 fc; > 50 fc;

Total Annual Energy Savings from Skylights



Total Annual Energy Cost Savings from Skylights



Total Cost Savings Breakdown Using Dimming Controls

SkyCalc: Skylight Design Assistant - Tabular Results

Company Name: Joseph Lookup
Project Description: Wegmans Grocery

Electric Lighting Usage	kWh/yr		
Ltg. Energy without Skylights	377,356	Lighting Fraction Saved	26%
Lighting Energy w/ Skylights	280,537	Full daylighting (h/yr)	1,645

	Savings from Design Skylighting System		
Savings		Annual Energy Savings (kWh/yr)	Annual Cost Savings ($/yr)
Lighting		96,819	$11,328
Cooling		9,908	$1,159
Heating		-30,276	-$1,033
Total		**76,450**	**$11,454**

Skylighting System Description

Skylight unit size (ft^2)	32.0
Number of Skylights	49
Total Skylight Area (ft^2)	1,568
Skylight to Floor Ratio (SFR)	4.9%
Effective Aperture	2.0%
Floor Area per Skylight	653
Skylight U-value	0.350
Skylight SHGC	38%
Skylight T_{vis}	67%
Well Efficiency (WF)	85%
Dirt and Screen Factor	70%
Overall Skylight System Tvis	40%
Skylight CU	67%

Site Description

Climate Location	Sterling, VA	
Climate Zone	ASHRAE B-13	
Building Type	Grocery	
Building Area	32,000	(ft^2)

Elecric Lighting System Description

Lighting Type	Industrial fluorescent	
Lighting Control	3 level + off switching	
Light Level Setpoint	50	fc
Lighting Density	1.43	W/ft^2
Connected Load	45.7	kW
Fraction Controlled	90%	

As compared to the design with 49 skylights but no photocontrols

	Savings from Functioning Photocontrol System		
Savings		Annual Energy Savings (kWh/yr)	Annual Cost Savings ($/yr)
Lighting		96,819	$11,328
Cooling		21,360	$2,499
Heating		-12,014	-$410
Total		**106,165**	**$13,417**

3.6 Conclusion

After analyzing the effects the addition of skylights will have on Wegmans Fairfax mechanical system, the skylight solution not only is a more energy efficient system, but it will lead to cost savings in the long run. With some higher initial costs to take into account, with the increased 6.4 tons on the air-handling units and the minimal increased costs associated with the structure defined in the structural breadth, a payback in the future will be expected. The reason for the energy and cost savings can be attributed to the almost 100,000kwh per year in energy saving due to the decreased demand in electric lighting loads. The decrease in electric lighting loads far exceeds additional yearly expenses with the increased mechanical loads.