Building Enclosure Breadth Study

Description:

The existing building enclosure of the Northwest Science Building is described below. A brief understanding of the makeup of the building enclosure is vital to this Building Enclosure Breadth Study.

Building Enclosure:

The building enclosure has a very modern appearance. Clear anodized aluminum panels clad the exterior bays with diagonal structural elements. The panels express the diagonal structural element lines with extruded aluminum fins. The bays that are clear of structural diagonal elements are equipped with fenestrations. These fenestrations are clear glass panels. Larger glass curtain walls can be found between the 2nd and 4th levels, exposing the cafe, and between the 13th and 15th levels, exposing laboratories and support spaces. Also, a large area of the East building elevation, plaza facade, is covered in glass curtain wall, which encloses office space.

The author is concerned with the building enclosure elements due to the relocation of the Northwest Science Building to Miami, FL. The hot climate of Miami, FL is a concern the author believes will have a great impact on the building's enclosure system.

Below is an image comparing design temperatures and relative humidity used for both New York, NY and Miami, FL. This noticeable difference will be addressed.

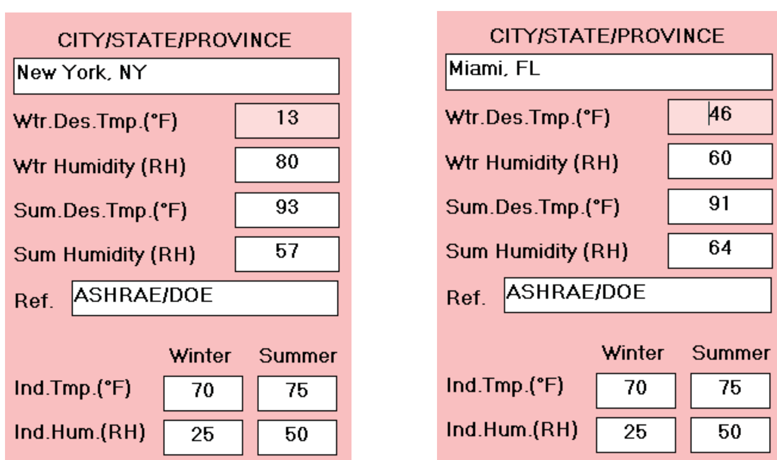


Figure 18: New York, NY vs. Miami, FL – Design Temperatures/Relative Humidity

The current building enclosure consists of the elements, described below.

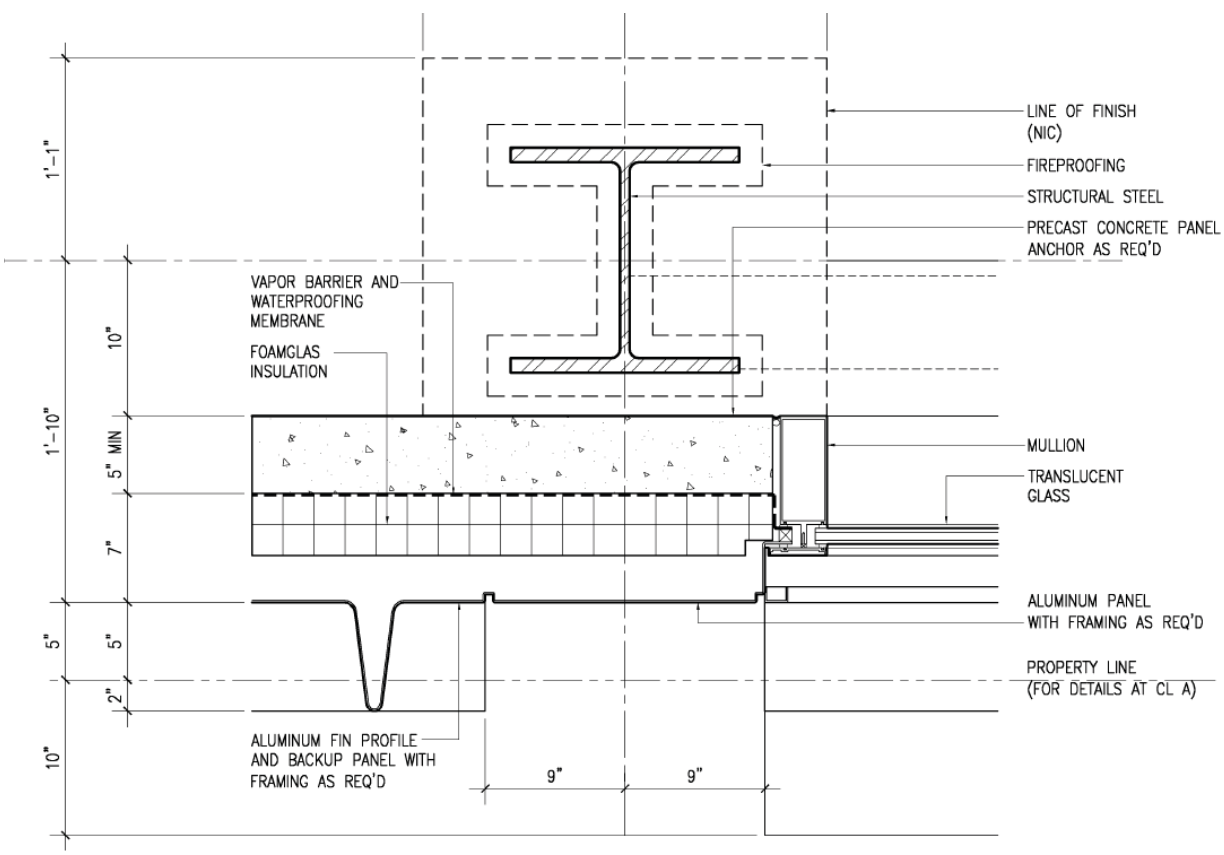
Unitized Curtain Wall System:

- Aluminum Panels (1/8")
  - Provides the surface seen on the exterior of the building.
  - This aluminum is anodize, which increases its resistance to corrosion.
  - At fenestrations and panel intersections aluminum mullions are used.
- 5" Precast Concrete Panels (Backup Structure)
  - Durable and wind support layer of wall system
- Foam Glass Insulation
  - The main thermal resistance layer of the curtain wall system.
- Vapor Barrier and Waterproofing Membrane
  - Located in between foam glass insulation and precast panel layers.
  - Used for vapor/air flow resistance.

Note: Described above is the widely used building enclosure system seen throughout the building envelope. Variations of this system do take place due to structural member intersections and coordination concerns. The system described above will be the building enclosure system researched and analyzed for this thesis project.

Below is a typical section detail of the building enclosure system.

Figure 19: Building Enclosure System Detail - Typical



This Building Enclosure Breadth will include the following steps.

- Research and document existing building materials of curtain wall system.
- Perform R-value, condensation, and air leakage analyses of curtain wall system.
- Research ASHRAE climate data and enclosure recommendations.
- Modify curtain wall system appropriately for Miami, FL.
- Perform cost analysis of existing enclosure versus redesign for Miami, FL.

Figures & Graphs:

Below is a bulleted list explaining the figures and graphs to follow, regarding this building enclosure study.

- Figure 20: R-Value Analysis – New York City
    - Depicts the existing wall system's thermal insulation analysis for NYC.
- Figures 21 & 22: Condensation Analysis – New York City
    - Depicts the existing wall system's water resistance analysis for NYC for both summer and winter seasons.
- Figures 23 & 24: Air Leakage Analysis – New York City
    - Depicts the existing wall system's energy loss due to air leakage through the building envelope for both summer and winter seasons.
- Figure 25: R-Value Analysis – Miami, FL
    - Depicts the redesigned wall system's thermal insulation analysis for Miami, FL.
- Figures 26 & 27: Condensation Analysis – Miami, FL
    - Depicts the redesigned wall system's water resistance analysis for Miami, FL for both summer and winter seasons.
- Figures 28 & 29: Air Leakage Analysis – Miami, FL
    - Depicts the redesigned wall system's energy loss due to air leakage through the building envelope for both summer and winter seasons.
- Graph 6: Air Leakage Analysis Comparison – Miami vs. NYC
    - Shows the differences in energy loss for Miami and NYC. Conclusions are made from this data.

Conclusions:

This building enclosure study revealed that less insulation will be needed for the building's relocation from New York City to Miami, FL. Four inches of foam glass insulation was used for the existing design (New York City). An R-value analysis (R-value of curtain wall system is 21.2), condensation analysis, and air leakage analysis on this curtain wall system yielded that it was sufficient for its New England climate. An R-value analysis (R-value of redesigned curtain wall system is 13.5), condensation analysis, and air leakage analysis of the redesigned was performed. These studies concluded that a 2.5 inch insulation layer was sufficient for Miami, FL. ASHRAE thermal insulations recommendations based on climate data also supported this analysis and research.

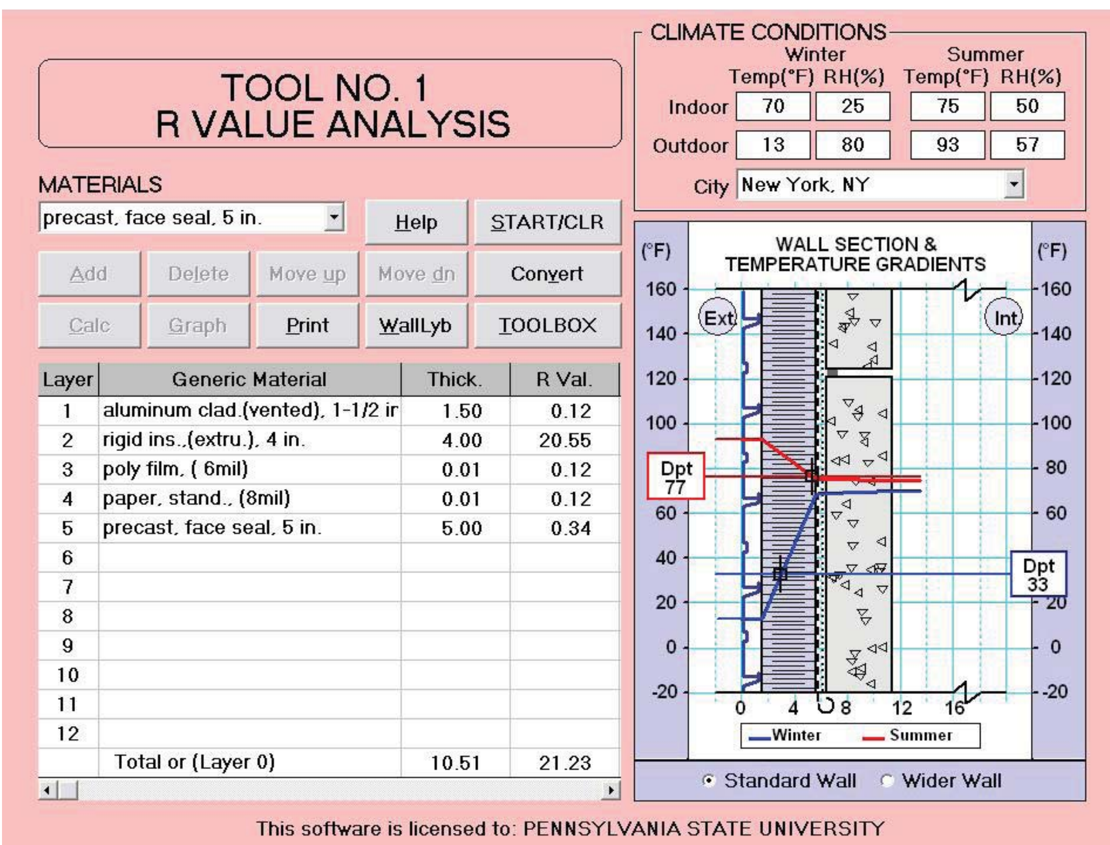
Summary of Existing Building Enclosure:

- Metal Panel Cladding with Infill Windows
    - Consists of 1/8" aluminum panels mounted onto a precast back-up structure. This system forms a rain screen cladding. The panel joints are unsealed, which allows for air ventilation.
    - Aluminum panels consist of extruded aluminum blades, which express the diagonal bracing of the structural system.
    - All glass is fully tempered or heat-strengthened as required.
    - The finish of all aluminum is clear anodized.
    - Between metal panel and precast layer non-combustible foam glass insulation of 4 inches is used.

R-Value Analysis – New York City:

An R-Value analysis of the existing building enclosure for New York City was performed. Below is an image of the R-Value analysis. H.A.M (Heat. Air. Moisture) Toolbox was the software program used for this analysis and several other analyses to follow.

Figure 20: R-Value Analysis – Existing Enclosure System – New York City



As shown above the dew point temperatures (for winter and summer) occur both on the exterior portion of the wall enclosure system, within the rigid insulation layer. This allows for water to condensate towards the exterior portion of the system, and be weeped to the exterior of the building, causing no interior condensation concerns.

Condensation Analysis – New York City:

Below is a condensation analysis, conveying that there are no condensation concerns for this existing enclosure system for New York City.

Figure 21: Condensation Analysis Winter – Existing Enclosure System – New York City

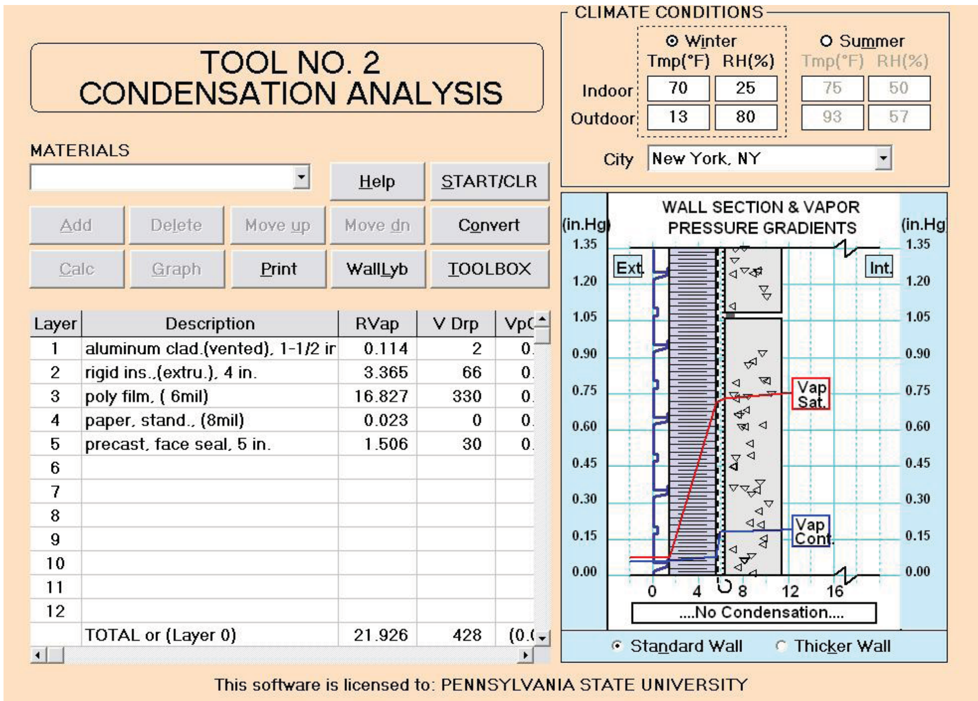
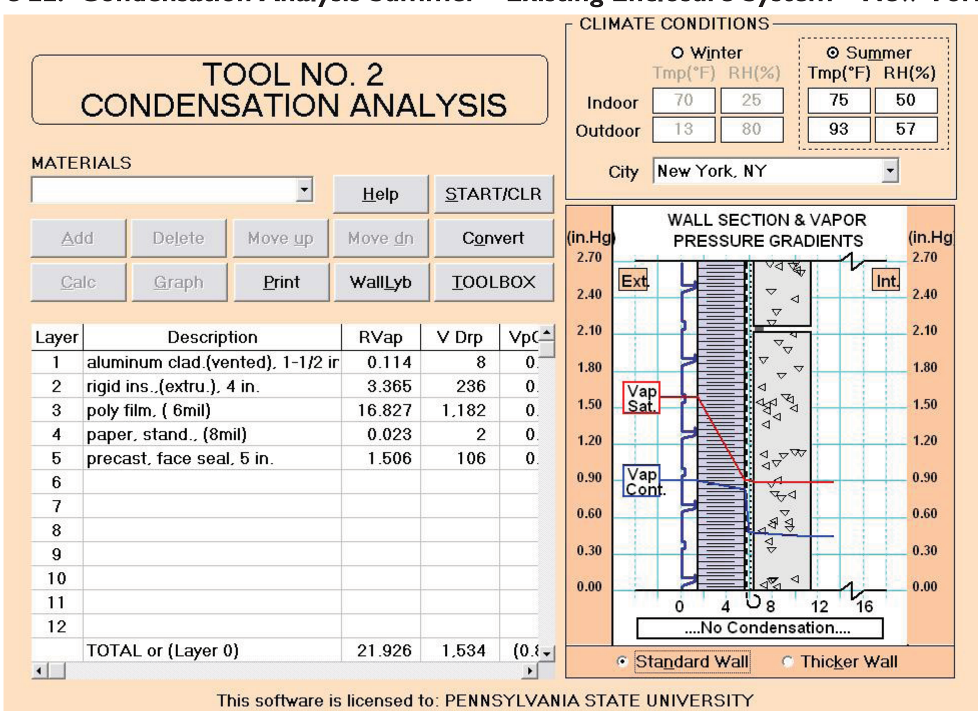


Figure 22: Condensation Analysis Summer – Existing Enclosure System – New York City



Air Leakage Analysis – New York City:

Below is an air leakage analysis for the building in New York City. This analysis estimates the energy loss for the whole building due to building enclosure air leakage during the summer and winter seasons.

Figure 23: Air Leakage Analysis Winter – Enclosure System – New York City

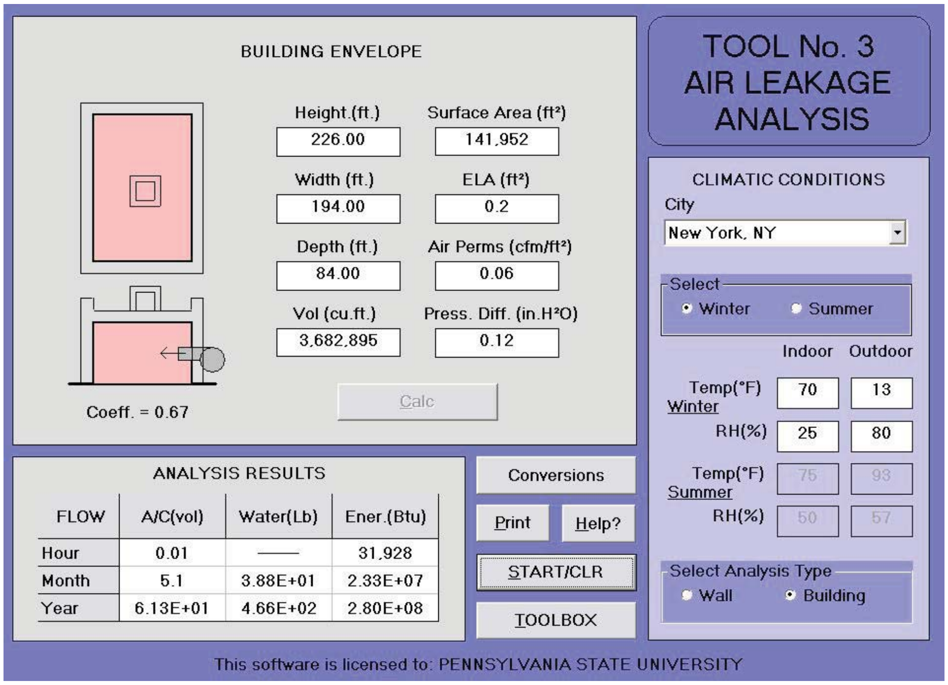
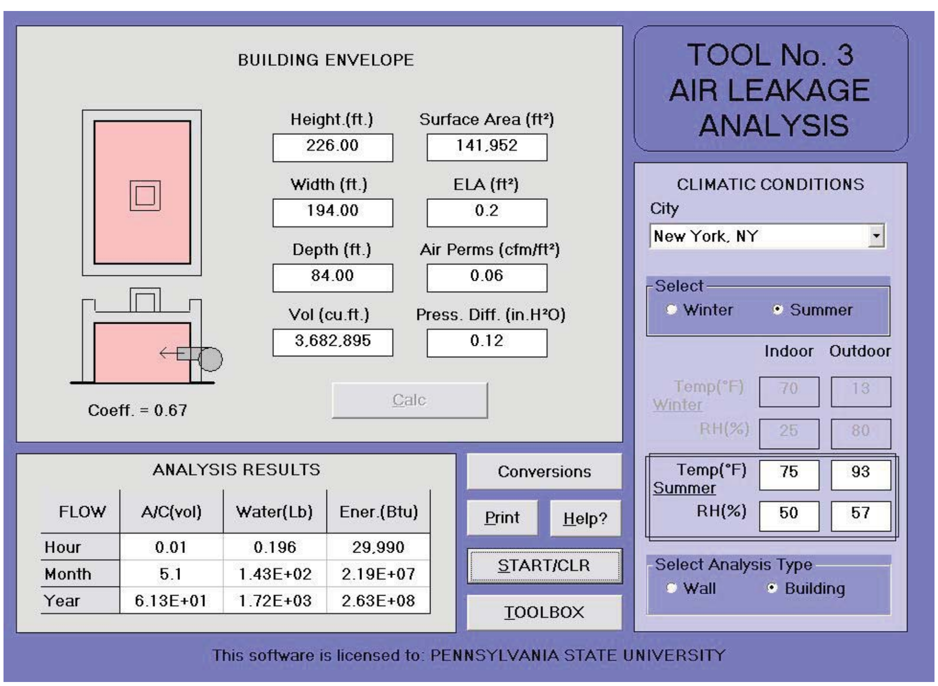


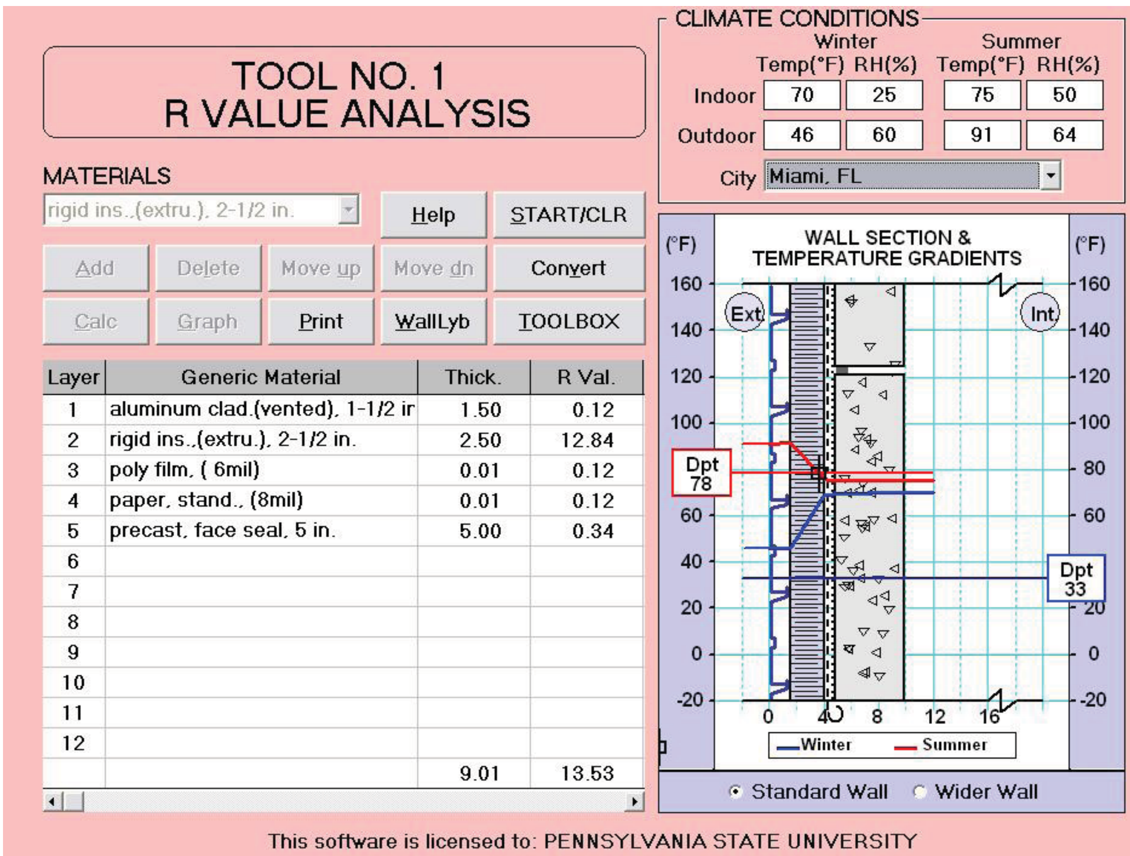
Figure 24: Air Leakage Analysis Summer – Enclosure System – New York City



R-Value Analysis – Miami, FL:

An R-Value analysis of the building enclosure system for Miami, FL was performed. Below is an image of the R-Value analysis. Notice that the existing wall closure was modified slightly for the relocation. A 2.5 inch insulation layer is used for Miami, FL (4 in. was used for New York City). This decrease in insulation was made possible due to Miami's warmer climate.

Figure 25: R-Value Analysis – Redesigned Enclosure System – Miami, FL



Condensation Analysis – Miami, FL:

Below is a condensation analysis, conveying that there are no condensation concerns for the enclosure system in Miami, FL. Notice again, that the existing wall closure was modified slightly for the relocation. A 2.5 inch insulation layer is used for Miami, FL (4 in. was used for New York City).

Figure 26: Condensation Analysis Summer – Redesigned Enclosure System – Miami, FL

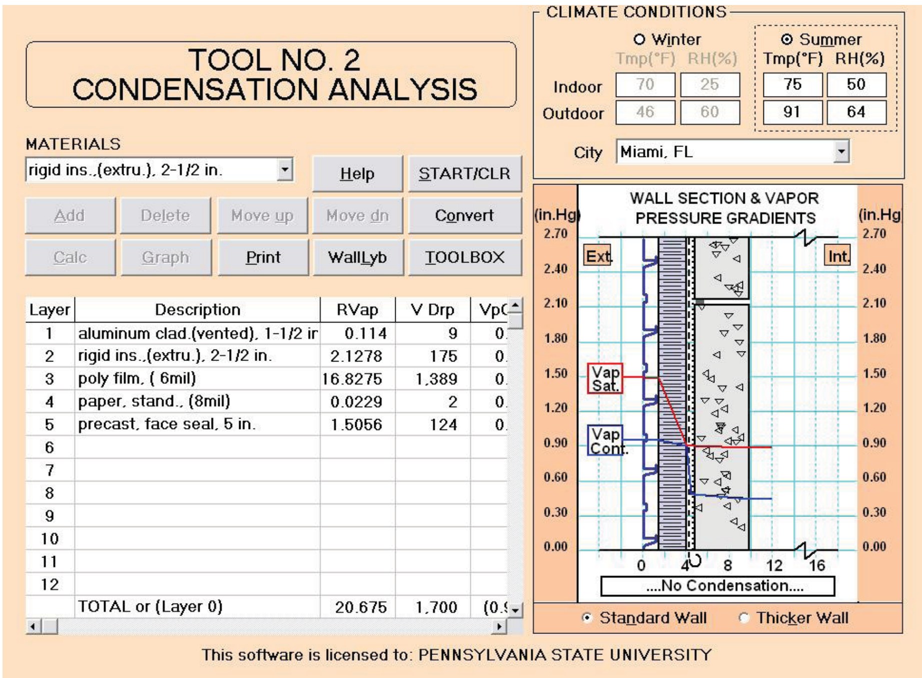
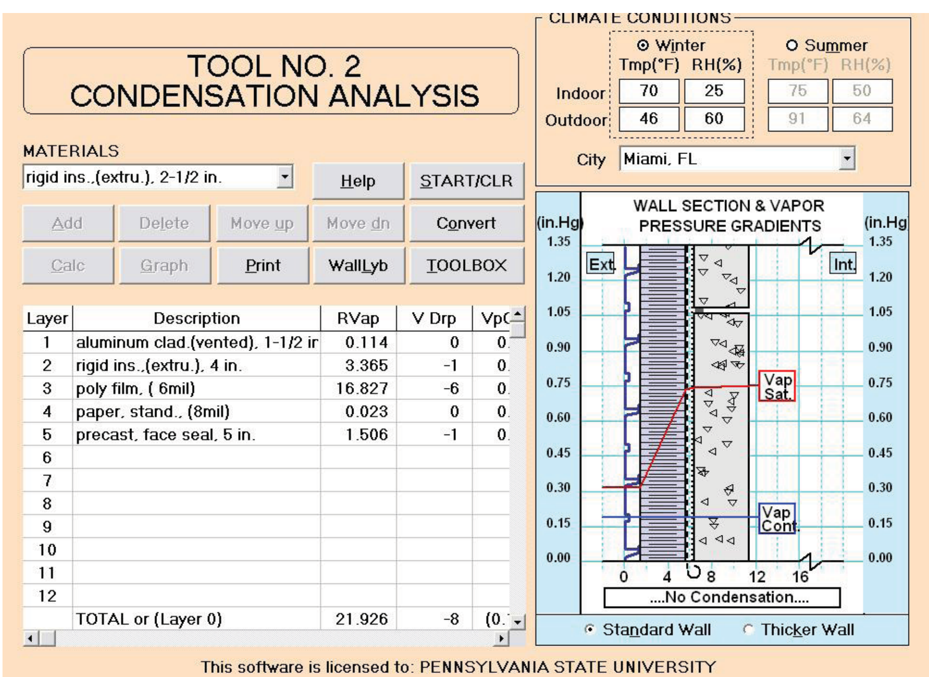


Figure 27: Condensation Analysis Winter – Redesigned Enclosure System – Miami, FL



<u>Air Leakage Analysis – Miami, FL:</u>

Below is an air leakage analysis for the building in Miami, FL. This analysis estimates the energy loss for the whole building due to building enclosure air leakage during the summer and winter seasons.

Figure 28: Air Leakage Analysis Winter – Enclosure System – Miami, FL

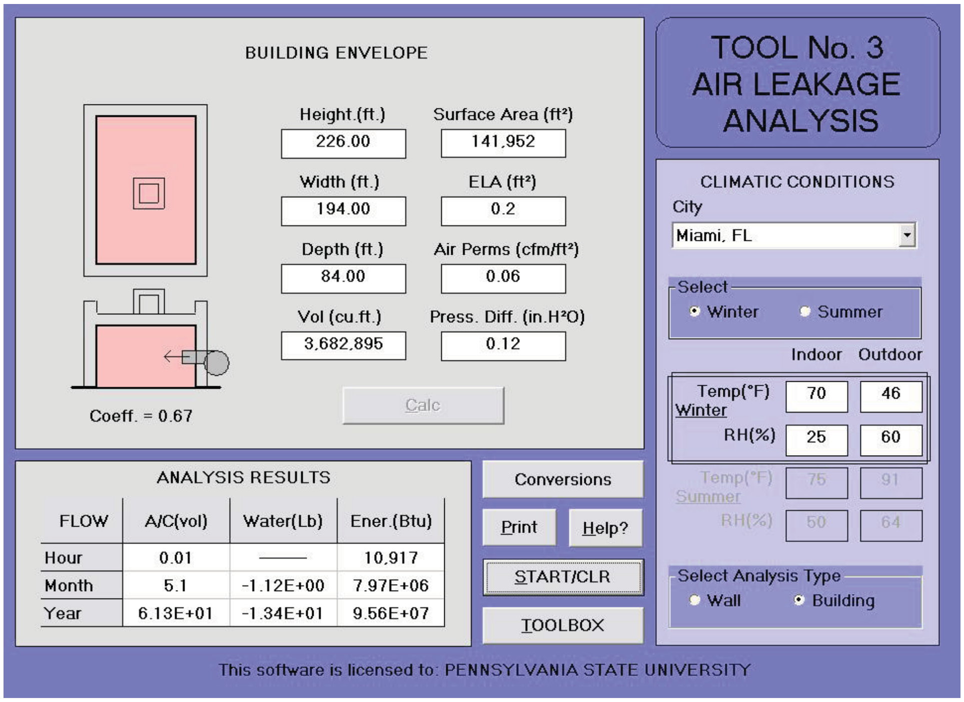
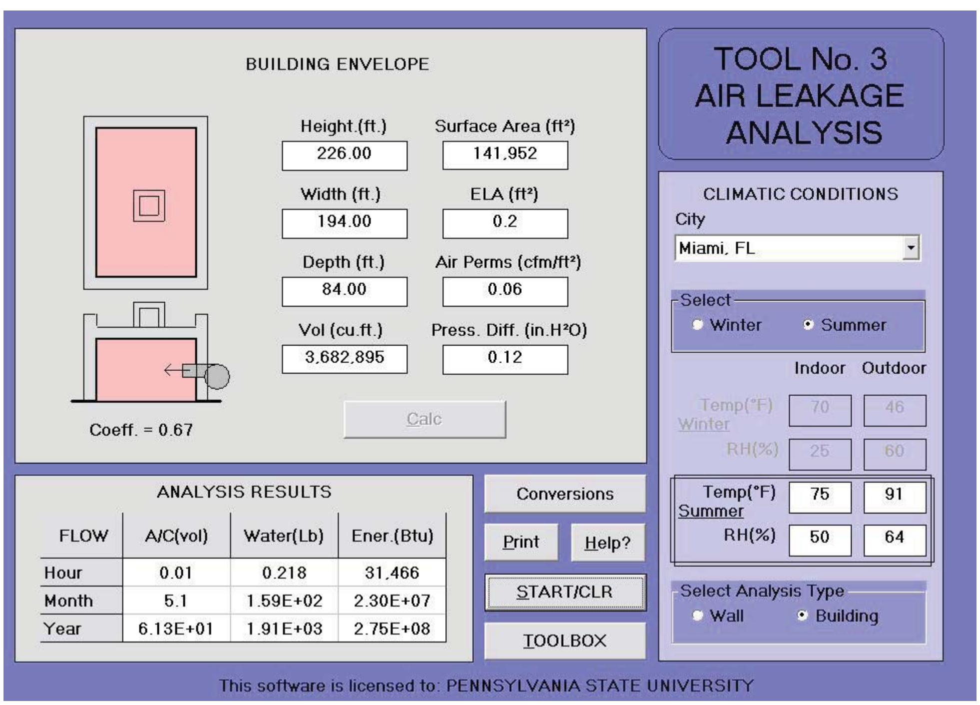
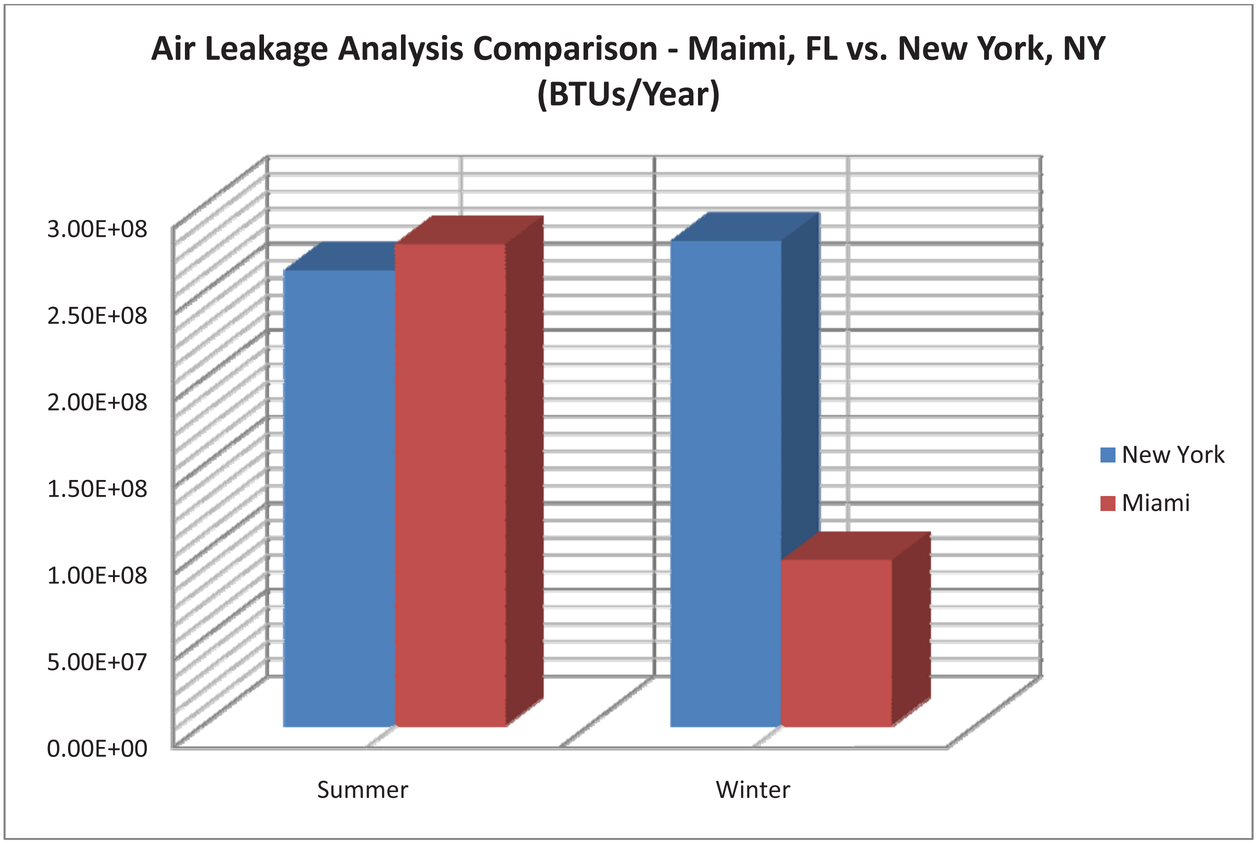


Figure 29: Air Leakage Analysis Summer –Enclosure System – Miami, FL



Air Leakage Analysis Comparison – Miami, FL vs. New York, NY



Graph 6: Air Leakage Analysis Comparison – Miami, FL vs. New York, NY

Air Leakage Analysis Comparison - Miami, FL vs. New York, NY		
All Values in BTUs per Year		
	Summer	**Winter**
New York	2.63E+08	2.80E+08
Miami	2.78E+08	9.56E+07
Difference	1.50E+07	**1.84E+08**

The comparison above shows that there is a small difference in energy loss due to air leakage during the summer season between New York, NY and Miami, FL. On the other hand, there is a large difference in energy loss during the winter season of 1.84E+08 BTUs/Year. This is equivalent to burning about 200,000 gallons of natural gas. This establishes that the building in New York City experiences an overall greater energy loss due to air leakage.

The R-value analysis, condensation analysis, and the air leakage analysis all support the building enclosure modification of the insulation layer from originally 4 inches thick (NYC) to a 2.5 inches thick for Miami, FL. ASHRAE recommended R-Values based on climate also support the redesign of this insulation layer. The following pages provide ASHRAE data and discussion.

ASHRAE Climate Zone - Roof, Walls, and Vertical Glazing Material Recommendations

Figure 30: Climate Zone 1 – Miami, FL

Climate Zone 1 Recommendation Table

	Item	Component	Recommendation	How-To's in Chapter 4
Envelope	Roof	Insulation entirely above deck	R-15 c.i.	EN1-2, 17, 20-21
		Metal building	R-19	EN1, 3, 17, 20-21
		Attic and other	R-30	EN4, 17-18, 20-21
		Single rafter	R-30	EN5, 17, 20-21
		Surface reflectance/emittance	0.65 initial/0.86	EN1
	Walls	Mass (HC > 7 Btu/ft^2)	No recommendation	EN6, 17, 20-21
		Metal building	R-13	EN7, 17, 20-21
		Steel framed	R-13	EN8, 17, 20-21
		Wood framed and other	R-13	EN9, 17, 20-21
		Below-grade walls	No recommendation	EN10, 17, 20-21
	Floors	Mass	R-4.2 c.i.	EN11, 17, 20-21
		Steel framed	R-19	EN12, 17, 20-21
		Wood framed and other	R-19	EN12, 17, 20-21
	Slabs	Unheated	No recommendation	EN17, 19-21
		Heated	No recommendation	EN17, 19-21
	Doors	Swinging	U-0.70	EN15, 20-21
		Non-swinging	U-1.45	EN16, 20-21
	Vertical Glazing	Window to wall ratio (WWR)	20% to 40% maximum	EN23, 36-37
		Thermal transmittance	U-0.56	EN25
		Solar heat gain coefficient (SHGC)	N, S, E, W - 0.35 / N only - 0.49	EN27-28
		Window orientation	$(A_N * SHGC_N + A_S * SHGC_S) > (A_E * SHGC_E + A_W * SHGC_W)$	A_x–Window area for orientation x EN26-32
		Exterior sun control (S, E, W only)	Projection factor 0.5	EN24, 28, 30, 36, 40, 42 DL5-6

Figure 31: Climate Zone 4 – New York, NY

Climate Zone 4 Recommendation Table

	Item	Component	Recommendation	How-To's in Chapter 4
Envelope	Roof	Insulation entirely above deck	R-20 c.i.	EN2, 17, 20-21
		Metal building	R-13 + R-19	EN3, 17, 20-21
		Attic and other	R-38	EN4, 17-18, 20-21
		Single rafter	R-38	EN5, 17, 20-21
		Surface reflectance/emittance	No recommendation	
	Walls	Mass (HC > 7 Btu/ft^2)	R-11.4 c.i.	EN6, 17, 20-21
		Metal building	R-13	EN7, 17, 20-21
		Steel framed	R-13 + R-7.5 c.i.	EN8, 17, 20-21
		Wood framed and other	R-13	EN9, 17, 20-21
		Below-grade walls	No recommendation	EN10, 17, 20-21
	Floors	Mass	R-8.3 c.i.	EN11, 17, 20-21
		Steel framed	R-30	EN12, 17, 20-21
		Wood framed and other	R-30	EN12, 17, 20-21
	Slabs	Unheated	No recommendation	EN17, 19-21
		Heated	R-7.5 for 24 in.	EN14, 17, 19-21
	Doors	Swinging	U-0.70	EN15, 20-21
		Non-swinging	U-0.50	EN16, 20-21
	Vertical Glazing	Window to wall ratio (WWR)	20% to 40% maximum	EN23, 36-37
		Thermal transmittance	U-0.42	EN25
		Solar heat gain coefficient (SHGC)	N, S, E, W - 0.46 / N only - 0.46	EN27-28
		Window orientation	$(A_N * SHGC_N + A_S * SHGC_S) > (A_E * SHGC_E + A_W * SHGC_W)$	A_x–Window area for orientation x EN26-32
		Exterior sun control (S, E, W only)	Projection factor 0.5	EN24, 28, 30, 36, 40, 42 DL5-6

Summary of Recommendations Provided by ASHRAE:

Walls:

- An R-value of 13 is recommended for Miami, FL
- An R-value of 13 + 7.5 of continuous insulation (total of 20.5) is recommended for New York City.

Roof:

- An R-value of 19 is recommended for Miami, FL
- An R-value of 13 + 19 (total of 32) is recommended for New York City.

Comparison of R-Values Provided - Existing vs. Redesign Enclosure:

- Miami, Fl: R-Value of Walls Provided = **13.5** (13 is recommended)
- New York, NY: R-Value of Walls Provided = **21.2** (20.5 is recommended)

The comparison above shows that the existing curtain wall design and the redesign curtain wall for Miami, FL both meet R-Value requirements. This also supports the reduction in the rigid insulation layer as previously discussed.

Note: Roof R-value recommendations of ASHRAE also suggest that a redesign of the roofing could be analyzed and redesign. This analysis was not included within the scope of this breadth. The author believes a redesign of the roofing will reduce material insulation. Construction costs are believed to decrease along with the redesign of the curtain wall system.

Building Envelope – RS Means – Cost Estimation Analysis:

Figure 32: Insulation Cost Data – Cost Works

0721 Thermal Insulation — Lines 1 - 50 of 201

Line Number		Description	Unit	Crew	Daily Output	Labor Hours	Bare Material	Bare Labor	Bare Equipment	Bare Total
072113100520	G	Foil faced,...	S.F.	1 C...	1000.00	0.008	0.92	0.32		1.24
072113100540	G	1-1/2" t...	S.F.	1 C...	1000.00	0.008	1.36	0.32		1.68
072113100560	G	2" thick,...	S.F.	1 C...	890.00	0.009	1.71	0.36		2.07
072113100580	G	2-1/2" t...	S.F.	1 C...	800.00	0.010	2.02	0.40		2.42
072113100600	G	3" thick,...	S.F.	1 C...	800.00	0.010	2.19	0.40		2.59
072113100670	G	6#/CF, unface...	S.F.	1 C...	1000.00	0.008	0.98	0.32		1.30
072113100690	G	1-1/2" t...	S.F.	1 C...	890.00	0.009	1.50	0.36		1.86
072113100700	G	2" thick,...	S.F.	1 C...	800.00	0.010	2.12	0.40		2.52
072113100721	G	2-1/2" t...	S.F.	1 C...	800.00	0.010	2.32	0.40		2.72
072113100741	G	3" thick,...	S.F.	1 C...	730.00	0.011	2.78	0.44		3.22
072113100821	G	Foil faced,...	S.F.	1 C...	1000.00	0.008	1.38	0.32		1.70
072113100840	G	1-1/2" t...	S.F.	1 C...	890.00	0.009	1.98	0.36		2.34
072113100850	G	2" thick,...	S.F.	1 C...	800.00	0.010	2.59	0.40		2.99
072113100880	G	2-1/2" t...	S.F.	1 C...	800.00	0.010	3.11	0.40		3.51
072113100900	G	3" thick,...	S.F.	1 C...	730.00	0.011	3.72	0.44		4.16
072113101500	G	Foamglass, 1-1/2...	S.F.	1 C...	800.00	0.010	1.37	0.40		1.77
072113101530	G	2" thick,...	S.F.	1 C...	765.00	0.010	1.94	0.42		2.36
072113101550	G	3" thick,...	S.F.	1 C...	730.00	0.011	3.29	0.44		3.73

A bare material cost analysis was performed for the foam glass rigid insulation layer.

The following table represents the data calculated.

RS MEANS RESULTS	**Bare Material Cost**
Miami, FL (2.5" Foamglass)	$344,250
New York, NY (4.0" Foamglass)	$530,150

This bare material cost analysis shows that a bare material savings of $185,900 can be obtained from using 1.5 inches less of foam glass insulation.