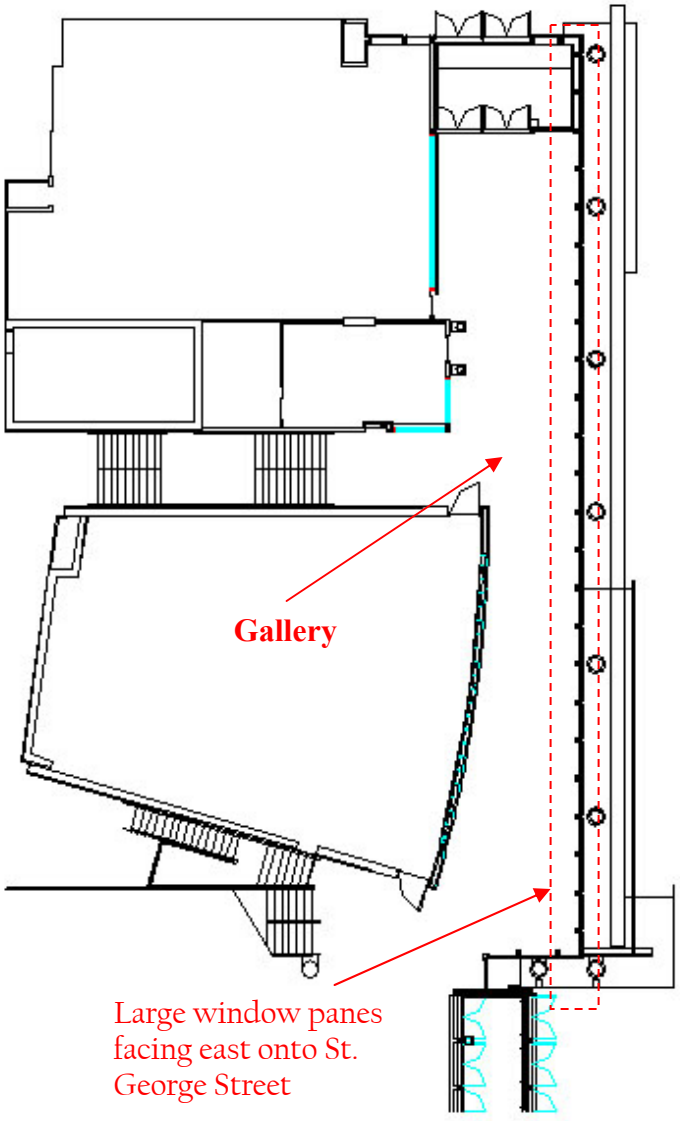
Glazing Studies of the Gallery

Introduction

The gallery in the Bahen Centre is a circulation space located in the northeast side of the building. One side of the corridor composed of the walls of an auditorium and a large computer lab. The other side is constructed of large windows throughout the entire length of the corridor. Due to the fact that materials used in windows has some of the lowest resistance (R) values, it is worth analyzing how efficient the windows of the gallery corridor is at insulating heat in the winter, and keeping heat out in the summer. If the windows perform poorly, it could cause extra use of the heating and cooling load in the building, increasing the cost of building operation. On the other hand, if the glazing of the windows is highly efficient, then money can be saved with the decreased heating and cooling load of the building.

This glazing analysis will examine the use of a few different glazing types, including glazing that are uncoated, coated, and glazing with different properties. Since no information on the glazing on the existing design was available, this analysis will also serve as a way to determine what type of glazing will be the most suitable in a building like the Bahen Centre. The heating and cooling loads related to the use of the different glazing in the gallery space will be analyzed as the mechanical component, along with a brief analysis on the shading effect on daylight of the different glazing. The mechanical analysis will be performed with the use of the Carrier Hourly Analysis Program 4.10 (HAP), and the daylight component will be analyzed by using the daylight function of the lighting software Luxicon.

Figure 10.1 - Gallery



Factors to analyze

The basis of the comparison for the glazing in the Gallery space is to examine the insulation and transmittance properties of the different types of glazing. The four major characteristics for comparison are listed as follow:

- U-Value

  The U value is the overall coefficient of heat transmission. It represents the rate of heat flow through surfaces, which could be layers of materials, air space, or combinations of such. A low U-Value corresponds to a lower the heat flow through the glazing, making it a more insulated material. U-value is equal to the inverse sum of the material resistance (R):

  $$U=1/\Sigma R$$

  The unit of the U-value is Btu/h ft^2 °F.

- Shading Coefficient

  The shading coefficient (SC) represents insulating ability of a glazing material has when it encounters sunlight. The coefficient depends on the tint of the glass, type of glass, reflective coatings, and shading

by other objects. The lower the shading coefficient, the more insulated the glazing is.

❖*The U value and shading coefficient will be used to analyze the ability of the glazing to withstand the outdoor environment. This study is particularly useful for the Bahen Centre, since it is located in Toronto, Canada, where there are some of the coldest winters and very hot summers.*

- **Transmittance**

  The transmittance value represents the fraction of the incident amount of light in the visible spectrum that is allowed to pass through a transparent material. Although this factor does not play a large role in the contribution or reduction of heat gain in a space, the visual quality of the glazing with different transmittance will still be analyzed (by using a daylight analysis software, such as Luxicon).

- **Reflectance**

  Another factor that has no effect on the heat gain properties of the material. However, the reflectance of the materials will be considered internally as it will reflect a certain amount of light back into the gallery corridor, aiding in the illumination of the space.

Glazing

All comparison will be done on glazing with thickness of ¼" for ease of evaluation. Data for this analysis is obtained from the glass manufacturer PPG Industries. Five different glazing types are tested in this glazing analysis:

- STARPHIRE Glass (uncoated)
- CLEAR Glass (uncoated)
- AZURIA Glass (uncoated)
- SOLARCOOL AZURIA Glass (coated)
- SUNGATE 100 AZURIA Glass (Low-E)

The corresponding properties and U-values of these glazing types are listed on the next two pages (Table 10.1 and 10.2). These values are inputted into the Hourly Analysis Program (HAP) to obtain the cooling and heating load for the gallery space, with that specific type of glazing being used on the east facing windows.

Table of Performance Values														
Glass Thickness		Transmittance			Reflectance		U-Value (Imperial)		K-Value (Metric)		Shading Coeffi-cient	Solar Heat Gain Coefficent	Light to Solar Gain (LSG)
Inches	mm	Ultra-violet %	Visible %	Total Solar Energy %	Visible Light %	Total Solar Energy %	Winter Night-time	Summer Day-time	Winter Night-time	Summer Day-time			
Uncoated STARPHIRE Glass													
3/16	5	86	91	90	8	8	1.10	1.00	6.23	5.67	1.05	0.90	1.01
1/4	6	85	91	89	8	8	1.09	1.00	6.19	5.65	1.04	0.90	1.01
5/16	8	83	91	88	8	8	1.07	0.98	6.09	5.58	1.03	0.89	1.02
3/8	10	82	91	87	8	8	1.06	0.98	6.03	5.54	1.03	0.88	1.02
1/2	12	80	91	86	8	8	1.04	0.96	5.89	5.45	1.02	0.87	1.04
Uncoated CLEAR Glass													
3/16	5	68	89	79	9	7	1.10	1.03	6.23	5.85	0.96	0.83	1.07
1/4	6	65	89	77	9	7	1.09	1.03	6.19	5.85	0.94	0.81	1.10
5/16	8	60	87	72	8	7	1.07	1.03	6.09	5.83	0.90	0.78	1.12
3/8	10	57	87	69	8	7	1.06	1.02	6.03	5.81	0.88	0.76	1.14
1/2	12	52	85	63	8	6	1.04	1.02	5.89	5.76	0.83	0.71	1.20

Table 10.1 - Table of Performance Values of various glazing types

Table of Performance Values													
Glass Thickness		Transmittance			Reflectance		U-Value (Imperial)		K-Value (Metric)		Shading Coeffi-cient	Solar Heat Gain Coefficent	Light to Solar Gain (LSG)
Inches	mm	Ultra-violet %	Visible %	Total Solar Energy %	Visible Light %	Total Solar Energy %	Winter Night-time	Summer Day-time	Winter Night-time	Summer Day-time			
Uncoated													
AZURIA Glass													
1/8	3.2	53	77	45	7	6	1.11	1.12	6.30	6.34	0.68	0.59	1.31
3/16	5	46	71	36	7	5	1.10	1.12	6.24	6.36	0.61	0.53	1.34
1/4	6	42	67	32	7	5	1.09	1.12	6.19	6.35	0.58	0.50	1.34
5/16	8	34	60	26	6	5	1.07	1.11	6.09	6.31	0.52	0.45	1.33
3/8	10	31	56	23	6	5	1.06	1.10	6.03	6.27	0.50	0.43	1.30
Coated													
SOLARCOOL (2) AZURIA Glass													
1/4	6	12	26	14	19	9	1.09	1.14	6.21	6.48	0.41	0.36	0.72
Insulating Glass (1" unit using 1/4" glass)													
SUNGATE 100 (3) Azuria Low-E Tinted Insulating Glass													
1/4	6	-	55	-	9	-	0.31	0.34	-	-	0.37	0.32	-

Table 10.2 - Table of Performance Values for various glazing types

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1000 COOLING OA DB / WB 75.7 °F / 67.6 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -4.0 °F / -5.3 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1347 ft²	102299	-	1347 ft²	-	-
Wall Transmission	317 ft²	417	-	317 ft²	5281	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	1347 ft²	-108	-	1347 ft²	99692	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	100 ft²	1073	-	100 ft²	4837	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	3193 W	10015	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	0 W	0	-	0	0	-
People	6	1510	1620	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	**-**	**115206**	**1620**	**-**	**109810**	**0**
Zone Conditioning	-	108283	1620	-	107607	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	5450 CFM	4244	-	5450 CFM	-2292	-
Ventilation Load	75 CFM	-210	1618	41 CFM	3166	0
Supply Fan Load	4559 CFM	4244	-	2463 CFM	-2292	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**116560**	**3238**	**-**	**106188**	**0**
Central Cooling Coil	-	116560	3242	-	0	0
Central Heating Coil	-	0	-	-	106188	-
>> Total Conditioning	**-**	**116560**	**3242**	**-**	**106188**	**0**

Table 10.3 - Design cooling and design heating load for STARPHIRE Glass

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1000 COOLING OA DB / WB 75.7 °F / 67.6 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -4.0 °F / -5.3 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1347 ft²	92462	-	1347 ft²	-	-
Wall Transmission	317 ft²	417	-	317 ft²	5281	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	1347 ft²	-111	-	1347 ft²	102683	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	100 ft²	969	-	100 ft²	4950	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	3193 W	10015	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	0 W	0	-	0	0	-
People	6	1510	1620	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	**-**	**105263**	**1620**	**-**	**112914**	**0**
Zone Conditioning	-	98276	1620	-	110377	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	4975 CFM	3854	-	4975 CFM	-2342	-
Ventilation Load	75 CFM	-208	1606	46 CFM	3536	0
Supply Fan Load	4140 CFM	3854	-	2516 CFM	-2342	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**105777**	**3226**	**-**	**109228**	**0**
Central Cooling Coil	-	105777	3231	-	0	0
Central Heating Coil	-	0	-	-	109228	-
>> Total Conditioning	**-**	**105777**	**3231**	**-**	**109228**	**0**

Table 10.4 - Design cooling and design heating load for CLEAR Glass

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1400 COOLING OA DB / WB 86.4 °F / 70.8 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -4.0 °F / -5.3 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1347 ft²	44444	-	1347 ft²	-	-
Wall Transmission	317 ft²	881	-	317 ft²	5281	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	1347 ft²	11659	-	1347 ft²	111655	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	100 ft²	1250	-	100 ft²	5288	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	3193 W	10208	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	0 W	0	-	0	0	-
People	6	1548	1620	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	**-**	**69990**	**1620**	**-**	**122224**	**0**
Zone Conditioning	-	63831	1620	-	117852	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	3308 CFM	2510	-	3308 CFM	-2449	-
Ventilation Load	73 CFM	631	1556	72 CFM	5492	0
Supply Fan Load	2696 CFM	2510	-	2630 CFM	-2449	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**69481**	**3176**	**-**	**118447**	**0**
Central Cooling Coil	-	69481	3181	-	0	0
Central Heating Coil	-	0	-	-	118447	-
>> Total Conditioning	**-**	**69481**	**3181**	**-**	**118447**	**0**

Table 10.5 - Design cooling and design heating load for AZURIA Glass

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1500 COOLING OA DB / WB 87.0 °F / 71.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -4.0 °F / -5.3 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1347 ft²	30132	-	1347 ft²	-	-
Wall Transmission	317 ft²	925	-	317 ft²	5281	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	1347 ft²	12839	-	1347 ft²	113649	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	100 ft²	1100	-	100 ft²	5363	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	3193 W	10249	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	0 W	0	-	0	0	-
People	6	1556	1620	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	**-**	**56800**	**1620**	**-**	**124293**	**0**
Zone Conditioning	-	50674	1620	-	118798	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	2693 CFM	1998	-	2693 CFM	-2436	-
Ventilation Load	72 CFM	668	1508	87 CFM	6660	0
Supply Fan Load	2146 CFM	1998	-	2617 CFM	-2436	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**55337**	**3128**	**-**	**120586**	**0**
Central Cooling Coil	-	55337	3129	-	0	0
Central Heating Coil	-	0	-	-	120586	-
>> Total Conditioning	**-**	**55337**	**3129**	**-**	**120586**	**0**

Table 10.6 - Design cooling and design heating load for SOLARCOOL AZURIA Glass

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1000 COOLING OA DB / WB 75.7 °F / 67.6 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -4.0 °F / -5.3 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1347 ft²	36395	-	1347 ft²	-	-
Wall Transmission	317 ft²	417	-	317 ft²	5281	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	1347 ft²	-37	-	1347 ft²	33895	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	100 ft²	381	-	100 ft²	2361	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	3193 W	10015	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	0 W	0	-	0	0	-
People	6	1510	1620	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	**-**	**48682**	**1620**	**-**	**41537**	**0**
Zone Conditioning	-	44585	1620	-	40641	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	2301 CFM	1752	-	2301 CFM	-869	-
Ventilation Load	74 CFM	-201	1535	37 CFM	2847	0
Supply Fan Load	1882 CFM	1752	-	933 CFM	-869	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**47888**	**3155**	**-**	**41750**	**0**
Central Cooling Coil	-	47888	3160	-	0	0
Central Heating Coil	-	0	-	-	41750	-
>> Total Conditioning	**-**	**47888**	**3160**	**-**	**41750**	**0**

Table 10.7 - Design cooling and design heating load for SUNGATE 100 AZURIA Low-E Glass

For Toronto, Ontario, Canada

- Latitude = 43.7°
- Longitude = 79.6°
- Elevation = 568.0 ft

	Cooling Load		Heating Load	
	Btu/hr	Ton	Btu/hr	Ton
STARPHIRE	116560	9.71	106188	8.85
CLEAR	105777	8.81	109228	9.10
AZURIA	69481	5.79	118447	9.87
SOLARCOOL AZURIA	55337	4.61	120586	10.05
SUNGATE AZURIA LOW-E	47888	3.99	41750	3.48

Table 10.8 - Summary of cooling and heating load with the use of different glazing

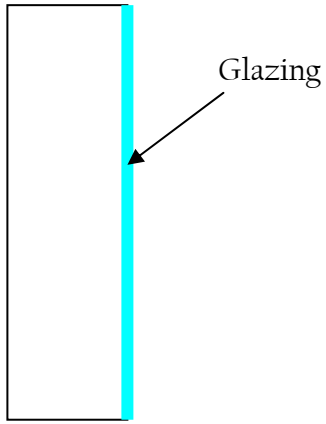
Peak Cooling and Heating Load Analysis Result

From the cooling and heating load analysis performed in the Hourly Analysis Program (HAP), the two best glazing are the **SOLARCOOL AZURIA**, and **SUNGATE LOW-E AZURIA** glass. They are considered as the best in regards to their ability to minimize heat loss in the winter and heat gain in the summer. The use of the glazing can lower the cooling and heating load, which in the end result in cost savings.

Daylight Availability

The two best glazing resulted from the previous analysis will be further examined for their transmittance and reflectance properties when interacting with daylight. These two glazing (**SOLARCOOL AZURIA** and **SUNGATE LOW-E AZURIA**) will be used in a test corridor in Luxicon that has the same width as the Gallery but only half on its length. This analysis will examine the ability of the glazing to transmit or reflect sunlight.

Figure 10.2 - Plan view of a section of the Gallery corridor



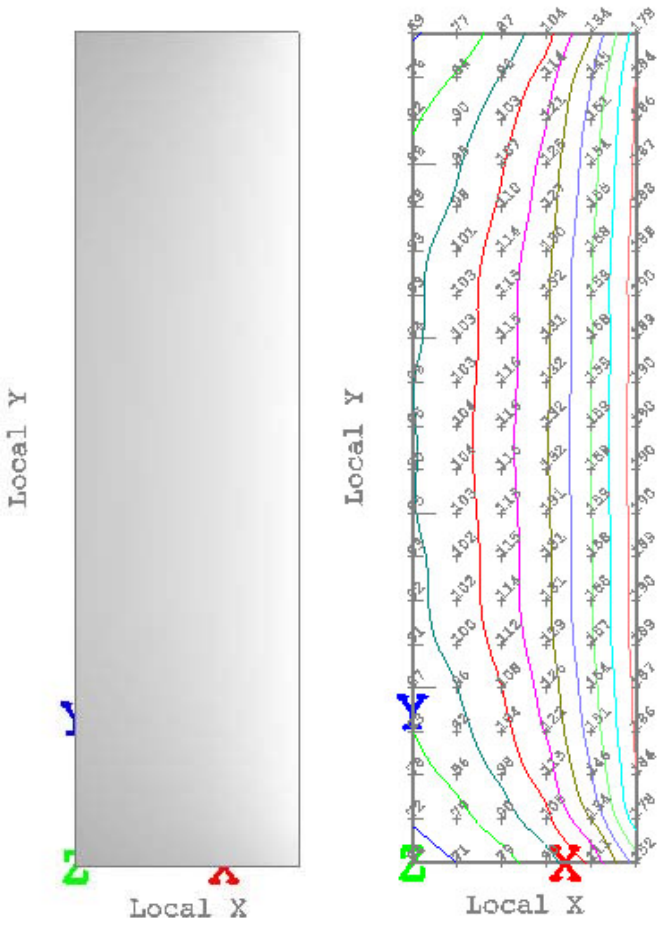
The window plane in the Gallery is approximately 9.87 ft high and runs along the entire length of the corridor (120 ft). The corridor model to be tested in Luxicon will have the same width (18.3 ft) as the Gallery but only half of the length (60 ft) of the actual Gallery space. This is because the only factor that is important for this analysis is how far the sunlight can penetrate into the space through the glass. The amount of penetration into the space will be the same up and down the corridor; therefore there is no need to analyze the entire 120 ft long corridor.

The Luxicon analysis will be performed on two different times of the year, at two different time of the day with two different sky conditions:

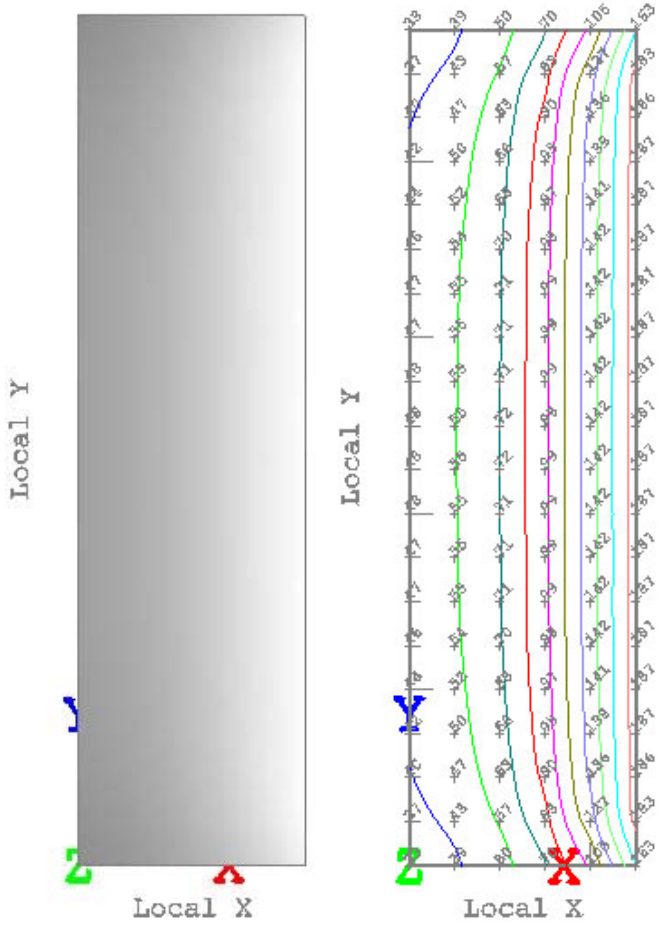
Month	Time	Sky Condition
June	12:00pm	Clear
		Cloudy
	5:00pm	Clear
		Cloudy
December	12:00pm	Clear
		Cloudy
	4:00pm	Clear
		Cloudy

The results will be shown in horizontal illumination distribution (at 0 ft, floor level) contour caused by the daylight, and the other will be a shaded plot, which can provide a more realistic look of the lighting distribution into the space.

SOLARCOOL (2) AZURIA Glass

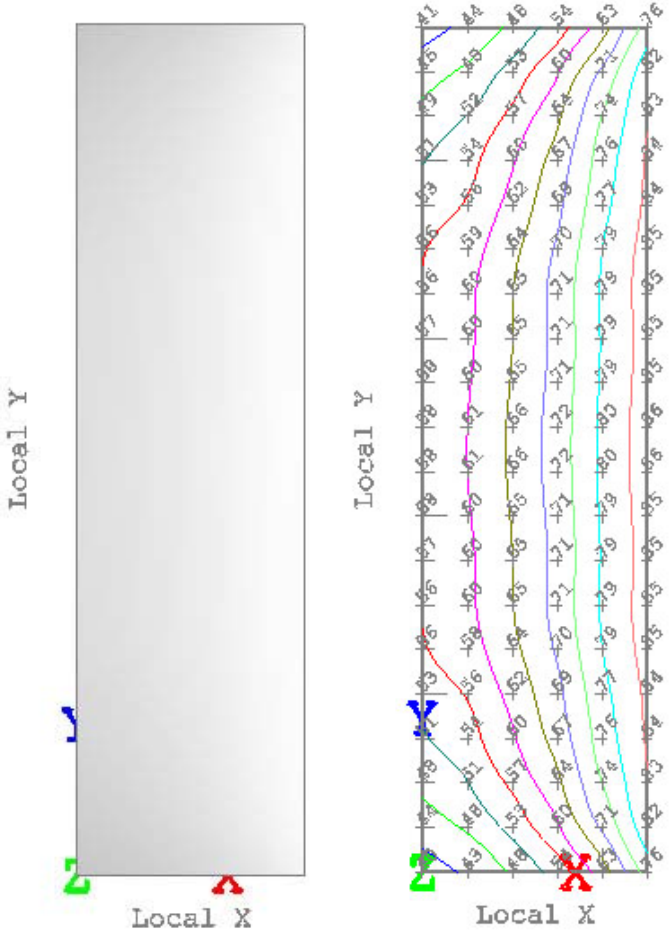


June 19, 12:00pm, Clear Sky

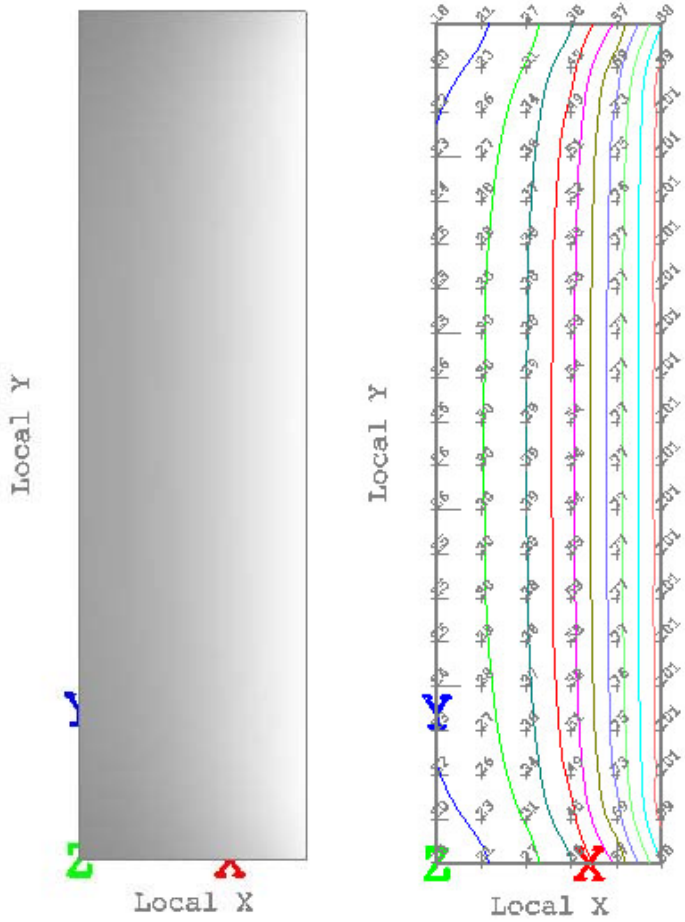


June 19, 12:00pm, Cloudy Sky

SOLARCOOL (2) AZURIA Glass

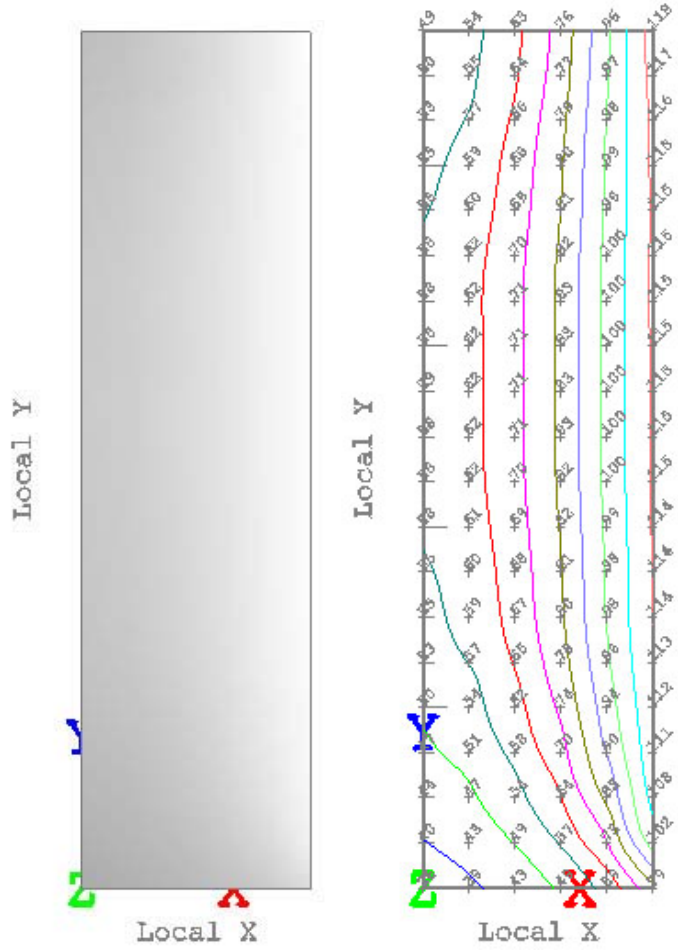


June 19, 5:00pm, Clear Sky

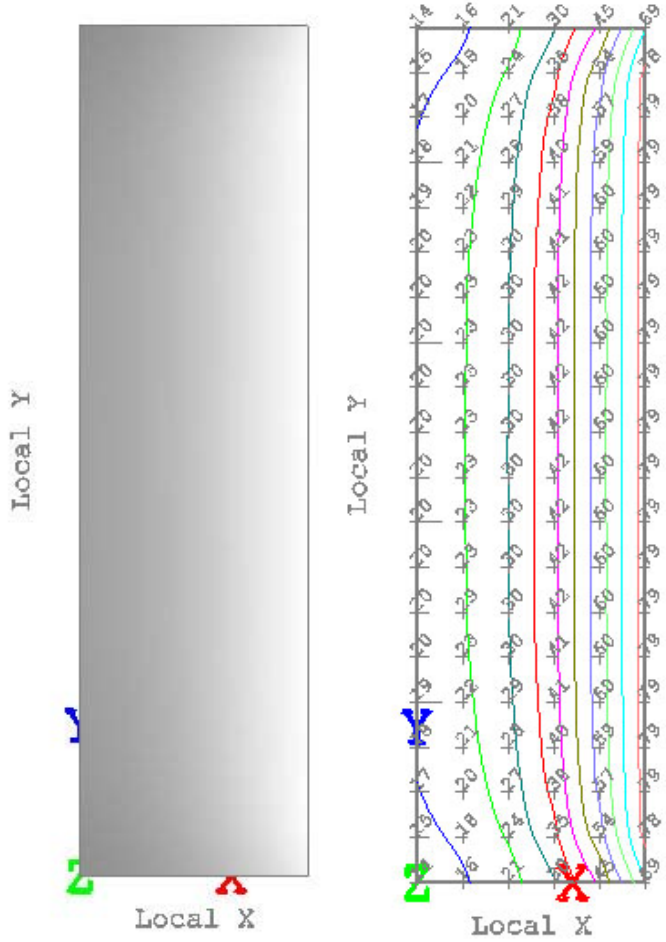


June 19, 5:00pm, Cloudy Sky

SOLARCOOL (2) AZURIA Glass

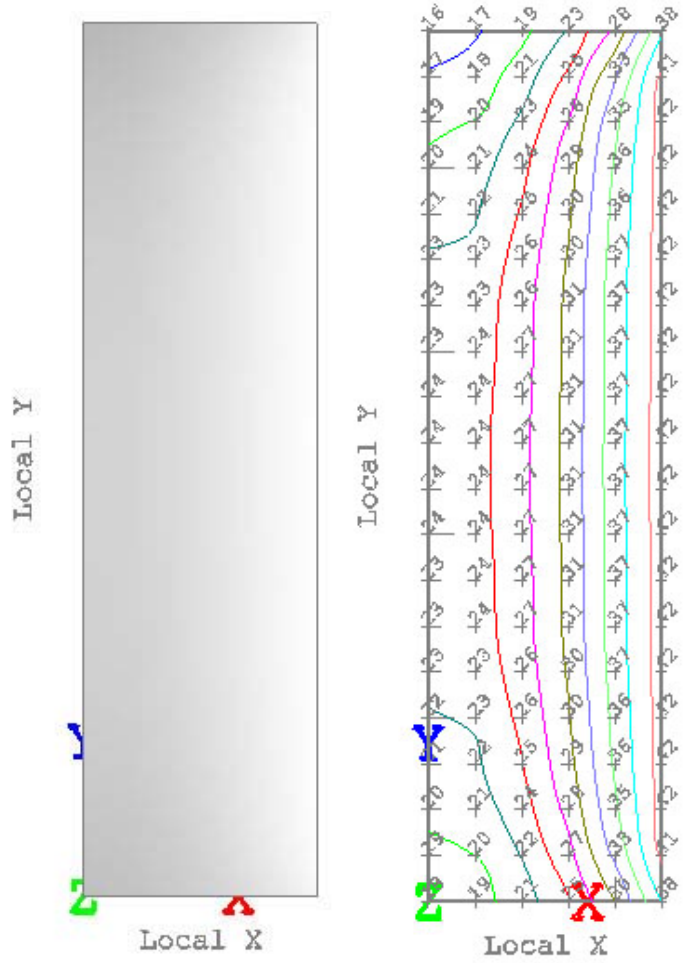


December 19, 12:00pm, Clear Sky

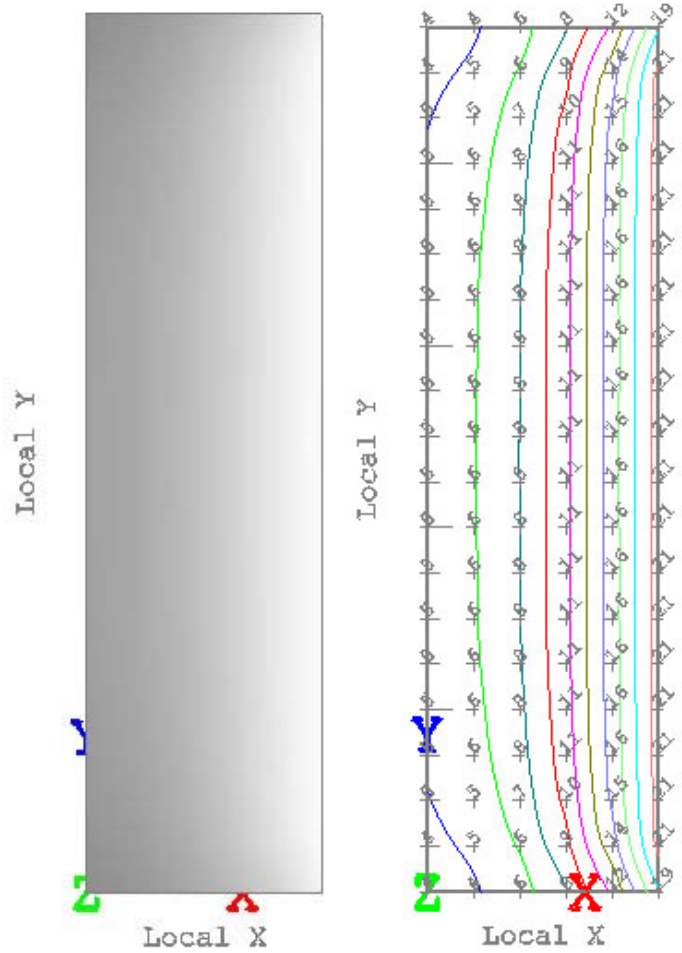


December 19, 12:00pm, Cloudy Sky

SOLARCOOL (2) AZURIA Glass

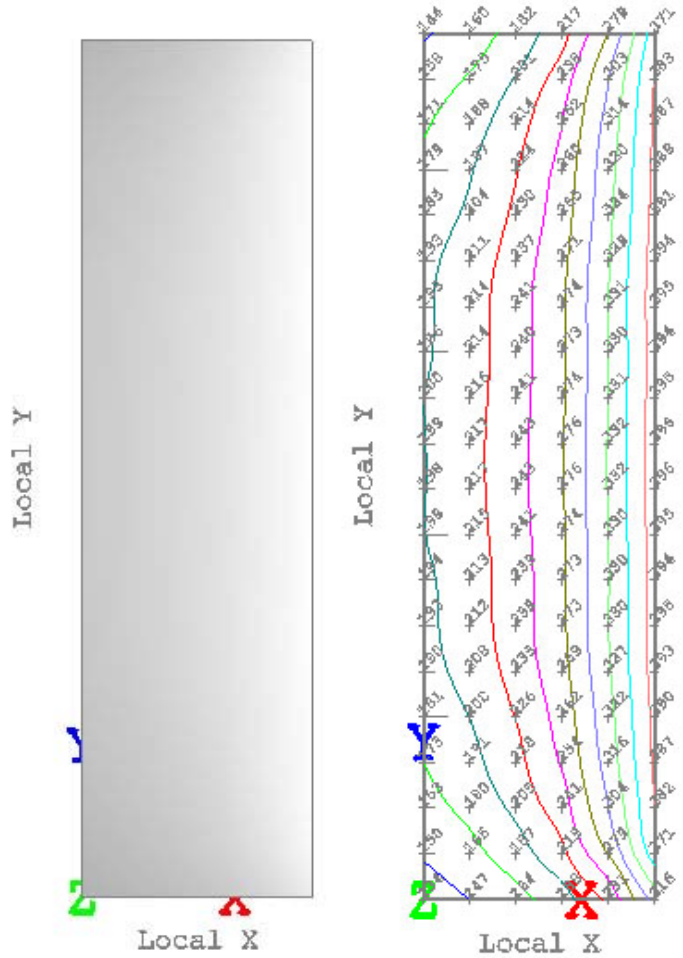


December 19, 4:00pm, Clear Sky

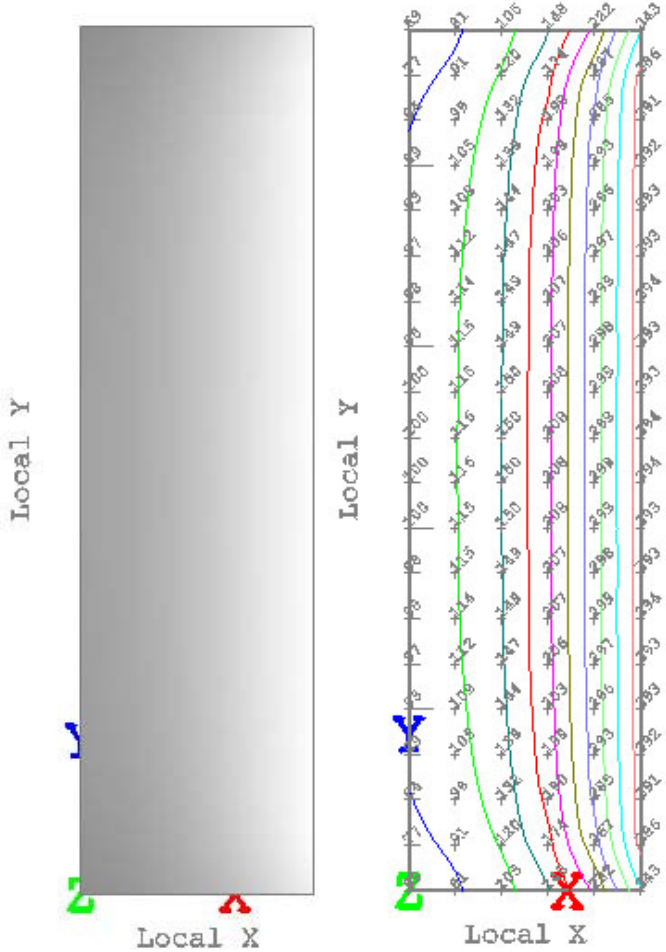


December 19, 4:00pm, Cloudy Sky

SUNGATE 100 (3) AZURIA LOW-E Glass

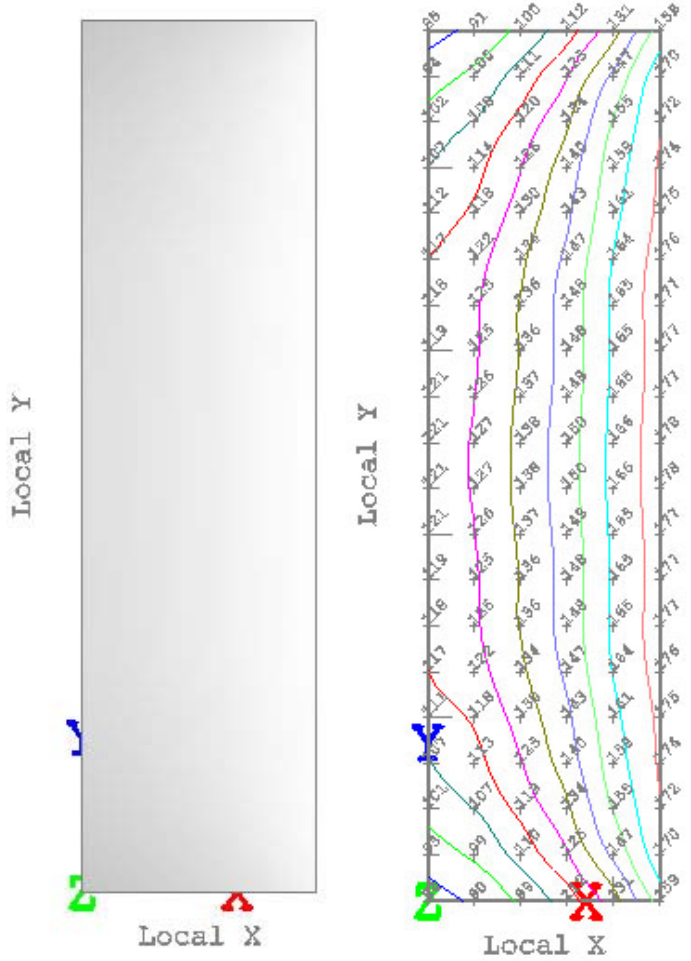


June 19, 12:00pm, Clear Sky

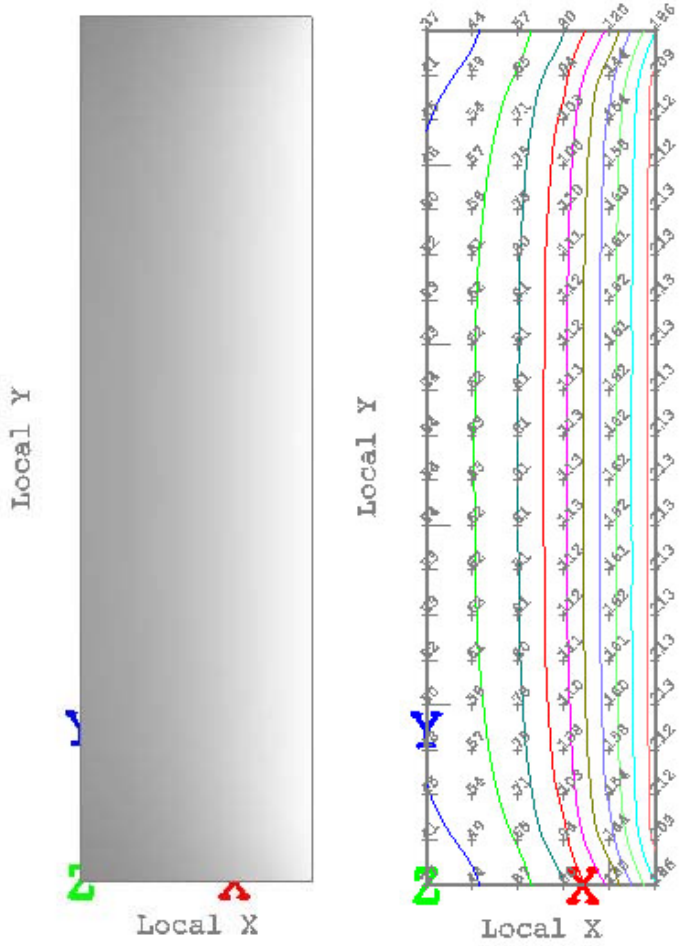


June 19, 12:00pm, Cloudy Sky

SUNGATE 100 (3) AZURIA LOW-E Glass



June 19, 5:00pm, Clear Sky



June 19, 5:00pm, Cloudy Sky

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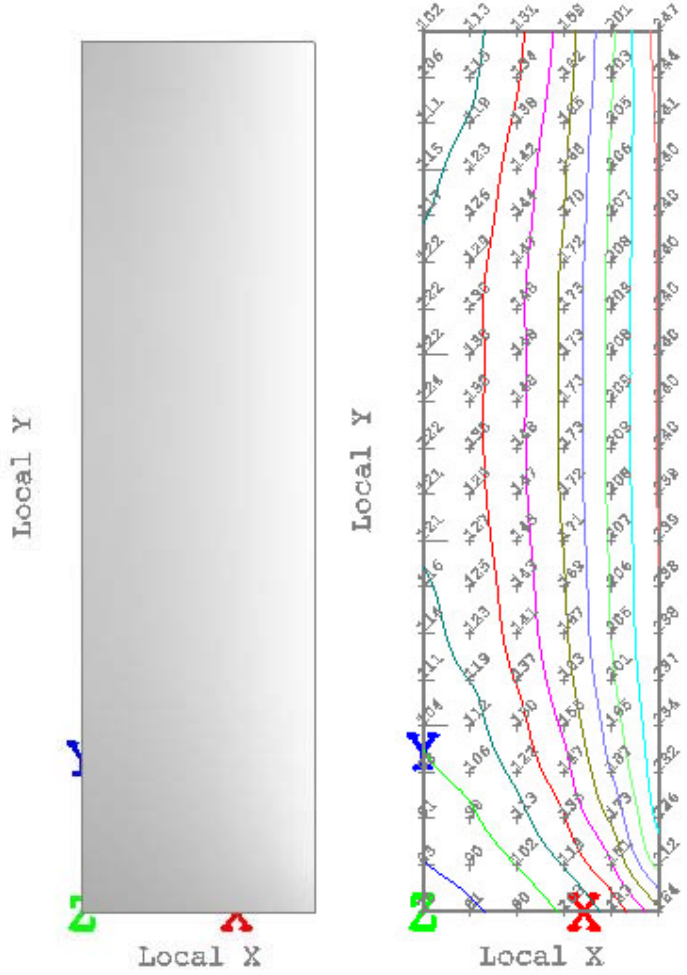
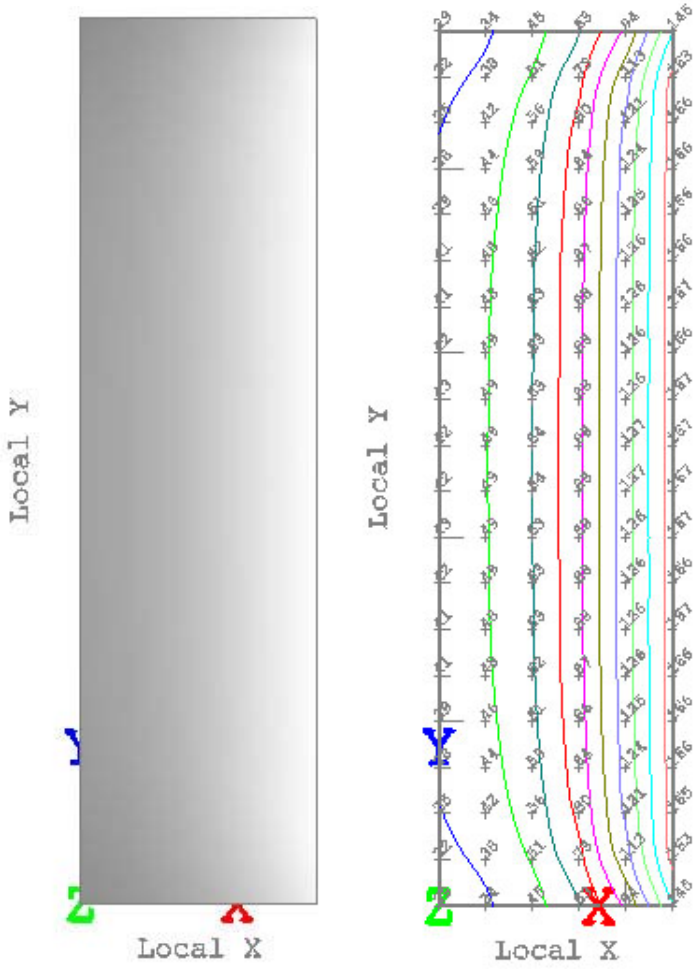
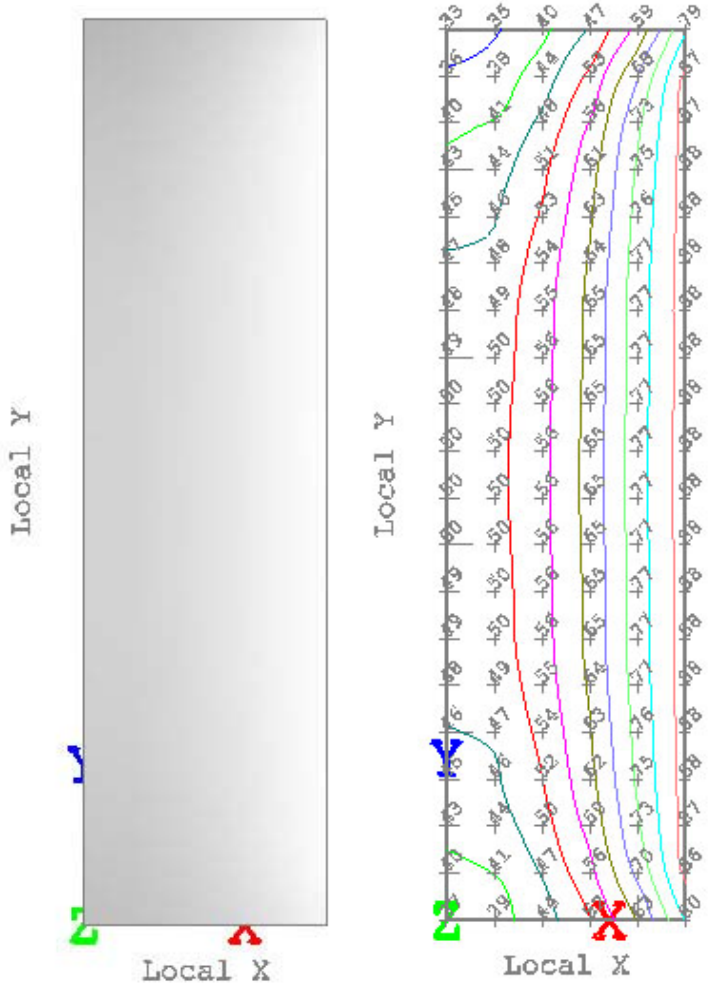


December 19, 12:00pm, Clear Sky

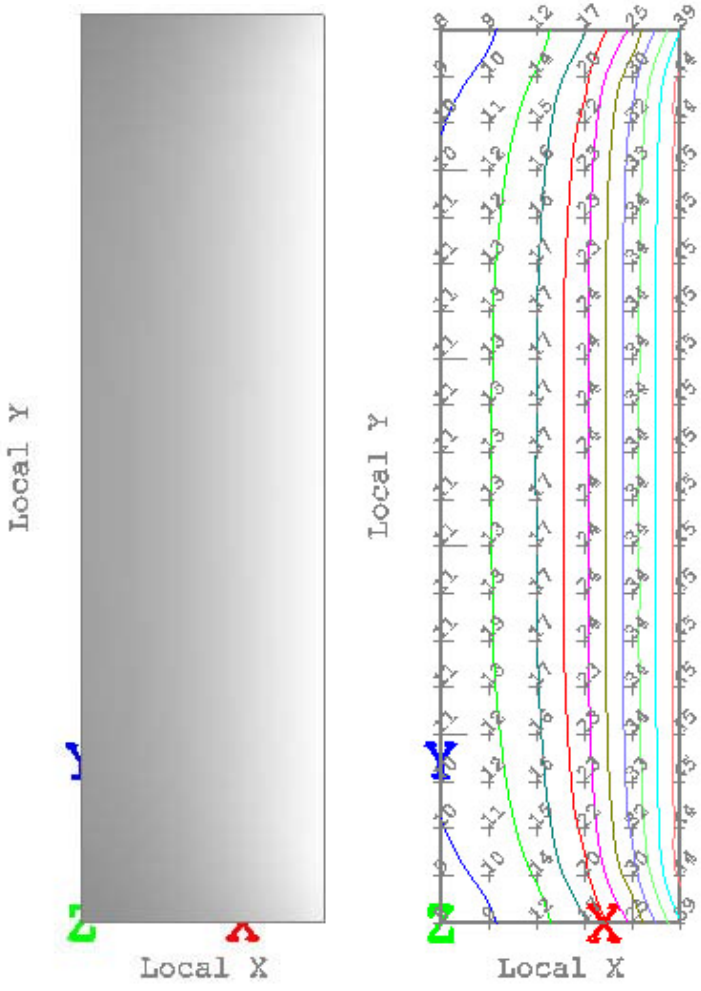


December 19, 12:00pm, Cloudy Sky

SUNGATE 100 (3) AZURIA LOW-E Glass



December 19, 4:00pm, Clear Sky



December 19, 4:00pm, Cloudy Sky

Daylight Availability Results

The daylight analysis demonstrates the effects the different transmittance and reflectance values of each glazing type. The SOLARCOOL AZURIA glass has a lower transmittance value, permitting less sunlight to transmit through the windows. On the other hand, the SOLARGATE LOW-E AZURIA glass has a transmittance value almost double that of the SOLARCOOL glazing. This may cause the gallery space to receive excess sunlight. However, since it is a corridor space, glare problem is less of an issue and therefore the excessive light will not cause any major problems.

Conclusion

From the cooling/heating load analysis and the daylight availability analysis, SOLARGATE Low-E AZURIA glass from PPG Industries resulted to be the best glazing for the use in the gallery. Its insulation ability reduces the heating and cooling load of the building dramatically (more than 50% of original load if existing glass is CLEAR glass), resulting in a large potential in cost savings.