23 70 01 – Passive Solar Cooling & Heating Design

The building will be designed to be passive solar cooled and heated. As such, the roof overhang depth will be greater than is normally specified and the south wall fenestration will be low-e glazing having a larger SHGC than is normally specified. The roof overhang will fully shade the south wall fenestration during the hotter months and allow irradiance to enter the south wall fenestration during the cooler months. The passive solar roof overhang design, solar fenestration heat gain analysis and thermal mass analysis specific for this building is as follows:

Design Date for Full Shade: 27 April (average daily high temperature reaches 68 degrees F)

Design Date for Full Sun: 25 December (average daily high temperature reaches the average historical low of 44 degrees F)

Design Solar Altitude Angle for Full Shade: 61.02 degrees

Design Solar Altitude Angle for Full Sun: 24.01 degrees

Design Depth of Roof Overhang from Glass: 52.92 inches

Design Height of Roof Overhang from Top of Glass: 23.52 inches

Design Indoor Temperature: 70 degrees F

Building HVAC Area: 1900 square feet (from ACCA Manual J8 analysis)

Building Latitude: 42.60 N

Building Passive Solar South Wall Orientation Deviation from True South: 0 degrees

Building Total Heat Loss: 10.3 Btu/hour/sq. ft. (from ACCA Manual J8 analysis)
428 Btu/hour/degrees F (from ACCA Manual J8 analysis)

Glass Total Area: 198 square feet

Glass Bottom Height above Floor: 24 inches

Glass Height: 72 inches

Glass SHGC: 0.609

Glass Total Width: 428 inches

Local Irradiance & Heating Degree Day Data:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clear Sky Optical Depth for Beam Irradiance	0.297	0.305	0.327	0.363	0.347	0.347	0.356	0.360	0.341	0.332	0.314	0.305
Clear Sky Optical Depth for Diffuse Irradiance	2.693	2.662	2.516	2.324	2.390	2.590	2.582	2.534	2.601	2.577	2.646	2.586
Climatic Sunshine (%)	32.26	28.57	32.26	43.33	53.33	66.67	90.32	87.10	76.67	54.84	35.48	29.03
Heating Degree Days (65F)	765	581	521	370	203	60	6	4	51	284	610	809

Local Terrain Obstacle Data - Azimuth & Altitude Angle (Degrees):

E	100	110	120	130	140	150	160	170	S	190	200	210	220	230	240	250	260	W
24	26	29	33	31	29	29	27	25	23	20	17	12	12	11	7	10	16	13

Supplemental Fuel Cost: $0.0845/Kwh

Supplemental Heat Source: Electric Boiler, COP=1

Thermal Mass Absorptivity: 70%

Thermal Mass Emissivity: 90%

Thermal Mass Convection Heat Transfer Coefficient: 1.5 Btu/degrees F-hour-square feet

Thermal Mass Density: 150 pounds/square foot

Thermal Mass Insulation R-value: R20

Thermal Mass Specific Heat Capacity: 0.18 Btu/degrees F-pound

Thermal Mass Thickness: 4 inches

Build Depth of Roof Overhang from Glass: 48 inches

Build Height of Roof Overhang from Top of Glass: 18 inches

Solar Fenestration Heat Gain & Thermal Mass Analysis Summary Table:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar Declination Angle (Degrees)	-21.27	-13.29	-2.82	9.41	18.79	23.31	21.52	13.78	2.22	-9.60	-19.15	-23.34
Solar Altitude Angle (Degrees)	26.13	34.11	44.58	56.81	66.19	70.71	68.92	61.18	49.62	37.80	28.25	24.06
Irradiance Allowed by Overhang (%)	92	80	59	23	0	0	0	4	47	73	89	95
Distance Irradiance strikes Floor (Feet)	15.37	10.03	5.64	2.21	0	0	0	1.23	4.08	8.25	13.68	17.27
Thermal Mass Minimum Area (Sq. Feet)	548	358	201	78	0	0	0	43	145	295	488	616
Temp of Thermal Mass prior to Irradiance (Degrees F)	70	70	70	70	70	70	70	70	70	70	70	70
Daily Irradiance Period (Hours)	4.1	6.1	7.4	6.1	0	0	0	2.8	7.7	6.7	4.8	3.4
Climatic Passive Solar Heat Gain (Btu/day)	36,969	39,937	35,230	13,263	0	0	0	6,622	58,202	71,491	43,765	27,910
Clear Sky Passive Solar Heat Gain (Btu/day)	114,598	139,785	109,205	30,610	0	0	0	7,602	75,913	130,363	123,351	96,142
Total Heat Gain during Irradiance Period (Btu/day)	66,470	92,291	76,487	20,210	0	0	0	3,893	53,765	88,603	75,371	52,406
Total Heat Gain after Irradiance Period (Btu/day)	46,376	45,265	30,923	9,912	0	0	0	3,595	20,888	39,652	46,073	42,280
Average Heat Gain during Irradiance Period (Btu/hour)	16,196	15,130	10,336	3,313	0	0	0	1,390	6,982	13,224	15,702	15,414

Max Temp of Thermal Mass at End of Irradiance Period (Degrees F)	79.6	84.4	87.6	84.5	70.0	70.0	70.0	79.5	86.5	85.4	80.7	77.8
Instantaneous Heat Gain at End of Irradiance Period (Btu/hour)	13,196	12,981	8,923	2,843	0	0	0	1,022	6,026	11,396	13,136	12,000
Average Heat Gain after Irradiance Period (Btu/hour)	2,330	2,529	1,863	554	0	0	0	170	1,281	2,292	2,400	2,052
Temp of Thermal Mass at end of Day (Degrees F)	70	70	70	70	70	70	70	70	70	70	70	70
Required Heat Gain (Therm)	78.58	59.68	53.52	38.01	20.85	6.16	0.62	0.41	5.24	29.17	62.66	83.10
Clear Sky Passive Solar Heating Percentage (%)	45	66	63	24	0	0	0	100	100	100	59	36
Climatic Passive Solar Heating Percentage (%)	15	19	20	10	0	0	0	100	100	76	21	10

Annual Clear Sky Passive Solar Heating Percentage: 57%

Annual Climatic Passive Solar Heating Percentage: 23%

Estimated Annual Cost of Supplemental Fuel: $869

Engineering Notes:

1) The methodology used to accomplish this analysis is based on the ASHRAE Fundamentals Handbook 2013. The thermal mass temperature at the start of the "Daily Irradiance Period" and at the end of the day is assumed to be the "Design Indoor Temperature" value. This implies that the thermal mass does not have a stored heat deficit or surplus (i.e., is cooler or hotter than the indoor temperature) prior to the daily passive solar heating cycle or after the daily passive solar heating cycle.

2) The "build" roof overhang depth/height values were adjusted from the "design" roof overhang depth/height values to accommodate the actual construction details associated with this specific building. The "build" roof overhang depth/height values were used to determine the values in the summary table.

3) The thermal mass is provided by a concrete slab floor. The thermal mass minimum area values shown in the summary table are based on the glass total width and distance that the irradiance strikes the floor each month. The actual thermal mass area shall not be less than the largest value shown in the

summary table and this thermal mass area shall be adjacent to the south wall solar fenestration allowing the irradiance to directly strike it. The actual thermal mass area may significantly exceed the largest value shown in the summary table and the passive solar heating analysis results will not significantly change.

4) The “Building Total Heat Loss” value and the “Heating Degree Days” were used to forecast the “Required Heat Gain” values.

5) With the exception of the “Climatic Passive Solar Heat Gain” values, all of the heat gain values in the summary table assume a “clear sky” day which implies the maximum heat gain possible. On any given day, these “clear sky” heat gain values could result in significant building/room overheating if these heat gain values exceed the actual heat loss of the building/room.

6) The “Clear Sky Passive Solar Heat Gain” values are the amount of irradiance heat gain that enters the building via the south wall solar fenestration during the irradiance period on a clear day. The thermal mass buffers these “Clear Sky Passive Solar Heat Gain” values resulting in the reduced “Total Heat Gain during Irradiance Period” values which are initially quickly released into the living space during the irradiance period and the “Total Heat Gain after Irradiance Period” values which are subsequently slowly released by the thermal mass into the living space after the irradiance period. The summation of the “Total Heat Gain during Irradiance Period” and the “Total Heat Gain after Irradiance Period” values are less than the original “Clear Sky Passive Solar Heat Gain” values because of the floor heat loss during the daily passive solar heating cycle. The “Clear Sky Passive Solar Heat Gain” values were used to forecast the “Clear Sky Passive Solar Heating Percentage” values.

7) The “Climatic Passive Solar Heat Gain” values are more representative of the actual monthly heat gain that can be expected each month. The “Climatic Passive Solar Heat Gain” values were used to forecast the “Climatic Passive Solar Heating Percentage” values. The “Required Heat Gain” values, “Climatic Passive Solar Heating Percentage” values, “Supplemental Heat Source” Coefficient of Performance (COP) value, and “Supplemental Fuel Cost” value were then used to forecast the “Estimated Annual Cost of Supplemental Fuel” value.