APPENDIX

APPENDIX A

CALCULATION OF OVERALL THERMAL TRANSFORM VALUE (OTTV)

To prove the calculation steps of OTTV (Over Thermal Transfer Value) from house in piece A2 follows (Figure 39):

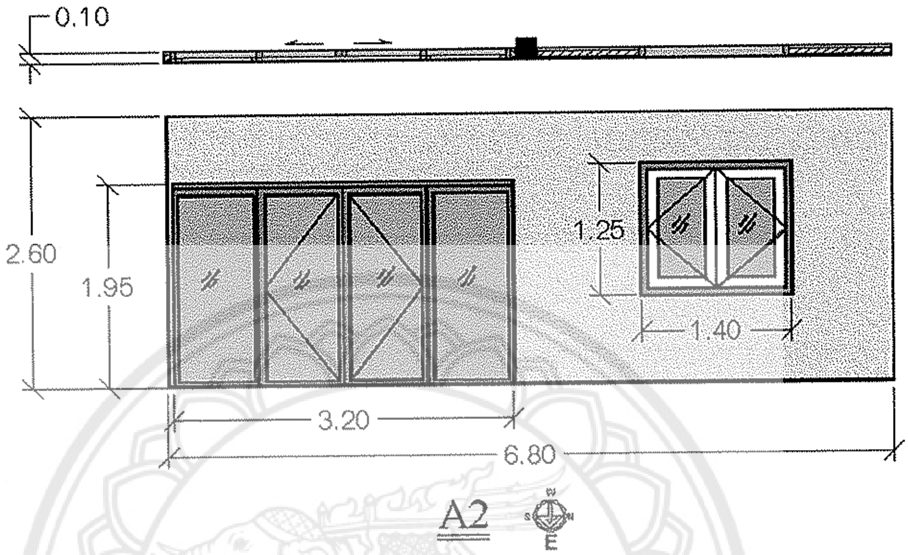

Figure 39 This is a side of wall (A2) that is showed detail about wall and glass window and section of wall and glass window.

In this case of OTTV calculation, the direction of wall, area of wall and detail of wall is necessary for the calculation process.

The reference conditions for the calculation are as follows (Figure 39):

1 Direction of wall is East

2 Total area of wall (A_i) = 17.68 m^2

3 Area of windows and doors (A_g) =7.99 m^2

4 Area of wall (A_w) = 9.69 m^2

5 Ratio of areas between glasses and walls = 0.4519

6 Temperature outside = 35 ^{O}C

7 Temperature inside(Room temperature) = 25 ^{O}C

8 Shading coefficient of clear glass = 0.92

9 Color of wall is white

10 External shading is not considerate for walls (SC_2 = 1.00)

Steps of calculation

Step 1: Find U_{w0} (Thermal transmittance of wall (W/m^2 °C)), Walls and roofs usually involve a composite of materials. The thermal transmittance of an opaque wall, transparent wall or roof should be derived by the following equation 2.6:

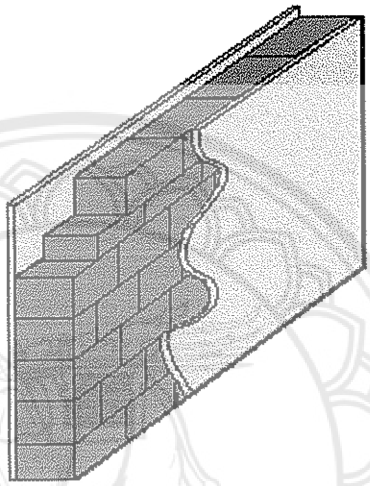

Figure 40 Section of brick with cement coated wall, thickness 0.10 m

So that $U_{w0} = 3.4733$ W/m^2 °C

Step 2: Find TD_w (Equivalent temperature difference for wall (°C)) by finding m_w and α (absorptive) of wall from Table 8 and get TD_w from Table 9

Then $m_w = 176$ kg/m^2

Thus, Absorptive of the wall (α) is

$\alpha = 0.3$ (Table 8)

So that $TD_w = 12$ °C (Table 9)

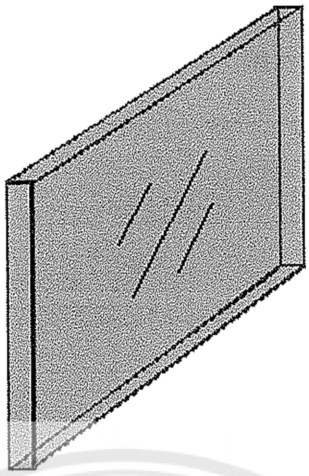

Figure 41 Section of glass window, thickness 0.008 m

Step 3: Finding the U_{g0} (Thermal transmittance of glass (W/m^2 °C)) use the equation 2.6

Then U_{g0} = 5.8276 W/m^2 °C

Step 4: Finding the ΔT (Equivalent temperature difference for glass (°C))

$$\Delta T = T_{out} - T_{in}$$

where T_{out} = Temperature outside of wall = 35 (°C)

T_{in} = Temperature inside of wall (room temperature) = 25 (°C)

Then ΔT = 10 °C

Step 5: Finding the SF (Solar factor for the vertical surface (W/m^2))

$$SF = 160 \cdot CF$$

where CF = Correction factor (Table 12)

- Slope of wall from horizontal to vertical axis = 90 °
- Orientation of wall is East

So CF = 1.12

Then SF = 179.2 W/m^2

Step 6: Calculation to finding the OTTV (Over Thermal Transmission Value)

$$OTTV = \frac{[(A_w \cdot U_w \cdot TD_w) + (A_g \cdot U_g \cdot TD_g) + (A_g \cdot SC \cdot SF)]}{A} \quad (2.3)$$

where A_W = Area of wall = 9.69 (m^2)

U_{W0} = Thermal transmittance of wall = 3.4733 ($W/m^2\,^{\circ}C$) (Step 1)

TD_w = Equivalent temperature difference for wall = 12 ($^{\circ}C$) (Step 2)

A_g = Area of glass = 7.99 (m^2)

U_{g0} = Thermal transmittance of glass = 5.8276 ($W/m^2\,^{\circ}C$) (Step 3)

TD_g = Equivalent temperature difference for glass = 10 ($^{\circ}C$) (Step 4)

SC= Shading coefficient of clear glass = 0.92

SF= Solar factor for the vertical surface = 179.2 (W/m^2) (Step 5)

A_i= Area of external walls, i.e. A_W+ A_g = 17.68 (m^2)

Then $OTTV$ = 123.6875 W/m^2

The value of $OTTV_0$ (original) from processing of calculation is equal 123.6875 W/m^2 more than value from standards stipulated by law in Thailand. The current OTTV limits are for new building, OTTV $\leq$ 45 W/m^2 and for old building, OTTV $\leq$ 55 W/m^2. So that we can change the result of OTTV to base on standard by install insulation for wall and change glass of window as following:

Finding the U_{w1} after install insulation with wall, finding the U_{g1} after change glass from clear glass to heat stop glass, finding the mass of materials of wall and finding the OTTV.

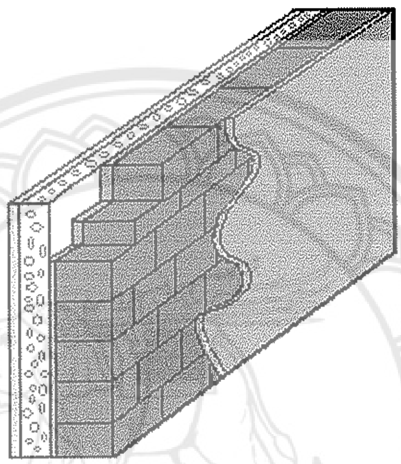

Figure 42 Brick with cement coating wall are installed glass fiber insulation

Therefore, constant values are A_i, A_g, A_w, T_{out}, T_{in}, and SF

Step 7: Finding the U_{w1} (Thermal transmittance of wall (W/m^2 °C)) after install insulation with wall (Figure 42)

Then $U_{w1} = 0.57636$ W/m^2 °C

Step 8: Find TD_w (Equivalent temperature difference for wall (°C)) by finding m_w and α of wall color from Table 8 and get TD_w from Table 9

$$\sum m_w = \sum(\rho \cdot \Delta x)$$

Then $\sum m_w = 186.3584$ kg/m^2

Thus, Absorptive of the wall (α) is

$\alpha = 0.3$ (Table 8)

So that $TD_w = 12\ ^{o}C$ (Table 9)

Heat stops glass that the air between the glass panes that does the insulating, while the panes stops the movement of air (Figure 43). Too close and heat will be transferred between panes. Too far and internal convection reduces the effectiveness. Standard Certain Teed panes are spaced at an optimum 16 mm and SC=0.19.

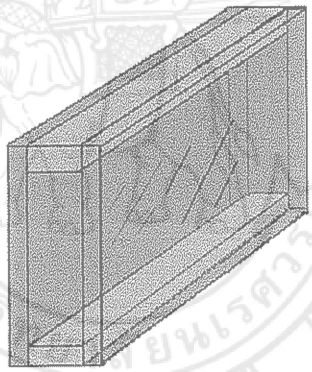

Figure 43 Heat stops glass that the air between the glass panes

Step 9: Finding the U_{g1} (Thermal transmittance of glass ($W/m^2\ ^{o}C$)) again after modify materials.

Then $U_{g1} = 1.1518$ $W/m^2\ ^{o}C$

After change the processes of calculation we can the new result of $OTTV_1$ follow:

Then $OTTV_1 = 24.3830$ W/m^2

The value of OTTV from processing of calculation is equal 24.3830 W/m^2 not more than value from standards stipulated by law in Thailand. The current OTTV limits are for new building, OTTV $\leq$ 45 W/m^2 and for old building, OTTV $\leq$ 55 W/m^2.
This is the floor plan which showed the detail of room in house model.

The value of OTTV from Table 19 before install insulation and change glass have high more than after modify materials. So that, Total of Overall Thermal Transfer Value of an external wall is calculated by

$$OTTV_T = \frac{A_{i1} \cdot OTTV_1 + A_{i2} \cdot OTTV_2 + ... + A_{in} \cdot OTTV_n}{A_{i1} + A_{i2} + ... + A_{in}}$$

where $OTTV_T$ = Total of Over Thermal Transmission Value, (W/m^2)
A_{in} = Area of external walls, i.e. $A_W + A_g$ in each side, (m^2)
$OTTV_n$ = Over Thermal Transmission Value of each side, (W/m^2)

Value of $OTTV_T$ before install insulation and change glass of windows and doors for living and parlor room

$$OTTV_T = 115.8963 \quad \text{W/m}^2$$

And $OTTV_T$ after install insulation and change glass from clear glass to insulation glass for living and parlor room

$$OTTV_T = 26.3154 \quad \text{W/m}^2$$

Value of $OTTV_T$ before install insulation and change glass of windows and doors for bed room No.1

$$OTTV_T = 71.2587 \quad \text{W/m}^2$$

And $OTTV_T$ after install insulation and change glass from clear glass to insulation glass for bed room No.1

$$OTTV_T = 20.5455 \quad \text{W/m}^2$$

Value of $OTTV_T$ before install insulation and change glass of windows and doors for bed room No.2

$$OTTV_T = 70.1926 \quad \text{W/m}^2$$

And $OTTV_T$ after install insulation and change glass from clear glass to insulation glass for bed room No.2

$$OTTV_T = 19.8327 \qquad W/m^2$$

Value of $OTTV_T$ before install insulation and change glass of windows and doors for bed room No.3

$$OTTV_T = 68.8971 \qquad W/m^2$$

And $OTTV_T$ after install insulation and change glass from clear glass to insulation glass for bed room No.3

$$OTTV_T = 18.9161 \qquad W/m^2$$

APPENDIX B

CALCULATION OF ROOF THERMAL TRANSFORM VALUE (RTTV)

Roof Thermal Transfer Value (RTTV)

In the case of RTTV calculation, the ceiling reference conditions for the calculation are parallel with floor. The RTTV equation for roofs is similar to wall, but external shading is not considerate for roofs. The terms and coefficients (TD_{eqr} and SF) may very different OTTV standards

Layers of ceiling are built in a variety of shapes. A conventional ceiling is parallel with floor. Some ceilings depart from these norms for structural, spatial or decorative reasons. Perhaps the most familiar departure is the cathedral ceiling that angles upward from walls to peak, following the roof's pitch.

1. Parallel with floor

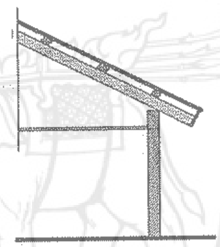

Figure 44 Show the ceiling that build to parallel with floor.

2. Cathedral ceilings are ceilings which follow the roofline

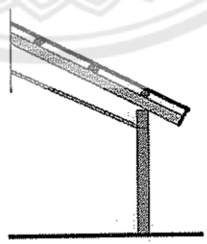

Figure 45 Show the ceiling that build to follow the roofline.

3. Built-up 90° are the ceilings that built under the flat roof.

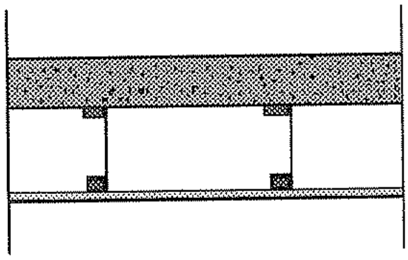

Figure 46 Show the built-up roof.

4. No ceiling

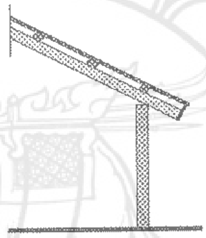

Figure 47 Show the roof that no ceiling.

We can reduce the RTTV equation if we not considerate the transparent roof, A_{tr} will equal 0 and the equation as follow:

$$RTTV = U_r \cdot TD_{eqr}$$

In the case of RTTV calculation, the ceiling reference conditions for the calculation are parallel with floor (Figure 47).

Steps of calculation RTTV

Step 1: Find U_{r0} (Thermal transmittance of roof (W/m^2 °C))

$$U_{r0} = \frac{1}{R_i + \frac{x_1}{k_1} + \ldots + \frac{x_n}{k_n} + R_a + R_o}$$

Then $U_{r0} = 1.41153$ W/m^2 °C

Step 2: Find TD_r (Equivalent temperature difference for roof (°C)) by finding m_w and α of wall color from Table 8 and get TD_r from Table 13

$$\sum m_w = \sum(\rho \cdot \Delta x)$$

Where $\sum m_w$ = Mass of materials of roof or ceiling (kg/m^2)

ρ_1 = Density of material (Gypsum) = 880 (kg/m^3)

Δx_1 = Thickness of building material of the wall = 0.009 (m)

Then $\sum m_w = 7.92$ kg/m^2

So that $TD_{eq} = 32\ ^{\circ}C$ (Table 13)

Then RTTV = 45.1690 W/m^2

The value of RTTV from processing of calculation is equal 45.1690 W/m^2 more than value from standards stipulated by law in Thailand. The current RTTV limits are for roof, OTTV $\leq$ 25 W/ m^2. So that we can change the result of RTTV to base on standard by install insulation for roof as following (Figure 48):

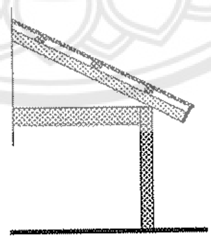

Figure 48 Show the insulation of ceiling

Step 3: Finding the U_{r1}(Thermal transmittance of roof (W/m^2 °C)) after install insulation on ceiling

Then $U_{r1} = 0.4743$ W/m^2 °C

Step 4: Find TD_{eqr} (Equivalent temperature difference for roof ($^{\circ}C$))

Then $\sum m_w = 9.5328$ kg/m^2

Then RTTV = 15.1776 W/m^2

APPENDIX C

ESTIMATE OF SOLAR RADIATION

THE HOURLY MEAN RADIATION ON A TILTED SURFACE

Table 25 Hourly Solar Radiation Data for Thailand

Month: April

	Hourly Solar Radiation (MJ/ m^2-hr)											
Surface/Hour	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00
Horizontal(It)	0.46599	1.12534	1.83261	2.48112	2.96314	3.19425	3.13292	2.79021	2.22724	1.54083	0.84131	0.22791
North	0.29531	0.41483	0.59582	0.79082	0.94840	1.02689	1.00546	0.88970	0.71017	0.51417	0.35320	0.26933
North-East	1.31065	1.36861	1.41829	1.42101	1.33842	1.14518	0.83897	0.44480	0.01218	0.000	0.000	0.000
East	1.62412	1.70979	1.75199	1.71246	1.55574	1.26154	0.83442	0.30761	0.000	0.000	0.000	0.000
South-East	1.05209	1.23853	1.40143	1.49444	1.47307	1.30781	0.99446	0.55849	0.05226	0.000	0.000	0.000
South	0.000	0.23088	0.57197	0.89465	1.13882	1.25689	1.22535	1.05048	0.76685	0.42887	0.09767	0.000
South-West	0.000	0.000	0.000	0.26445	0.74880	1.13861	1.39184	1.49538	1.46485	1.33741	1.15992	0.97593
West	0.000	0.000	0.000	0.000	0.53148	1.02224	1.39639	1.63257	1.73736	1.73872	1.67477	1.58166
North-West	0.000	0.000	0.000	0.19103	0.61416	0.97597	1.23635	1.38169	1.42476	1.39772	1.34061	1.28898

Table 26 Hourly Solar Radiation Data for Thailand

Month: April

	Hourly Solar Radiation (W/ m^2)												
Surface / Hour	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	Average
Horizontal	129.4414	312.5947	509.0577	689.1992	823.0943	887.2927	870.2550	775.0594	618.6776	428.0093	233.6969	63.3081	528.3072
North	82.0302	115.2300	165.5052	219.6710	263.4447	285.2470	279.2934	247.1398	197.2684	142.8246	98.1121	74.8136	180.8817
North-East	364.0694	380.1682	393.9703	394.7263	371.7832	318.1046	233.0476	123.5569	3.3820	0.0000	0.0000	0.0000	215.2340
East	451.1444	474.9430	486.6634	475.6846	432.1508	350.4276	231.7825	85.4482	0.0000	0.0000	0.0000	0.0000	249.0204
South-East	292.2478	344.0367	389.2861	415.1218	409.1851	363.2817	276.2391	155.1373	14.5166	0.0000	0.0000	0.0000	221.5877
South	0.0000	64.1324	158.8807	248.5146	316.3390	349.1371	340.3754	291.8013	213.0151	119.1304	27.1301	0.0000	177.3713
South-West	0.0000	0.0000	0.0000	73.4593	208.0005	316.2795	386.6212	415.3842	406.9015	371.5015	322.2010	271.0929	230.9535
West	0.0000	0.0000	0.0000	0.0000	147.6329	283.9565	387.8864	453.4929	482.5998	482.9769	465.2135	439.3507	261.9258
North-West	0.0000	0.0000	0.0000	53.0639	170.5987	271.1024	343.4297	383.8038	7669	388.2558	372.3928	358.0491	228.0386

APPENDIX D

CALCULATION OF HEAT FLOW RATE FOR BUILDING MATERIALS

This calculation example is heat flow rate from building materials. In the calculation follows these calculation steps.

For this appendix, the example which used the steps of calculation consists of the following conditions:

1. Direction of walls that absorbed radiation are North, East and South
2. Shading coefficient of clear glass = 0.92
3. External shading is not considerate for walls (SC_2 = 1.00)
4. Temperature outside = 35 ($^{\circ}C$)
5. Temperature inside(Room temperature) = 25 ($^{\circ}C$)
6. Number of occupants = 4 (people)
7. Volume of room = 5X7X2.88 (m) = 100.8 (m^3)

This method does not account the effect of heat capacity of building materials. The heat balance under this approach can be written as:

$$Q_m = Q_e + Q_i + Q_v + Q_{st}$$

where Q_m = Heat balance load (W)

Q_e = External load (W)

Q_i = Internal load (W)

Q_v = Ventilation load (W)

Q_{st} = Storage load (W)

First step: finding the external load (Q_e) consists of load due to condition (Q_c) and load through transparent openings (Q_s) and hence can be written as:

$$Q_e = Q_c + Q_s$$

The conduction (Q_c) heat flow rate through a building component (e.g. wall, roof, glass, etc.) is given by the following equation 2.24:

For this case is not considerate heat from ceiling.

So that Q_c = 2,095.4541 W

The radiation through transparent elements (Q_s) are the solar gain through transparent elements can be written as following equation 2.25:

Then Q_s = 5,877.9522 W

Next step is finding the storage heat load of a room intermittently air conditions (Q_{st}), (2.26)

Then Q_{st} = 1,594.6813 W

Next step is finding the internal heat gain (Q_i) is estimated as follows equation 2.27:

Calculation of heat load in interior zone is transmission heat load of partition and ceiling but this case not considerate heat load from ceiling.

- Transmission heat load of partition

$$Q_p = \sum_{i=1}^{n} (A_{pi} \cdot U_{pi}) \cdot (T_{out} - T_{in}) \tag{2.28}$$

Where Q_p = Transmission heat gain through partition (W)

A_p = Area of partition (m^2)

= Area of concrete wall + Area of wood + Area of glass

$=11.79+1.52+4.37 \qquad = 17.68\ m^2$

U_{pc} = Thermal transmittance of concrete = 2.7479 ($W/m^2\ ^oC$)

U_{pw} = Thermal transmittance of wood = 2.1863 ($W/m^2\ ^oC$)

U_{pg} = Thermal transmittance of glass = 4.03882 ($W/m^2\ ^oC$)

Then $\quad Q_p = 266.8528 \quad$ W

So that $\quad Q_t = 4X80 + 266.8528$

$= 586.8528 \quad$ W

Next step is finding the ventilation (Q_v) of air between the interior of a building and the outside depends on the rate of air exchange. It is given from equation 2.29:

If the number of air changes is known, then

$$V_r = \frac{N \cdot V}{3600}$$

where N= Number of air change per hour = 3

V = Volume of the room or space = 100.8 (m^3)

Then $\quad V_r = 0.084 \quad m^3/s$

So that $\quad Q_v = 1{,}013.04 \quad$ W

Then the balance heat load of this room can calculated from equation as follow:

So that $\quad Q_m = 11{,}167.9804 \quad$ W

$= 38{,}102.9155 \quad$ Btu/hr

This is the calculation step after install insulation and change the glass. The heat load will change the value as follows:

Step 1: finding the external load (Q_e) consists of load due to condition (Q_c) and load through transparent openings (Q_s) and hence can be written as:

So that	$Q_c = 445.6503$	W
Then	$Q_s = 1{,}439.6123$	W
Then	$Q_{st} = 377.0525$	W

The others value of heat flow rate is constant.

So that	$Q_{m1} = 3{,}862.2079$	W
	$= 13{,}177.0810$	Btu/hr
The heat flow rate difference equal	$= 7{,}305.7725$	W
	$= 24{,}925.8346$	Btu/hr

Table 27 Result of Hourly Heat Flow Rate Value of the Parlor and Living Room before and after Install Insulation and Change the Glass Wall.

Parlor Room and Living Room									
Direction	North			East			South		
Time	Heat(a) W	Heat(b) W	Δ Heat W	Heat(a) W	Heat(b) W	Δ Heat W	Heat(a) W	Heat(b) W	Δ Heat W
7.00	975.419	313.535	661.884	4185.773	843.930	3341.842	623.723	115.030	508.693
8.00	1126.458	370.995	755.463	4360.712	880.059	3480.653	991.894	191.066	800.829
9.00	1355.180	458.009	897.171	4446.866	897.852	3549.014	1535.825	303.399	1232.426
10.00	1601.602	551.757	1049.845	4366.163	881.185	3484.978	2050.396	409.669	1640.726
11.00	1800.746	627.518	1173.228	4046.155	815.096	3231.059	2439.762	490.082	1949.680
12.00	1899.934	665.252	1234.681	3445.424	691.032	2754.392	2628.049	528.967	2099.082
13.00	1872.848	654.948	1217.900	2573.287	510.917	2062.370	2577.750	518.579	2059.171
14.00	1726.568	599.298	1127.270	1497.613	288.767	1208.846	2298.896	460.990	1837.906
15.00	1499.684	512.983	986.700	869.501	159.048	710.453	1846.600	367.581	1479.019
16.00	1251.997	418.755	833.242	869.501	159.048	710.453	1307.627	256.271	1051.356
17.00	1048.582	341.368	707.213	869.501	159.048	710.453	779.472	147.196	632.276
18.00	942.588	301.045	641.543	869.501	159.048	710.453	623.723	115.030	508.693
Average	1425.134	484.622	940.512	2700.000	537.086	2162.914	1641.976	325.322	1316.655

Table 28 Result of Hourly Heat Flow Rate Value of the Bed Room 1 before and After Install Insulation and Change the Glass Wall.

Bed Room No. 1									
Direction	North			East			West		
Time	Heat(a) W	Heat(b) W	Δ Heat W	Heat(a) W	Heat(b) W	Δ Heat W	Heat(a) W	Heat(b) W	Δ Heat W
7.00	870.728	251.841	618.887	1197.607	379.876	817.731	461.814	103.550	358.264
8.00	977.631	292.511	685.121	1235.923	394.452	841.470	461.814	103.550	358.264
9.00	1139.518	354.098	785.420	1254.792	401.631	853.161	461.814	103.550	358.264
10.00	1313.932	420.451	893.480	1237.117	394.907	842.210	461.814	103.550	358.264
11.00	1454.883	474.074	980.809	1167.027	368.242	798.785	699.503	193.975	505.528
12.00	1525.086	500.782	1024.305	1035.453	318.187	717.266	918.984	277.473	641.511
13.00	1505.916	493.489	1012.427	844.434	245.517	598.917	1086.311	341.130	745.181
14.00	1402.381	454.100	948.281	608.836	155.887	452.949	1191.938	381.314	810.624
15.00	1241.795	393.008	848.787	471.264	103.550	367.714	1238.800	399.142	839.658
16.00	1066.486	326.314	740.172	471.264	103.550	367.714	1239.407	399.373	840.034
17.00	922.512	271.541	650.970	471.264	103.550	367.714	1210.808	388.493	822.315
18.00	847.491	243.001	604.490	471.264	103.550	367.714	1169.169	372.652	796.517
Average	1189.030	372.934	816.096	872.187	256.075	616.112	883.515	263.979	619.535

Table 29 Result of Hourly Heat Flow Rate Value of the Bed Room 2 before and after Modify Materials.

Bed Room No. 2						
Direction	North			East		
Time	Heat(a) W	Heat(b) W	Δ Heat W	Heat(a) W	Heat(b) W	Δ Heat W
7.00	546.2318	144.3180	401.9138	1140.5057	370.4004	770.1052
8.00	599.6834	164.6528	435.0306	1178.8215	384.9771	793.8444
9.00	680.6265	195.4464	485.1801	1197.6913	392.1558	805.5355
10.00	767.8336	228.6230	539.2106	1180.0155	385.4313	794.5841
11.00	838.3092	255.4344	582.8748	1109.9260	358.7669	751.1591
12.00	873.4109	268.7883	604.6226	978.3517	308.7114	669.6403
13.00	863.8256	265.1417	598.6839	787.3330	236.0413	551.2918
14.00	812.0583	245.4476	566.6107	551.7348	146.4115	405.3233
15.00	731.7654	214.9014	516.8640	414.1632	94.0745	320.0887
16.00	644.1109	181.5546	462.5563	414.1632	94.0745	320.0887
17.00	572.1236	154.1681	417.9555	414.1632	94.0745	320.0887
18.00	534.6132	139.8978	394.7153	414.1632	94.0745	320.0887
Average	705.3827	204.8645	500.5182	815.0860	246.5995	568.4865

Table 30 Result of Hourly Heat Flow Rate Value of the Bed Room 3 before and after Modify Materials.

	Bed Room 3					
Direction	East			South		
Time	Heat(a) W	Heat(b) W	Δ Heat W	Heat(a) W	Heat(b) W	Δ Heat W
7.00	1140.5057	370.4004	770.1052	612.5581	126.9962	485.5619
8.00	1178.8215	384.9771	793.8444	715.8112	166.2773	549.5340
9.00	1197.6913	392.1558	805.5355	868.3560	224.3106	644.0454
10.00	1180.0155	385.4313	794.5841	1012.6666	279.2114	733.4552
11.00	1109.9260	358.7669	751.1591	1121.8639	320.7538	801.1101
12.00	978.3517	308.7114	669.6403	1174.6688	340.8426	833.8262
13.00	787.3330	236.0413	551.2918	1160.5626	335.4761	825.0864
14.00	551.7348	146.4115	405.3233	1082.3582	305.7245	776.6337
15.00	414.1632	94.0745	320.0887	955.5124	257.4679	698.0445
16.00	414.1632	94.0745	320.0887	804.3580	199.9635	604.3945
17.00	414.1632	94.0745	320.0887	656.2376	143.6134	512.6242
18.00	414.1632	94.0745	320.0887	612.5581	126.9962	485.5619
Average	815.0860	246.5995	568.4865	898.1260	235.6361	662.4898

APPENDIX E

CALCULATION OF ENERGY SAVING AND PAYBACK PERIOD

After finding the reducing heat load you can calculate power saving by:

$$Power\ Saving = Heat\ Difference \cdot \frac{1}{Average\ EER\ of\ \ Air\ Condition}$$

when EER of air condition = 8.17 Btu/hr-W

Then Power Saving = 3.0509 kW

When you find power saving, you can find energy saving by: (Assume time of wall and glass receive solar energy 10 hr/day, efficiency of air condition is 80%, day use air 365 day/yr and cost of electric = 3 Bath/Unit)

Energy Saving = Power Saving X Time X Day/yr. X Efficiency

Then Energy Saving = 8,908.6214 kWh/yr.

So that Cost of Energy Saving = 26,725.8643 Baht/yr.

And the calculation of percentage of energy saving is determined by:

$$Energy\ Saving = \frac{Q_m - Q_{m1}}{Q_m}$$

Where Q_m = Heat balance load before install insulation (W)

Q_{m1} = Heat balance load after install insulation (W)

Then Energy Saving = 65.4171 %

Economic analysis

The economic analysis for this study is only Pay Back Period method. The calculation of Pay Back Period is determined by:

$$n = \frac{Investment\ Cost}{Cost\ of\ Energy\ Saving}$$

Where $n =$ Pay back period (years/months/days)

Investment cost of insulation for wall and glass

- Cost of fiber glass 2 inch. = 250 Baht/m^2
- Cost of laminated glass = 900 Baht/m^2
- Cost of heat stop glass = 1200 Baht/m^2
- Total area of fiber glass in this room = 85.57 m^2
- Total area of laminate glass in this room = 18.75 m^2
- Total area of heat stop glass in this room = 14.23 m^2

Then Investment Cost = 55,345 Baht

And Pay Back Period = 2 Year and 26 Days

APPENDIX F

PROPERTIES OF INSULATION

Thermal Insulation

Insulation is an essential part of all modern buildings; it performs many functions, all of the cost of the building and its operating expenses. It is essential not only in the floors, walls, and ceilings of the buildings, but also in their mechanical systems such as heating, cooling, plumbing and air-conditioning, as well. Most of all insulations installed in buildings are installed at the time of the original construction.

The characteristics of a thermal insulation are mainly determined by its composition. For that reason thermal insulations are divided into five major types, although in many instances particular insulations are hybrids of these types.

1. Flake is composed of small particles or flakes which finely divide the air space. These flakes may or may not be bonded together, Vermiculite, or expanded Mica is commonly used for flake insulation.

2. Fibrous insulation is composed of small diameter fibers which finely divide the air space. These fibers may be organic or inorganic and may or may not be bonded together. Organic fibers may be - hair, wood, cane, wool or synthetic. Inorganic fibers may be Glass, Rock wool, Slag wool, alumina silica, asbestos or carbon.

3. Granular insulation is composed of small nodules which contain voids or hollow spaces. It is not considered a true cellular material since gas can be transferred between the individual spaces. The material may be Magnesia, Calcium Silicate, diatomaceous earth and vegetable cork.

4. Cellular is composed of small individual cells sealed from each other; it is produced of Glass, rubber and plastic.

5. Reflective insulation is composed of parallel thin sheets or foil of high thermal reflectance and spaced to reflect radiant heat back towards its source. The spacing also is designed to provide restricted air (or gas) spaces. The restricted air space reduces heat transfer caused by convection and conduction.

Laminated Glass

Insulating Laminated Glass provides the solar controlling properties of an insulating unit along with the safety features of the laminated inboard component. This allows the flexibility to design with hundreds of combinations of tinted glass, high-performance coatings, silk-screen patterns and pigmented interlayer, together or alone. In addition, Insulating Laminated Glass enhances acoustical performance, ultraviolet light protection, and the laminated component is designed to remain integral in the opening should glass damage occur.

The laminated component features a strong, PVB interlayer bonded between two or more glass plies using heat and pressure.

Often the laminated inboard component is required to provide protection against man-made threats or natural disasters such as hurricanes, bomb blasts or forcible-entry. For detailed information on these applications please see the Protective Glass section.

Solar Reflective Glass

This is an ordinary float glass with a metallic coating to reduce solar heat. This special metallic coating also produces a mirror effect, preventing the subject from seeing through the glass. It is mainly used in façades.

Solar Reflective Glass helps the architects provide more option for design and energy saving requirements. With solar control, solar reflective glass controls heat that transmits through buildings and, therefore, makes rooms more comfortable. Solar Reflective Glass helps extend the lifetime of air conditioning system and helps reduce power consumption by obtaining optimum efficiency. The solar reflective glass also helps create colorful architecture with reflective properties of mirror-like surfaces. It provides several different shades of color for the purpose of decoration. It is easy to install and to maintain. Because of highly advanced technology, it has been highly accepted for its strength and endurance.

For use in:

- Buildings such as offices, hotels, condominiums and residential houses which require energy saving and splendid appearance.
- A place that requires light or heat transmittance control such as gymnasiums, libraries, and museums.
- Places such as hotels and department stores which require uniquely luxurious image.

Low-Emissive Glass

Energy conservation, maximum daylight transmittance and minimal reflectance are the benefits of Low-Emissive coated glass.

Sealed within an INSULITE unit, Low-Emissive coatings substantially improve the unit's energy efficiency by selectively transmitting the sun's visible light (short-wave radiation) while reflecting a majority of radiant heat (long-wave infrared radiation). In cold weather conditions, both coatings transmit the sun's energy while it retains radiant heat inside the building. In warm weather conditions, the sun's high angle results in an increase of exterior radiant heat. The coatings reflect the radiant heat thus reducing heat gain into the building.

Additional thermal insulation and sound transmittance reduction can be achieved through special gas-filling in the INSULITE units.

Aesthetically, Low-Emissive coatings appear transparent from the interior and similar to uncoated glass on the exterior. The Low-Emissive coating is applied to glass substrate through state-of-the-art magnetically enhanced vacuum deposition (sputtering) technology.

Heat Stop Glass or Insulating Glass

Heat stop glass is an insulating glass made of two glass light (or three glass light in special cases) hermetically sealed with an aluminum spacer bar between the individual light. The spacer bar is filled with a special desiccant to absorb moisture within the air space. The air space between two glass light can be filled with a special gas for an application that requires improvement of noise reduction and thermal performance.

Clear and fresh vision for condensation can occur on the glass surface and obstruct your views of the outside scenery. This phenomenon generally occurs with single glass due to the temperature difference between the inside and the outside.

Heat stop glass reduces the temperature differences between the inside and the outside and, therefore, prevents condensation on the glass surface.

Heat stop glass has a high thermal insulating performance due to the insulating effect of the air space between the two light. The coefficient of overall heat transmittance (U-Value) is reduced by approximately 50% or more, as compared to single glass light. Consequently, your air-conditioning load will be reduced.

Various Applications of insulation

- Windows of general office buildings
- Residential houses in tropical and cold climates
- Places such as factories, laboratories, conference rooms or buildings near airports or railways which require environmental control (temperature, humidity, sound)
- Freezers and refrigerators

Recommendations for heat stop glass

- Specify and verify the correct size when ordering since the size and specification of heat stop glass cannot be changed after production.
- Store heat stop glass inside a well ventilated room without direct sunlight.
- Avoid using heat stop glass in places with temperature exceeding 70 degrees Celsius since the lifetime of the seals of heat stop glass will be shortened.
- Do not allow air flow from air-conditioners to blow directly onto heat stop glass

Fiber Glass

Fiberglass is a man-made mineral fiber that is widely used in America. First produced in the 1920's, fiberglass became a popular substitute for asbestos in the 1950's when some of the deleterious health effects from asbestos were first becoming apparent. Due to the similarity in shape between the fiberglass and the asbestos fibers, fiberglass was able to effectively replace asbestos in many applications such as in electrical, thermal, and acoustic insulation and in adding structural reinforcement and heat resistance to a material.

The similarities to asbestos, which have allowed fiberglass to be so versatile, are also sources of concern for some who suggest that fiberglass may also exhibit similar deleterious health effects. There are three main types of fiberglass. Each type has different physical dimensions and properties which affect the suitability for specific applications and may also impact human health in different ways. These types are continuous fibers (used in electrical insulation, cement and plastics reinforcement), insulation wool (for thermal and acoustic insulation), and special purpose fibers (used for heat resistance and light-weight materials).

There are many ways to protect yourself and lower your exposure if you are working with fiberglass. Always wear goggles and appropriate work gloves. Be sure to cover all exposed skin with long sleeve shirts and long pants. During low level exposure to airborne fibers at least a dust mask should be worn to protect your throat and lungs. After the work is done always wash your hands and face thoroughly.

Fiberglass is extremely useful in workplace and residential applications, but it should be treated with care to avoid some of its irritating properties. In the future more scientific studies will be conducted to determine if there are truly any far reaching health effects. For now, safe handling and work practices will go a long way toward insuring a safe and healthy treatment of fiberglass. Fiberglass bats are the most common materials for insulating walls and ceilings

Rock wool Insulation

Rock wool manufactures a wide range of products for all kinds of insulation purposes, including insulation for the offshore sector. On account of the unique properties of the rock wool insulation and specially developed products, rock wool insulation can be used everywhere. This applies, for example, to:

- H and A constructions
- Deck and bulkhead constructions
- Engine rooms
- Pipe and air ducts
- Doors and panels
- Floating floors
- Comfort insulation
- Sub sea pipe lines

Cellulose Insulation

Having a well-insulated building envelope is crucial to creating an environmentally sound building. By minimizing heat transfer through the envelope, energy used to maintain the interior climate is similarly minimized, reducing both utility bills and the environmental costs of fossil fuel use. Cellulose insulation is made from recycled paper that is applied as either loose fill into attics and closed wall cavities or damp-sprayed into open wall cavities. Due to its recycled content and potentially higher energy and acoustic performance, cellulose is an environmentally-preferable product.

Although cellulose insulation's R-value of roughly 3.7 per inch is similar to high-density fiberglass bats, it has a significant advantage over fiberglass. Because of its method of installation, it seals all cavity spaces very effectively, greatly reducing air infiltration and higher frequency sound transmission. The overall R-value of bats, on the other hand, can be significantly lower than its idealized rating due to typically deficient installation. Loose-fill cellulose settles over time, requiring it be installed at its predicted settled density to achieve its rated R-value. Some manufacturers have created "stabilized" products that reduce settling.

Polyurethane

Polyurethane foams are used as insulation in garage door panels, roof insulation on commercial buildings, wall insulation in newer high efficiency homes, office chairs, refrigerators, freezers, walk in coolers, furniture and in automobiles for dashboards, armrest's, suspension bushings and many other areas. Polyurethane foam is a two-part system. It begins with two chemical blends that when mixed together expand and cure to fill the garage door panel. During the expansion, the foam flows and completely fills the inside of the panel and comes in complete contact with and becomes fully adhered to the steel skins of the garage door panel to form a composite structure that is of exceptional strength and rigidity.

Polyurethane foams are very stable when encapsulated (fully enclosed) inside a garage door section. The polyurethane foam in a Haas garage door section is fully enclosed inside the steel skins and therefore protected from R-Value loss! This design puts the insulation properties of polyurethane foam way ahead of polystyrene foam for performance and value

Polystyrene

Polystyrene foam board is used as insulation in garage door panels, houses, as vapor barriers, and most commonly as an inexpensive packing material. Polystyrene foam board must be attached to or inserted into the door sections. The foam must be held in place by mechanical means or by bonding the foam to the door skins by using adhesives (glue).

Perlite

Perlite is a light gray, glassy volcanic rock with a vitreous, pearly luster and a characteristic concentric or perlitic fracture. It differs from other volcanic glasses principally in its combined water content, which produces the unusual characteristic of expanding up to 20 times its original volume upon being exposed to rapid, controlled heating. The resulting expanded particles are spherical in shape, usually fluffy or frothy, highly porous due to a foam-like cellular internal structure, and have a very low density. Expanded perlite exhibits very low thermal conductivity, low sound transmission, high fire resistance, a large surface area and low moisture retention. It is chemically inert, sterile, non-toxic and non-fibrous, free of organic impurities and has a neutral pH. Perlite, obsidian perlite, and a related product, pumice are regarded as essentially "environmentally safe" building materials. Expanded perlite can be manufactured to weigh as little as 2 pounds per cubic foot (32 kg/m^3) making it adaptable for numerous applications.

Table 31 Types of Insulation, Basic Forms

Form	Method of Installation	Where Applicable	Advantages
Blankets: Bats or Rolls - Fiber glass - Rock wool	Fitted between studs, joists and beams	All unfinished walls, floors and ceilings	Do-it-yourself Suited for standard stud and joist spacing, which is relatively free from obstructions
Loose-Fill (blown-in) or Spray-applied - Rock wool - Fiber glass - Cellulose - Polyurethane foam	Blown into place or spray applied by special equipment	Enclosed existing wall cavities or open new wall cavities Unfinished attic floors and hard to reach places	Commonly used insulation for retrofits (adding insulation to existing finished areas) Good for irregularly shaped areas and around obstructions
Rigid Insulation - Extruded polystyrene foam (XPS) - Expanded polystyrene foam (EPS or bead board)Form	Interior applications: Must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety Exterior applications: Must be Method of Installation	Basement walls Exterior walls under finishing (Some foam boards include a foil facing which will act as a vapor retarder. Please read the discussion about where Applicable	High insulating value for relatively little thickness Can block thermal short circuits when installed continuously over frames or joists.Advantages
- Polyurethane foam - Polyisocyanurate foam	covered with weather-proof facing	where to place, or not to place, a vapor retarder) Unvented low slope roofs	
Reflective Systems - Foil-faced paper - Foil-faced polyethylene bubbles - Foil-faced plastic film - Foil-faced cardboard	Foils, films, or papers: Fitted between wood-frame studs joists, and beams	Unfinished ceilings, walls, and floors	Do-it-yourself All suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present Effectiveness depends on spacing and heat flow direction
Loose-Fill (poured in) Vermiculite or Perlite	not currently used for home insulation, but may be found in older homes		

Table 32 ASTM Standard and Properties of Insulation

Type of Insulation	R (m.°C/W)	k (W/m.°C	ρ (kg/m³)	ASTM Standard
Fibrous materials				
- Fiber Glass	22.4	0.045	9.6-16.0	C553, C592 C665, C892
- Rock Wool	22.4	0.045	24.0-40.0	C553, C592 C665, C892
Lose fill				
- Cellulose	22.4-25.7	0.039-0.045	35.2-51.3	C739
- Fiber Glass	19.8	0.05	9.6-16.0	C764
- Rock Wool	21.7	0.046	24.0	C764
- Perlite	17.4-25.7	0.039-0.058	32.0-176.2	C549
- Vermiculite	14.8-15.8	0.063-0.068	64.1-192.2	C516
Spay Foam				
- Polyurethane	40.8-43.4	0.023-0.024	32	
Block, Plate				
- Polystyrene	34.7	0.029	28.8-41.6	C578