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Short Article

Thermal Resistances for Reflective Airspaces at 50°F and ΔT Equal 30 °F

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Abstract

Enclosed reflective air spaces (reflective insulation assemblies) typically require thermal performance determinations using a hot-box test facility. In the case of single sheet assemblies (one enclosed air space), however, labeling and advertising based on ASHRAE Handbook values is allowed. The handbook tabulation of R-values, however, contains a limited number of entries for the specified average air space temperature of 50°F and temperature difference of 30°F. The following analysis provides an array of R-values for a single enclosed reflective air space for conditions typically encountered.

Key Words: reflective insulation; enclosed reflective air space; thermal resistance; single sheet reflective insulation

Introduction

The U.S. Federal Trade Commission Rule for "Labeling and Advertising of Home Insulation: Trade Regulation Rule" (FTC 16 CFR Part 460) allows the use of tabulated values from the ASHRAE Handbook-Fundamentals to establish the thermal resistance (R-value) of "single sheet systems of aluminum foil" (§460.12 (5)) intended for use in residential building applications . This is taken to mean one enclosed reflective air space. The "Rule" further states that the R-values listed for average air-space temperature of 50°F and temperature difference 30 °F (ΔT=30°F) must be used for labeling and advertising of products. The ASHRAE tables identified in the Rule are on pages 26.14-26.15 of the 2017 Edition of The ASHRAE Handbook-Fundamentals[1]. The ASHRAE Tables use "Effective Emittance (E) " as the characteristic physical property of the reflective insulation assembly. Effective emittance is obtained from the emittance of the surfaces (ε1 and ε2) on the sides of the air space that are perpendicular to the heat flow direction as shown by the following equation[2].

$$E = 1/(1/ \varepsilon 1 + 1/ \varepsilon 2 -1) \qquad (1)$$

If an enclosed reflective air space is bounded on one side by a low-emittance film or foil with emittance ε1 and the opposing side is a common building material such as wood, gypsum, or masonry, then ε2 ≈ 0.9 and E ≈ ε1. E in this case is approximately the emittance of the foil or film surface of the reflective insulation material.

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Discussion

Unfortunately, the ASHRAE Handbook has a limited number of entries for the temperatures specified in FTC §460.12 (5). The handbook table contains R-values for E values of 0.03 and 0.05 which are typical for reflective insulation assemblies, five air-space dimensions and five major heat-flow directions. The Handbook table provides 50 values if all heat flow directions are considered or 30 values if the heat-flow directions are limited to up, horizontal, and down. Interpolation in the ASHRAE Table is generally allowed, but the R-values do not vary linearly with air-gap size as shown by Figure 1 for horizontal heat flow making interpolation difficult. The R-values in Figure 1 and those that follow were calculated using correlations for the Nusselt number as a function of the Grashof Number based on numerical analysis of Yam et al. [3] and test data from Robinson and Powell [4].

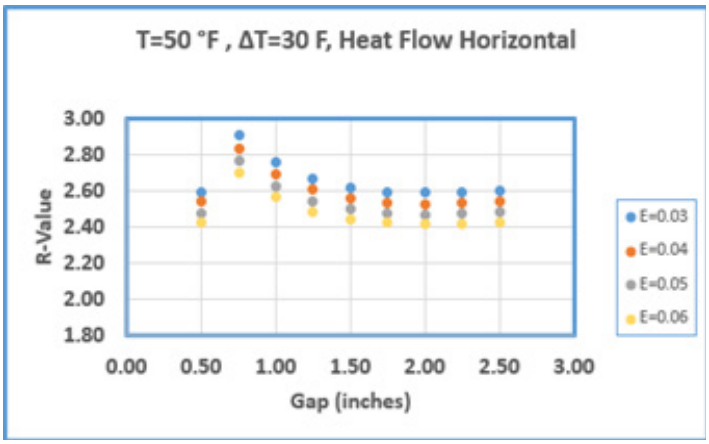

Figure 1: R-values with units ft2·h·°F/Btu for a Single Enclosed Reflective Air at an Average Temperature of 50 °F and Temperature Difference 30°F

Numerical Results for R-value

The analysis and resulting model from Yam have been used to calculate R-values for a range of E values and air space dimensions with the results displayed in Tables 1-5. These R-values are shown graphically in the appendix. Table 6 contains comparisons of ASHRAE Handbook R-values with calculated R-values based on the hot-box data from Robinson and Powell. The differences are expressed as percent difference of the calculated R-value from the R- values for "Plane Air Spaces" in the ASHRAE Handbook-Fundamentals. The percent differences are generally less than 1%. There are two entries for heat flow up 45° that have larger than 1% differences. Table 6 is provided to show the agreement of reflective air space R-values published by ASHRAE and the correlations used in this paper.

Table 1: R-values for Heat Flow Up

R for T50^{0}F and ΔT 30^{0}F with units ft^2.h.^{0}F/Btu

UP	E=0.03	0.04	0.05	0.06
0.50	1.606	1.583	1.560	1.538
0.75	1.698	1.673	1.648	1.623
1.00	1.767	1.740	1.712	1.686
1.25	1.823	1.793	1.764	1.737
1.50	1.870	1.838	1.808	1.779
1.75	1.910	1.877	1.846	1.815
2.00	1.946	1.912	1.879	1.848
2.25	1.978	1.943	1.909	1.877
2.50 Inches	2.007	1.971	1.936	1.903

Table 2: R-values for Heat Flow Up at 45^0

R for T50^{0}F and ΔT 30^{0}F with units ft^2.h.^{0}F/Btu

UP 45^0	E=0.03	0.04	0.05	0.06
0.50	2.063	2.025	1.989	1.953
0.75	2.070	2.032	1.995	1.960
1.00	2.085	2.046	2.009	1.973
1.25	2.013	2.063	2.025	1.989
1.50	2.121	2.081	2.042	2.005
1.75	2.140	2.099	2.060	2.022
2.00	2.158	2.117	2.077	2.038
2.25	2.176	2.134	2.093	2.054
2.50 Inches	2.194	2.151	2.110	2.070

Table 3: R-values for Heat Flow Horizontal

R for T50^{0}F and ΔT 30^{0}F with units ft^2.h.^{0}F/Btu

HOR	E=0.03	0.04	0.05	0.06
0.50	2.593	2.543	2.476	2.422
0.75	2.912	2.837	2.765	2.697
1.00	2.740	2.674	2.610	2.550
1.25	2.649	2.586	2.527	2.470
1.50	2.599	2.539	2.482	2.427
1.75	2.575	2.516	2.460	2.406
2.00	2.566	2.507	2.452	2.398
2.25	2.568	2.509	2.453	2.399
2.50 Inches	2.576	2.517	2.461	2.407

Table 4: R-values for Heat Flow Down at 45^0

R for T50^{0}F and ΔT 30^{0}F with units ft^2.h.^{0}F/Btu

Down 45^0	E=0.03	0.04	0.05	0.06
0.50	2.643	2.581	2.521	2.465
0.75	3.416	3.313	3.216	3.124
1.00	3.704	3.583	3.470	3.364
1.25	3.660	3.542	3.431	3.327
1.50	3.557	3.445	3.340	3.242
1.75	3.497	3.389	3.288	3.192
2.00	3.465	3.359	3.259	3.165
2.25	3.451	3.346	3.247	3.154
2.50 Inches	3.450	3.345	3.246	3.153

Table 5: R-values for Heat Flow Down

R for T50^{0}F and ΔT 30^{0}F with units ft^2.h.^{0}F/Btu

Down	E=0.03	0.04	0.05	0.06
0.50	2.680	2.616	2.556	2.497
0.75	3.792	3.666	3.547	3.437
1.00	4.747	4.551	4.370	4.202
1.25	5.571	5.302	5.058	4.836
1.50	6.287	5.947	5.641	5.366
1.75	6.914	6.504	6.141	5.816
2.00	7.466	6.991	6.573	6.202
2.25	7.955	7.418	6.949	6.536
2.50 Inches	8.394	7.798	7.281	6.829

Table 6. Comparison of ASHRAE Handbook and Calculated R-values

UP	E	D(in.)	R HB	R Calc	%Diff
	0.03	0.50	1.62	1.606	-0.86
		0.75	1.71	1.698	-0.70
		1.50	1.87	1.870	0.00
	0.05	0.50	1.57	1.560	-0.64
		0.75	1.66	1.648	-0.72
		1.50	1.81	1.808	-0.11
UP 45^0	**E**	**D(in.)**	**R HB**	**R Calc**	**%Diff**
	0.03	0.50	2.06	2.063	0.15
		0.75	1.99	2.070	4.02
		1.50	2.14	2.121	-0.89
	0.05	0.50	1.98	1.989	0.45
		0.75	1.92	1.995	3.91
		1.50	2.06	2.042	-0.87
HOR	**E**	**D(in.)**	**R HB**	**R Calc**	**%Diff**
	0.03	0.50	2.57	2.593	0.89
		0.75	2.91	2.912	0.07
		1.50	2.58	2.599	0.74
	0.05	0.50	2.46	2.476	0.65
		0.75	2.77	2.765	-0.18
		1.50	2.46	2.482	0.89
Down 45^0	**E**	**D(in.)**	**R HB**	**R Calc**	**%Diff**
	0.03	0.50	2.64	2.643	0.11
		0.75	3.43	3.416	-0.41
		1.50	3.58	3.557	-0.64
	0.05	0.50	2.52	2.521	0.04
		0.75	3.23	3.216	-0.43
		1.50	3.36	3.340	-0.60
Down	**E**	**D(in.)**	**R HB**	**R Calc**	**%Diff**
	0.03	0.50	2.66	2.680	0.75
		0.75	3.77	3.792	0.58
		1.50	6.27	6.287	0.27
	0.05	0.50	2.54	2.556	0.63
		0.75	3.52	3.547	0.77
		1.50	5.63	5.641	0.20

Closing

The R-values contained in this paper for temperatures specified in the Federal Trade Commission Rule for Labeling and Advertising have been calculated using correlations that were developed from laboratory data and compared with R-values published in the ASHRAE Handbook -Fundamentals. The R-values at average temperature 50
°F and 30° ΔT were calculated to provide quick estimates for reflective insulation R-value claims for single-sheet assemblies.

References

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2. Robert Seigel and John R. Howell, "Thermal Radiation Heat Transfer', McGraw-Hill Book Company (1972) pp. 240-241.

3. Kah Wei Yam, Khar San Teh , Patrick Loi and David W. Yarbrough, "Reflective Insulation Assemblies for Above Ceiling Applications" J. of Building Physics 2020;44(3).

4. H.E. Robinson and F.J. Powell, "The Thermal Insulation Value of Air Spaces", Housing Research Paper 32, United States National Bureau of Standards (1956).

Appendix

Graphical presentations of the R-values contained in Tables A-1 to A - 5 are shown below

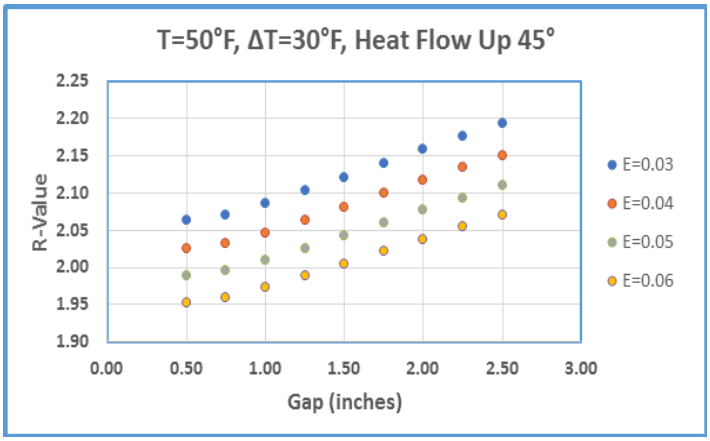

Figure A-1:R-values (ft2·h·°F/Btu) as a Function of Effective Emittance and Gap for Heat Up

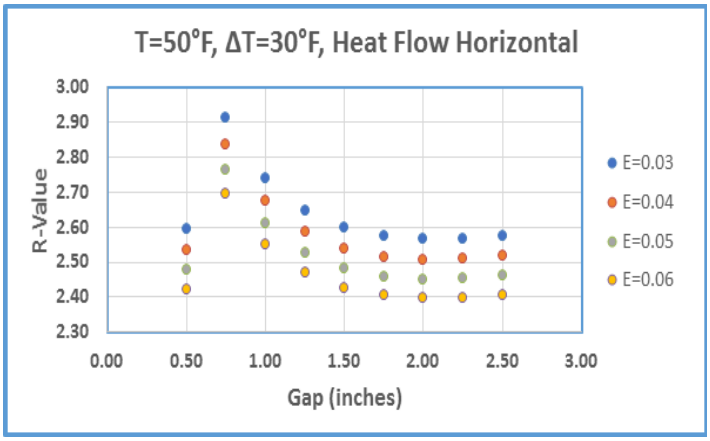

Figure A-2: R-values (ft2·h·°F/Btu) as a Function of Effective Emittance and Gap for Heat Flow 45° Up

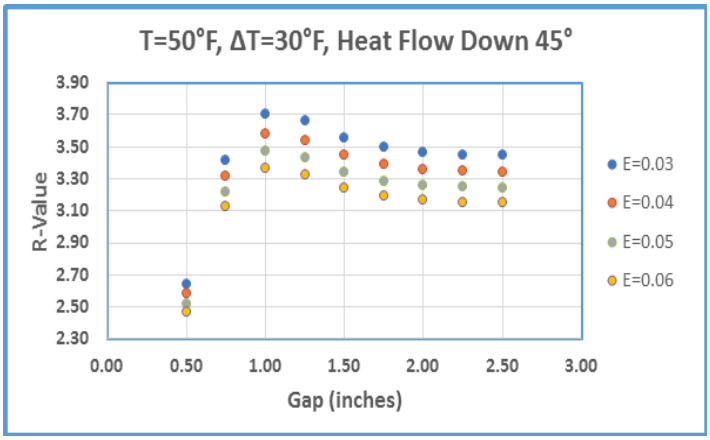

Figure A-3: R-values (ft2·h·°F/Btu) as a Function of Effective Emittance and Gap for Heat Flow Horizontal

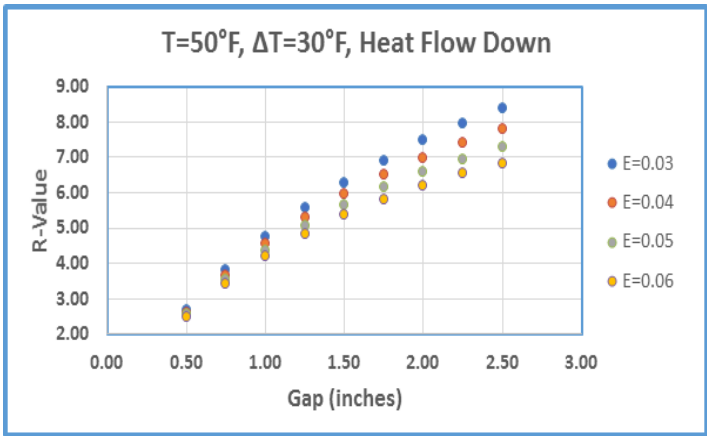

Figure A-4: R-values (ft2·h·°F/Btu) as a Function of Effective Emittance and Gap for Heat Flow 45°down

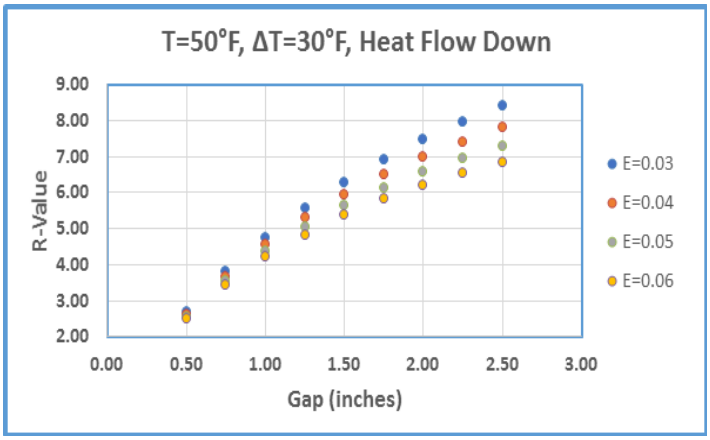

Figure A-5: R-values (ft2·h·°F/Btu) as a Function of Effective Emittance and Gap for Heat Flow Down