# Thermo-Fold Drapery System

$$q=(SC)(SHGF)+U(T_2-T_1)$$

STUDY AND REPORT

*Prepared By*

MANHATTAN COLLEGE TESTING LABORATORY

1979

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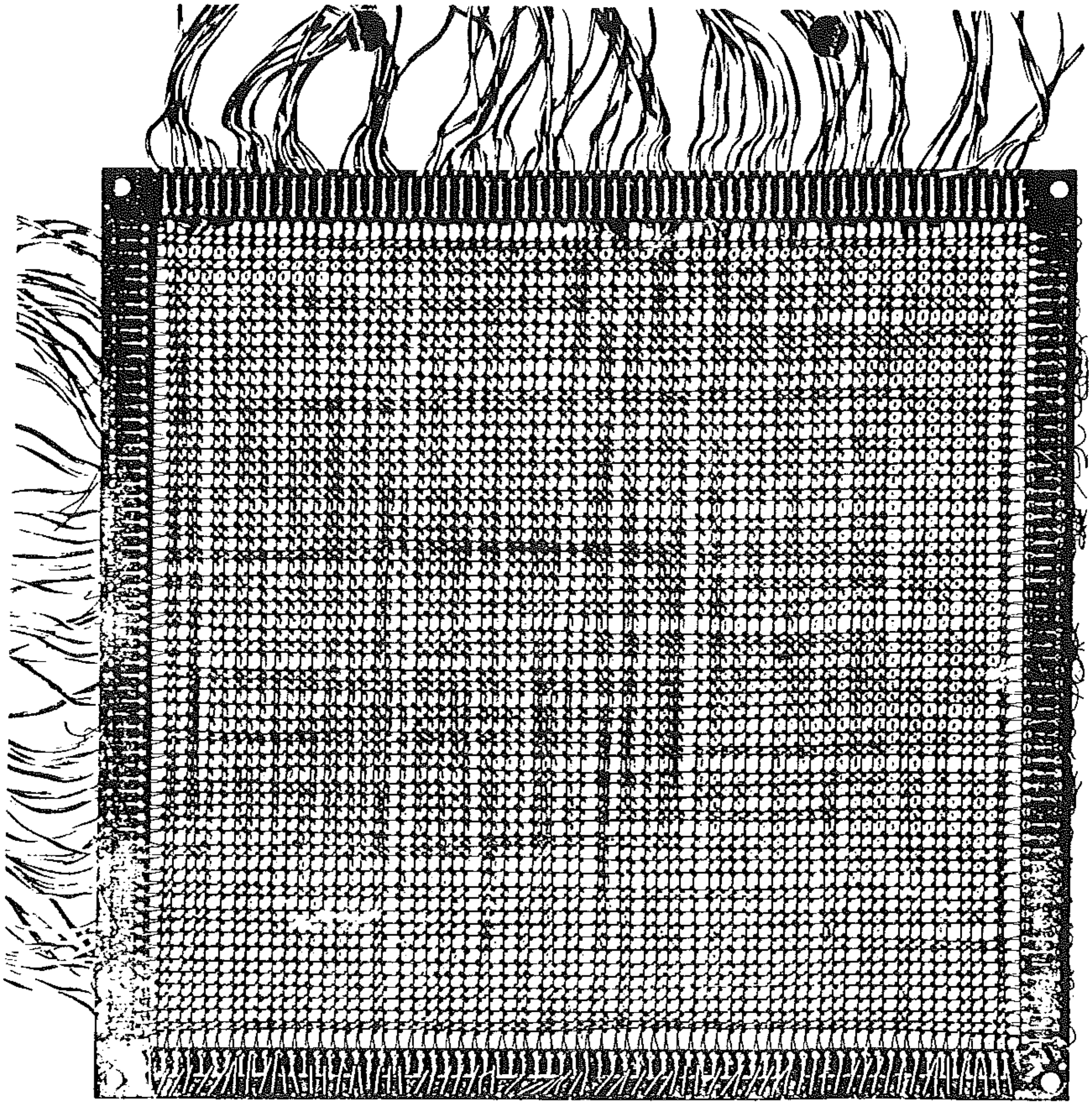

*MEMORIES ARE MADE OF THIS*

# MANHATTAN COLLEGE TESTING LABORATORY

Thermo-fold drape studies
using Dual Calorimeters and
Guarded Hot Box testing apparatus

July 1979

# *THERMO DRAPE HEAT TRANSFER COEFFICIENTS*

Although most of the equations of heat transfer are generally quite complex, the modern desk top computer, with its stored data and stored program can solve standardized heat flow computations with ease and with economy. A whole year of weather data, for example, can be held in disk storage to be accessed by the stored program automatically. This "handbook plus personal computer" approach is likely to increase in popularity in the years ahead because of the exponentially decreasing costs of computers themselves, plus the availability of apt and able programmers, now graduating from Schools of Business in ever-increasing numbers.

By contrast to the "handbook plus personal computer" approach, is the scale model testing technique. Devotees of this "laboratory-like" search for truth believe literally, that "one test is worth a thousand computations." A judicious blend of both laboratory testing and personal computer analysis is probably the winning number. Modern fenestration studies seem to rely heavily on scale model testing.

The two fundamental laboratory tools for fenestration studies are the so-called "guarded hot box" for the measurement of U and R, and twin calorimeters for the direct measurement of SC, the shading coefficient. Here at Manhattan College it has been found possible to design and build twin calorimeters which with very minor redesign, can serve as an excellent guarded hot box. Thermo-fold R values were measured during July 1979.

## *THE GUARDED HOT BOX*

The guarded hot box is really two identical insulated boxes capable of being joined together face to face.

Each of the two halves is well insulated on five sides, and completely open on the sixth side. Inside box #1 is a distributed heat source (in our case the original calorimeter heat exchanger) and a point heat source with a small fan for convection (a 150 watt clear light bulb). In addition, thermometer #1 is placed within the box, but must be readable from the outside to tenths of a degree.

The second box also has a thermometer, T2, and a calorimeter which is read on thermometers T3 and T4. The calorimeter has an adjustable flow rate but for our purposes we have standardized our flow rate at 30 pounds of water per hour. Thus 30 times T4-T3 gives the heat gain of the second box in BTU per hour.

The specimen to be tested is placed over the entire open front face of the second box, usually with a plain glass window as part of the fenestration. The two boxes are tightly sealed together face to face, and left this way during the entire test.

Heat is generated continually in the first box by means of either the point source or the distributed heating coil. Ideally, all heat generated will flow through the fenestration, and be removed from the second box by means of the calorimeter. The fact is, this ideal cannot be reached, due to some inevitable heat leakage, but nevertheless, the real-world wintertime roomheating condition can be reasonably well simulated. Readings of all four thermometers are taken at five minute intervals for about an hour, and the curves of (T2-T1) and (T4-T3) versus time are plotted immediately. As the curves begin to flatten out, readings may be taken at longer intervals, but the testing should not stop until both curves are almost flat, since this is the criterion for a steady state. It seems to take about four hours for steady state to be reached, using the Manhattan College Guarded Hot Box apparatus. Centigrade thermometers were used.

## *Guarded Hot Box Test Results*
## *August 2 and 3, 1979  Manhattan College Lab.*

PLAIN GLASS

| MTI | T2 | T1 | T4 | T3 | T2-T1 | T4-T3 | CTD / GHBTD | U | R |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 41.0 | 34.0 | 24.0 | 22.0 | 7.0 | 2.0 | .286 | | |
| 5 | 45.5 | 35.5 | 24.0 | 22.0 | 10.5 | 2.0 | .200 | | |
| 5 | 47.5 | 37.0 | 24.0 | 22.0 | 11.0 | 2.0 | .195 | | |
| 5 | 49.0 | 38.0 | 24.0 | 22.0 | 11.5 | 2.0 | .182 | | |
| 5 | 50.5 | 39.0 | 24.5 | 22.3 | 12.0 | 2.0 | .174 | | |
| 5 | 52.0 | 40.0 | 24.7 | 22.3 | 12.5 | 2.5 | .208 | | |
| 5 | 53.0 | 40.5 | 25.0 | 22.3 | 12.7 | 2.5 | .220 | | |
| 5 | 54.0 | 41.3 | 25.0 | 22.3 | 13.3 | 2.7 | .216 | | |
| 5 | 55.5 | 42.3 | 25.3 | 22.3 | 13.7 | 3.0 | .226 | | |
| 5 | 56.7 | 43.0 | 25.5 | 22.5 | 14.0 | 3.3 | .236 | | |
| 10 | 58.3 | 44.3 | 26.0 | 22.5 | 14.3 | 3.7 | .268 | | |
| 10 | 59.7 | 45.5 | 26.0 | 22.5 | 14.5 | 3.7 | .263 | | |
| 10 | 61.0 | 46.5 | 26.0 | 22.5 | 15.3 | 3.7 | .259 | | |
| 10 | 63.0 | 47.7 | 26.5 | 22.5 | 15.7 | 4.0 | .279 | | |
| 10 | 64.0 | 48.3 | 26.5 | 22.5 | 15.7 | 4.3 | .269 | | |
| 10 | 64.5 | 48.7 | 26.7 | 22.5 | 16.0 | 4.5 | .286 | | |
| 15 | 66.0 | 50.0 | 26.7 | 22.5 | 16.3 | 4.5 | .281 | | |
| 15 | 67.0 | 50.7 | 27.0 | 22.5 | 16.5 | 4.7 | .284 | | |
| 15 | 68.0 | 51.5 | 27.0 | 22.5 | 16.7 | 4.7 | .288 | | |
| 15 | 69.0 | 52.0 | 27.3 | 22.5 | 17.0 | 5.0 | .294 | 1.74 | .575 |

PLAIN GLASS PLUS THERMO FOLD    TEST #1    3½ hour test

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 61.0 | 43.0 | 24.5 | 22.5 | 18.0 | 2.0 | .11 | | |
| 30 | 70.3 | 49.0 | 25.0 | 22.5 | 21.3 | 2.5 | .12 | | |
| 30 | 73.0 | 52.0 | 25.0 | 22.5 | 21.0 | 2.5 | .12 | | |
| 30 | 76.7 | 55.0 | 25.3 | 22.5 | 21.7 | 2.7 | .13 | | |
| 30 | 79.0 | 57.0 | 25.7 | 22.7 | 22.0 | 2.7 | .13 | | |
| 30 | 81.5 | 59.0 | 26.0 | 23.0 | 22.5 | 3.0 | .13 | | |
| 30 | 84.5 | 61.7 | 26.0 | 23.0 | 22.8 | 3.0 | .13 | .78 | 1.28 |

PLAIN GLASS PLUS THERMO FOLD    TEST #2    3½ hour test

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 33.0 | 28.0 | 25.0 | 24.7 | 5.0 | .3 | | | |
| 30 | 51.5 | 36.0 | 25.3 | 24.7 | 15.5 | .5 | .03 | | |
| 30 | 60.5 | 42.0 | 26.0 | 24.7 | 18.3 | 1.3 | .07 | | |
| 30 | 67.0 | 46.7 | 26.5 | 24.7 | 20.3 | 1.7 | .09 | | |
| 30 | 72.0 | 50.5 | 26.5 | 24.7 | 21.5 | 1.7 | .08 | | |
| 30 | 77.0 | 54.0 | 26.7 | 24.7 | 23.0 | 2.0 | .09 | | |
| 30 | 79.0 | 55.7 | 27.0 | 25.0 | 23.3 | 2.0 | .09 | .54 | 1.85 |

| | | | |
|---|---|---|---|
| *NOMENCLATURE:* | MTI | Minutes time interval between observations | |
| | CTD | Calorimeter Temperature Difference. | T4-T3 |
| | GHBTD | Guarded Hot Box Temperature Diff. | T2-T1 |
| | U | Thermal Transmittance | BTU/(hr · ft$^2$ · F$^o$ ) |
| | R | Thermal Resistance | (hr · ft$^2$ · F$^o$) BTU |
| | K | Steady State Ratio of CTD/GHBTD<br>This K should be a constant for a satisfactory Hot Box Test | |
| | SC | Ratio of Solar Heat Gain using test specimen to solar heat gain using sheet glass only under the same conditions | |

Let R1 and U1 represent the test results from test #1 and R2 and U2 the test results from test #2. RG and UG are the test results from the first table on the preceding page, and refer to the R and U values of glass alone.

It is very interesting to take some ratios of these quantities. For example:

$$R1/RG = 2.23$$
$$R2/RG = 3.22$$

The above ratios suggest that a fenestration using double (thermo-fold) drapes introduces a resistance to heat flow which is two to three times as great as glass alone. That this figure is in the same ballpark as the summertime (shading coefficient) ratios is quite interesting. Summertime solar heat acts principally through radiation, and is kept out of the house largely by reflection from the outer thermo-fold drape. Wintertime heat flow, on the other hand, is mainly from the inside of the house to the outside, and is transferred mainly by conduction and convection.

Table 2 of Chapter 22 of the 1977 ASHRAE Handbook, which was based on a National Bureau of Standards Housing Research Paper #32, which is available from the Government Printing Office, Housing and Home Finance Agency (1954) deals explicitly with the Thermal Resistance of Plane Air Spaces. This table shows air spacing widths from .5 inches to 3.5 inches. It does show a variation of resistance with air pocket thickness, which maximizes at some value between the two extremes. Possibly this maximization occurs as a result of the fact that a narrow spacing would favor conductive heat transfer, while a wide one would favor convective heat transfer. If total heat transfer is the sum of the two, a maximum would be expected somewhere in the middle.

In any event, both experiments performed here and published theory and tables substantiate the claim that "air in our pocket puts money in yours."

A copy of Table 2 is included as an appendix to this report.

## *APPENDIX A*

GUARDED HOT BOX COMPUTATIONAL METHODS - MANHATTAN COLLEGE LABORATORY

By definition $q = U \cdot A \cdot (F2-F1)$

If Centigrade thermometers are used, however,

$$q = U \cdot A \cdot (C2-C1) \cdot 1.8$$

Consider now, the meaning of q on the left side of the equation.

By definition $q = \text{BTU per hour}$

Also by definition $\frac{\text{BTU}}{\text{hour}} = \text{Mass flow rate x Change of temperature}$

In our lab it is convenient to adopt 30 lbs. of water per hour as a standard mass flow rate. Also, $A = 5 \text{ ft.}^2$

Therefore, $q = 30 \cdot (C4-C3) \cdot 1.8$

Finally, $30(C4-C3)\ 1.8 = U \cdot A \cdot (C2-C1) \cdot 1.8$

or $U = (30/5) \cdot (C4-C3) / (C2-C1)$

And $U = 6 \cdot K$

Since the ratio of the CTD and the GHBTD must be (almost) a constant in the steady state condition of the guarded hot box.

The entire effort in the Guarded Hot Box experimentation is thus seen to be nothing more than an effort to evaluate K as accurately as possible.

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**Table 2 Thermal Resistances of Plane[a] Air Spaces[d,e*]**

All resistance values expressed in (hour)(square foot)(degree Fahrenheit temperature difference) per Btu

Values apply only to air spaces of uniform thickness bounded by plane, smooth, parallel surfaces with no leakage of air to or from the space.

Thermal resistance values for multiple air spaces must be based on careful estimates of mean temperature differences for each air space.

See the Caution section, under Overall Coefficients and Their Practical Use.

| Position of Air Space | Direction of Heat Flow | Air Space Mean Temp,[b] (F) | Air Space Temp Diff,[b] (deg F) | 0.5-in. Air Space[d] Value of $E$[b,c] 0.03 | 0.05 | 0.2 | 0.5 | 0.82 | 0.75-in. Air Space[d] Value of $E$[b,c] 0.03 | 0.05 | 0.2 | 0.5 | 0.82 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horiz. | Up | 90 | 10 | 2.13 | 2.03 | 1.51 | 0.99 | 0.73 | 2.34 | 2.22 | 1.61 | 1.04 | 0.75 |
| | | 50 | 30 | 1.62 | 1.57 | 1.29 | 0.96 | 0.75 | 1.71 | 1.66 | 1.35 | 0.99 | 0.77 |
| | | 50 | 10 | 2.13 | 2.05 | 1.60 | 1.11 | 0.84 | 2.30 | 2.21 | 1.70 | 1.16 | 0.87 |
| | | 0 | 20 | 1.73 | 1.70 | 1.45 | 1.12 | 0.91 | 1.83 | 1.79 | 1.52 | 1.16 | 0.93 |
| | | 0 | 10 | 2.10 | 2.04 | 1.70 | 1.27 | 1.00 | 2.23 | 2.16 | 1.78 | 1.31 | 1.02 |
| | | −50 | 20 | 1.69 | 1.66 | 1.49 | 1.23 | 1.04 | 1.77 | 1.74 | 1.55 | 1.27 | 1.07 |
| | | −50 | 10 | 2.04 | 2.00 | 1.75 | 1.40 | 1.16 | 2.16 | 2.11 | 1.84 | 1.46 | 1.20 |
| 45° Slope | Up | 90 | 10 | 2.44 | 2.31 | 1.65 | 1.06 | 0.76 | 2.96 | 2.78 | 1.88 | 1.15 | 0.81 |
| | | 50 | 30 | 2.06 | 1.98 | 1.56 | 1.10 | 0.83 | 1.99 | 1.92 | 1.52 | 1.08 | 0.82 |
| | | 50 | 10 | 2.55 | 2.44 | 1.83 | 1.22 | 0.90 | 2.90 | 2.75 | 2.00 | 1.29 | 0.94 |
| | | 0 | 20 | 2.20 | 2.14 | 1.76 | 1.30 | 1.02 | 2.13 | 2.07 | 1.72 | 1.28 | 1.00 |
| | | 0 | 10 | 2.63 | 2.54 | 2.03 | 1.44 | 1.10 | 2.72 | 2.62 | 2.08 | 1.47 | 1.12 |
| | | −50 | 20 | 2.08 | 2.04 | 1.78 | 1.42 | 1.17 | 2.05 | 2.01 | 1.76 | 1.41 | 1.16 |
| | | −50 | 10 | 2.62 | 2.56 | 2.17 | 1.66 | 1.33 | 2.53 | 2.47 | 2.10 | 1.62 | 1.30 |
| Vertical | Horiz. | 90 | 10 | 2.47 | 2.34 | 1.67 | 1.06 | 0.77 | 3.50 | 3.24 | 2.08 | 1.22 | 0.84 |
| | | 50 | 30 | 2.57 | 2.46 | 1.84 | 1.23 | 0.90 | 2.91 | 2.77 | 2.01 | 1.30 | 0.94 |
| | | 50 | 10 | 2.66 | 2.54 | 1.88 | 1.24 | 0.91 | 3.70 | 3.46 | 2.35 | 1.43 | 1.01 |
| | | 0 | 20 | 2.82 | 2.72 | 2.14 | 1.50 | 1.13 | 3.14 | 3.02 | 2.32 | 1.58 | 1.18 |
| | | 0 | 10 | 2.93 | 2.82 | 2.20 | 1.53 | 1.15 | 3.77 | 3.59 | 2.64 | 1.73 | 1.26 |
| | | −50 | 20 | 2.90 | 2.82 | 2.35 | 1.76 | 1.39 | 2.90 | 2.83 | 2.36 | 1.77 | 1.39 |
| | | −50 | 10 | 3.20 | 3.10 | 2.54 | 1.87 | 1.46 | 3.72 | 3.60 | 2.87 | 2.04 | 1.56 |
| 45° Slope | Down | 90 | 10 | 2.48 | 2.34 | 1.67 | 1.06 | 0.77 | 3.53 | 3.27 | 2.10 | 1.22 | 0.84 |
| | | 50 | 30 | 2.64 | 2.52 | 1.87 | 1.24 | 0.91 | 3.43 | 3.23 | 2.24 | 1.39 | 0.99 |
| | | 50 | 10 | 2.67 | 2.55 | 1.89 | 1.25 | 0.92 | 3.81 | 3.57 | 2.40 | 1.45 | 1.02 |
| | | 0 | 20 | 2.91 | 2.80 | 2.19 | 1.52 | 1.15 | 3.75 | 3.57 | 2.63 | 1.72 | 1.26 |
| | | 0 | 10 | 2.94 | 2.83 | 2.21 | 1.53 | 1.15 | 4.12 | 3.91 | 2.81 | 1.80 | 1.30 |
| | | −50 | 20 | 3.16 | 3.07 | 2.52 | 1.86 | 1.45 | 3.78 | 3.65 | 2.90 | 2.05 | 1.57 |
| | | −50 | 10 | 3.26 | 3.16 | 2.58 | 1.89 | 1.47 | 4.35 | 4.18 | 3.22 | 2.21 | 1.66 |
| Horiz. | Down | 90 | 10 | 2.48 | 2.34 | 1.67 | 1.06 | 0.77 | 3.55 | 3.29 | 2.10 | 1.22 | 0.85 |
| | | 50 | 30 | 2.66 | 2.54 | 1.88 | 1.24 | 0.91 | 3.77 | 3.52 | 2.38 | 1.44 | 1.02 |
| | | 50 | 10 | 2.67 | 2.55 | 1.89 | 1.25 | 0.92 | 3.84 | 3.59 | 2.41 | 1.45 | 1.02 |
| | | 0 | 20 | 2.94 | 2.83 | 2.20 | 1.53 | 1.15 | 4.18 | 3.96 | 2.83 | 1.81 | 1.30 |
| | | 0 | 10 | 2.96 | 2.85 | 2.22 | 1.53 | 1.16 | 4.25 | 4.02 | 2.87 | 1.82 | 1.31 |
| | | −50 | 20 | 3.25 | 3.15 | 2.58 | 1.89 | 1.47 | 4.60 | 4.41 | 3.36 | 2.28 | 1.69 |
| | | −50 | 10 | 3.28 | 3.18 | 2.60 | 1.90 | 1.47 | 4.71 | 4.51 | 3.42 | 2.30 | 1.71 |

### Table 2 Thermal Resistances of Plane[a] Air Spaces[d,e,*]

| Position of Air Space | Direction of Heat Flow | Air Space Mean Temp,[b] (F) | Air Space Temp Diff,[b] (deg F) | 1.5-in. Air Space[d] Value of $E^{b,c}$ 0.03 | 0.05 | 0.2 | 0.5 | 0.82 | 3.5-in. Air Space[d] Value of $E^{b,c}$ 0.03 | 0.05 | 0.2 | 0.5 | 0.82 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horiz | Up | 90 | 10 | 2.55 | 2.41 | 1.71 | 1.08 | 0.77 | 2.84 | 2.66 | 1.83 | 1.13 | 0.80 |
| | | 50 | 30 | 1.87 | 1.81 | 1.45 | 1.04 | 0.80 | 2.09 | 2.01 | 1.58 | 1.10 | 0.84 |
| | | 50 | 10 | 2.50 | 2.40 | 1.81 | 1.21 | 0.89 | 2.80 | 2.66 | 1.95 | 1.28 | 0.93 |
| | | 0 | 20 | 2.01 | 1.95 | 1.63 | 1.23 | 0.97 | 2.25 | 2.18 | 1.79 | 1.32 | 1.03 |
| | | 0 | 10 | 2.43 | 2.35 | 1.90 | 1.38 | 1.06 | 2.71 | 2.62 | 2.07 | 1.47 | 1.12 |
| | | −50 | 20 | 1.94 | 1.91 | 1.68 | 1.36 | 1.13 | 2.19 | 2.14 | 1.86 | 1.47 | 1.20 |
| | | −50 | 10 | 2.37 | 2.31 | 1.99 | 1.55 | 1.26 | 2.65 | 2.58 | 2.18 | 1.67 | 1.33 |
| 45° Slope | Up | 90 | 10 | 2.92 | 2.73 | 1.86 | 1.14 | 0.80 | 3.18 | 2.96 | 1.97 | 1.18 | 0.82 |
| | | 50 | 30 | 2.14 | 2.06 | 1.61 | 1.12 | 0.84 | 2.26 | 2.17 | 1.67 | 1.15 | 0.86 |
| | | 50 | 10 | 2.88 | 2.74 | 1.99 | 1.29 | 0.94 | 3.12 | 2.95 | 2.10 | 1.34 | 0.96 |
| | | 0 | 20 | 2.30 | 2.23 | 1.82 | 1.34 | 1.04 | 2.42 | 2.35 | 1.90 | 1.38 | 1.06 |
| | | 0 | 10 | 2.79 | 2.69 | 2.12 | 1.49 | 1.13 | 2.98 | 2.87 | 2.23 | 1.54 | 1.16 |
| | | −50 | 20 | 2.22 | 2.17 | 1.88 | 1.49 | 1.21 | 2.34 | 2.29 | 1.97 | 1.54 | 1.25 |
| | | −50 | 10 | 2.71 | 2.64 | 2.23 | 1.69 | 1.35 | 2.87 | 2.79 | 2.33 | 1.75 | 1.39 |
| Vertical | Horiz. | 90 | 10 | 3.99 | 3.66 | 2.25 | 1.27 | 0.87 | 3.69 | 3.40 | 2.15 | 1.24 | 0.85 |
| | | 50 | 30 | 2.58 | 2.46 | 1.84 | 1.23 | 0.90 | 2.67 | 2.55 | 1.89 | 1.25 | 0.91 |
| | | 50 | 10 | 3.79 | 3.55 | 2.39 | 1.45 | 1.02 | 3.63 | 3.40 | 2.32 | 1.42 | 1.01 |
| | | 0 | 20 | 2.76 | 2.66 | 2.10 | 1.48 | 1.12 | 2.88 | 2.78 | 2.17 | 1.51 | 1.14 |
| | | 0 | 10 | 3.51 | 3.35 | 2.51 | 1.67 | 1.23 | 3.49 | 3.33 | 2.50 | 1.67 | 1.23 |
| | | −50 | 20 | 2.64 | 2.58 | 2.18 | 1.66 | 1.33 | 2.82 | 2.75 | 2.30 | 1.73 | 1.37 |
| | | −50 | 10 | 3.31 | 3.21 | 2.62 | 1.91 | 1.48 | 3.40 | 3.30 | 2.67 | 1.94 | 1.50 |
| 45° Slope | Down | 90 | 10 | 5.07 | 4.55 | 2.56 | 1.36 | 0.91 | 4.81 | 4.33 | 2.49 | 1.34 | 0.90 |
| | | 50 | 30 | 3.58 | 3.36 | 2.31 | 1.42 | 1.00 | 3.51 | 3.30 | 2.28 | 1.40 | 1.00 |
| | | 50 | 10 | 5.10 | 4.66 | 2.85 | 1.60 | 1.09 | 4.74 | 4.36 | 2.73 | 1.57 | 1.08 |
| | | 0 | 20 | 3.85 | 3.66 | 2.68 | 1.74 | 1.27 | 3.81 | 3.63 | 2.66 | 1.74 | 1.27 |
| | | 0 | 10 | 4.92 | 4.62 | 3.16 | 1.94 | 1.37 | 4.59 | 4.32 | 3.02 | 1.88 | 1.34 |
| | | −50 | 20 | 3.62 | 3.50 | 2.80 | 2.01 | 1.54 | 3.77 | 3.64 | 2.90 | 2.05 | 1.57 |
| | | −50 | 10 | 4.67 | 4.47 | 3.40 | 2.29 | 1.70 | 4.50 | 4.32 | 3.31 | 2.25 | 1.68 |
| Horiz. | Down | 90 | 10 | 6.09 | 5.35 | 2.79 | 1.43 | 0.94 | 10.07 | 8.19 | 3.41 | 1.57 | 1.00 |
| | | 50 | 30 | 6.27 | 5.63 | 3.18 | 1.70 | 1.14 | 9.60 | 8.17 | 3.86 | 1.88 | 1.22 |
| | | 50 | 10 | 6.61 | 5.90 | 3.27 | 1.73 | 1.15 | 11.15 | 9.27 | 4.09 | 1.93 | 1.24 |
| | | 0 | 20 | 7.03 | 6.43 | 3.91 | 2.19 | 1.49 | 10.90 | 9.52 | 4.87 | 2.47 | 1.62 |
| | | 0 | 10 | 7.31 | 6.66 | 4.00 | 2.22 | 1.51 | 11.97 | 10.32 | 5.08 | 2.52 | 1.64 |
| | | −50 | 20 | 7.73 | 7.20 | 4.77 | 2.85 | 1.99 | 11.64 | 10.49 | 6.02 | 3.25 | 2.18 |
| | | −50 | 10 | 8.09 | 7.52 | 4.91 | 2.89 | 2.01 | 12.98 | 11.56 | 6.36 | 3.34 | 2.22 |

[a] See Chapter 20, section on Factors Affecting Heat Transfer across Air Spaces.

[b] Interpolation is permissible for other values of mean temperature, temperature differences, and effective emittance *E*. Interpolation and moderate extrapolation for air spaces greater than 3.5 in. are also permissible.

[c] Effective emittance of the space *E* is given by $1/E = 1/e_1 + 1/e_2 - 1$, *where* $e_1$ and $e_2$ are the emittances of the surfaces of the air space (See section B of Table 1.)

[d] Credit for an air space resistance value cannot be taken more than once and only for the boundary conditions established.

[e] Resistances of horizontal spaces with heat flow downward are substantially independent of temperature difference.

[f] Thermal resistance values were determined from the relation $R = 1/C$, *where* $C = h_c + Eh_r$, $h_c$ is the conduction-convection coefficient, $Eh_r$ is the radiation coefficient $\cong 0.00686\ E\ [(460 + t_m)/100]^3$, and $t_m$ is the mean temperature of the air space. For interpretation from Table 2 to air space thicknesses less than 0.5 in. (as in insulating window glass), assume $h_c = 0.795\ (1 + 0.0016)$ and compute *R*-values from the above relations for an air space thickness of 0.2 in.

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[*] Based on National Bureau of Standards data presented in Housing Research Paper No. 32, Housing and Home Finance Agency 1954, U. S. Government Printing Office, Washington 20402.

### Table 3A Thermal Properties of Typical Building and Insulating Materials—(Design Values)[a]

(For Industrial Insulation Design Values, see Table 3B). These constants are expressed in Btu per (hour) (square foot) (degree Fahrenheit temperature difference). Conductivities *(k)* are per inch thickness, and conductances *(C)* are for thickness or construction stated, not per inch thickness. **All values are for a mean temperature of 75 F, except as noted by an asterisk (*) which have been reported at 45 F.** The SI units for Resistance (last two columns) were calculated by taking the the values from the two Resistance columns under Customary Unit, and multiplying by the factor 1/k (r/in.) and 1/C (R) for the appropriate conversion factor in Table 18.

| Description | Customary Unit Density (lb/ft³) | Conductivity (*k*) | Conductance (*C*) | Resistance[b] (*R*) Per inch thickness (1/*k*) | For thickness listed (1/*C*) | Specific Heat, Btu/(lb) (deg F) | SI Unit Resistance[b] (*R*) (m·K)/W | (m²·K)/W |
|---|---|---|---|---|---|---|---|---|
| **BUILDING BOARD** | | | | | | | | |
| **Boards, Panels, Subflooring, Sheathing** | | | | | | | | |
| **Woodboard Panel Products** | | | | | | | | |
| Asbestos-cement board | 120 | 4.0 | — | 0.25 | — | 0.24 | 1.73 | |
| Asbestos-cement board 0.125 in. | 120 | — | 33.00 | — | *0.03* | | | *0.005* |
| Asbestos-cement board 0.25 in. | 120 | — | 16.50 | — | *0.06* | | | *0.01* |
| Gypsum or plaster board 0.375 in. | 50 | — | 3.10 | — | *0.32* | 0.26 | | *0.06* |
| Gypsum or plaster board 0.5 in. | 50 | — | 2.22 | — | *0.45* | | | *0.08* |
| Gypsum or plaster board 0.625 in. | 50 | — | 1.78 | — | *0.56* | | | *0.10* |
| Plywood (Douglas Fir) | 34 | 0.80 | — | 1.25 | — | 0.29 | 8.66 | |
| Plywood (Douglas Fir) 0.25 in. | 34 | — | 3.20 | — | *0.31* | | | *0.05* |
| Plywood (Douglas Fir) 0.375 in. | 34 | — | 2.13 | — | *0.47* | | | *0.08* |
| Plywood (Douglas Fir) 0.5 in. | 34 | — | 1.60 | — | *0.62* | | | *0.11* |
| Plywood (Douglas Fir) 0.625 in. | 34 | — | 1.29 | — | *0.77* | | | *0.19* |

# ANALYSIS OF DOUBLE-DRAPED FENESTRATION CONFIGURATIONS

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In recent years there has been a great increase in the use of double drape arrangements, particularly in hotels and motels. Such arrangements are also used extensively in offices in commercial buildings and in apartments and private residences. Since this type of shading is not presently covered in the ASHRAE Guide or Handbook, some analysis of the arrangement should be made with a view to include significant information in future issues.

The common arrangement now in use is a heavy opaque roomside drape, usually boxed at the top and extending to the floor; and in some cases overlapping a considerable area of the wall. Often these drapes are lined, usually with a light colored reflective material. Some are sprayed with a coating on the windowside, and some have a thin layer of insulation. The inner drape, between the roomside drape and the window, is usually open weave to admit light, and light colored to increase reflectance; however, there is a wide variety of types used.

## *SELECTION OF FENESTRATION PARAMETERS*

The double drape arrangement affects two factors which are of significance; the "U" factor for the fenestration, and the shading coefficient. The "U" factor affects both heating and cooling load calculations, and will be discussed first.

The "U" factor is affected in that a second partially enclosed air space has been included in the barrier. A rough determination of the effect of this can be made by assuming that "U" = 0.81 for a single glass and drape combination as listed in the ASHRAE Fundamentals Handbook. Based on this, an air space conductance of 3.22, or resistance of 0.31 can be calculated. Using this value for the second air space, the overall "U" becomes 0.65. When it is considered that the double drape arrangement usually provides a much tighter air space than the conventional single drape or closed venetian blind, and that the drape itself is of dense heavy material, it seems that a lower air space coefficient would be justified. A totally enclosed air space between high emissivity surfaces would range from 1.00 to 1.20. Using an air space coefficient of 2.00 would seem to be appropriate for the usual installation. This would yield an overall "U" value of about 0.5 Btu/sq ft/hr F.

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The determination of shading coefficients for double drape arrangements, without conducting suitable tests, is somewhat more difficult. However, some approximations can be made by assuming drapes with various solar properties, and using the analysis procedure developed for insulating glass and drape arrangements, with suitable changes in air space conductance values. This method has a fallacy in that it assumes a convective as well as radiative exchange between the drape and glass. A more logical method is to assume that all heat picked up by the air circulating in the air space between the glass and drape is delivered to the indoor space. If the drape is at a higher temperature than the glass, which will normally be the case with clear glass, then most of the heat delivered to the glass by radiation will be delivered to the outside space. Solar heat delivered to the indoor space is then the transmitted heat, plus the heat absorbed in the roomside drape, plus the heat absorbed in the windowside drape, less heat radiated to the glass from this drape. It is necessary to determine glass and drape temperatures, and this can be done using an adaptation of the method illustrated in Example 5, Chap. 22 of the Handbook. It must be noted that the drape properties used are for the drape in place, and not flat fabric.

Several calculations were made to determine the relative effectiveness of single vs double drape arrangements for the solar heat control. For single drape arrangements, a Shading Coefficient can readily be determined by reference to Fig. 10 and Table 19 of Chap. 22 of the Handbook. As an example, a single drape with flat fabric properties $\tau = 0.03$, $\rho = 0.60$, $\alpha = 0.37$ in combination with clear glass would have a shading coefficient of 0.42. If a second drape having properties $\tau = 0.60$, $\rho = 0.30$, $\alpha = 0.10$ were placed between the first drape and window, the combination would have a Shading Coefficient (S.C.) of 0.45. If the second drape alone were used, the S.C. would be 0.65.

Fig. 10 and Table 19, Chap. 22 of the Handbook are based on drapes with double (100%) fullness, that is, the width of the drapery material is twice that of the window. If the material when stretched out is flat or almost flat, as is often the case with the heavier roomside drapes, a lower Shading Coefficient will result. In this case, using the roomside drape only, the Shading Coefficient would be 0.32.

## *FENESTRATION ANALYSIS*

In order to study the relative effectiveness of single vs double drape arrangements for solar heat control, it was necessary to set up a simplified model of several drape-glass combinations. Fig. 1 and 2 illustrate those "ray-type" models used for this analysis. It was assumed that one ray having an intensity of 250 Btuh/ft$^2$ impinges on the outside glass at some arbitrary angle. For the purpose of simplifying this study, angle effects on the solar properties of the materials were neglected. It would be possible, however, to include these effects in the analysis if it were necessary. It was further assumed that the energy impinging on the fenestration would be either reflected back into the environment, absorbed by the elements making up the fenestration, or transmitted into the interior space. The ray penetrating the outside glazing was followed through its many reflections, transmissions, and absorbtances until at least 99% of the incident ray intensity was considered.

The equations listed in Tables 1 and 2 are simplified versions of the equations describing the attenuation of each ray. These equations are derived in such a way as to greatly simplify calculating the portions of insolation being reflected, transmitted, and absorbed by the various fenestration elements. A discussion of a desk top computer application of these equations follows. With the results of this ray analysis, it is possible to calculate the temperatures of the glazing and drapes making up fenestration and to determine a shading coefficient which is based upon these calculated values.

## *CALCULATION PROCEDURE*

An iterative calculation was used to calculate the temperatures and shading coefficients for the single glass - double drape fenestrations. To initiate the calculations, an outside glass temperature ($t_{go}$) was selected and substituted into Eq. 1.

$$t_{s1} = \frac{h_a AT^3 + (h_i + h_a)AT^2 + h_i h_a t_i + h_a(h_i + h_a)t_{go}}{2h_a(h_i + h_a) - h_a^2} \tag{1}$$

The windowside drape temperature was calculated and substituted into Eq. 2.

$$\text{error} = h_o(t_{go} - t_i) + h_a(t_{go} - T_{s1}) - AT1 - \sigma\, F_a F_e A(T_{s1}^4 - T_{go}^4) \tag{2}$$

The trends in the error function were observed and corrections made to $t_{go}$. The value of $t_{s1}$ corresponding to the correct $t_{go}$ value was then substituted into Eq. 3 in order to calculate the Shading Coefficient.

$$\text{S.C.} = (TT3 + AT3 + AT2 - \sigma\, F_a F_e A[T_{s1}^4 - T_{go}^4])\frac{1}{I_{DN} T_{CS}} \tag{3}$$

The double glass - double drape analysis involved an additional equation. In this case an inside glass temperature ($t_{gi}$) was assumed. Eq. 4 and 5 were used to calculate the windowside drape temperature and an outside glass temperature. Eq. 6 was then used to check the assumed value. The trends of the error function with changes in $t_{gi}$ can be quickly recognized. When using the desk top calculator, very small errors were achieved in three to four trials. The correct $t_{gi}$ value was then substituted into Eq. 7 in order to calculate the shading coefficient.

$$ts_1 = \frac{h_a AT4 + AT3\ (h_i + h_a) + h_a h_i t_i + h_a(h_i + h_a)t_{gi}}{h_a(2h_i + h_a)} \tag{4}$$

$$t_{go} = \frac{AT_1 + h_o t_o + h_{as} t_{gi} + \sigma\, F_a F_e A(T_{si}^4 - T_{gi}^4)}{h_a + h_{as}} \tag{5}$$

$$h_{as}(t_{gi} - t_{go}) + h_a(t_{gi} - t_{s1}) - AT1 - \sigma F_aF_eA(T_{si}^4 - T_{gi}^4) = \text{error} \qquad (6)$$

$$\text{S.C.} + [TT4 + AT4 + AT3 - \sigma F_aF_eA(T_{s1}^4 - T_{gi}^4)]\frac{1}{I_{DN}T_{CS}} \qquad (7)$$

Example Problem - Analysis of a Single Glass - Double Drape Fenestration

Given:

| | $\tau$ | $\alpha$ | $\rho$ |
|---|---|---|---|
| glass properties | 0.47 | 0.48 | 0.05 |
| windowside drape | 0.54 | 0.235 | 0.225 |
| roomside drape | 0.03 | 0.37 | 0.60 |

Using the relations as given in Table 1, the following values were determined:

$RT1 = 36.26$ Btuh ft$^2$
$AT1 = 144.15$ Btuh ft$^2$
$AT2 = 38.54$ Btuh ft$^2$
$AT3 = 27.57$ Btuh ft$^2$
$TT3 = 2.23$ Btuh ft$^2$

A glass temperature was estimated and substituted into Eq. 1 along with the following values:

$h_a = 2.0$ Btuh ft$^2\cdot$F
$h_i = 1.5$ Btuh ft$^2\cdot$F
$t_i = 75$ F

An initial guess of $t_{go} = 110$ F yielded a value of $t_{s1} = 118.503$. This was substituted into Eq. 2 resulting in an error of -32.189. A second guess of $t_{go} = 120$ F yielded values for $t_{s1}$ and the error function of 125.503 and 17.38163 respectively. Subsequent guesses indicated that a glass temperature of 116.5 F yielded a very small error when substituted into Eq. 2. When the appropriate values were substituted into Eq. 3, a Shading Coefficient of 0.274 was obtained.

## *DISCUSSION OF RESULTS*

Since the function of the windowside drape is to admit light when needed, and to provide for outward vision, it will normally be an open-weave material with high transmittance. This will, in most cases, result in a higher Shading Coefficient with the two drapes acting together than with a high reflectance opaque drape acting alone. The difference may not be significant unless the windowside drape is one with high absorptance. In this case, the difference may be considerable. A different arrangement, placing the open weave drapery on the roomside of the heavy drape, has the advantages of maintaining the better Shading Coefficient provided by the light colored heavy drape or its lining. It still provides a second air space, and may be pulled over the window alone to reduce heat or glare, and to provide semi-privacy. An added advantage of either double drape arrangement is that it provides a better comfort condition through modifying the roomside drape temperature. This is true both for the summer and the winter condition. The roomside drape will be more nearly the temperature of the indoor space.

Table 3 contains the data input and the calculated results for fenestration configurations using single glazing and double draperies. An examination of the tabulated section headed 'Component Properties' shows that the windowside drape properties remain constant while the roomside drape properties are varied. Examination of the glass column shows that two types of glass were considered--heat absorbing glass, and quarter-inch clear plate. Examination of the roomside drape column shows that the drape was first considered in a flat configuration and subsequently as material with 100% fullness. All rows having an asterisk (*) beside the reflectance value for the roomside drape refer to the preceding material with 100% fullness. Examination of the shading coefficients associated with each set of input data reveals that the shading coefficient is always greater for fenestrations containing draperies with 100% fullness. This is to be expected since the effect of pleating a drapery tends to reduce its reflectivity. The range of shading coefficients calculated for the fenestration configurations considered varied from .274 to .500. The higher shading coefficient values are associated with the quarter-inch clear plate glass fenestrations while the lower shading coefficient values are associated with configurations with heat-absorbing glass. Examination of the values calculated for single plate heat absorbing glass in combination with double draperies indicates that they compare quite favorably to the shading coefficients which are obtained using updraped insulating panels with reflective coatings.

Table 4 contains the data associated with double drape - insulating glass fenestrations. Examination of the 'Component Properties' columns shows that heat-absorbing glass is sued for the outside plate while quarter-inch clear plate glass is used for the inside surface. Four different types of room side drapery material were considered in both the flat and 100% fullness configuration. An examination of the shading coefficients calculated reveals that only a slight decrease is produced through the addition of the extra plate of clear glass. The shading coefficients vary from .26 to .307. When these values are compared with comparable data lines in Table 3 the advantage of insulating glass panel over single glass glazing may be observed from the standpoint of shading coefficient reduction. Since quarter-inch clear glass plate has a low reflectance and a high transmittance value, it is evident that only a slight decrease in the shading coefficient should be expected. However, during periods of heating, the more favorable "U" value of the insulating glass panel becomes advantageous.

The foregoing is a very superficial discussion of double drape arrangements. It concerns itself only with a very limited selection of drapery materials, in combination with single clear glass, heat-absorbing glass, and insulating panel with heat-absorbing plate on the outside surface. It could be extended to include insulating tinted, or reflective glass types in combination with an endless variety of drapery materials. Caution should be observed in using high reflective drapes in combination with tinted or heat-absorbing glass. While draperies have a major effect in reducing solar heat gain through clear glass, they have only a minor effect in reducing this gain through reflective glass. Double drapes would be effective, however, in reducing winter heat loss through this as well as other glass types.

## *CONCLUSIONS AND RECOMMENDATIONS*

It is emphasized that this discussion is based on experience, assumptions, and theory, not all of which have been experimentally verified. A testing program with equipment which was once proposed by Mr. John Yellott would be in order. This consisted of a room with a window wall, fully controlled and instrumented, and pivoted to face in any direction. Devices such as the Solar Calorimeter and Guarded Hot Box at the University of Florida are not satisfactory for such testing, due to the limited window size and inadequate interior space.

The data contained in Tables 3 and 4 are representative of fenestration materials which are commonly used. An analysis of these data leads to the following conclusions:

1) Double drape arrangements offer extreme flexibility in providing for full entry of light and outward vision when desired, limited entry of light and outward vision, or almost complete elimination of light and of outward vision.

2) The lowered "U" factor with this arrangement provides for lower air-to-air heat gains in summer, and lower heat losses in winter. A "U" value of 0.5 seems reasonable for single glazed-double draped fenestrations.

3) Indoor comfort conditions are improved due to drape temperatures being more nearly that of the occupied space.

4) The double drape system may either raise or lower solar heat gains, depending upon the solar properties of the materials used, and the arrangement of the two draperies.

5) In the usual case, i.e., an opaque room side drape with high reflectance to the outdoor side, and an open weave drape on the windowside, the room side drape acting alone will provide a lower solar heat gain. This is particularly true if the window side drape is of dark material. If the open weave drapery is placed on the room side of the heavy or opaque drape, then the lower solar heat gain is not lost, and the advantages of the second drape are still attained.

6) Each combination of glass and drapery materials should be analyzed to determine the most economical operating condition.

7) The true performance of any arrangement can be determined only by tests and measurements. A set-up to do this would be fairly costly. However, it is the only method by which theoretical calculations can be verified.

8) After the foregoing analysis has been checked via experiment, desk top, programmable calculators can be used to provide accurate data when the properties of the fenestration components are known.

*NOMENCLATURE*

$U$ = Overall heat transfer coefficient for fenestration

$T$ = Transmittance property of glass or drapery

$\rho$ = Reflectance property of glass or drapery

$\alpha$ = Absorptance property of glass or drapery

S.C. = Shading Coefficient for fenestration

$t_{s1}$ = Windowside drapery temperature, F

$t_{s2}$ = Roomside drapery temperature, F

$t_{go}$ = Outside glass temperature, F

$t_{gi}$ = Inside glass temperature, F

$T_{gi}$ = Absolute temperature of inside glass, °R

$T_{ti}$ = Temperature of the indoor space, F

$T_{s1}$ = Absolute temperature of windowside drape, °R

$T_{go}$ = Absolute temperature of 1/8 in. clear plate glass

$T_{cs}$ = Transmittance of double strength, assumed to be 0.87

$F_a$ = View factor for radiation heat transfer

$F_e$ = Emittance factor for radiation heat transfer

$A$ = Area of heat exchange

$\sigma$ = Stefan Boltzmann constant

$I_{DN}$ = Insolation on fenestration

$h_a$ = Heat transfer coefficient for air space between draperies and glass surface

$h_i$ = Heat transfer coefficient for room side fenestration element

$h_{as}$ = Heat transfer coefficient for air space in the insulation glass

## *TABLE 1*
## *Symbol Identification for a Double Drape-Single Glass Fenestration*

$I_{DN} = 250$ Btuh ft$^2$
$A = I\rho_1$
$B = I\alpha_1$
$C = I\tau_1$
$D = C\alpha_2$
$E = C\tau_2$
$F = E\alpha_3$
$G = E\tau_3$
$H = C\rho_2$
$J = H\rho_1$
$K = H\alpha_1$
$L = H\tau_1$
$M = E\rho_3$
$N = M\alpha_2$
$O = M\rho_2$

$P = O\alpha_3$
$Q = O\tau_3$
$R = M\tau_2$
$S = R\rho_1$
$T = R\alpha_1$
$U = R\tau_1$
$V = O\rho_3$
$W = V\alpha_s$
$X = V\rho_2$
$Y = X\alpha_3$
$Z = X\tau_3$
$AA = V\tau_2$
$BB = (AA)\alpha_1$
$CC = (AA)\tau_1$
$DD = (AA)\rho_1$

$EE = J+S+(DD)$
$FF = (EE)\alpha_2$
$GG = (EE)\tau_2$
$JJ = (GG)\tau_3$
$HH = (GG)\alpha_3$
$KK = (GG)\rho_3$
$LL = (EE)\rho_2$
$MM = (LL)\tau_1$
$NN = (LL)\alpha_1$
$OO = (KK)\alpha_2$
$PP = (KK)\tau_2$
$QQ = (PP)\rho_1$
$RR = (PP)\alpha_1$
$SS = (PP)\tau_1$

## Summation Equations for Identification for Double Drape-Single Glass Fenestration

$RT1 = A+L+U+(CC)+(NN)+(SS)$
$AT1 = B+K+T+(BB)+(MM)+(RR)$
$AT2 = D+N+W+(FF)+(OO)$
$AT3 = F+P+Y+(HH)$
$TT3 = G+Q+Z+(JJ)$

## *TABLE 2*

### *Symbol Identification for a Double Drape-Insulation Glass Fenestration*

$I_{DN}$ = 250 Btuh $ft^2$
A = I ($\rho 1$)
B = I ($\alpha 1$)
C = I ($\tau 1$)
D = C ($\alpha 2$)
E = C ($\tau 2$)
F = E ($\alpha 3$)
G = E ($\tau 3$)
H = G ($\alpha 4$)
J = G ($\tau 4$)
K = C ($\rho 2$)
L = K ($\rho 1$)
M = K ($\alpha 1$)
N = K ($\tau 1$)
O = E ($\rho 3$)
P = O ($\rho 2$)
Q = O ($\alpha 2$)
R = O ($\tau 2$)
S = R ($\rho 1$)
T = R ($\alpha 1$)
U = R ($\tau 1$)
V = G ($\rho 4$)
W = V ($\rho 3$)

X = V ($\alpha 3$)
Y = V ($\tau 3$)
Z = Y ($\rho 2$)
A1 = Y ($\alpha 2$)
B1 = Y ($\tau 2$)
C1 = B1 ($\rho 1$)
D1 = B1 ($\alpha 1$)
E1 = B1 ($\tau 1$)
F1 = W ($\tau 4$)
G1 = W ($\alpha 4$)
H1 = W ($\rho 4$)
J1 = H1 ($\rho 3$)
K1 = H1 ($\alpha 3$)
L1 = H1 ($\tau 3$)
M1 = L1 ($\rho 2$)
N1 = L1 ($\alpha 2$)
O1 = L1 ($\tau 2$)
P1 = O1 ($\rho 1$)
Q1 = O1 ($\alpha 1$)
R1 = O1 ($\tau 1$)
S1 = L+S+(C1) + (P1)
T1 = S1 ($\alpha 2$)
U1 = S1 ($\tau 2$)

V1 = U1 ($\alpha 3$)
W1 = U1 ($\tau 3$)
X1 = W1 ($\alpha 4$)
Y1 = W1 ($\tau 4$)
Z1 = S1 ($\rho 2$)
A2 = Z1 ($\rho 1$)
B2 = Z1 ($\alpha 1$)
C2 = Z1 ($\tau 1$)
D2 = V1 ($\rho 3$)
E2 = D2 ($\alpha 2$)
F2 = D2 ($\rho 2$)
G2 = D2 ($\tau 2$)
H2 = G2 ($\rho 1$)
J2 = G2 ($\alpha 1$)
K2 = G2 ($\tau 1$)
L2 = W1 ($\rho 4$)
M2 = L2 ($\rho 3$)
N2 = L2 ($\alpha 3$)
O2 = L2 ($\tau 3$)
P2 = O2 ($\rho 2$)
Q2 = O2 ($\alpha 2$)
R2 = O2 ($\tau 2$)
S2 = R2 ($\rho 1$)
T2 = R2 ($\alpha 1$)

U2 = R2 ( 1)
V2 = (F2) + (P2) +P+Z+ (M1)
W2 = V2 ($\tau 3$)
X2 = W2 ($\alpha 4$)
Y2 = W2 ($\tau 4$)
Z2 = V2 ($\rho 3$)
A3 = V2 ($\alpha 3$)
A4 = Z2 ($\rho 2$)
B3 = Z2 ($\alpha 2$)
C3 = Z2 ($\tau 2$)
D3 = C3 ($\rho 1$)
E3 = C3 ($\alpha 1$)
F3 = C3 ($\tau 1$)
G3 = W2 ($\rho 4$)
H3 = G3 ($\rho 3$)
J3 = G3 ($\alpha 3$)
K3 = G3 ($\tau 3$)
L3 = K3 ($\rho 2$)
M3 = K3 ($\alpha 2$)
N3 = K3 ($\tau 2$)
O3 = N3 ($\rho 1$)
P3 = N3 ($\alpha 1$)
Q3 = N3 ($\tau 1$)

RT1 = A+N+U+(E1)+(R1)+(C2)+(K2)+(U2)+(F3)+(Q3)

AT1 = B+M+T+(D1)+(Q1)+(B2)+(J2)+(T2)+(E3)+(P3)

AT2 = D+Q+(A1)+(N1)+(T1)+(E2)+(Q2)+(B3)+(M3)

AT3 = F+X+(K1)+(V1)+(N2)+(A3)+(J3)

TT4 = J+(F1)+(Y1)+(Y2)

# TABLE 4

*Shading Coefficients and Properties of*
*Double Drape - Insulation Glass Fenestrations*

| Component Properties | | | | | | | | | | | | Calculated Effective Properties | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outside Glass | | | Inside Glass | | | Windowside Drape | | | Roomside Drape | | | Note: Values Listed Assume $I_{DN}$=250 Btuh/sq. ft. | | | | | | |
| $\tau_1$ | $\alpha_1$ | $\rho_1$ | $\tau_2$ | $\alpha_2$ | $\rho_2$ | $\tau_3$ | $\alpha_3$ | $\rho_3$ | $\tau_4$ | $\alpha_4$ | $\rho_4$ | RT1 | AT1 | AT2 | AT3 | AT4 | TT4 | S.C. |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .03 | .37 | .60 | 32.07 | 39.99 | 20.94 | 31.59 | 22.20 | 1.80 | 0.260 |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .03 | .52 | .45* | 30.01 | 137.88 | 20.21 | 29.14 | 30.17 | 1.74 | 0.282 |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .20 | .20 | .60 | 32.07 | 39.99 | 20.94 | 31.59 | 12.00 | 12.00 | 0.266 |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .18 | .37 | .45* | 30.01 | 137.88 | 20.21 | 29.14 | 21.46 | 10.44 | 0.287 |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .03 | .57 | .40 | 29.35 | 137.21 | 19.97 | 28.46 | 32.79 | 1.72 | 0.288 |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .03 | .67 | .30* | 28.07 | 135.90 | 19.51 | 26.84 | 37.54 | 1.68 | 0.302 |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .20 | .40 | .40 | 29.35 | 137.21 | 19.47 | 28.46 | 23.04 | 11.57 | 0.294 |
| .47 | .48 | .05 | .80 | .13 | .07 | .54 | .235 | .225 | .18 | .52 | .30* | 28.07 | 135.90 | 19.51 | 26.84 | 29.13 | 10.85 | 0.307 |

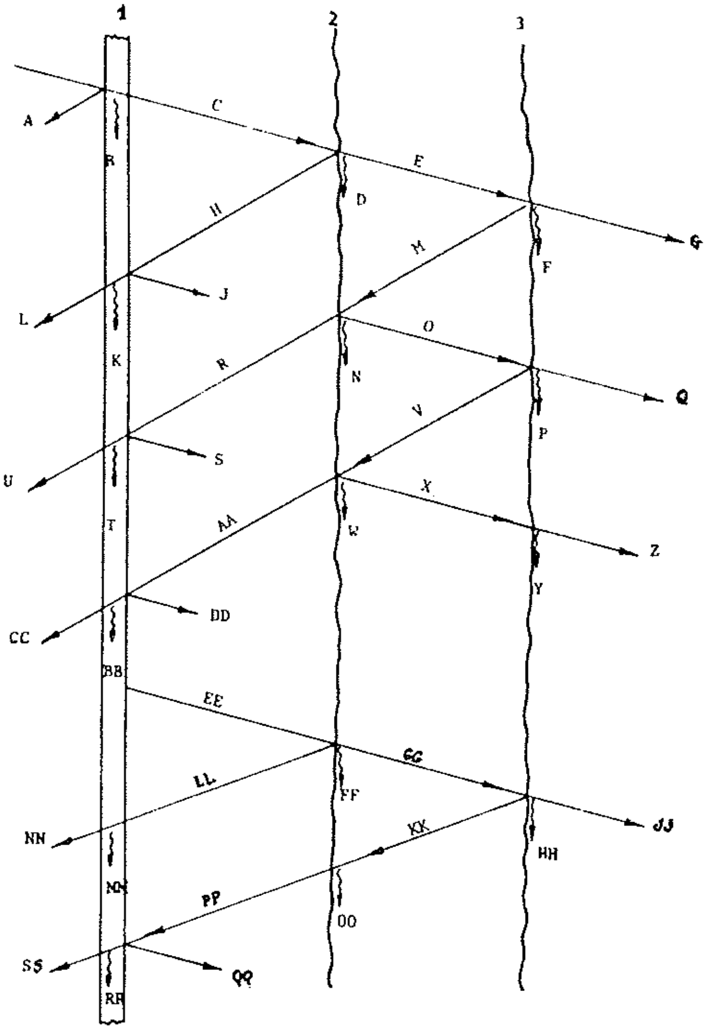

Fig. 1 Schematic drawing of double drape - single glass fenestration

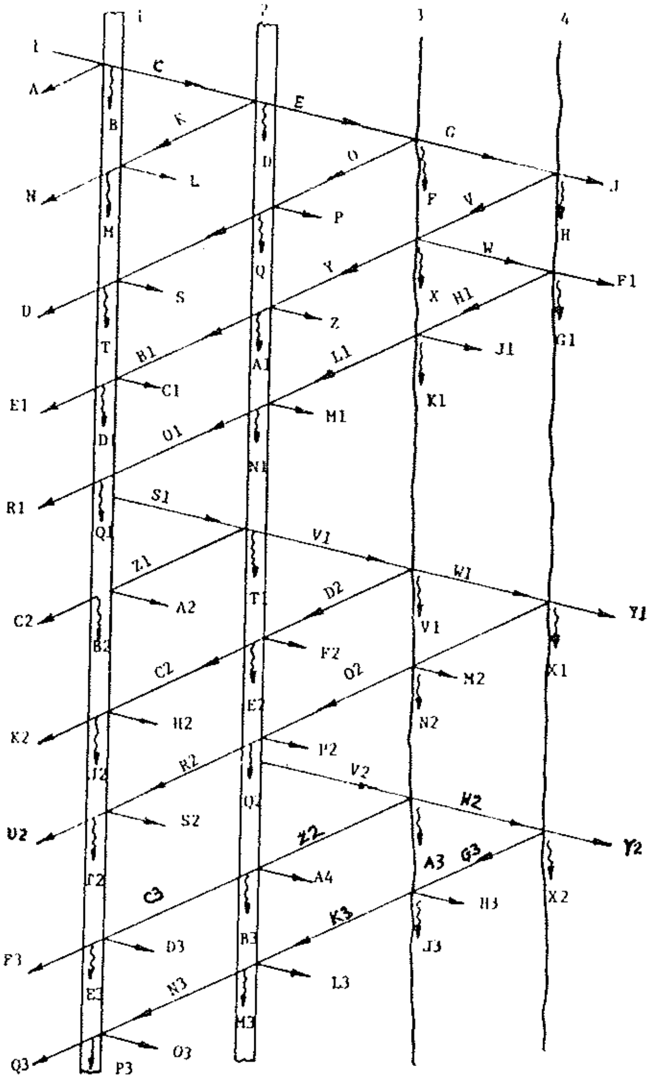

Fig. 2 Schematic drawing of double drape - insulation glass fenestration