Improving Glass Walls Thermal Resistance in Air–Conditioned Buildings

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ABSTRACT

The solar radiation through an air conditioned building depends on what is called the building envelope. Building envelope consists of the surfaces that separate the inside from the building outdoors. Area, direction, and specifications of glass walls; as one of envelope surfaces; has an important impact on solar radiation. Design and construction of glass walls have significant effects on building comfort and energy consumption. This paper describes methods of improving glass walls thermal resistance in air conditioned buildings. Effect of glass wall radiation temperature on the indoor temperature distribution of building rooms is also investigated. Heat gain through various types of glass is discussed. Optimization and testing of these types are carried out theoretically and experimentally as well. A series of experiments on different types of glass with special strips is performed.

Keywords: Glass, Solar radiation, Human Comfort, Air conditioning buildings

1. INTRODUCTION

In modern office buildings large areas of glass are used to give an even distribution of light The load, thus calculated, constitutes total sensible load. Normal practice is that, depending on the building type, certain percent of it is added to take care of latent load. Applying the laws of heat transfer and solar radiation makes load estimations. Step by step calculation procedure has been adequately reported in the literature [1-4]. It is a scientific and exact approach, but time consuming and lengthy. Overall heat transfer coefficients for all the components of building envelope are computed with the help of thermal properties of the building materials. For the design conditions and the building materials used, cooling load temperature difference, solar heat gain factors and cooling load factors are calculated. The low Energy loss glass can be manufactured by normal glass types with extremely thin special film layers as metallic oxide. The glass permits light to pass through but reflects off heat. This allows outside temperatures whether too hot or too cold to be kept out and inside climate control measures to be better retained. Low-E glass acts like a "sunscreen" by blocking ultraviolet rays. The best location for and, in the case of large open-plan offices, to give workers an uninterrupted view and a sense of contact with the outside world. Such large window areas have, however, created problems. Intense sunlight causes overheating in these offices, necessitating extensive air-conditioning. Glass is extensively used in building construction such as in doors and windows for architectural features and interior decorations. It is used as a physical barrier between exterior and interior without obstructing visibility. Foamed or cellular glass is used for vapor proof insulation and span form glass fibers are used as acoustic and thermal insulation. Ordinary window glass is almost completely transparent to radiation extending from the ultraviolet to the infra-red. This range represents the spectrum of solar radiation received at the earth's surface. The distribution of solar spectral energy is dependent partly on the height of the sun, and partly on the moisture concentration and the amount of dust in the atmosphere. Basically, half of all solar radiation is infra-red, lying outside the visible range. Building cooling load components are; direct solar radiation, transmission load, ventilation/infiltration load and internal load. Calculating all these loads individually and adding them up gives the estimate of total cooling load.

your sunroom depends in the area you live in and what exactly you going to be using your sunroom for. A northern exposure will allow lower level and be partially shaded most of the day. Depending in the area you live in a heating system may be required. But if you live in the south, this is good for the hot season. A southern exposure allows the most sunlight in, which is best if you live in the north. However, in the south it can get hot requiring a cooling system. An eastern exposure provides just enough sun in the morning and shade in the afternoon. *What options can be added to a sunroom for climate control?* The skylights can be added if your roof is a solid roof not all glass. Skylights provide an extra amount of light and airiness. Simply because they are opened directly to the sky, they allow nearly twice as much light to enter the room as regular windows. Also, the window glass should be designed to give protection from sunlight must conform to various requirements of light transmission. For example, in large open-plan offices with floor-to-ceiling glazing, the use of normal double-glazing with 80

% light transmission has little point; the window area would be too bright by comparison with the artificially lit area at the back of the room. On the Continent, in such cases, glass windows with a 30 to 40 per cent transparency are used; in the Kuwait the transparency used is much lower, from 10 to 20 per cent to prevent heat loss at very hot days in summer. This study directly investigates the methods of improving wall glass thermal resistance in air conditioned buildings. The study was carried out analytically and experimentally. Different types of efficient glass types were studied with using building simulator.

2. GLASS COATING FILMS TECHNIQUES

Effective sun-insulating glass for medium light transmission can be produced by a single gold deposit. Light transmission (as compared with the sensitivity to light of the human eye) is 40% and total energy transmission 26 %. This will combine with the structural lines of the building to give better proportions and give the architect greater scope in the design of the facade than can be achieved with a paler shade of gold. So the problem is one of changing the optical properties of the gold film in such a way as to retain high heat-reflectivity while greatly reducing visible reflectivity and increasing transmission, rendering it achromatic. The method used is closely related to the well known process of reducing the reflectivity of glass surfaces used for instance in photographic apparatus and the blooming of instrument lenses. By applying thin dielectric films with a suitable refractive index and thickness, the reflected light rays at the surface and the interface of this additional film can be obtained with almost similar amplitudes. The high reflectivity of gold film at long wavelengths is caused by the high electrical conductivity of the metal and this, in turn, by the number and mobility - . of its free s-electrons. A necessary condition is that "the gold film is not made up of isolated "islands" but that it is homogeneous and continuous. Methods of applying gold by firing on to the glass often do not produce continuous films, whereas vacuum-evaporated or vacuum-sputtered coatings on suitable substrates produce very low surface resistances of a few ohms per square with a 30 to 40 per cent transparency. By combining gold films with interference layers for sun-insulating glass, new applications have been developed, particularly in cases where high light transmission is needed. This is to a large extent governed by the greater heat caused by the higher light transmission engendered by solar radiation in the visible range. Looked at from outside, the typical gold effect is lost because of the anti reflection effect of the interference layers; instead, they have a slightly blue appearance. The illustration on page 65 shows a building glazed with this type of glass. In recent years developments in sun-insulating glass have tended to extend the color palette so as to give architects more scope in designing the office air conditioned buildings. Plate glass with varying shades of blue, gold or bronze, when looked at from the outside, is available. In all these cases the gold film is the actual selective filter element. Various technical values and different colors are obtained by a combination of the gold film with interference layers and alloy layers and the selection of the appropriate film thicknesses, (Rolf G. 2007). Double-glazing treated with a gold coating film is better solution for decreasing energy loss in building, especially the part from that of protection from solar radiation. Its heat transfer value is much lower than that of normal double-glazing. This means that in summer, with low very high outdoor temperatures, cooling energy can be reduced by about 40-50 % approximately.

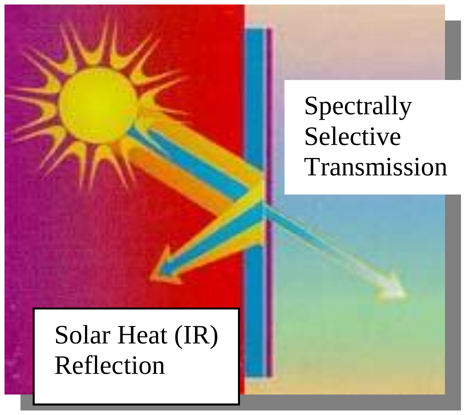

Figure 1. Preferred Solar Control insulation Film

In this range of wave lengths, transparent gold films possess very high reflectivity. Figure 2 shows as an example the spectral reflectivity of a gold interference coating system on the side of the glass exposed to the atmosphere. In the visible range, reflectivity-including the effect of the interference layer-is very low and transmission correspondingly high (light transmission of the corresponding insulating glass pane 66 per cent). In the near infra-red range, reflectivity increases steeply, reaching more than 96 per cent in the 4 pm wave length region. This corresponds to an emission figure of 0.04 compared with c=0.84 for non-layered window glass. The heat-reflecting film is applied to the inner surface of the glass which is on the outer wall of the building, and is thus protected from mechanical damage. The performance of this type of sun-insulating glass is best shown by an energy saving. This shows how much of the effective total solar radiation is directly reflected (solar reflection) and how much is transmitted (solar transmission).

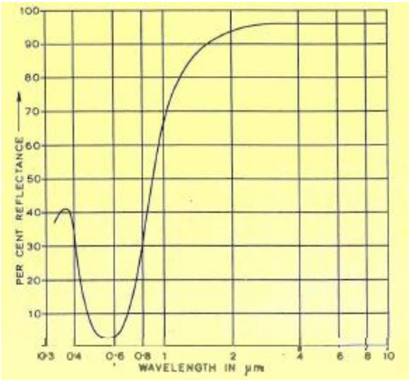

Figure 2 Shows an example of the spectral reflectivity of gold interference coating system on the side of the glass (Rolf G. 2007)

This coating reduces the heat exchange between the two window panes to almost nil, with a considerable increase in the heat resistance of the air space and a corresponding improvement in the heat loss. In all, heat loss, 2.6 kcal/m^{2}h^{o}C for normal double glazing with an air space of 12 mm is reduced to 1.5 kcal/m^{2}h^{o}C. The degree of heat insulation resulting from the film is approximately equivalent to that given by a 30 cm thick wall of polished brick or tiles.

3. EXPERIMENTAL SET UP

A series of experiments on different types of efficient glass was tested in the simulation heating system. A different temperature was measured on the system. Fig 3. shows the experimental set up system used in the test the glass types. As shown the test rig was consisted of an insulated metal box from all faces, the dimensions of box is 40 cm x 40cm x 40 cm. The box was prepared by hall from one side to install the glass test part (specimen). The test rig was consists of heating source to simulate different ambient temperature in the room.

Figure 3. Shows Test Rig Used in the Study

Different temperature was measured with using low temperature copper/constantan thermocouples. There are five temperature were measured as: inner room temperature (Ti), surface inner glass (Tgi), surface outer glass (Tgo), outer room temperature (To) and the ambient temperature (To). It was using digital temperature indicator to read the temperature. The reading was recorded for 2 hrs for different types of glasses. Multi-point selection switch was used to select different temperatures.

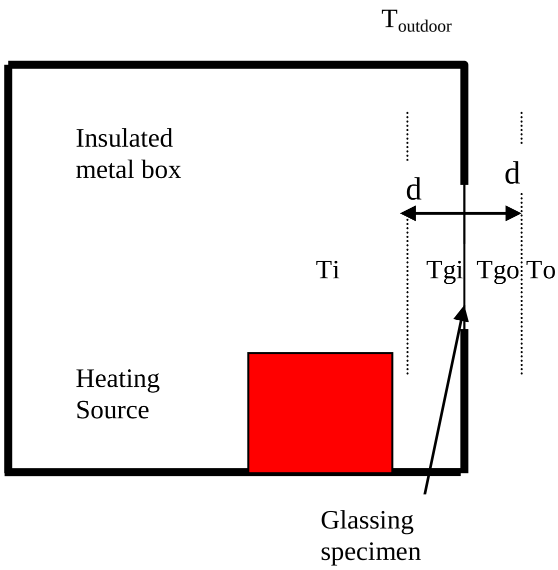

Figure 4. shows the test rig used in the study.

It was used a HOBO's (shown in Fig. 5), Smart Sensors, for measuring solar radiation in and out the box (test rig). This Micro Station Data Logger can make up to 500,000 measurements of solar radiation in W/m^2. Launched from a computer, it can be placed on windows or in the open to read the solar radiation transmitted.

Figure 5. HOBO Micro Station Data Logge (also known as Pyranometer)

This sensor is very considered proper sensitive for measuring small values of solar radiation in small test rig; it was used to measure solar radiation through different types of commercial efficient glass which test in the glass. In very hot climates, the solar radiation takes a big part from the cooling load through buildings. The solar heat gain through glazing system can be simulated as following flow chart:

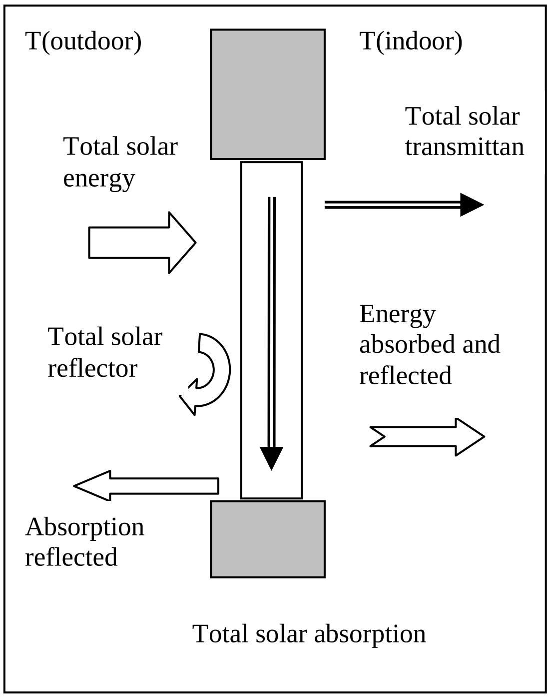

Figure 6. Shows Flow Chart of Solar Heat through Glass

The different solar heat gains were estimated experimentally for most types of glasses. Figure 7 shows of data determined for solar radiation heat gains rations in glass of K-80 (4mm).

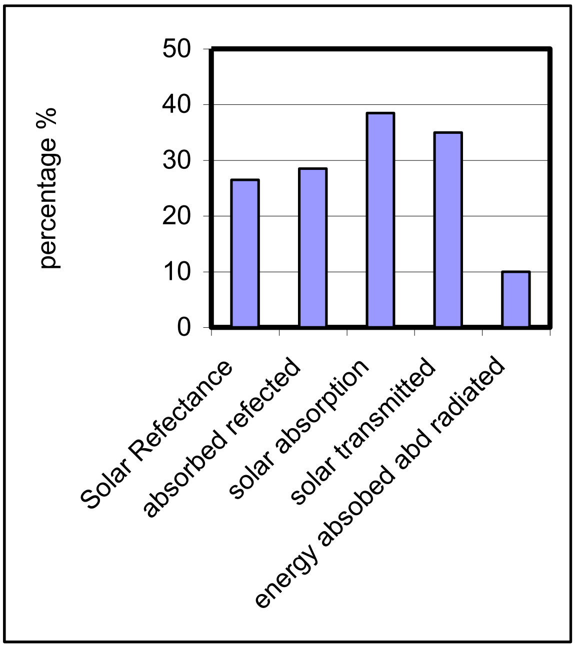

Figure 7. Shows the Percentage Solar Radiation through Film Coating using Glass K-70 type

These values were compared with 4 mm normal clear glass. It sis shown that the total solar heat reduced reached 45%. The efficiency of glass is 1.37, the shading coefficient is reached 0.45, and the U-factor for this glass is 0.94 W/m^2K. so this type of efficient glass can reduce solar energy transmitted to building with 45%.

4. MAIN PERFOMANCE EQUATIONS

The rigorous approach to the calculation of the space cooling load consists of (1) finding the inside surface temperatures of the building structures that enclose the conditioned space due to heat balance at time *t* and (2) calculating the sum of the convective heats transferred from these surfaces as well as from the occupants, lights, appliances, and equipment in the conditioned space at time *t*. The inside surface temperature of each surface $T_{i,t}$, in °C, can be found from the following simultaneous heat balance equations:

$$q_{i,t} = \left[h_{ci}(T_{r,t} - T_{i,t}) + \sum_{j=1}^{m} g_{ij}(T_{j,t} - T_{i,t}) \right] A_i + S_{i,t} + L_{i,t} + P_{i,t} + E_{i,t} \qquad (2)$$

Where

h_{ci}: convective heat transfer coefficient, $kW/m^2.°K$

g_{ij} : radioactive heat transfer factor between inside surface i and inside surface *j*,

$T_{r,t}$: space air temperature at time *t*, °C

$T_{i,t}$, $T_{j,t}$: average temperature of inside surfaces *i* and *j* at time *t*, °F
A_i : area of inside surface *i*, m^2
$S_{i,t}$, $L_{i,t}$, $P_{i,t}$, $E_{i,t}$: solar radiation transmitted through windows and radiative heat from lights, occupants, and equipment absorbed by inside surface *i* at time *t*, kW

In Eq. (1), $q_{i,t}$, in kW, is the conductive heat that comes to surface *i* at time *t* because of the temperature excitation on the outer opposite surface of *i*. This conductive heat can be found by solving the partial differential equations or by numerical solutions. The number of inside surfaces *i* is usually equal to 6, and surface *i* is different from *j* so that radiative exchange can proceed. *qi,t* could also be expressed in Btu/min or even Btu/sec. Radiant energy from the sun spaces transparent materials such as glass and becomes a heat gain to the room. Its value varies with time, orientation, shading, and storage effect. The solar cooling load can be found from the following equation:

$$Q = SHGF \times A \times SC \times CLF \qquad (2)$$

Where
Q : solar radiation cooling load for glass, kW
SHGF: maximum solar heat gain factor, kW/m^2
A : area of glass, m^2.
SC: shading coefficient
CLF: cooling load factor for glass.

Actually, the maximum solar heat gain factor (SHGF) is the maximum solar heat gain through single clear glass at a given month, orientation, and latitude. The values for the SHGF is depends on the site of building and the direct solar radiation – when the sun shines on the glass. External shading from building projections may shade all or part of the glass. In the cases, only an indirect radiation reaches the glass from the sky and ground. The SHGF values for any shaded glass are the same as the N (north) side of the building, which also receives only indirect radiation. The heat that flows from interior unconditioned spaces to the conditioned space through glass windows can be estimated from Eq. (3):

$$Q = U \times A \times \Delta T \qquad (3)$$

Where
Q: heat gain by glass, kW.
U: overall heat transfer coefficient for glass, kW/m^2K.
A: area of structure, m^2.
ΔT: temperature difference between two sides of glass, ^oC

The glass overall coefficient depends on the thickness, conductivity, of glass coating materials layers. The U-factor can be calculated from:

$$U = \frac{1}{\frac{1}{h_i} + \frac{L}{K} + \frac{1}{h_o}} = \frac{1}{R} \qquad (4)$$

Where
hi, ho are indoor and outdoor heat transfer coefficients, k glass conductivity, and R is the thermal resistance of window glass. The energy saving ratio can be calculated with using the following simple Eq. 5:

$$\Delta E = \sum \begin{bmatrix} 0.001\ .(SGHF\ .\Delta SC\ . \\ +\Delta U.\Delta T.t).S \end{bmatrix} \qquad (5)$$

Where: ΔE is reduction of solar heat admission, SHGF is local solar radiation value, ΔU is difference in U factor, ΔT is the temperature difference, daily solar time, and S is glass area at each orientation.

5. RESULTS & DISCUSSION

A series of experiments was carried out on the different commercial glasses types in market of Kuwait. The measurement depends on the fixing indoor temperature at 21 ^oC. The sample of results was shown in the following Fig. the results was compared with 4 mm clear glass. With Bf = 1. In the simulated test rig the time is neglected because it using heating source as instead of sun. also it is assumed that every kW reduction of solar heat gain can save at 1 kW of cooling electricity. A normal double glazing unit with the usual 12 mm air space has a heat loss of 2.6 $kcal/m^2h^oC$ compared with 5 $kcal/m^2\ h^oC$ for single glazing. This improvement is due to the additional heat insulation of the enclosed air space. Heat transfer between the colder outer pane and the inner pane is due first to the thermal conductivity of the air space with additional convection and secondly to the radiation exchange between the two panes of glass. The radiation exchange with an air gap of 12 mm is about double that of the figure of thermal conductivity and convection.

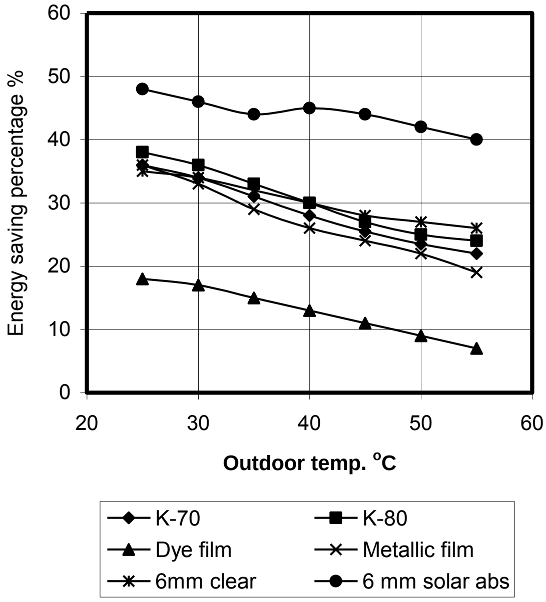

Figure 8 : shows the Energy saving percentages for different commercial glasses

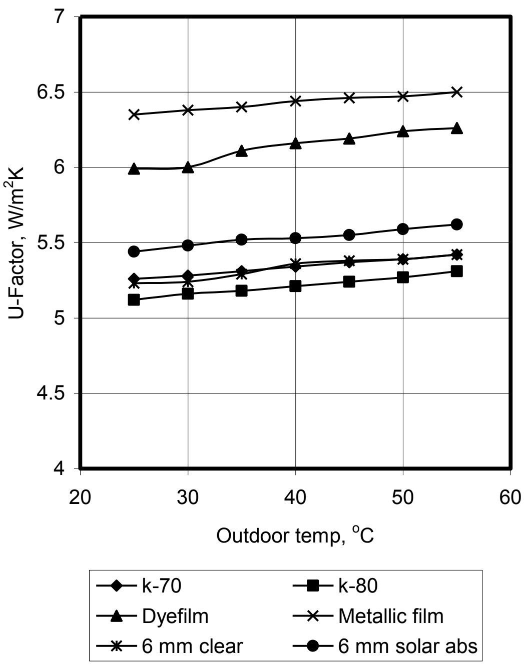

Figure. 9: shows the overall heat transfer coefficients with outdoor temperatures for different efficient of glasses

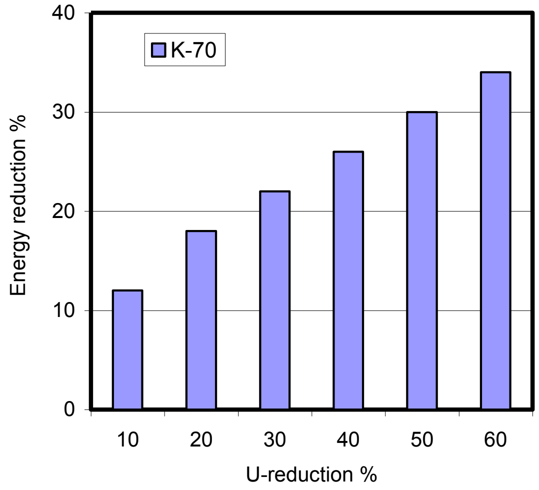

Figure. 10. Shows energy reduction rate with U-reduction percentage for glass K-70.

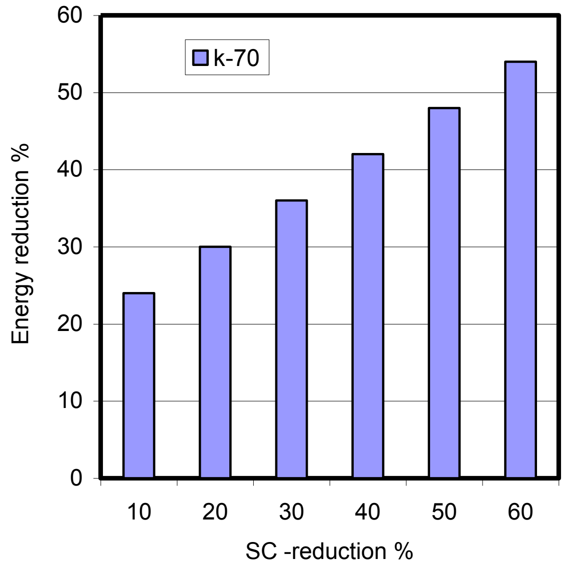

Figure 11. Shows the effect of decreasing shading coefficient of the energy reduction.

The glass window efficiency is defined as the ratio of visible light to the total transmitted solar energy, so :

η_G= Tvit / SC
where, Tvit is the visible light, and SC is shading coefficient.

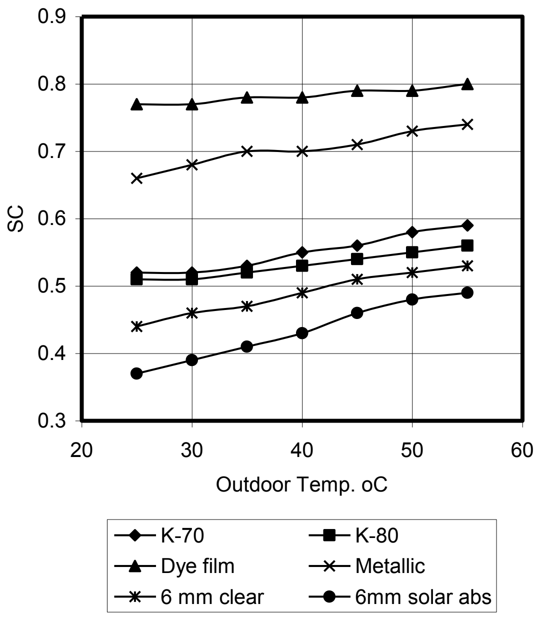

Figure 12. shows the shading coefficient (SC) with outdoor temperatures for different types og glasses. For effective lighting through a sun-insulating glass, a high degree of opacity will be required in this area of infra-red radiation. Attenuation of infrared radiation must take place mainly by reflection and not by absorption, as the absorption of solar radiation leads to heating of the glass, which at a high temperature will transfer a considerable amount of the absorbed solar radiation into the room by convection and long-wave secondary radiation. Then there is the secondary heat emission of the glass by convection and long-wave temperature radiation outwards and inwards, depending on the rise in temperature of the glass produced by the amount of solar radiation absorbed. The total amount of heat reaching the interior of the room (total energy transmission) is therefore the sum of the solar transmission and the secondary emission into the room. Obviously the transparency of the glass (in relation to the sensitivity to light of the human eye) is also important. It is usual to give both figures in the form of a coefficient, transparency1 energy transmission. The figures shown in the energy diagram of Figure **2** relate to double-glazing with semi-transparent gold applied to a single glass pane. The interference layers increase transmission in the visible range considerably. Transmission is increased from 40-60% which is only 15% less than that of a clear glass double-glazing unit (80% per cent). In the infra-red range, on the other hand, the reflectivity of the gold film is largely retained. That the reflectivity values differ somewhat for wavelengths of about 2pm for which the effect of the interference layering is almost nil is due to the fact that the thickness of the gold films is somewhat different in these products. By its very nature, the total energy transmission, 45% of the type with the interference layer, is higher than in the type with the single gold film.

6. CONCLUSION

This experimentation on the using V-KOOL glazing film types shows that the applying special glazing films on its windows would significantly reduce the solar radiation which enters the tugboat, and therefore, not surprisingly, lower the temperature of its cabin. This results in cabin crew enjoying greater comfort while working in the open sea on a hot day. If the air-conditioning system of the tugboat runs on a thermostat, then there would be energy and financial savings resulting from the use of V-KOOL film. The better glassing leads to more energy effective glazing. Towards energy saving glazing in hot climate, it should be select glazing of lower shading coefficient, lower U-factor, higher visible light transmission, higher efficiency and lower visible light reflectance.

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