# KELLY COLOR THERM SYSTEM

Tinting System based on COOL technology

## 1 THE PROBLEM OF DARK COLORS

It's well known that a black or dark object exposed to the sun's rays warms more than a white or light-colored one, which tends to remain colder. This is due to the interaction between the object surface and the infrared component of solar radiation. When solar radiation strikes the object and is absorbed, it is transformed into heat.

Dark surfaces, whether they are facades or roofs, tend then to heat more easily than clear ones and with them the entire housing. The darker the color tone, the higher the thermal stress that the surface undergoes; for the gray tints and shades of black the accumulation of heat can reach temperatures over 80 ° C.

Consequently, the building as a whole increases in temperature. This creates discomfort for those who live in the house and worsens indoor environmental quality. It increases the energy consumption for the increased use of air conditioning systems.

If we add to these energy efficiency issues those linked to the nature of the materials exposed to heat, such as stress and temperature changes, we can easily guess that the most exposed dark surfaces like facades and / or roofing can give, in medium to long term, problems of degradation even structural.

It should also be considered that the dark facades are the most affected by the ravages of time; deterioration caused by sun, rain, condensation and pollutants is more evident on darker colors than on the light areas.

In the energy balance of the building a key role is played by its thermal properties and in particular by its heat reflection capacity. The greater the degree of thermal reflection of the materials used, the more rapid will be the surface dissipation of heat.

As a consequence, it appears evident that the natural aging process of the dark surfaces may be limited and / or slowed down thanks to the use of dyes able to counteract the action of solar radiation.

The tinting system "KELLY COLOR THERM SYSTEM" is an innovative mixing system integrated with COOL technology that allows you to create thick coatings and colorful paints, even in the darkest tones, capable of avoiding the overheating of interiors.

The pigment dispersions, which constitute the backbone of the system, have been developed studying the characteristics of the solar light in order to obtain external dyes capable of reducing the heating of dark shades.

The color is not to be considered as merely a matter of aesthetic and decorative order: it involves technical, structural and building protection aspects.

## 2 SOLAR RADIATION AND INFRARED COMPONENT (IR)

Solar radiation is one of the meteorological parameters responsible for the degradation of the coating used for the protection of buildings. The study of solar radiation allows to understand how to design coatings able to resist to it, and therefore to protect the walls.

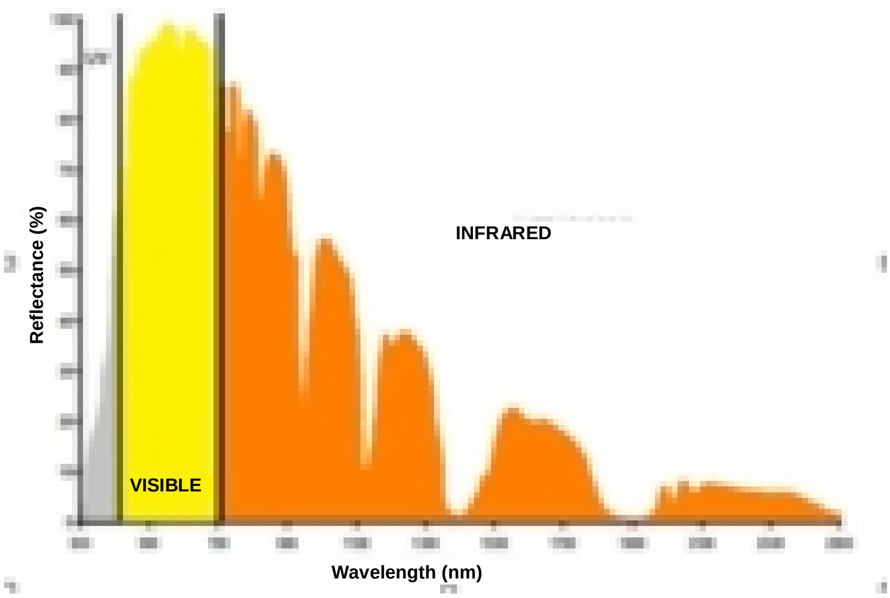
The solar radiation that reaches the earth is divided into three main components (ref. Picture 1) characterized by different wavelengths and different energy levels:

**Ultraviolet radiation (295-400 nm).** It represents about 5% of solar energy. Ultraviolet radiation (UV-A and UV-B) is responsible for the degradation of the resins (organic polymers) present in the painted products in that their energy level is sufficient to break the chemical bonds of the polymers.

**Visible radiation (400-700 nm).** It represents about 50% of solar energy and it is the component that allows the display of colors. If an object reflects all the wavelengths its color is white, while if it absorbs all visible wavelengths its color is black. At last, if it absorbs certain wavelengths and it reflects others, the object appears colored.

**Infrared radiation (700-2500 nm).** It represents about 45% of solar energy. Infrared rays are the electromagnetic waves with the lowest frequency corresponding to the red color and they are the most responsible for the production of heat. Their wavelength coincides with the transmission of heat. The sensation we feel when we expose ourselves to the sun has to do with our perception of infrared sunlight.
Infrared radiation is the main responsible for the degradation phenomena of the surfaces related to excessive heating; for example, thermal changes produce mechanical stresses (eg. Cracks) and the increase of the interior temperature.

The visible component is probably the most important for life on earth, but the infrared radiation is also crucial, as it is responsible for heat.




Picture 1 - Spectrum of sunlight

## 3 HEAT TRANSFER

Heat is defined as the energy transferred from one system to another due to the temperature difference between them. The heat is transferred spontaneously from higher temperature environments to lower temperature ones; the phenomenon ceases when the two environments reach the same temperature, intermediate if compared with the initial ones.

Heat can be transmitted in three ways: conduction, convection and radiation.

*Conduction* – It is the mode of transmission of heat arising from the difference in temperature between two parts of a body in contact with each other without any transport of matter. The conduction is caused by the transfer of energy from one body to the other, which causes the increase of the energy level. The parameter that measures conduction is thermal conductivity ($\lambda$)

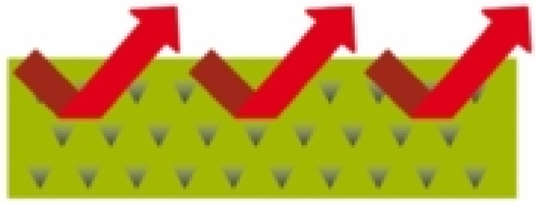
*Convection* – It is the heat transmission mode peculiar of fluids. It happens because of the movement of matter. An example of convection is that of hot air that moving in an environment; the air moves transporting energy and therefore heat ($\alpha$).

*Radiation* – It is the heat transfer that occurs between two bodies at different temperatures without a direct contact between the two materials. The transmission of heat, in this case, takes place thanks to electromagnetic waves, such as those of solar light, which are transmitted even in a vacuum. The parameter that characterizes it is the emissivity of the radiating body ($\varepsilon$).

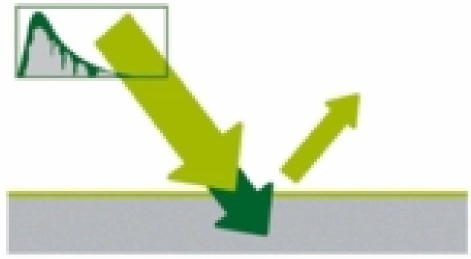
It is possible to control the movement of heat using materials with specific thermal characteristics. The heat flow is proportional to the temperature difference between two environments and inversely proportional to the thermal resistance of the material interposed between them.
In summer, when a building is surrounded by heat, you need to mitigate and dissipate this energy. To enhance the comfort of the interiors, it is better to have reflective facades and shells with high emissivity to reduce the heat load and cool surfaces.
The use of coatings and paints colored with "KELLY COLOR THERM SYSTEM" reduces heat absorption during the hottest hours of the day so that the temperature of the walls is kept low and the accumulated heat can be released easily during cool evening hours.

## 4 WHAT IS '"KELLY COLOR THERM SYSTEM" AND HOW IT WORKS

The "KELLY COLOR THERM SYSTEM" is an integrated system consisting of:
• 10 Concentrated pigment dispersions with COOL technology
• 1 "color card" with THERM colors
• 1 manual tinting machine for semi-automatic dosing of colorants
• 1 formulation database to easily prepare the colors of the sample collection.
The formulas have been developed for all thick coatings and paints for facades based on organic polymers (Intonachino Therm- Intonachino Silox Therm- Quartz Therm Medio and Liscio - Silox Therm e Silox Therm granulato - Tegum Therm).
The main element of the system is represented by 10 pigment dispersions. They have been developed from so-called COOL pigments, ie capable of reflecting part of the solar radiation wavelengths, in particular those present in the infrared region, thus decreasing the absorption that generates heat (ref. picture 2). Therefore, the surfaces coated with these pigments remain colder and transmit less heat to the building.



**Sunlight creates heat when absorbed on the surface** That's why we need to reflect light. The higher is reflection of sunlight, the higher the thermal insulation effect will be.



Color reflectance by **KELLY COLOR THERM SYSTEM**

Picture 2 – Heat reflection with KELLY COLOR THERM SYSTEM

It is possible to measure the contribution of the "KELLY COLOR THERM SYSTEM" through thermal measurements on coatings for exteriors, appropriately colored with pigment dispersions. In this regard we have developed several dyes capable of covering all the typical color areas of external surfaces (facades and roofs) and having outstanding thermal reflection performance.

## 5 THE BEHAVIOR OF "KELLY COLOR THERM SYSTEM"

The "KELLY COLOR THERM SYSTEM" has been certified through thermal measurements, performed on coating products for exteriors, such as thick coatings and organic paints (based on acrylic emulsions, styrene-acrylic, siloxane, etc ...), appropriately colored with the 10 pigment dispersions of the pigment system. All the shades which constitute the system have been tested in order to verify their effectiveness experimentally. The following results of thermal tests carried out on the selection of the shades indicated in table 1 are given as an example.

| Color Code THERM | Color Code traditional | Description | Photo of the color |
|---|---|---|---|
| T-141 | NCS S 6020 – Y80R | DARK RED OXIDE | |
| T-106 | NCS S 4005 – G20Y | OXIDE MEDIUM GREEN | |
| T-6 | NCS S 1580 – Y90R | ORGANIC RED | |

Table 1 – Tints of "KELLY COLOR THERM SYSTEM" subjected to laboratory tests
(N.B. The colors listed - here and later - may differ from the real due to print)

The tints have been realized using a paint based on styrene-acrylic and siloxane binders and have been selected to cover the main color shades and all the color intensities: dark, average and light tones.

To have evidence of a direct performance comparison between the colors based on the COOL technology and the traditional ones, all the paints have been prepared both with the pigment dispersions of the "KELLY COLOR THERM SYSTEM" and with classic pigment dispersions for emulsion paints. The COOL version are indicated with the codes of the "color card" (T-141, T-106, T-6), the traditional version hues are displayed with the international NCS standard code (NCS S 6020 - Y80R, NCS S 4005 - G20Y, NCS S 1580 - Y90R).

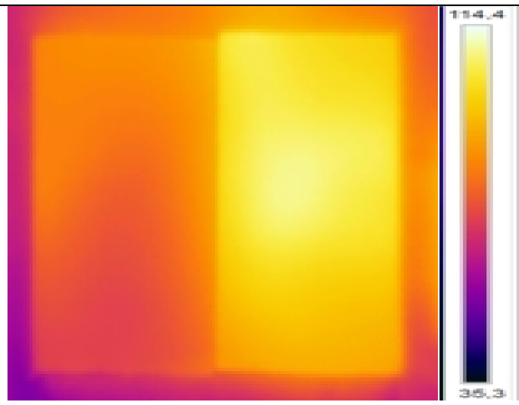
**5.1 Thermal tests on tints T-141 (THERM) and NCS S 6020 – Y80R (TRADITIONAL)**

Pictures 3 and 4 show the photographs, taken respectively with traditional camera and IR infrared camera, of the colored paints; the surface on the left is painted with the THERM system, while the surface on the right is painted with traditional pigment dispersions.

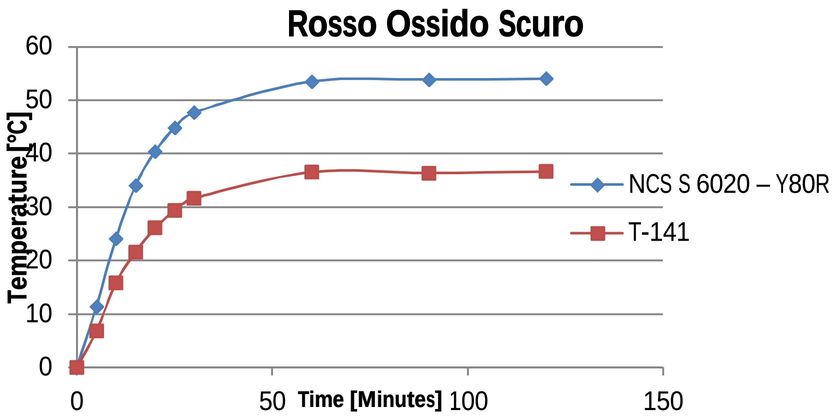
Both surfaces were irradiated with special infrared lamps in order to have a homogeneous front of heating.
The thermal image clearly shows that the surface painted with the pigment dispersions of the "KELLY COLOR THERM SYSTEM" keeps a much lower temperature than that painted in the traditional way and this at equal tones and intensities of color.

The temperature rise was supervised as the surfaces were heated. Picture 5 shows the temperature trend versus time. In this graph the advantage of using the "KELLY COLOR THERM SYSTEM" is clear. The maximum temperature reached by the THERM tint is around 37 ° C, the one with the traditional painting arrives at 54 ° C. It is quite evident that a facade painted with the THERM system heats less than one colored with a traditional tint and thus reduces the energy used for air-conditioning systems and increases the living comfort.
It is also interesting to observe that the temperature difference (equal to 17 ° C) is constant in time. This means that the THERM system paint can reduce the heat absorption during the hottest hours of the day and keep the temperature of the wall constantly less hot during the whole day. The accumulated heat, being significantly lower than that of a facade colored in a traditional way, is released more rapidly during the cool evening hours, further increasing the well-being in the interior rooms.
This behavior, typical of COOL pigments, is not found in other thermal materials, hence the choice of developing "KELLY COLOR THERM SYSTEM" system with this technology.

Picture 3 – Comparison between a paint based on THERM system (on the left) and a traditional paint (on the right) in the same dark red tint




Picture 4 – Thermographic image of the comparison between paint with THERM system (left) and traditional paint (right)



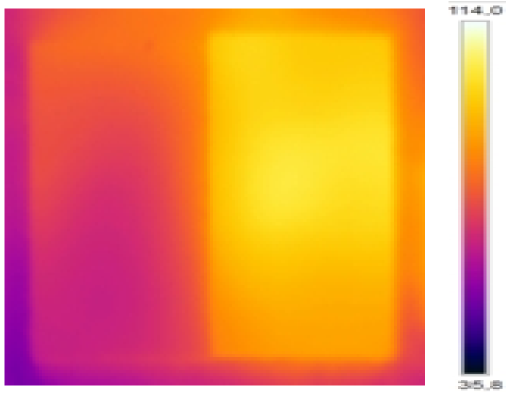

Picture 5 – Trend graph of temperature over time.
Comparison between paint with THERM system (red line) and traditional paint (blue line)

### 5.2 Thermal tests on tints T-106 (THERM) and NCS S 4005 – G20Y (TRADITIONAL)

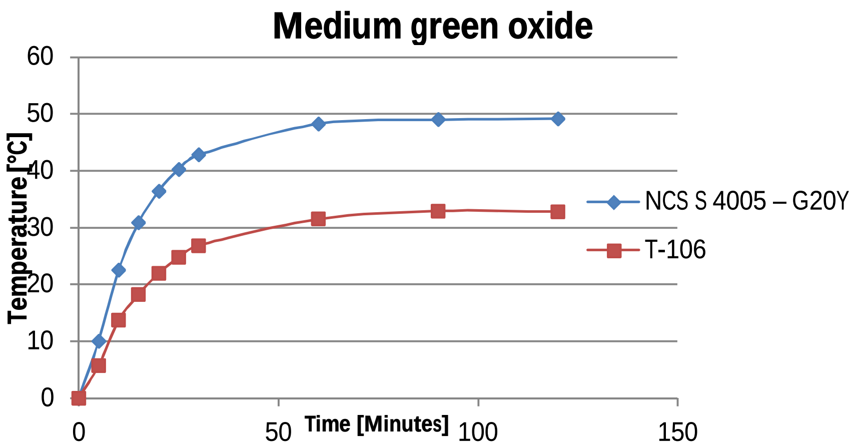
In pictures 6 and 7 you can see photos of the colored paints taken respectively with traditional camera and infrared thermal imaging IR camera. Picture 8 shows the graph of the temperatures trend in function of time. The measures have been acquired in the same way as in the previous test.

The thermal image and the graph show, also in this hue, that the surface painted with the pigment dispersions of the "KELLY COLOR THERM SYSTEM" remains at a much lower temperature than that painted with traditional products, the tones and color intensity being equal. The maximum temperature reached by the THERM tint is around 33° C, the one with the traditional paint almost reaches 50 ° C.

Picture 6 – Comparison between a paint based on THERM system (on the left) and a traditional paint (on the right) in the same dark red tint



Picture 7 – Thermographic image of the comparison between paint with THERM system (left) and traditional paint (right)



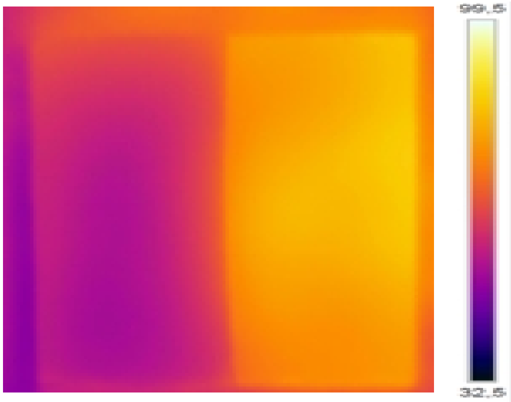

Picture 8 – Trend graph of temperature over time.
Comparison between paint with THERM system (red line) and traditional paint (blue line)

## 5.3 Thermal tests on tints T-6 (THERM) and NCS S 1580 – Y90R (TRADITIONAL)

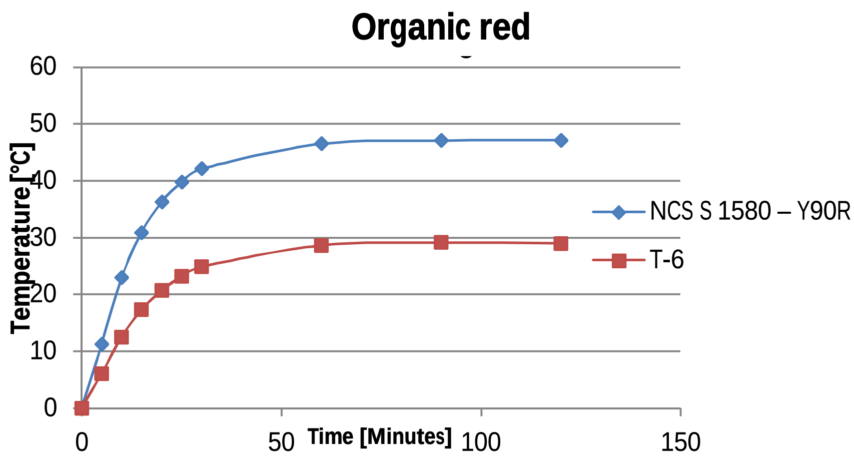
In pictures 9, 10 and 11 you can see photographs, taken respectively with traditional camera and infrared thermal imaging IR camera, and the time / temperature graph of the dyes in organic red tone.

Tests show, once again, that the surface painted with the coloring pastes of the "KELLY COLOR THERM SYSTEM" remains at a lower temperature than the surface painted in the traditional way. The maximum temperature reached by the THERM tint is about 29 ° C, the one with the traditional painting exceeds 47 ° C.

Picture 9 – Comparison between a paint based on THERM system (on the left) and a traditional paint (on the right) in the same dark red tint




Picture 10 – Thermographic image of the comparison between paint with THERM system (left) and traditional paint (right)




Picture 11 – Trend graph of temperature over time.
Comparison between paint with THERM system (red line) and traditional paint (blue line)

## 6 FROM COLOR TO HEAT: SRI and TSR parameters

Measures and thermal photographs are not enough to explain the "KELLY COLOR THERM SYSTEM" performance. To better understand the potential of the system it is necessary to understand how the colored paint is able to reflect the sun's heat. In this regard it is necessary to study the thermal parameters describing the interaction between solar radiation and the surface of the material, in particular:

- The solar reflection index SRI
- The total solar reflectance TSR
- The thermal emissivity (ε)
- The solar reflectance (and the related solar absorption factor)

**SRI (Solar Reflection Index)**

It is the parameter that combines the solar reflectance and thermal emittance values and expresses the ability of a material to reflect solar heat. It is defined in such a way that for the standard black SRI = 0, and for the standard white SRI = 100.
The materials with higher SRI value allow to reduce the temperature of the surfaces. The general rule is that "hot" materials assume SRI values close to zero or even slightly negative, while "cold" materials may have values above 100.
The solar reflection "SRI" is determined according to the following formula (ref. ASTM E1980):

$$SRI = 100\frac{T_b - Ts}{T_b - Tw}$$

where:
Tw = stationary temperature of the white standard surface expressed in K;
Tb = stationary temperature of the black standard surface expressed in K;
Ts = stationary surface temperature, expressed in K.

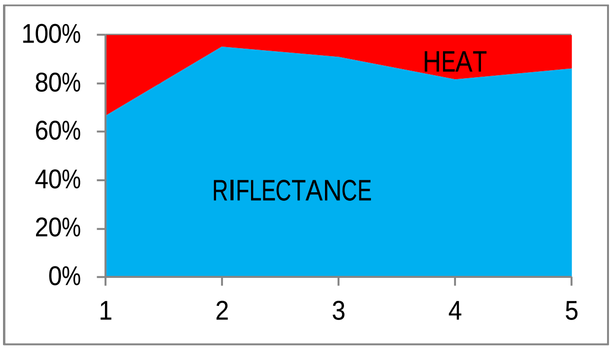
The solar reflection index "SRI" therefore represents the stationary temperature of a surface "Ts", dependent on the solar reflection factor, on the thermal emissivity and on the coefficient of convective heat exchange, evaluated with respect to that of the white and the black standard in standard environmental and solar conditions.

**TSR (Total Solar Reflectance)**

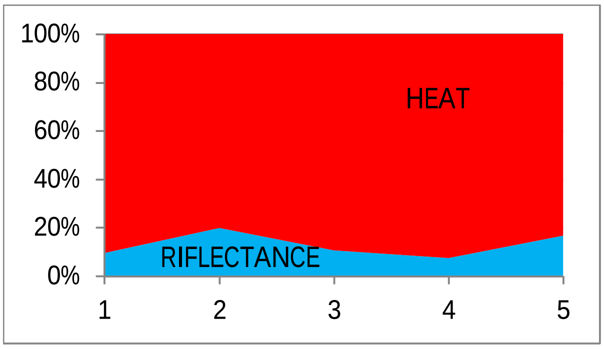
Total solar reflectance is the ability of a material to reflect incident solar radiation; its value ranges from 0 for a totally absorbing surface up to 1 (or 100% if expressed in percentage) for a perfectly reflecting surface.
A high degree of reflection corresponds to a high value of the TSR factor, while a low TSR value indicates a high degree of absorption. White pigments, first of all titanium dioxide, have by their nature a TSR factor higher than all the other colored pigments. By contrast, dark pigments have a very low TSR factor. In general the rule is that: the higher the TSR factor, the more efficient is the solar reflection.

The TSR parameter takes into account the entire spectrum of solar radiation; for this reason in addition to the percentage value of the TSR it is interesting to assess the shape and performance of the UV-VIS-NIR spectrum in the whole. The higher the profile of the reflectance spectrum the better the heat-reflection; on the other hand, the more "flattened" the spectrum towards low values of reflectance, the higher the overheating due to heat.

TSR profile with high reflectance
(heat is efficiently reflected)




TSR profile with low reflectance
(heat accumulates)



**Solar reflectance factor (and solar absorption factor)**

When solar radiation is incident on a transparent material it is transmitted, reflected and absorbed as a function of the characteristics of the radiation, for example the spectral distribution and the angle of incidence,and the nature of the material itself.

The involved energy coefficients are:

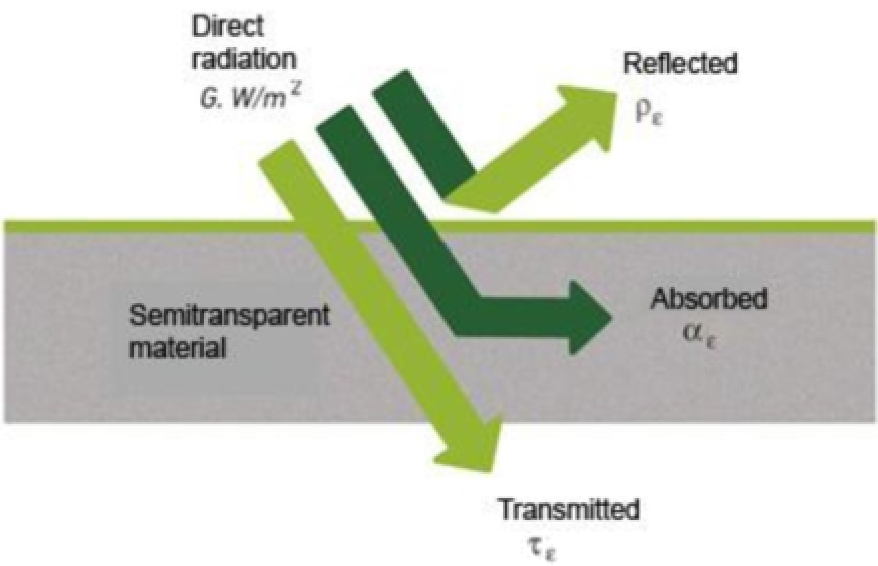
- Coefficient or solar transmission factor ($\tau_\varepsilon$):the ratio between the radiation that passes through the material and the incident radiation.
- Coefficient or solar reflectance factor ($\rho_\varepsilon$ ):the ratio between the radiation reflected by the material and the incident radiation.
- Coefficient or solar absorption factor ($\alpha_\varepsilon$ ):the ratio between the radiation absorbed by the material and the incident radiation.

The three factors are interrelated through the formula:

$$\tau\varepsilon + \rho\varepsilon + \alpha\varepsilon = 1$$

For opaque materials, such as paints and thick coatings for facades, consider transmission $\tau_\varepsilon$ =0, therefore remains:

$$\rho\varepsilon + \alpha\varepsilon = 1$$




**How direct radiation is composed:**
absorption, reflection and transmission
(for transparent and semitransparent materials only)

Picture 12 - Decomposition of the incident radiation:
absorption, reflection and transmission (for transparent or semi-transparent materials)

**Thermal emissivity (ε)**

The emissivity of a material is a measure of its ability to radiate energy. It can be defined as the ratio between the thermal energy radiated from the surface of the material itself and the energy radiated by a black body which is at the same temperature. It varies between 0 and 1.

A surface with high thermal emissivity can effectively dissipate heat in the environment. Conversely, a low thermal emissivity may limit the exchanges between a surface and the surrounding environment. Control of the thermal emissivity of the surfaces can be used to reduce the summer heat load on the opaque elements of the buildings.

In general, metals have rather low emissivity; it increases with temperature. Materials other than metals, such as paints and coatings, have relatively high emissivity and it is decreasing as the temperature increases.

## 7 THE THERMAL PERFORMANCES OF "KELLY COLOR THERM SYSTEM"

In Tables 2 and 3 are shown the thermal parameters of solar reflection "$\rho_\varepsilon$" (and absorption "$\alpha_\varepsilon$"), emissivity "ε"and solar reflection index "SRI" respectively for tint T-141 (THERM) and tint NCS S 6020 - Y80R (TRADITIONAL).
These parameters were determined at three different values for the convection heat transfer coefficient " hc":
- hc = 5 W / (m² • K) which corresponds to a low air speed (0 to 2 m / s);
- hc = 12 W / (m² • K) which corresponds to medium air speed (2 to 6 m / s);
- hc = 30 W / (m² • K) which corresponds to a high air speed (from 6 to 10 m / s);

and in standard environmental and solar conditions defined by:
- Solar flux = 1000 W / m²;
- Ambient air temperature = 310 K (equal to 37 ° C);
- Temperature of the air = 300 K (equal to 27 ° C).

The measurements were performed three times.
As you can see from the comparison tables, THERM tint maintains, for the same tone and color saturation, a solar reflection index SRI approximately three times the traditional dye SRI (THERM) = 32.7, SRI (TRADITIONAL) = 10.4 (values reported to the convection coefficient hc = 30 W / m2K).
This shows that the pigment dispersions of "KELLY COLOR THERM SYSTEM" allow you to create colorful paints able to reject heat more efficiently than a traditional colored tinting system.
This trend is confirmed, and clearly visible, even by the TSR total solar reflectance spectrums (Pictures 13 and 14) and the overlapping spectrum TSR (Picture 15). The spectrum of the T-141 dye (THERM) has a reflectance of around 60% in the infrared region, while the the traditional dyed has an almost flat profile (maximum value 20%). Simplifying, it can be said that the THERM tint reflects up to 60% of the heat against only 20% of the traditional one.

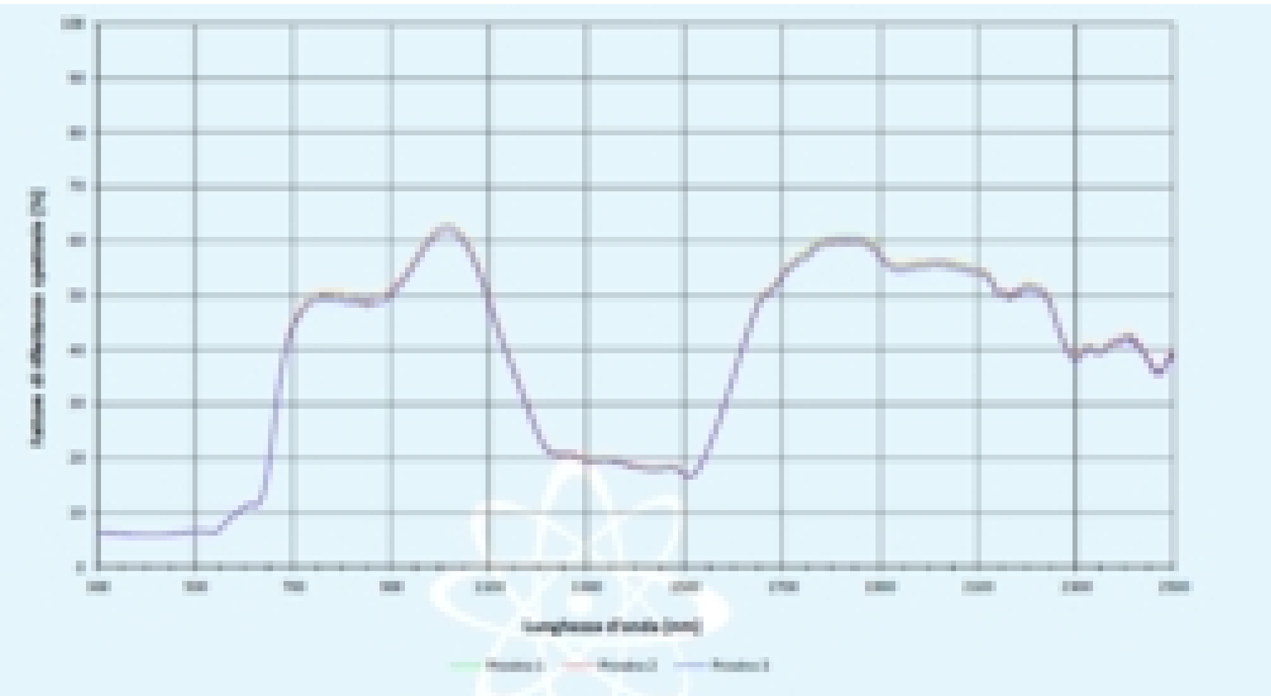
| Specimen | **Solar reflectance factor "$\rho_\varepsilon$"** | **Solar absorption factor "$\alpha_\varepsilon$"** | **Thermal emissivity "ε"** |
|---|---|---|---|
| 1 | 0.295 | 0.705 | 0.925 |
| 2 | 0.295 | 0.705 | 0.927 |
| 3 | 0.290 | 0.710 | 0.922 |
| **Solar Reflectance Index "SRI"** | | | |

| | $h_c$ = 5 W/(m² · K) | $h_c$ =12 W/(m² · K) | $h_c$ = 30 W/(m² · K) |
|---|---|---|---|
| 1 | 32.7 | 33.0 | 32.9 |
| 2 | 32.8 | 33.0 | 33.0 |
| 3 | 31.8 | 32.1 | 32.1 |
| **Average value** | **32.5** | **32.7** | **32.7** |

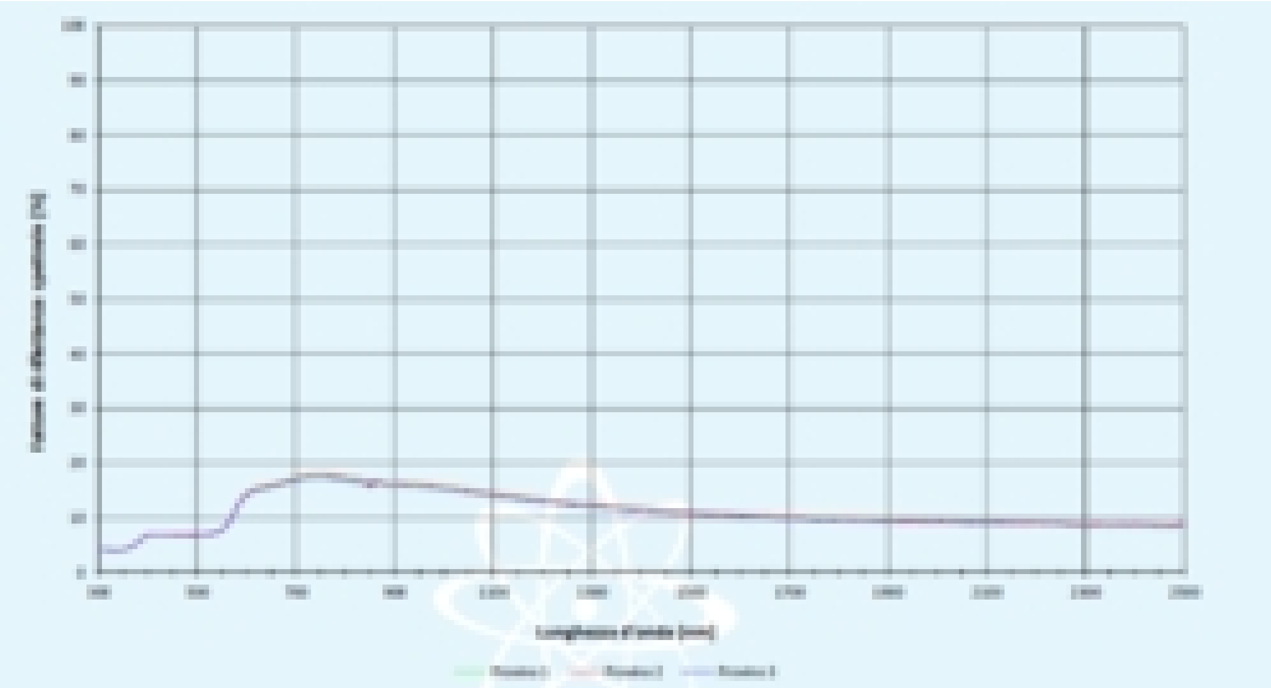
Table 2 – Heat data of tint T-141 (THERM)

| Specimen | **Solar reflectance factor “$\rho_\varepsilon$”** | **Solar absorption factor “$\alpha_\varepsilon$”** | **Thermal emissivity “ε”** |
|---|---|---|---|
| 1 | 0.124 | 0.876 | 0.923 |
| 2 | 0.126 | 0.874 | 0.924 |
| 3 | 0.122 | 0.878 | 0.921 |
| **Solar Reflectance Index “SRI”** | | | |
| | $h_c$ = 5 W/(m² · K) | $h_c$ =12 W/(m² · K) | $h_c$ = 30 W/(m² · K) |
| 1 | 11.1 | 10.8 | 10.5 |
| 2 | 11.4 | 11.1 | 10.7 |
| 3 | 10.6 | 10.3 | 10.0 |
| **Average value** | **11.0** | **10.7** | **10.4** |

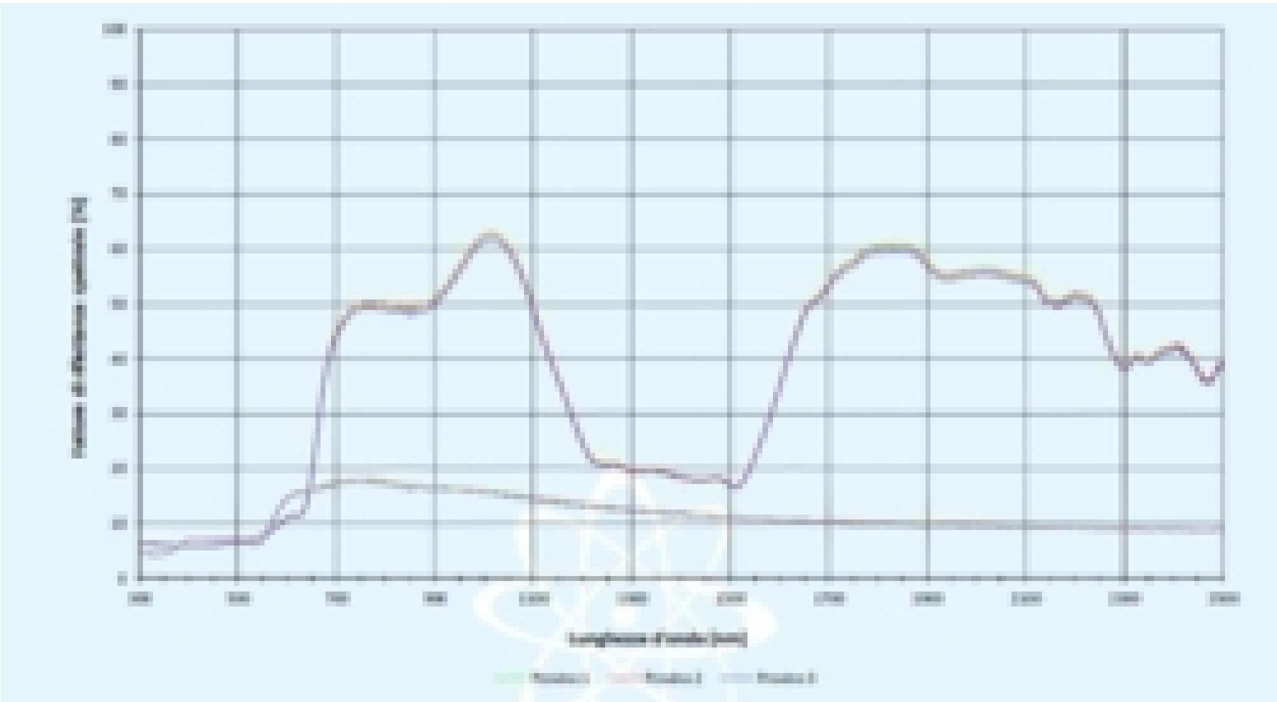
Table 3 – Heat data of tint NCS S 6020 – Y80R (TRADITIONAL)



Picture 13 – TSR spectrum of tint T-141 (THERM)



Picture 14 – TSR spectrum of tint NCS S 6020 – Y80R (TRADITIONAL)

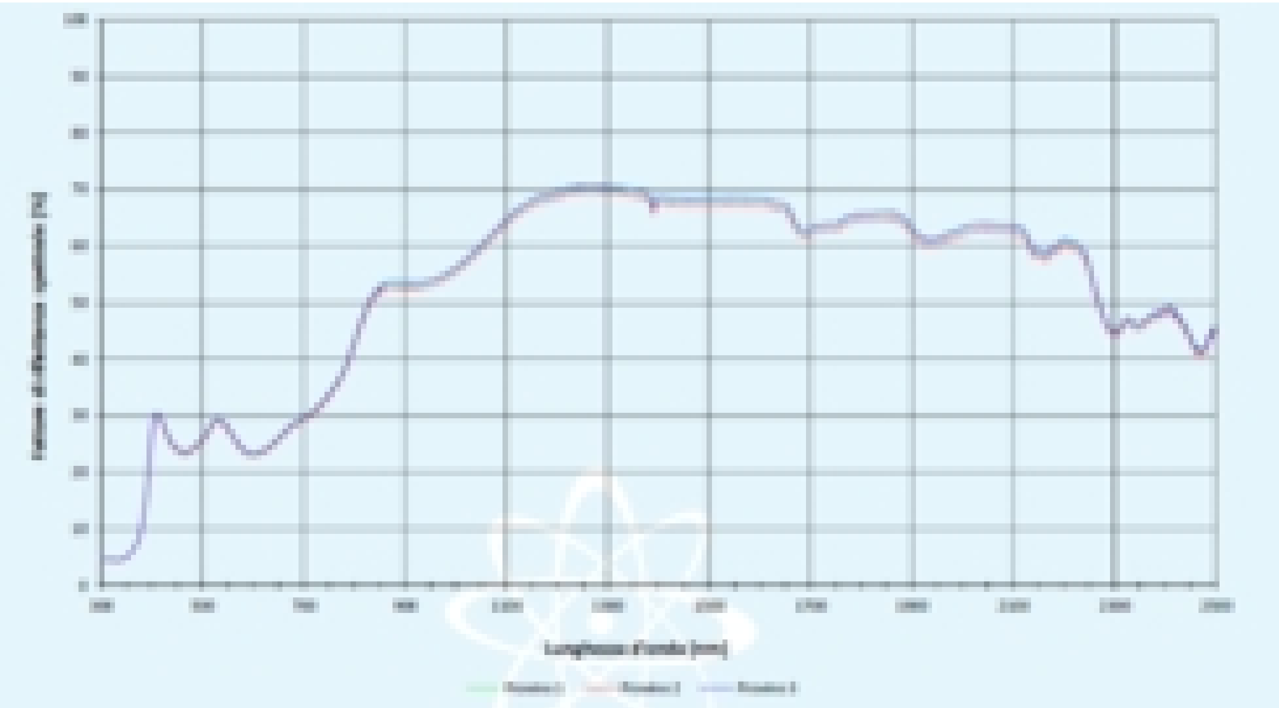


Picture 15 –TSR overlapping spectrum THERM and TRADITIONAL

Table 4 and the graph of Picture 16 show the thermal parameters (“ρε”,“αε”, “ε” e “SRI”) and the TSR spectrum of the T-106 dye (THERM). Even if it has a very dark and intense color tone this tint has a rather high solar reflectance index, too (SRI around 45) with a reflectance profile which reaches 70%.

| Specimen | **Solar reflectance factor “$\rho_\varepsilon$”** | **Solar absorption factor “$\alpha_\varepsilon$”** | **Thermal emissivity “$\varepsilon$”** |
|---|---|---|---|
| 1 | 0.401 | 0.599 | 0.893 |
| 2 | 0.394 | 0.606 | 0.896 |
| 3 | 0.401 | 0.599 | 0.893 |
| **Solar Reflectance Index “SRI”** | | | |
| | $h_c = 5\ W/(m^2 \cdot K)$ | $h_c = 12\ W/(m^2 \cdot K)$ | $h_c = 30\ W/(m^2 \cdot K)$ |
| 1 | 44.6 | 45.6 | 46.2 |
| 2 | 43.8 | 44.7 | 45.4 |
| 3 | 44.6 | 45.6 | 46.2 |
| **Average value** | **44.3** | **45.3** | **45.9** |

Table 4 – Heat data of tint T-106 (THERM)

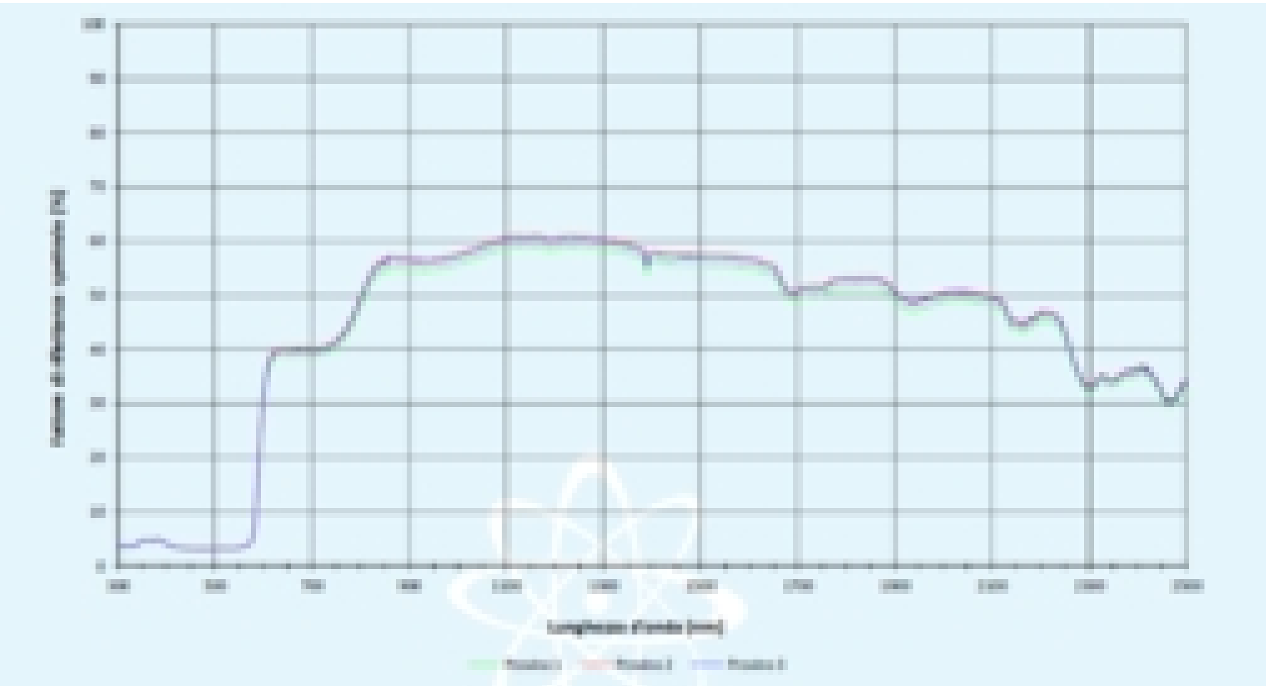


Picture 16 – TSR spectrum of tint T-106 (THERM)

Table 5 and the graph of picture 17 show the thermal parameters and the TSR graphic of tint T-6 (THERM). Also in this case the thermal data indicate that the hue, while having a strong and intense color tone, has a rather high solar reflectance index (SRI around 38.) with a reflectance profile which reaches 60%.

| Specimen | **Solar reflectance factor “$\rho_\varepsilon$”** | **Solar absorption factor “$\alpha_\varepsilon$”** | **Thermal emissivity “$\varepsilon$”** |
|---|---|---|---|
| 1 | 0.339 | 0.661 | 0.914 |
| 2 | 0.350 | 0.650 | 0.918 |
| 3 | 0.347 | 0.653 | 0.908 |
| **Solar Reflectance Index “SRI”** | | | |
| | ***$h_c$ = 5 W/(m² · K)*** | ***$h_c$ =12 W/(m² · K)*** | ***$h_c$ = 30 W/(m² · K)*** |
| 1 | 37.6 | 38.1 | 38.4 |
| 2 | 39.4 | 39.8 | 40.0 |
| 3 | 38.2 | 38.9 | 39.3 |
| **Average value** | **38.4** | **38.9** | **39.2** |

Table 5 – Heat data of tint T-6 (THERM)



Picture 17 – TSR spectrum of tint T-6 (THERM)

## 8 "KELLY COLOR THERM SYSTEM" LIGHT RESISTANCE

Dark colors, in addition to the problem of overheating, are affected by a greater and more rapid deterioration caused by atmospheric agents compared with clear ones. In other words the darker the color of a facade or a roof awning, the more noticeable are the signs of agening. This degradation typically occurs with:

-alteration of the color tone (which tends to brighten);

- formation of cracks and deformations due to the higher mechanical stress and temperature changes;

- chalking surfaces caused by the deterioration of the polymer binder.

We can therefore conclude that the factors influencing the stability of the color are: the exposure to atmospheric agents (heat-rain cycles, condensation, contaminants, etc ...) and the type of materials used.
Of course you cannot intervene on environmental conditions, and indeed, given the climatic upheavals we are going to meet, they will be more and more aggressive and decisive. Much can instead be done on the side of materials. In this sense, the tinting system "KELLY COLOR THERM SYSTEM" offers an important technological contribution to limit and / or slow down the natural aging process of the dark surfaces.

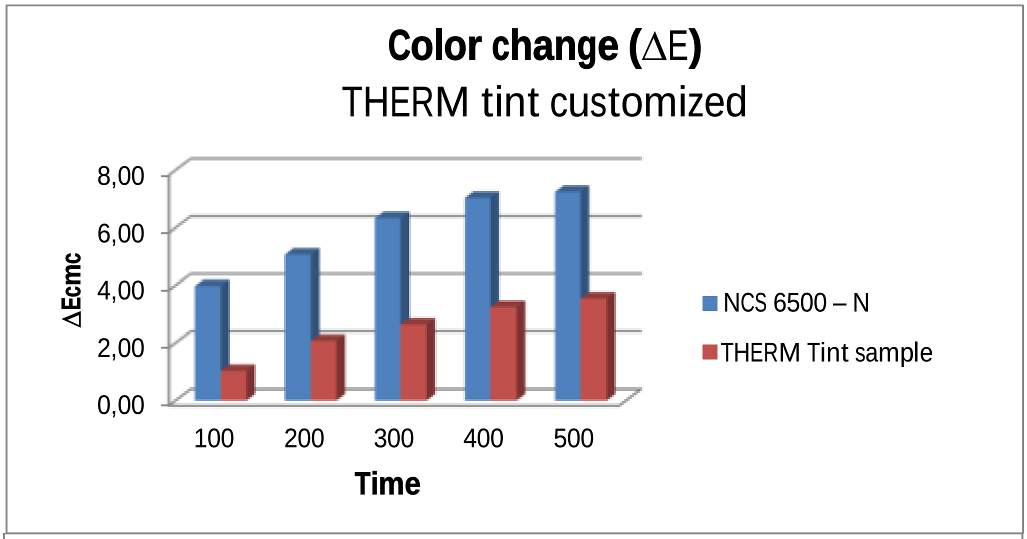
In this regard, comparisons of some facade paints having the same formulation (based on styrene-acrylic emulsion) and different colors are reported below. For each color two tints were prepared: one with traditional pigment dispersions (based on inorganic pigments and iron oxides) and one with the THERM system. In particular were examined:

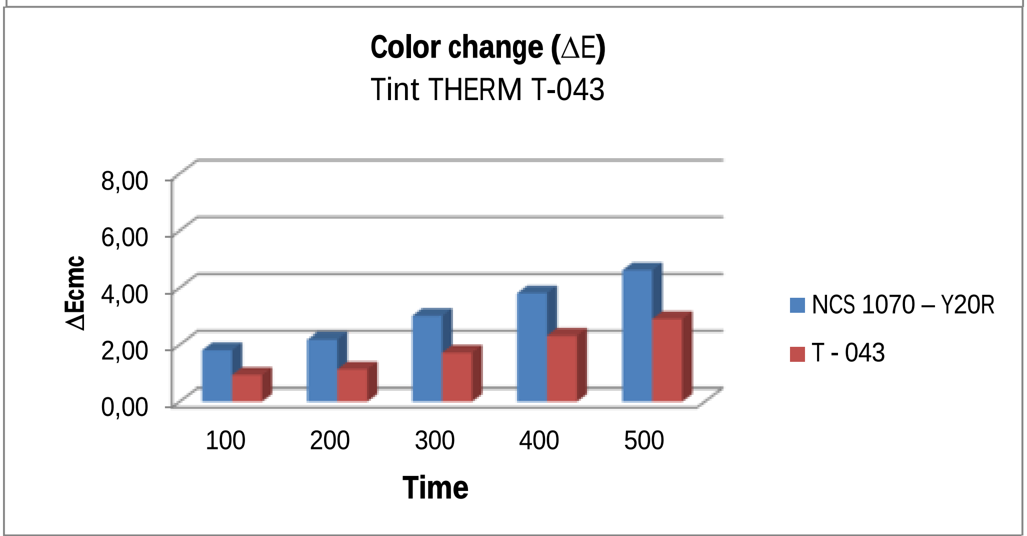
| **TRADITIONAL TINT** | **THERM SYSTEM TINT** |
|---|---|
| NCS 1070 – Y20R<br>yellow-orange tint based on:<br>bismute vanadate, yellow iron oxide and red iron oxide) | T-043 |
| NCS 4005 – B80G<br>(medium green oxide tint based on:<br>Black iron oxide, green iron oxide, cobalt blue) | T-106 |
| NCS 6500 – N<br>(grey tint based on black iron oxide) | Tinta THERM<br>(customized) |

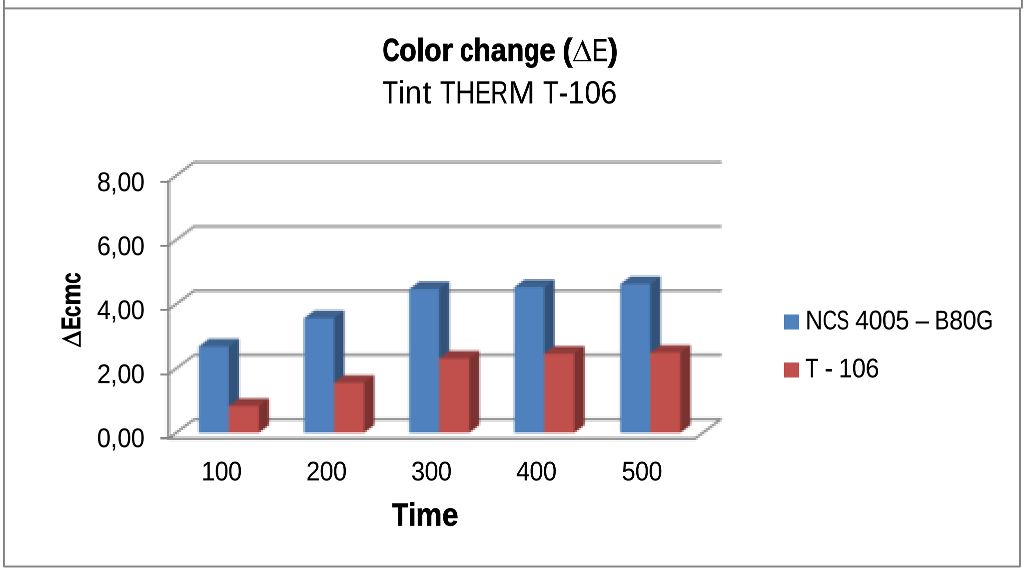
All the paints were exposed to accelerated aging cycles in Solarbox environmental simulator (Xenon lamp test with 1500 W / m2) for a time of 500 hours. At regular intervals of irradiation were carried out readings of the chromatic variation using as comparison parameter the value of $\Delta$***ECMC(l:c)*** defined as:

$$\Delta ECMC(l:c) = \{[\Delta L/(l\ SL)]2 + [\Delta C/(c\ SC)]2 + (\Delta H/SH)2\}½.$$

| | **ΔEcmc (exposure time in hours)** | | | | |
|---|---|---|---|---|---|
| | **100** | **200** | **300** | **400** | **500** |
| **NCS 6500 – N**<br>**THERM tint customized** | 3,97<br>1,02 | 5,07<br>2,07 | 6,33<br>2,63 | 7,04<br>3,24 | 7,25<br>3,54 |
| **NCS 1070 – Y20R**<br>**T - 043** | 1,81<br>0,93 | 2,18<br>1,13 | 3,01<br>1,72 | 3,81<br>2,31 | 4,61<br>2,90 |
| **NCS 4005 – B80G**<br>**T - 106** | 2,69<br>0,82 | 3,56<br>1,55 | 4,47<br>2,31 | 4,53<br>2,46 | 4,63<br>2,49 |



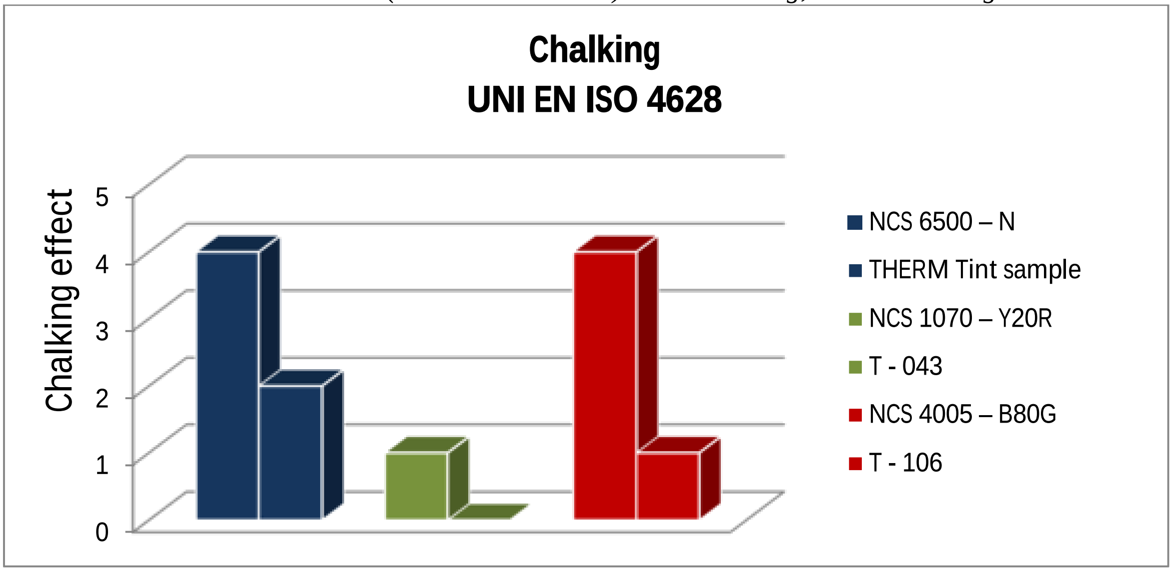




The paints colored with conventional pigments based on inorganic pigments (mainly iron oxides) have shown quite noticeable chromatic variations ($\Delta E_{CMC}$ between 4 and 7) after 500 hours of exposure to environmental simulator. In particular the colors always tend to lighten. On the contrary, the paints containing the pigment dispersions of THERM line have shown a much inferior degradation ($\Delta E_{CMC}$ between 2 and 3.5).

In addition to the chromatic change of the hue, it was observed that the traditional paints have a high chalking degree. Touching the specimens with the hand, the surface dusted fingers. This means that the polymer deteriorates and is no longer able to bind the components (fillers and pigments) which are then freed. On the contrary, the paints containing THERM line pigment dispersions have a very slight chalking degree, quite acceptable after prolonged exposure in the simulator.

| | **CHALKING (UNI EN ISOM 4628-6)** |
|---|---|
| **NCS 6500 – N** | 4 |
| **THERM tint customized** | 2 |
| **NCS 1070 – Y20R** | 1 |
| **T - 043** | 0 |
| **NCS 4005 – B80G** | 4 |
| **T - 106** | 1 |

*Evaluation scale (UNI EN ISO 4628-6): 1= no chalking; 5= max chalikng.*




Considering that the deterioration occurs both in the color component (hue discoloration) than in the polymeric binder (chalking), and considering the chemical quality of the materials used (styrene-acrylic emulsion and inorganic pigments based on iron oxides), it can be assumed that the deterioration is mainly attributable to the surface warming. The solar radiation emitted from Solarbox simulator is constituted, just like the real sunlight, of ultraviolet components (UV), visible (Vis) and infrared (IR). The latter seems to have a dominant effect on degradation in comparison with the others. THERM pigment pastes are therefore able to limit the surface overheating stressing less the polymeric binder. This results in an increase in the durability and resistance of colored paints in outdoor contexts.

## 9 CONCLUSIONS

The "KELLY COLOR THERM SYSTEM" allows to obtain thick coatings and colored paints, even in darker shades, which reduce the absorption of solar heat. In this way the temperature of the surfaces, whether they are facades or roofs, is kept low and the stored heat is released more easily compared with the paints colored with traditional tinting systems. This allows buildings to be fresher

in the summer period with improvement of the living comfort and reduction of the energy consumption because of the lower use of air conditioning systems. The lower heat absorption also improves the durability of the facades and roofs, no longer stressed by excessive temperature changes typical of dark colored paintings.
The main element of "KELLY COLOR THERM SYSTEM" is represented by the pigment dispersions that have been developed from so-called COOL pigments, capable of reflecting part of the wavelengths of solar radiation, in particular those present in the infrared region. It’s just the reflection of these radiations which decreases the heat absorption keeping the building cooler.
The advantage of using the "KELLY COLOR THERM SYSTEM" is demonstrated by the tests and thermal measurements on the colored paints made using the system. For darker shades of paints colored with THERM system and those colored with traditional mixing systems you have a difference of average temperature around 15 ° C. In addition, with the same tone and color saturation, the colors of the THERM system have solar reflectance index (SRI) significantly higher than those of traditional colors. This means that they are able to reject heat more efficiently compared with those colored in the traditional way.