# THE INSULATION VALUE OF STAINLESS STEEL



***Since the chromium oxide layer that naturally develops on the surface of stainless steel is thin and invisible is a near-perfect solar and thermal reflector. This translates to both and energy savings in hot as well as cold climates, and a reduction in the heat island effect, therefore mitigating climate change (see Stainless Steel Buildings Combat Climate Change on our website). A basic understanding of the Thermal and Solar Reflectance of Stainless Steel can also be gained on our website.***

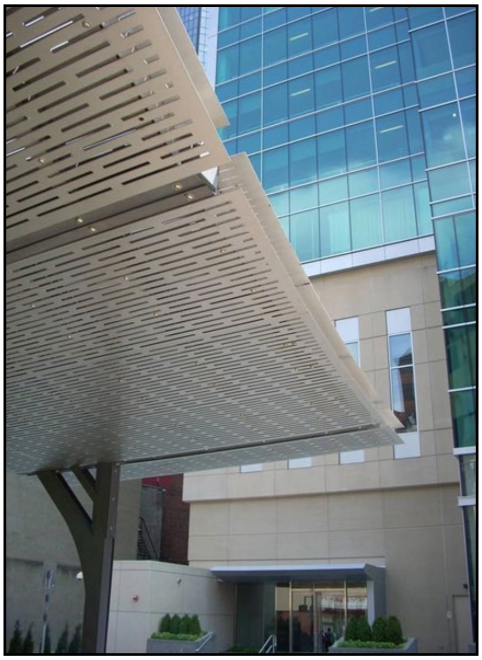
The remarkable thermal properties of stainless steel result in R value for the metal itself, thereby lessening the demands of panel insulation systems to meet design criteria. More importantly, it gives designers and opportunity to improve the energy efficiency of buildings, given a set panel and an insulation system. This document provides information regarding the contribution stainless steel makes toward insulating buildings.

The benefits of having a high solar reflectance roof on the environment are huge (see **Stainless Steel Buildings Combat Climate Change** on our website), but do they come with any operating cost penalties? Fortunately, the benefits of a stainless steel solution to the problem are just as great from an energy conservation perspective, manifesting in lower operating costs. Our website contains further information regarding cost benefits to owners of stainless steel buildings in the section entitled **Reduce Operating Costs** on our website.

## THE R VALUE

It is difficult to translate high reflectance into an "R" value benefit directly, but if one looks at the different insulation requirements for black and stainless roofs under normal summer peak loads one can calculate the different insulation requirements. This can be translated into different costs to insulate versus the excess energy cost to air condition.

It is well established that a black roof reaches 40° C above ambient on clear summer days at the 30 to 40° latitudes. This comes from 90% absorption of about 800 W/m2.



A stainless steel roof absorbs 10% and thus rises to only 10° C above ambient. So if ambient is 35° C, the temperature difference between a building which is air-conditioned to 25° C and its roof surface is 50° C for a black roof and 20° C for a stainless steel roof. This difference must be negated by insulation or by using more energy to cool the black-roofed building.

The heat flow into the black-roofed building without insulation is half the absorbed solar energy, or 360 W/m2. The necessary thermal gradient is 45° C to make the roof interior temperature equal to the indoor air temperature. This requires 360 W/m2 /50° C of R value (in metric). This is R=7.2 in metric or R=41 in normal US units. The stainless roof reaches only 20° C above the inside temperature and needs to overcome a heat flow of 40 W/m2, so it requires R= 2 in metric or R=11 in US units. This gives the stainless roof in summer the equivalent of 30 R units savings over a black roof.

At a cost for a good building insulation, such as isocyanurate or polyurethane foams with R=5, of $1.00 per R unit per square meter, a black roof incurs an additional cost of $30/ square meter over a stainless roof to obtain equal energy performance.

In the wintertime heating by the solar effect is negligible because the isolation (total daily solar energy received) is low due to the low angle of the sun and the cloudiness normal in colder climates. However, the emissivity becomes a much bigger factor than the reflectance. Why? An example: for the same building with the same insulation, the final step in heat loss is the radiation from the exterior surface. Again with no wind to distort comparisons, with equal insulation, the heat loss is directly proportional to the emissivity, which by definition is the ability of a surface to emit, or lose, heat. Since all the loss is by radiation of infrared wavelengths, the emitted heat is trapped by the atmosphere. The stainless steel roof with its emissivity of 0.21 versus the black roof with emissivity of 0.90 requires 0.21/0.90 or 23% of the insulation of the black roofed building for equal heat loss. So the advantage of stainless steel in the winter is almost identical to that in the summer. The importance of this is that cold climates have greater annual energy expenditures than hot climates. There is no cold climate penalty for high reflectance/low emissivity roofs, especially stainless steel roofs. The myth that black roofs help in the winter is simply without basis. A black roof, while it may warm fleetingly during the few sunny winter hours, loses heat much more readily than a low emissivity roof. Likewise, some "cool roofs" which boast of enhanced emissivity to counter the heat island effect will have enhanced heat loss in the winter.

So a cool stainless roof has a major warm climate and cold climate year-round advantage that translates into insulation savings of R=30. Besides this savings in pure insulation cost, there is the freedom this lack of bulk – 5 to 7 inches less insulation thickness – gives the architect, as well as cost savings in installation, the dead weight avoided, and space gained for no cost.

We have shown that stainless steel and other high reflectance, low emissivity materials, have surface properties which repel solar warming of both the structure they cover and the world itself. In addition, by virtue of the same surface properties they minimize energy losses to and from the structure by acting as a radiant barrier. This is a level of perfection for which it is difficult to find comparison. They prevent global warming and heat islands, while minimizing energy usage. How can one improve on that?

## REFLECTANCE DOES NOT DEGRADE

Arguably the most obvious benefit of stainless steel among the numerous high SRI products for building exteriors is its imperviousness to the environment. The great enemy of metals is corrosion. The metals historically which resist corrosion are the most prized: gold, silver and platinum. With rare exceptions these are not affordable building materials. When aluminum was first popularized it had great promise, but its corrosion resistance is inadequate for architecture without coating. The same is true for steel. Zinc and copper corrode readily, but its corroded appearance finds some admirers. Lead is used for the same reason despite its being toxic, weak and dense. Only stainless steel and titanium are both resistant to corrosion in any environment in which humans can live. They thus stand out as the two viable bare metals which can keep their initial surface qualities indefinitely.

Why is corrosion resistance so important? When metals oxidize, i.e. corrode, their surfaces take on the physical properties of the oxide. Oxides have low reflectance and high emissivity. Thus, as metals corrode, their initial superior performance, in terms of SRI, degrades. This can happen quickly. Steel rusts in hours, copper oxidizes in days, aluminum in months. The first stainless steel used in buildings has been there for nearly 100 years with no sign of degradation. Non-metallic materials have their own problems with aging. Coatings are organic chemicals. They are degraded by light (UV, primarily), temperature, abrasion, and chemicals in the environment. These are aggregated in the term weathering. When materials weather, their SRI and appearance change and not for the better. That is the reason initial SRI values must be accompanied by field tested SRI values after at least three years of weathering.

SRI weathering data have been published on over 1400 commercial coatings. Selected results are in the table below.

| **Material** | **Initial SRI** | **3 year SRI** |
|---|---|---|
| #209 white paint | 103 | 102 |
| #418 white paint | 111 | 105 |
| #425 white paint | 109 | 101 |
| #981 white paint | 117 | 110 |
| #982 white paint | 108 | 102 |
| 304 stainless InvariMatte | 112 | 112 |

*From www.facilitize.com/.../AdditionalRoofingProducts-w-SRI-Values.xls*

The aged stainless data point is not three year weathering; it is 10 year, taken from the 140,000 square meter roof of the David L Lawrence Convention Center in Pittsburgh. It is clear that even the very best coatings degrade, by an average of 5% over three years. There is no reason to expect that to decelerate. Thus, for a building with a 30 year lifespan a degradation of 50% cannot be ruled out; indeed it should be expected for coatings. Stainless steel changes only as much as the dirt that lands on it and isn't removed by wind and rain.

The insulation savings of high SRI materials can't be justifiably credited to a material which only saves insulation initially, so an architect must be wary of judging materials.

## ALL THE SAME?

Are all stainless steels the same? No. There are many types of stainless steel based on chemical composition and then there are many surface finishes for each. Both of these factors determine the corrosion resistance and the resistance to soiling in service. The most common stainless steel for architecture is type 304. It fully resists corrosion in non-marine climates. In marine climates, 316, which has 2% molybdenum, an expensive ingredient, is used. In even more severe environments 2003 or 2205 may be used. These latter two have more molybdenum and are harder to form into shapes, but have been used successfully in roofs in the extremely inhospitable climates of the Arabian Peninsula and Hawaii. The selection of the correct stainless is important but not difficult for the many available expert sources.

The effect of surface finish is more subtle. Stainless steel is heat-treated to achieve the desired mechanical and physical properties at the manufacturer. After this step the oxide scale from heating must be removed by very strong acids (i.e. pickling), which also dissolve the surface layer removing any places in which the corrosion resistance is lower, which could lead to pitting corrosion and perforation in service. As long as the surface is not removed this corrosion resistance is intact.

Unfortunately, some stainless is abraded after it if manufactured into sheet. This surface finish dates back to the 1930's when it was the only way to make a quasi-uniform finish on stainless steel, since the as-pickled surface is mottled. Abrading stainless steel, as in the case of producing a #4 finish, tears away the surface. Because it is not subsequently pickled, the corrosion resistance is harmed. The magnitude of this loss is approximately equal to the difference between 304 and 316. This is pretty significant, so it is prudent to not use abraded stainless steel for exteriors of structures.

What's the alternative? There are some very good ones. An abraded surface finish can be replicated by rolling the surface with textured rolls. This avoids surface removal and loss of corrosion resistance. Additionally, there are other rolled-in finishes that offer a variety of appearances, including those that replicate media blasted finishes (media blasting is another abrasive process that compromises corrosion resistance). Architecturally, a possibly greater benefit is that rolled-in finishes have extremely uniform and reproducible surfaces. This is never the case with abrasively-made finishes which continually vary with degradation of the abrasive media.

Rolled-in finishes can replicate abraded or shot blasted finishes without the surface damage, and can decrease the visual glare or gloss from a surface without diminishing solar reflectance or increasing the emissivity significantly.

## STAYING CLEAN

Among the high SRI finishes the ability to stay clean varies a lot. Coatings are organic; so, is most dirt. The polarity of organic molecules attracts other polar molecules. Metals have no polarity because of their dispersed electron cloud bonding. This eliminates one type of soiling for metals and accounts for some of the differences from coatings in terms of soiling.

The second factor is mechanical damage. Metals are much, much harder than any organic coating so particles of dirt cannot embed in stainless when driven by wind and rain.

The last factor is trapping. This is controlled by surface configuration on a micro scale. Most coatings are quite smooth, at least initially, so in this regard they are okay.

## MAINTENANCE

The roof is often the highest maintenance burden of a building, especially as it ages. One of the great, unanticipated benefits of the stainless roof on the David L Lawrence Convention Center (detailed below) is that it has required absolutely no maintenance in its lifetime. It probably never will. This building just received a Platinum award from LEED for maintenance and operations. Its management is happy that the roof has never been a source of difficulty. Interestingly, the same 304 stainless with an abraded finish on exterior wall panels has soiled sufficiently that expensive hand cleaning was required for the hosting of the G20 meetings there several years ago.

## A CASE STUDY, PITTSBURGH

The David L. Lawrence Convention center in Pittsburgh (DLCC) is a building highly praised for its green qualities and receipt of a Gold LEED certification. It is however a greater contributor to the environment than it was even intended to be. The 140,000 square meter roof is made of type 304 stainless steel which despite having a low gloss appearance is highly reflective of solar radiation. It reflects 90% of solar radiation into space versus 15% were it the average for US cities. This avoids 160 w/m2 of solar energy and its global warming effect. That amounts to an earth energy credit of 25 Megawatts (calculated on a US average of 200W//m2 full year average solar radiation) versus urban average: the equivalent of a 15 large windmills costing $60 million running the US average of 36% of nameplate. The DLCC only uses only about 2 MW, so it is incredibly beneficial to the environmental balance. The DLCC has wonderful energy efficiency, consuming very little energy for its size and use. But its benefit to the environment in passive reflective solar efficiency far outstrips the more limited view of energy efficiency which is rewarded by LEED. With its footprint of 1% of downtown Pittsburgh, it by itself raises the downtown's albedo sufficiently to negate global warming in the Golden Triangle. The 25 MV wind farm that did not need to be built equals the power usage of the rest the rest of the Pittsburgh downtown's office buildings.

The incremental cost of stainless steel roofing for DLCC over plain black polymer was about $20 per square meter, or a premium of $2.8 million. It avoided environmental costs of $60 million. The roof of the DLCC was not intended to be central to its green design. It was specified for sustainability and maintenance savings. The serendipity of it is that little was known of the exceptional reflectivity of stainless steel when it was designed and its implications regarding energy savings and heat island mitigation. It was a risk taken and rewarded. It's SRI has not measurably changed in ten years and it has required zero maintenance. Because it is stainless steel its life will exceed 100 years.

## CONCLUSION

*We hope it is clear to the reader that stainless steel-clad buildings save energy. The heat island mitigation of stainless steel buildings is an equally powerful argument that is further explored in* ***Stainless Steel Buildings Combat Climate Change*** *on our website. We are hopeful that we can encourage further study in these areas. Should you have questions or comments regarding our work, we would be pleased to hear from you.*

**Primary Author:**
*Michael F. McGuire, PHD Metallurgical Engineering*

**Contributor:**
*Frederic J. Deuschle, BS Metallurgy & Materials Engineering*

CONTRARIAN METAL RESOURCES

Phone: 724-779-5100
Toll-Free: 866-360-5100

Visit us on the web at:
**www.metalresources.net**