**THE EFFECTIVENESS OF ROOFING COOL COATINGS ON THE BUILDING ENERGY
DEMAND IN A COLD CLIMATE**

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Abstract

An average temperature increase of 2°C over the last 140 years in Toronto may not seem significant, but in reality heating demand for buildings will go down by impacting natural gas usage while cooling demand will go up by impacting electricity-usage. For preparedness against hot summer in cold climate, passive cooling needs to be adopted for building energy efficiency. In warm climate, cool roof technology proves effectiveness in reducing cooling energy demand of buildings but its use in cold climate is not much seen. Thus it is interesting to investigate the effectiveness of cool roofs in cold climate. This study investigates the properties of cool coatings available in North America, their performance on aging and energy saving benefits. The first phase of research includes selection of building, collection of information, field measurement of surface temperatures of the studied building and also lab testing of collected samples. The second phase includes energy modelling of the studied building with validation to understand their energy saving benefits. Finally the most effective cool coating for the studied building is recommended.

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Tahmina Begum
August 07, 2017

Dedication

**To
My loving children**

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THE EFFECTIVENESS OF ROOFING COOL COATINGS ON THE BUILDING ENERGY DEMAND IN A COLD CLIMATE

1. Introduction

Global warming is an issue of concern today. According to Staff Background Report of Energy Efficiency Office, Business & Strategic Innovation, Facilities & Real Estate Division of the City of Toronto, a further 2°C increase in temperature is projected in the next 30 years alone. The number of days that Toronto experiences temperatures above 30°C is expected to grow from an average of 17 days per year in the period of 1961-1990 to 38 days per year by the 2050s. While a 2°C temperature change does not seem significant, the reality is heating demand for buildings will go down which will impact the use of natural gas while cooling demand for buildings will go up that will impact the use of electricity (Toronto's Sustainable Energy Plan, 2007).

As mentioned in the recent literature, in 2005, residents of Ontario suffered a hot summer with long stretches of high temperatures and humidity; in particular, Toronto sustained 41 days with temperatures above 30°C, and 25 nights with minimum temperature above 20°C (Hengeveld et al., 2005; Wang et al., 2016). In Toronto, days with temperatures above 30°C are expected to increase from an average of 13 nights per year in the 1970s to 65 by the end of this century (Hengeveld et al., 2016; Tam et al., 2015; Berardi et al., 2016). Due to the expected warming of up to 9°C by the 2080s in the Arctic and the southern and central Prairies (Natural Resource Canada, 2004) the number of days with average temperatures above 30°C is likely to increase in cities across Canada, and particularly in those located in the Windsor-Quebec corridor (such as Toronto) and portions of British Columbia (Wang et al., 2016). Every 0.6°C increase in air temperature resulted by the UHI effect can add 1.5% to 2% to the peak demand for cooling (Akbari, 2005; Berardi et al., 2016).

The policies actually adopted in developed countries are insufficient to guarantee a significant reduction in their building energy consumption in the years to come. In the current scenario, at least a doubling of the global energy demand in buildings compared to today's levels will occur by 2050 (Berardi, 2017). To avoid this forecast, cost-effective best practices and technologies as well as behavioral and lifestyle changes need to be diffused and accepted globally (Berardi, 2017). For the preparedness against hot summer in cold climate, passive cooling options need to be adopted for energy efficiency and Urban Heat Island (UHI) mitigation. In warm climate, the

use of cool coating on roof has proven to be a very effective solution in reducing cooling energy demand of the buildings and mitigating UHI effect. However, the use of cool coating on roof in cold climate is not much seen. The following chapter presents literature review regarding cool roof coating contribution in energy performance.

This study analyses some selected cool coatings available in North American market, tests their properties, behaviour while new and aged in the laboratory environment and also compares energy use intensity for different cool coatings as well as surface temperature profiles, and finally recommends whether it is worthwhile to use any cool coating for the studied building regarding its cooling energy efficiency.

As a case study, a storage building in Ajax of Greater Toronto area, Ontario was selected for assessing the benefits of using highly reflective coating to reduce cooling energy use. The building complex consists of two parts; one part has non-heated and non-conditioned self-storage facilities and the other part has an air-conditioned office cum residence for the site manager. The storage part has white painted low metal roof to have lower temperature inside during hot weather, but the office building has flat roof construction finished with roofing membrane (Appendix B) and requires 24 hours cooling during summer. Therefore, it was interesting to analyse this part of building for the reduction of cooling energy. The study is interesting and new in a sense that the properties of some cool coating were tested in the laboratory and those tested properties were used in energy simulation to analyse the cooling energy use intensity for a studied building in cold climate and also Toronto specific climate need is different than most of the studies done in the temperate and Mediterranean climate. The energy bill collected for validation of energy model stands for the whole complex including the office and storage structures.

2. Literature Review

A considerable amount of current literature review on cool roof technology and related publications regarding urban heat island has been conducted to get the understanding of the topic that helped to form the research questions for this study.

2.1 Summary of Current Studies

Petrie et al. (2004) documented how the CoolCalcPeak version was added to include estimates of savings in demand charges that large facilities often incur for electricity. Their study obtained differences in peak deck heat fluxes with solar radiation control and without it over the cooling season for varying location (as characterized by average solar insolation), R-value of the low-slope roof, and solar reflectance and infrared emittance of the roof surface. Peak solar insolation is relatively constant over the United States. Thus, lower demand charges save about the same amount of annual operating costs for a particular set of circumstances in all U.S. climates that have significant cooling requirements. The Cool CalcPeak version of the DOE Cool Roof Calculator was exercised with Miami, Knoxville and Minneapolis climatic data to estimate the effect of solar radiation control on annual energy costs for cooling only, annual energy costs for cooling and heating and annual demand costs for various roof surfaces and insulation R-values. The energy costs show the expected heating penalty for a white (R70E90) surface in all climates. It makes this surface show no energy cost savings for heating and cooling in Minneapolis.

Hoff, JL. (2005) mentioned although effective and accurate means of calculating the economic value of reflective roofing are now easily available, some roofing industry leaders have expressed concern that the benefits of reflective roofing may be misunderstood by many building owners and designers. The first area of possible misunderstanding involves the magnitude of savings offered by reflective roofs and the second involves the application of generalized reflective roofing principles in areas of the country where solar radiation is not a significant climate factor. Misunderstandings due to the lack of effective caveats in programs such as Energy Star and LEED may be further distorted by the marketing messages of commercial organizations with a vested interest in selling reflective roofs. Although this assertion may have some validity in a warm and sunny climate, it is unlikely that a reflective metal roof will provide any more energy savings than any other roof system in a cool and cloudy

environment, such as Oregon, or a cold climate region, such as Minnesota. The author (Hoff, J.L., 2005) developed two graphic representations of the geographic variation in reflective roofing energy savings. The first is a simple tabular representation of the energy data for over 40 cities in the United States that allows direct comparison of the key input variables and calculated outputs for each location. The second graphic representation is a map of the United States dividing the cities into common geographic bands representing different increments of energy savings.

Akbari et al. (2005) summarized laboratory measurements of the solar spectral reflectance of un-weathered, weathered, and cleaned samples collected from single-ply roofing membranes at various sites across the United States. Results indicate that although the majority of samples after being washed with detergent could be brought to within 90% of their un-weathered reflectivity, in some instances an algacide was required to restore this level of reflectivity. They summarized that a simple cleaning with water and cloth allowed the samples to regain a substantial part of their original reflectivity. The roofing materials evaluated in their study did not lose any of its inherent reflectivity with aging, but rather, in-situ reflectivity diminishment occurred because of atmospheric deposition (primarily by soot) and other "local" environmental factors.

Synnefa et al. (2007) estimated the impact of using cool roof coatings on the cooling and heating loads and on the indoor thermal comfort conditions of residential buildings for various climatic conditions. They studied 27 locations around the world and selected 5 locations for representative results. Those selected locations are Abu Dhabi where there is no heating load, New Delhi where cooling load is significantly more important than heating load, Casablanca where heating load is almost half compared to cooling load, Damascus where cooling and heating loads are almost equal and Tokyo that is heating load dominated.

In an effort to estimate also the heating penalty from increasing solar reflectance, they calculated the cooling loads as well. Figure-2.1.1 depicts the changes in cooling and heating loads resulting from an increase in roof solar reflectance of 0.65. It shows that the potential savings are greater in cooling dominated climates. The decrease in cooling loads always exceeded the increase in heating load (except for the case of Mexico City). They concluded that increasing solar reflectance of a roof is typically more beneficial in hot climates where cooling load dominates most of the year.

Figure-2.1.1: Climate effect on cooling & heating load changes for a change in roof solar reflectance of 0.65
(Synnefa et al. 2007)

They found that an increase in roof solar reflectance by 0.65 resulting from the application of a cool coating reduces cooling loads by 8–48 kWh/m², the hours of discomfort by 9–100% and the maximum temperature by 1.2–3.7 °C, depending on the climatic conditions. They also demonstrated that the heating penalty (0.2–17 kWh/m² year) is less important compared to the cooling load reduction (9–48 kWh/m² year) for the climates studied and that increasing the reflectance of the roof would be more beneficial regarding the reduction of energy savings and energy costs for lower or no roof insulation levels.

Santamouris et al. (2011) presented the actual state of the art on the development and the assessment of cool materials (i.e. materials with high solar reflectance and infrared emittance) for buildings and urban structures. The research in this field is roughly divided in four phases and includes the development and assessment of: (a) highly reflective and emissive light coloured materials, (b) cool coloured materials, i.e. coloured materials with increased near infrared and thus overall solar reflectance compared to similarly coloured conventional ones, (c) phase change materials and (d) dynamic cool materials. The study concluded that the development of materials with dynamic optical characteristics seems to be a very efficient solution to increased heating load problem in winter, that is, in balancing the heating penalty.

Figure-2.1.2: The basic principles of cool materials (Santamouris et al. 2011)

If the cool surface is on the building envelope, this would result in decreasing the heat penetrating into the building. Moreover, for a surface in the urban environment, this would contribute to decrease the temperature of the ambient air, as the heat convection intensity from a cooler surface is lower (Figure-2.1.2).

Figure-2.1.3: The spectral reflectance of a conventional and a cool black coating (Santamouris et al. 2011)

A surface that absorbs in the visible part of the solar spectrum in order to have a specific colour, but strongly reflects in the near infrared part, would have an overall solar reflectance that is higher compared to a similarly coloured surface (same visible reflectance) that absorbs also in the near infrared part (Figure-2.1.3).

Figure-2.1.4: The spectral reflectance of conventional (asphalt and aged asphalt) and cool (thin layer green and off-white) asphalt. (Santamouris et al. 2011)

The spectral reflectance of conventional black asphalt (new with $SR = 0.06$ and aged with $SR = 0.15$) and of cool coloured thin layer asphalt (green with $SR = 0.27$ and off-white with $SR = 0.55$) can be applied over existing asphalt paving and increase their solar reflectance (Figure-2.1.4) for reducing urban heat island effect and improving urban thermal comfort condition. So Santamouris et al. (2011) described all major aspects related to each cool roof technology and reported the benefits and impacts of these materials at building, city and global scale. Later after two years, **Kolokotsa et al. (2013)** presented similar benefits of cool materials for the built environment by addressing multiple aspects of the materials and their effects. They covered physical characterization of cool materials, their modelling, rating, testing, energy and environmental impacts, economics and marketing, and related policy aspects.

The study by **Bozonnet et al. (2011)** investigated the potential benefit of cool roof technology in a temperate climate by focusing on a case study in Poitiers (France) on a cool roof for a low-rise public housing, without any active cooling system. The study showed that the cool roof decreases the mean outside surface temperature by more than 10°C , with low differences for lower temperatures, but a strong impact on the highest temperatures. The mean effect of the cool coating on the indoor operative temperature appears to be very low for their studied building, but the difference for the highest temperatures is not negligible. This is mainly due to the strong insulation consistent with building standards in France for all new buildings. Thus, the indoor temperature differences are very clear for the non-insulated building (Figure-2.1.5).

Figure-2.1.5: Operative temperatures evolution for both default roof and cool painted roof: (a) in the attic with insulated roof; (b) in room 1 with insulated roof; (c) in the attic with non-insulated roof; and (d) in room 1 with non-insulated roof (Bozonnet et al. 2011)

Romeo et al. (2013) addressed positive effects of a cool roof application in reducing cooling demand and increasing thermal comfort in Mediterranean climate. Their experiment was carried out in two phases (monitoring and simulation) in an office/laboratory building belonging to a school campus in Trapani, on the west coast of Sicily.

Figure-2.1.6: Outdoor air and roof surface temperature profiles of the non-treated surface and cool roofs from August 1st to 20th (Romeo et al. 2013)

Figure-2.1.6 from their study shows that the difference between the original roof and the air temperature reached 20°C in nine days, while the difference between the cool roof and the air was never higher than 5°C. Romeo et al. (2013) also found that high ratio of the roof surface to the building volume is suitable to achieve significant results. The impact of cool roofs will decrease with the reduction of the above ratio and lower relative savings have to be expected for multi-storey buildings, while the specific savings, typically expressed for roof square meters, will not significantly change.

Pisello et al. (2013) investigated coupled passive–active effect produced by cool roofs on an industrial-office building in Rome, where active effect has the capability to decrease suction air temperature of roof top heat pump external units. While decreasing the suction air temperature, it also decreases the temperature lift between source (intake air) and output (supply air) of the heat pump in cooling mode. Thus the energy efficiency of the heat pump increases in summer.

Figure-2.1.7: Temperature probes of the suction air in (a) before cool roof application and (b) after cool roof application (Pisello et al. 2013)

Their experiment was conducted before and after application of cool roof (Figure-2.1.7). The optical-thermal performance of the chosen cool roof coating was characterized by in-field albedo measurement through albedo meter facility. The albedo before cool roof application was 0.07 (bitumen covering) while the albedo after cool roof application was 0.75.

Figure-2.1.8: External roof surface temperature versus outdoor temperature before and after cool roof application (Pisello et al. 2013)

Figure-2.1.8 taken from their study reports the daily profiles of measured suction temperatures, Ts,B (measured) and Ts,A (measured), and measured outdoor temperatures, To,B (measured) and To,A (measured), for scenarios B (Before cool roof application) and A (After cool roof application), respectively. Therefore, the cool roof “active” effect consists of the reduction of the amplitude difference between Ts and To by 1.2°C , i.e. from 0.7°C to -0.5°C .

Cool roof's passive cooling effect of decreasing suction air temperature (Figure-2.1.8) actively contribute to decrease the temperature lift between source air and output air of the heat pump in cooling mode, thus increases energy efficiency of the heat pump. The overall cool roof benefit corresponds to 34% of energy saving during the day and to 47% during the night.

Pisello et al. (2014) quantified both the summer benefits and the winter penalties of an innovative “cool roof” solution (brick tiles that have been produced through the same industrial process of the other existing tiles and the actual colour is basically light beige-white) with the prototype clay tile to improve thermal condition in residential buildings in temperate climate (Figure-2.1.9).

Figure-2.1.9: Scenario with traditional clay tile and reflective brick tiles.
(Pisello et al. 2013)

During summer, the high reflection tiles are able to decrease the average external roof surface temperature by more than 10°C and the indoor operative temperature by more than 3°C and during winter, the average external surface temperature is lower with high reflection tiles by about 1 °C (Figure-2.1.10). Their study showed that cool roof strategies constitute effective solutions for optimizing indoor thermal performance in summer while winter penalties of the same configurations are very much lower than summer benefits (Fig-2.1.11), in terms of indoor thermal behaviour of the free running attic, also in climate contexts with high seasonal thermal variability.

Figure-2.1.10: Roof overheating with respect to global radiation of location in (a) July and (b) January
(Pisello et al. 2014)

Figure-2.1.11: Indoor environment overheating with respect to the global radiation of the location in (a) July and (b) January (Pisello et al. 2014)

The study shows how this kind of roof element optimization in terms of reflectance and emissivity could decrease the roof external temperature and to reduce also the attic overheating when the sloped roof is directly impacted by sunbeams.

Hosseini et al. (2014) quantified the heating energy penalties of a cool roof accounting for the effect of roof snow. The researchers simulated the annual heating and cooling energy use in conventional and cool roof buildings in four cities (Anchorage, Milwaukee, Montreal & Toronto) in cold climates.

In cold climates, the sun angle is low, days are short, the sky is cloudy, and most the heating occurs early in the morning or in the evening hours during winter when the solar intensity is low. In addition, the roof may be covered with snow for most of the heating season. Snow on the roof provides an additional layer of insulation and increases the solar reflectance of the roof. All these lead to a lower (than what is commonly thought) wintertime heating penalties for cool roofs (Figure-2.1.12). Thus it is found that the penalties for cool roofs in cold climates are very small, if any. Cool roofs also save peak demand electricity use during summer (Figure-2.1.13) and potentially lead to downsizing of the HVAC equipment.

Figure-2.1.12: Small office building monthly electrical heating consumption (Hosseini et al. 2014)

Figure-2.1.13: Small office building monthly electrical cooling consumption (Hosseini et al. 2014)

Antonaia et al. (2016) conducted the experimental investigation of the optical and thermal properties of several types of “cool paints” in terms of solar reflectance, thermal-emittance, and durability in Mediterranean climate. The main steps of the research were selection of new products for cool roof; development of the samples and in-lab experimental analysis for the characterization of thermal-optical properties; numerical analysis for the evaluation of energy saving and reduction of polluting emission, with indicative economic feasibility study. The result showed only the white acrylic paint has good values for spectral reflectance (77 - 80%) and thermal emissivity (92%) that are comparable with commercial products. Globally summer benefits are very satisfying but the annual energy saving varies between 0.3-3.0%. Their research differs with the other studies reviewed in this chapter because they evaluated the potentialities of commercial products (paints of automotive sector) not specialized for cool roofing application.

Sharma et al. (2016) examined the efficacy of green and cool roofs as potential UHI mitigation strategies to make cities more resilient against UHI. Their study discussed green/cool roof mechanisms, evaluated UCM's performance with observations and assessed impacts of UHI on different urban land-use, regional lake breeze circulations, and boundary layer effects. Even though the results of the modelling system are site-specific and location dependent, they, especially qualitative impacts on the convective boundary layer, can be interpolated to other urban areas which strive for similar sustainability goals as Chicago.

Figure-2.1.14. Angular distribution of reflected radiation: RR sample (Source: Castellani et al. (2016))

According to **Castellani et al. (2016)**, retro-reflective (RR) materials, due to their ability to reflect most of the incident energy towards the same incoming direction, represent an opportunity to reduce UHI phenomenon. The optical properties of retro-reflective materials

suggest that they could be effectively applied as coatings in order to reflect the solar radiation beyond the urban canyon. Retro-reflective samples show the preponderance of retro-reflected radiation for 10° and 30° . At 60° retro-reflection property is maintained, although symmetrically-reflected radiation percentage is higher than the retro-reflected one. At 70° , retro-reflection is completely lost and there is only specular reflection (Fig-2.1.14).

Figure-2.1.15 from their study depicts the global reflected radiation profiles of Beige diffusive and Retro-reflective tested sample over the wavelength in a reproduced urban canyon in laboratory.

Figure-2.1.15. Reflectance spectrum: Beige diffusive and Retro-reflective (Source: Castellani et al. (2016))

Morini et al. (2017) showed that for high angles of incidence (greater than 60°) the retro-reflectivity is lost by the retro-reflective samples. Their experimental characterization showed that retro-reflective materials could be effectively applied as coatings on building envelope, in order to reduce the energy trapped within the urban canopy and thus to reduce the UHI effect.

Figure-2.1.16: Glass beads for retro-reflective property (Source: Morini et al. (2017))

Their study is connected to the international research activities on retro-reflective materials and aims at giving a contribution on the development of retro-reflective coatings suitable for building applications (Figure-2.1.16).

The paper of **Morini et al. (2017)** aims at investigating the relationship between the global (direct and diffuse) solar radiation and its reflection from an experimental model resembling urban districts with different geometries and different materials. They found that the increase of the average daily urban albedo and thus the reduction of urban heat island formation and the improvement of the urban comfort can be obtained by the use of retro-reflective envelopes.

Rossi et al. (2014) dealt with an experimental and analytical study for the assessment of the angular reflectance of retro-reflective films. The experimental campaign and a novel analytical model showed that retro-reflective materials could be effectively applied as coatings on urban paving and building envelope, in order to reflect the solar radiation beyond the urban canyon and the urban canopy in general.

The specific research target of **Rossi et al. (2015)** was to investigate the benefit that can be obtained by the application of new retro-reflective cool materials on building envelopes in urban canyons. The results suggest that retro-reflective materials have a cooling potential as coatings in urban canyons, and can thus improve urban climate conditions during summer.

Figure-2.1.17: Samples' angular distribution of reflected radiation (Source: Rossi et al. (2015))

The paper of **Rossi et al. (2015)** aimed at the assessment of angular reflectance of retro-reflective films for several inclination angles of solar radiation. The experimental characterization and energy evaluations showed that retro-reflective materials could be effectively applied as coatings on urban paving and building envelope, in order to reduce the circulating energy into the canyon.

Rossi et al. (2016) studied the positive effect of retro-reflective pavements on the energy kept inside the canyon on a physical model that represents an urban canyon layout. The performance of retro-reflective materials was compared to that of white and beige traditional cool diffusive materials in the spectral range of the incoming radiation from 360 to 1100 nm (Figure-2.1.21). The results show a cooling potential of the retro-reflective material with respect to the white and the beige diffusive materials, with a maximum albedo increase of 4.6%.

The paper of **Zinzi et al. (2017)** investigates the impact of the urban environment on the energy and thermal response of residential buildings, considering the case of the city of Rome, Italy. Ambient air temperature and relative humidity were continuously measured in four neighbourhoods in 2015 and 2016. The monitored neighbourhoods were characterized by location in the urban area; construction materials for buildings and pavements; geometry of the urban texture. Data were also measured by a non-urban station, used as undisturbed reference. The climatic data were then used to calculate the thermal response of a typical Italian residential building, ideally located in the monitored areas of the city. Two envelope configurations were taken into account: with and without thermal insulation. Heat island intensities up to 8 °C were detected, with maximum monthly averages equal to 2 °C. The urban heat island increases the building cooling energy needs by 12% in the peripheral neighbourhood and by up to 46% in the city centre, respect to the undisturbed zone.

2.2 Analysis for Future Research Area

From the literature review, an overall understanding on the contribution of cool roof technology on energy performance has been gained. Petrie et al. (2004) documented how the CoolCalcPeak version was added to include estimates of savings in demand charges that large facilities often incur for electricity. Hoff, J. L. (2005) developed two graphic representations of the geographic variation in reflective roofing energy savings. The study from Synnefa et al. (2007) estimated the impact of using cool roof coatings on the cooling and heating loads and on

the indoor thermal comfort conditions of residential buildings for various climatic conditions. Santamouris et al. (2011) reported all major aspects related to each cool technology such as benefits and impacts at building, city and global scale. The wide use of such materials can significantly contribute to the mitigation of the heat island effect and the improvement of urban environmental quality. A further research can be initiated regarding cooling energy efficiency by the use of cool coating on exterior walls of buildings.

Kolokotsa et al. (2013) elaborated the same concepts like Santamouris et al. (2011) with some other related aspects later, which gave a detail understanding on the technology.

Akbari et al. (2005) summarized the majority of collected roofing samples could be brought to within 90% of their un-weathered reflectivity after being washed with detergent, in some instances an algacide was required to restore this level of reflectivity. A further study can be conducted regarding aging of cool roof technology using different types of substrates.

Bozonnet et al. (2011) showed that the cool roof decreases the mean outside surface temperature, with low differences for lower temperatures, but a strong impact on the highest temperatures. Thus, direct impact on high temperatures depending on the building use and the ceiling insulation highlights the interest of the cool coating on the summer comfort. The study by Romeo et al. (2013) concluded that the impact of cool roofs will decrease with the reduction of 'roof surface to building volume ratio' and lower relative savings have to be expected for multi-storey buildings, that means, cool roof impacts on the immediate lower storey under the roof. A future work can be done to understand the reduction of cooling energy for the lower stories of multi-storey buildings while using the cool coating on vertical facades of the envelope.

The result from the study of Pisello et al. (2013) gave an understanding that the cool roof is able to decrease the suction air temperature of the heat pumps external units, when these units are located over the roof and thus increases the efficiency of the heat pump. A further study can be done regarding increasing efficiency of heat pump by comparing different type of cool roof technology.

The study of Pisello et al. (2014) showed that cool roof strategies constitute effective solutions for optimizing indoor thermal performance in summer while winter penalties of the same configurations are very much lower than summer benefits, in terms of indoor thermal behaviour of the free running attic, also in climate contexts with high seasonal thermal variability. Hosseini

et al. (2014) found that the penalties for cool roofs in cold climates are very small, if any. Cool roofs save peak demand electricity use during summer and potentially lead to downsizing of the HVAC equipment; this is the one of the cold climate based study among the literature reviewed for this report, but it emphasized on heating penalty. Antonaia et al. (2016) evaluated the potentialities of commercial products not specialized for cool roofing application in Mediterranean climate. Sharma et al. (2016) examined the efficacy of green and cool roofs as potential UHI mitigation strategies to make cities more resilient against UHI.

According to Morini et al. (2017) retro-reflective (RR) materials have been proposed as innovative cool materials. RR materials are characterized by optical properties that reflect most of the incident solar energy backward towards the same incident direction. A number of studies contributed to understand the application of retro-reflective materials on building envelopes in decreasing circulating energy in urban canyons to reduce of UHI by (Rossi et al. (2014), Rossi et al. (2015), Rossi et al. (2016) and Morini et al. (2017). Regarding retro-reflective materials, Castellani et al. (2016) and Morini et al. (2017) showed in addition that for higher angles of incidence (greater than 60°) of solar radiation the retro-reflectivity is lost by the retro-reflective samples. Researchers at present are already actively studying for using retro-reflective paint as cool coating on reducing heat island effect in urban canyons, thus further studies can be done how the use of retro-reflective paints effect on cooling energy of buildings.

Zinzi, M. et al. (2017) investigated the impact of the urban environment on the energy and thermal response of residential buildings, considering the case of a Mediterranean city. Another future study can be done for residential buildings with slope roof in cold climate with hot summer.

3. The Research

3.1 Conceptual Framework & Research Questions

From literature review, it has been found that most of the studies regarding cool roof technology for energy performance have been conducted in temperate and Mediterranean climate. And considerably few works regarding this technology have focused on energy savings in cold climate especially on cooling energy in cold climate.

According to ASHRAE 90.1-2007, Toronto is in climate zone 6. Heating degree-days (HDDs) based on 18°C in zone 6 is 4000. Here it is useful to understand the definition of cold climate with hot humid summer. According to ASHRAE 90.1-2010, *degree-day* is the difference in temperature between the outdoor *mean temperature* over a 24-hour period and a given base temperature. For the purposes of determining *building envelope* requirements, the classifications are defined as follows: *cooling degree-day(CDDs) base 50°F*: for anyone day, when the *mean temperature* is more than 50°F or 10°C, there are as many *degree-days* as degrees Fahrenheit temperature difference between the *mean temperature* for the day and 50°F. Annual *CDDs* are the sum of the *degree-days* over a calendar year. And annual HDDs are the sum of the *degree-days* over a calendar year. As mentioned by John Straube, 2012, many parts of eastern cold climate regions have similar cooling demand as locations in the southern US, such as, Toronto has significant cooling and humidity control challenges. Hence, high performance of buildings in these climates needs to manage hot and humid weather as well as cold dry weather.

Considering the climate of Toronto, that experiences high temperature during summer and is getting higher every year, it is the right time to think about the preparedness against hot summer with an aim of reducing cooling energy in buildings. In warm climate cool roof technology has been proven to be a very effective solution, therefore, it was interesting to investigate the effectiveness of roofing cool coatings on the building energy demand in a cold climate with hot summer like Toronto. As discussed in Chapter 1, this study is new because the properties of some cool coating were tested in the laboratory and those tested properties were used in energy simulation to analyse the cooling energy use intensity for a studied building in cold climate and also Toronto specific climate need is different than most of the studies done in the temperate and Mediterranean climate.

The study is based on an experimental research and has three research questions as follows:

- What are the reflectance values of some cool coatings available in North America?
- Do the selected cool coatings lose some reflectance value due to aging?
- What are the energy saving benefits of the selected cool coatings in cold climate?

3.2. Methodology/Research Design

The methodology of this research has been divided into two main phases and has been elaborated as follows:

First Phase:

The first phase of the research consists of the experiment of cool coatings in the laboratory and the steps are as follows:

1. Identify and collect five cool or high reflective coatings available in North American market.
2. Understand the properties (specifically reflectance) of cool coatings from manufacturers' technical data sheets.
3. Prepare substrates for experiment by cutting ceramic tiles into pieces of 6 cm X 10 cm size using appropriate tools (eg. glass cutter and/or tile cutter) to apply coating for test (Figure-3.2.1 & 3.2.2).

Figure-3.2.1: Glass cutter

Figure-3.2.2: Tile cutter

4. Apply the selected cool coatings on substrates to get five sample sets (Figure-3.2.3), one of the sets kept for aging test.

Figure-3.2.3: Cool coating sample sets

5. Measure and record the reflectance values of the cool coatings using spectrophotometer in the laboratory (Figure-3.2.4).

Figure-3.2.4: Spectrophotometer

6. Keep one set of samples in the Aging machine (Accelerated Weathering Tester-QUV) in the laboratory to let them age for one month (1 month = 20 years time) (Figure-3.2.5).

Figure-3.2.5: Aging Machine

7. Measure the reflectance values of the aged samples in the laboratory using spectrophotometer.
8. Compare the recorded reflection data to find the changes on reflective behaviour between the newly coated and aged samples.

Second Phase:

The second phase of the research includes energy modelling for the energy saving value of the selected cool coatings in cold climate using Design Builder software that uses Energy Plus as its simulation engine. The methodology for this phase is as follows:

1. Selection of a building that uses air-conditioning during summer and may require reduction of cooling energy usage.
2. Collect detail drawings of the selected building complex and the electricity bills during summer time.
3. Measure indoor air temperature, roof surface temperature and ceiling surface temperature by using data logger (MadgeTech Oct Temp 8-channel thermo-couple temperature recorder with USB data-logger interface ICF 200) for the selected building at least for 20 days during summer to understand the temperature profile on the location.

Figure-3.2.6: MadgeTech Oct Temp 8-channel thermo couple temperature recorder

4. Model the building complex in Design Builder using the properties of materials mentioned in the collected drawings.
5. Run simulation using the local weather station file (Toronto Pearson International Airport) and compare the measured and simulated temperatures on roof and ceiling surface to understand the variation in temperature profile of that location.
6. Calibration/Validation of model by comparing collected and simulated energy use intensity to check reasonable accuracy ($\pm$) of the experiment.
7. Further simulation by applying five selected cool coatings with their properties, determined from lab test, on the roof surface of the studied portion of the building to understand the variation of energy use intensity.
8. Compare the results of energy use intensity for five different selected cool coatings from the simulation.
9. Recommend the effective cool coating, if worthwhile, for cooling energy reduction for the studied part of the complex.

3.3 Limitations

- It would be effective to validate the energy model by using the on-site temperature of roof, ceiling and indoor temperature of the air-conditioned part of the complex. But it was not possible as there is no existing roof hatch in this part of the building. Furthermore, the workplace privacy did not allow the long-time measurement process to take place. Thus, the measurement was taken on the non-air-conditioned part of the complex, which is the storage area, and has been used to have an idea about variation of inside and outside surface temperature profile of that location by comparing with simulation data.
- A variety of cool coating samples are not available in Canada. The reason may be the use of cool roof is not common in cold climate. Therefore, two of the coatings out of five samples have been collected from USA and used for the experiment.
- Due to the unavailability and workability of the latest weather data (epw file of 2016), the 2002 weather file built in Design Builder software has been used for the simulation which definitely gives a different picture rather than it would have given in the real situation; but the result was close and did not deviate more than 20 to 30% for this study.
- The electricity bill collected is for the whole complex. But the energy simulation model was done for the office cum residence part of the complex only (as shown in Figure-4.3.1). And Building-8 has been simulated for comparing on-site temperature measurement. Thus to compare energy use between collected and simulated data, the electricity usage for non-air-conditioned storage parts (Building 1 to 7) has been calculated manually following Building-8 electricity usage.
- One of the samples, Albedo 100 permanent silver reflective spray, is not manufactured for use on the roof and does not mention any reflectance value anywhere. But it has been selected for being a reflective coating applicable to any surface and also available in Canada; thus the average value found in the laboratory test for this has been used for energy simulation.

3.4 Possible Outcome and Motivation

The possible outcome of the study may help the designers in decision making for selecting cool roof material for buildings and houses in cold climate, either for retrofit or new construction purposes. The study may help the manufacturers regarding the introduction of innovative cool roof products for cold climate further. The availability and use of different cool roof product on roof will help to improve indoor comfort of building and reduce cooling energy demand and thus will contribute to cool the globe by mitigating urban heat island in a passive way.

4. Analysis

The analysis of the selected cool coatings has been done by using collected technical datasheets from the manufacturers, laboratory testing of the collected samples and energy simulation using the sample properties.

4.1 Analysis of Cool Coatings from Manufacturer's Datasheet

The manufacturer's technical data sheets of the selected cool coatings have been collected and the properties studied have been outlined from their data sheets in the following sub-sections.

4.1.1 Kool Seal Premium White Elastomeric Roof Coating (63-600)

As per manufacturer's technical data sheet (Appendix-A), Kool Seal® Premium White Elastomeric Roof Coating (63-600) is formulated with 100% acrylic elastomeric resin. The coating forms a thick rubber-like blanket of protection that expands and contracts with roofs. It remains flexible from -30°F to 160°F for long-lasting protection and provides superior reflectivity to lower interior temperatures and save energy. The features of this coating are:

- Energy saving up to 35%
- Reflects 90%+ of the sun's rays

4.1.2 Kool Seal Premium White Elastomeric Roof Coating (KS0063600-16)

As per response from query to KST coatings, Kool Seal Premium White Elastomeric Roof Coating (KS0063600-16) reflects 90% of the sun's rays.

4.1.3 LANCO Urethanizer™ RC-994

According to manufacturer's technical data sheet (Appendix-A), LANCO® Urethanizer™ is a high performance, rubberized, ceramic urethane, elastomeric, roof coating and sealer. A highly durable, fibre reinforced roof coating with superior adhesion properties. The ceramic composition of this product will significantly lower interior temperature of structures by reflecting 79% of the sun's rays and reducing heat by 89%.

Due to high content of highly reflective pigments, it will allow the finish to remain white for longer periods maintaining an average solar reflectance of 82% *7, three years after initial application (as independently tested, ASTM C 1549).

As per laboratory test by Cool Roof Rating Council, the solar reflectance of LANCO Urethane RC-994 is initially 0.83 and after 3 years 0.72 (Appendix-A).

4.1.4 LANCO Ultra Siliconizer™ RC-905

According to manufacturer's technical data sheet (Appendix-A), LANCO Ultra Siliconizer™ RC-905 is a single component 100% acrylic silicone sealer for roofs and walls with adhesive properties that will provide a thick, high performance, water and weather resistant seal on most surfaces, usually without need of a primer coating. It will significantly lower the interior temperature of the structure by reflecting 78% of the sun's rays and reducing heat received by 90%. Product will not crack, peel or blister even under severe weather conditions.

Due to high content of highly reflective pigmentation, it will maintain an average solar reflectance of 84% three (3) years after application (as independently tested ASTM C 1549).

As per laboratory test by Cool Roof Rating Council, the solar reflectance of LANCO Ultra Siliconizer RC-905 is initially 0.84 and after 3 years 0.69 (Appendix-A).

4.1.5 Albedo 100 Reflective Spray Permanent

As from the website of Albedo 100, it is a spray with light-reflective properties that sticks to most surfaces, and resists wind and rain. The spray is UV-resistant and is durable on materials such as wood, concrete, metal, stone, etc.

From the description on the spray container, the information gathered is as follows:

- Developed for night safety
- Reflects light back to source.
- No reflectance value is mentioned anywhere and no response received against query for reflectance from Albedo 100 Reflective Spray North American office.

4.1.6 Summary of Properties of Selected Cool Coatings from Manufacturer' Data Sheet

The properties, ie, reflectance values of the selected cool coatings from the manufacturer's technical data sheets have been summarised as table form (Table-4.1.1) with reduction of reflection values due to aging.

Table-4.1.1: Solar reflectance of Cool Coatings from Manufacturer's Data Sheet and Additional Information

Selected Cool Coatings	Solar Reflectance (%)		Reduction of Reflection due to Aging (%)
	Newly Coated	Aged	
Kool Seal 1 (63-600)	90	Not found	-
Kool Seal 2 (KS0063600-16)	90	Not found	-
LANCO Ultra-Siliconizer RC-905	84	69	17.86
LANCO Urethanizer RC-994	83	72	13.25
Albedo 100 Permanent Silver Reflective Spray	Not found	Not found	-

4.2 Analysis of Cool Coatings for Lab Test

The cool coating samples were analysed in the laboratory for their properties while these are newly coated, after aging and also for the variation due to different number of coats.

4.2.1 Samples for Laboratory Test:

The sample sets for laboratory test were prepared by applying the coatings on the substrates cut out of the ceramic tiles of equal sizes (6 cm x 10 cm) using appropriate instruments. These samples were named to keep track of their identity as follows:

Sample # 1 Kool Seal® Premium White Elastomeric Roof Coating (63-600)

1A
1B
1C
1D
1E

Sample # 2 Kool Seal Premium White Elastomeric Roof Coating - KS0063600-16

2A
2B
2C
2D
2E

Sample # 3 LANCO Urethanizer™ RC-994

3A

3B

3C

3D

3E

Sample # 4 LANCO Ultra Siliconizer™ RC-905

4A

4B

4C

4D

4E

Sample # 5 Albedo 100 Reflective Spray Permanent 4.6oz

5A

5B

5C

5D

5E

4.2.2 Reflection behaviour of Samples from Laboratory Test

The reflection values of the newly coated sample sets were measured using the spectrophotometer. The documented values showed the following behaviours of the selected cool coatings.

Table-4.2.1: Average Solar reflectance measured for newly coated samples in laboratory

Newly Coated Samples	Solar Reflectance %
Kool Seal 1 (63-600)	77.3
Kool Seal 2 (KS0063600-16)	75.2
LANCO Ultra-Siliconizer RC-905	79.6
LANCO Urethanizer RC-994	77.1
Albedo 100 Permanent Silver Reflective Spray	25.0

4.2.3 Reflection behaviour due to Aging

The aging test was done using QUV Accelerated Weathering Tester in the laboratory with -----
--standard. The QUV accelerated weathering tester reproduces the damage caused by sunlight, rain and dew. In a few days or weeks, the QUV UV tester can reproduce the damage that occurs over months or years outdoors. One set from the coated samples were kept inside the aging machine in the laboratory to document the change for one month. The reflection values of the aged sample sets were measured using the spectrophotometer. The documented values showed the following behaviours of the selected cool coatings.

Table-4.2.2: Solar reflectance measured for aged samples

Aged Samples	Solar Reflectance %
Kool Seal 1 (63-600)	77.0
Kool Seal 2 (KS0063600-16)	74.5
LANCO Ultra-Siliconizer RC-905	79.1
LANCO Urethanizer RC-994	76.1
Albedo 100 Permanent Silver Reflective Spray	24.7

4.2.4 Comparison of results from Laboratory Test

The comparison of laboratory test shows that reflectance values are reduced insignificantly due to aging of cool coatings as shown in Table 4.2.4.

Table 4.2.4: Comparison of Solar Reflection for Newly Coated and Aged Cool Coatings in laboratory

Samples	Solar Reflectance (%)		Reduction of Reflection due to Aging (%)
	Newly Coated	Aged	
Kool Seal 1 (63-600)	77.3	77.0	0.39
Kool Seal 2 (KS0063600-16)	75.2	74.5	0.93
LANCO Ultra-Siliconizer RC-905	79.6	79.1	0.63
LANCO Urethanizer RC-994	77.1	76.1	1.43
Albedo 100 Permanent Silver Reflective Spray	25.0	24.7	1.2

4.3 Analysis of Cool Coatings by Energy Simulation

The properties of cool coating samples determined from laboratory test were assigned in the energy model to analyse energy use intensity for their properties while those samples are newly coated.

4.3.1 Selection of Study building

Sentinel Storage, located at 75 Harwood Avenue North, Ajax, Ontario (Figure-4.3.1) was selected for the study. The complex consists of eight non-heated and non-conditioned storage buildings (Building 1 to 8) with a small heated and air-conditioned office cum residence for site manager. The air-conditioned part of the complex has typical flat roof construction with roofing

membrane with insulation R-20, while the storage parts have white painted metal roofs with insulation (R-20 for Building 8 and R-7 for Building 1-7). The office cum residence has an area of 125.20 m² which has been considered for this study. The studied part shares a common wall with the largest storage building (Building 8) and the rest of the storage buildings are all isolated as shown in Figure-4.3.2.

Figure-4.3.1: Sentinel Storage Ajax in Google Map

Figure-4.3.2: The location of studied building in the complex

The walls and roof details were studied from the drawings collected from the site manager. The following table (Table-4.3.1) shows the wall and roof details influencing the part of the building studied (See Appendix B for sectional details). Wall Construction 1, 2 and 3 are for the studied part of the building and wall construction 4 is for Building-8 only. Building 8 shares a common wall with the studied part. Roof Construction 1 is typical for the studied part of the building and Roof Construction 2 is for Building-8 only.

Table-4.3.1: Wall and Roof Construction Types (See appendix B for assembly sections)

<u>Wall Construction 1</u> 8" Architectural Block 1" Air Space 6" Metal Studs @ 16" O.C. R20 Fibrous Insulation Continuous 6 mil VB ½" Gypsum Board	<u>Wall Construction 2</u> Pre-engineered Wall System 10" Concrete Block 6" Metal Studs @ 16" O.C. Continuous 6 mil VB R20 BATT Insulation ½" Gypsum Board 2 hours Fire Resistance Rating
<u>Wall Construction 3</u> 10" Architectural Block 4" Pre-engineered Wall System R20 BATT Insulation	<u>Wall Construction 4</u> Precast/Tilt-up Concrete Wall Pre-engineered Wall System R20 Insulation
<u>Roof Construction 1</u> Roofing Membrane R20 Rigid Insulation Vapour Retarder 1 ½" Metal Deck	<u>Roof Construction 2</u> Pre-finished Metal Roof Purlins by Pre-engineered Building Manufacturer R20 Insulation Vapour Barrier

4.3.2 Onsite Measurement

The measurement process was undertaken in one of the storage units as shown in Figure-4.3.2. Indoor air temperature, roof surface temperature and ceiling surface temperature were measured by using data logger (MadgeTech Oct Temp 8-channel thermo-couple temperature recorder with USB data logger interface ICF 200) during summer 2016 starting from 8th July to 28th July for 20 days to understand the temperature profile on the location. Two thermocouples were attached on the outside roof surface and inside ceiling surface respectively by connecting with two of the eight channels of the device to get the readings in every 5 minutes interval.

4.3.3 Modelling the Study Building

The energy model was created for simulation of the air-conditioned part of the complex and each of the selected cool coatings was applied using their properties from lab test to get the results. Additionally Building-8 was also modelled for comparing the simulated roof and ceiling surface temperature with the real scenario from on-site temperature measurement so that an idea about variation of temperature profile can be found.

4.3.4 Understanding Surface Temperature from Model & On-site Measurement

From on-site measurement of the temperature of outside surface (roof), inside surface and outside dry-bulb of the storage part of the complex on July 2016, it has been observed that ceiling surface temperature is always 10 to 15°C lower than the roof surface temperature (Figure 4.3.3). The reason may be for the use of white painted roof over the storage part of the complex.

Figure-4.3.3: Hourly Roof Surface, Ceiling Surface & Outside Dry-Bulb Temperature from Measurement on July 2016

Figure-4.3.4: Hourly Roof Surface, Ceiling Surface & Outside Dry-Bulb Temperature from Model using 2002 Weather Data on July 2016

From energy modelling of the storage part of the complex where the onsite measurement was taken, the temperature of outside surface (roof), inside surface and outside dry-bulb of the storage part of the complex on July 2002 were studied (Figure 4.3.4); it has been observed that ceiling surface temperature is also always much lower than the roof surface temperature. Thus an understanding has been gathered from the comparison of on-site observation and modelling result of similar behaviour of having lower temperature on inside ceiling surface than roof surface while the roof of existing storage is of white pre-finished metal on roof purlins by pre-engineered building manufacturer.

Figure 4.3.5 shows the comparison of on-site measurement and energy model results together.

Figure-4.3.5: Comparison of Hourly Roof Surface, Ceiling Surface & Outside Dry-Bulb Temperature between Measurement taken in July 2016 & Model using 2002 Weather Data

4.3.5 Validation of Model

The electricity bills from three billing periods during summer were collected for the complex (see Appendix). The billing periods are 15th May to 15th June, 15th June to 15th July and 15th July to 15th August in 2016. The bill includes the total electricity usage for the complex. To match total electricity use (kWh) from collected utility bill (by Veridian) with total electricity use (kWh) from the model, electricity usage of the total complex was calculated. The office and residence part (Studied portion) as well as Building-8 (Attached storage part) was taken from energy simulation but rest of the storage parts (Building 1 to 7) was manually calculated following the electricity usage of Building-8. Then total electricity usage from the model was found by addition.

4.3.6 Total Energy Use Behaviour from Collected Data

The electricity usage collected from utility bill (Appendix-D) of the complex for May-June billing period was found as 10160 kWh, for June-July billing period was 9840 kWh and for July-August billing period was 10560 kWh (Figure-4.3.6).

Figure-4.3.6: Total Electricity (kWh) used from Collected Data (Electricity Bill) for the Complex

4.3.7 Total Energy Use Behaviour from Simulation

The electricity usage from energy simulation was found as 7889.55 kWh, 8697.31 kWh and 8913.61 kWh (Figure-4.3.7) for three similar billing periods (May-June, June-July and July-August).

Figure-4.3.7: Total kWh used from Energy Simulation for the Complex

4.3.8 Deviation & Accuracy

Total electricity use of the complex from utility bills (Appendix-D) and energy model were compared (Figure 4.3.8) to check the deviation and accuracy of the model.

Figure-4.3.8: Comparison of Current Electricity Use between Utility Bill & Model

The deviation of model is found 22.35%, 11.62% and 15.6% for billing period May-June, June-July and July-August respectively (Figure 4.3.9). This deviation may seem higher, but 2002 weather file has been used for simulation which is the reason for such deviation as mentioned in the limitations.

Figure-4.3.9: Model Deviation %

Figure-4.3.10: Accuracy %

The accuracy of model is 77.65%, 88.38% and 84.4% for the same three billing period respectively (Figure 4.3.10).

4.3.9 Energy Use Behaviour of Cool Coatings from Energy Simulation

The energy use behaviour in kWh per m² was studied by simulating the model with each type of selected cool coating property for annual, all summer (01 April to 30 September), summer design week (08 July to 14 July), summer typical week (19 August to 25 August) and also for three billing periods (15 May-15 Jun, 15 Jun-15 Jul and 15 Jul-15 Aug) as shown from Figures 4.3.11 to 4.3.18.

Figure-4.3.11: Annual Cooling Energy Use per m²

Figure-4.3.12: All Summer Cooling Energy Use per m²

Figure-4.3.13: Summer Design Week Cooling Energy Use per m²

Figure-4.3.14: Summer Typical Week Cooling Energy Use per m²

Figure-4.3.15: 15 May to 15 August Cooling Energy Use per m²

Figure-4.3.16: 15 May to 15 June Cooling Energy Use per m²

Figure-4.3.17: 15 June to 15 July Cooling Energy Use per m²

Figure-4.3.18: 15 July to 15 Aug Cooling Energy Use per m²

Analysing energy use intensity per m² from Figure 4.3.11 to 4.3.18, it has been revealed that all the cool coating samples depending on their own reflectance values possess the ability to reduce cooling energy usage compared to existing roof having bitumen roofing membrane. All the eight figures mentioned above show that existing roof has the highest usage of cooling energy per unit area. Sample # 4, LANCO Ultra-Siliconizer, which has the highest reflectance value of 80% results in the lowest energy usage and saves 7.43% of cooling energy annually and 6.39% for three billing period compared to the existing roofing membrane. Sample#5 Albedo 100 has the lowest reflectance and highest energy usage among the tested coatings. Thus higher the reflectance value, lower the energy use.

5. Surface Temperature Analysis from Simulation

From model, the surface temperature of roof (exterior surface) and ceiling (inside surface) of the studied part have been analysed considering conditioned and non-conditioned option for June 21-22, July 21-22 and August 21-22. As the temperature is the highest around July 21; thus taking the day one month before and one month after from July 21 has been considered as representative of summer for energy simulation. The conditioned option has been simulated with mechanical ventilation on, cooling on and natural ventilation off. The non-conditioned option uses both, one with mechanical ventilation on and the other with natural ventilation on. The non-conditioned mechanical ventilation option has been simulated with mechanical ventilation on, cooling off and natural ventilation off. The non-conditioned natural ventilation option has been simulated with mechanical ventilation off, cooling off and natural ventilation on.

5.1 Surface Temperature Analysis for June 21 & 22

The graphs in Figure 5.1.1, 5.1.2 and 5.1.3 show that the ceiling and roof surface temperature of the studied part of building starting from June 21 at 00.01 hours midnight to June 22 at 23:59 hours for three options (conditioned, non-conditioned with mechanical ventilation and non-conditioned with natural ventilation). Outside dry-bulb temperature is around 18 and 23 in peak time. The existing bitumen roof surface reaches at 47 and 75°C at peak times. All coating samples except Sample#5 Albedo 100 (as it has lower reflectance 25%) show very low temperature on outside surface or roof than the existing bitumen roof with 25 to 55°C difference for all options,. Inside surface or ceiling temperature does not show notable reduction for conditioned option. Considering non-conditioned options, inside surface or ceiling temperature gets little higher than that of conditioned option for both cases, mechanical and natural ventilation. But the total effect of cool coating combined with roof and ceiling surface temperature reduces the cooling energy as found from simulation result in Chapter 4.

Figure 5.1.1: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from June 21 to 22 considering Conditioned Space

Figure 5.1.2: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from June 21 to 22 considering Non-Conditioned Space with mechanical Ventilation

Figure-5.1.3: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from June 21 to 22 considering Non-Conditioned Space with Natural Ventilation

5.2 Surface Temperature Analysis from July 21 to 22

Similarly the graphs in Figure 5.2.1, 5.2.2 and 5.2.3 show that the ceiling and roof surface temperature of the studied part of building starting from July 21 at 00.01 hours midnight to July 22 at 23:59 hours for three options (conditioned, non-conditioned with mechanical ventilation and non-conditioned with natural ventilation). Outside dry-bulb temperature is around 20 and 21 in peak time. The existing bitumen roof surface reaches at 36 and 56°C temperature, lower than the case of June, at peak times. All coating samples except Sample#5 show very low temperature on outside surface or roof than the existing bitumen roof with 15 to 35°C difference for all options,. Inside surface or ceiling temperature does not show notable reduction for conditioned option. Considering non-conditioned options, inside surface or ceiling temperature gets little higher than that of conditioned option for both cases, mechanical and natural ventilation. Comparing with June results, July cases for non-conditioned options get 2 to 3°C higher temperature because of the outdoor dry-bulb temperature increase.

Figure 5.2.1: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from July 21 to 22 considering Conditioned Space

Figure-5.2.2: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from July 21 to 22 considering Non-Conditioned Space with Mechanical Ventilation

Figure 5.2.3: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from July 21 to 22 considering Non-Conditioned Space with Natural Ventilation

5.3 Surface Temperature Analysis from August 21 to 22

Similarly the graphs in Figure 5.3.1, 5.3.2 and 5.3.3 show that the ceiling and roof surface temperature of the studied part of building starting from August 21 at 00.01 hours midnight to August 22 at 23:59 hours for three options (conditioned, non-conditioned with mechanical ventilation and non-conditioned with natural ventilation). Outside dry-bulb temperature is around 28 and 22 in peak time. The existing bitumen roof surface reaches at 62 and 55°C temperature at peak times. All coating samples except Sample#5 show very low temperature on outside surface or roof than the existing bitumen roof with 30 to 35°C difference for all options,. Unlike June and July, inside surface or ceiling temperature does not show notable reduction for conditioned option. Non-conditioned option with mechanical ventilation shows 8 to 10°C higher inside surface or ceiling temperature than that of conditioned option whereas non-conditioned option with natural ventilation shows 4 to 5°C higher ceiling temperature than that of conditioned option. Comparing June, July and August cases, it seems that for higher outdoor dry-bulb temperature natural ventilation option keeps lower ceiling temperature than mechanical ventilation option.

Figure 5.3.1: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from August 21 to 22 considering Conditioned Space

Figure 5.3.2: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from July 21 to 22 considering Non-Conditioned Space with Mechanical Ventilation

Figure 5.3.3: Hourly Temperature Profile of Ceiling (Inside) & Roof (Outside) Surface from July 21 to 22 considering Non-Conditioned Space with Natural Ventilation

5.4 Findings from Surface Temperature Analysis

The result from on-site measurement showed higher outside or roof surface temperature than that of inside or ceiling. But the energy simulation result gives opposite picture by showing higher inside or ceiling surface temperature than that of outside or roof surface temperature. The reason may be the roof and wall assemblies and roofing technology as well as the function of the space are different for two areas. As mentioned in the limitation, on-site measurement and energy simulation could not be done for the same location. Though the roof and ceiling surface temperature in the storage and office part show different behaviour, regardless the findings are clear about the reduction of cooling energy demand with the cool coatings as found in the section 4.3.9.

6. Recommendation & Conclusion

The reflectance properties of the selected cool coatings have been studied from manufacturer's technical data sheet and also from lab test. The results from lab test have shown lower reflectance values of the tested newly coated samples than that of technical data sheets. All the samples are in the range of 75 to 80% reflectance except for the Sample # 5 (Albedo 100 has 25%) which is not a roof coating. From the aging test, a little reduction in reflectance value has been found which is up to 1.2% and not that significant whereas from manufacturers' data the reduction due to aging was found more around 13 to 18%. It is to be noted that the test method in laboratory for this study is different than the test method followed by the manufacturer; this may be the reason why the reduction due to aging came insignificant.

The energy saving benefits for all the cool coatings has shown similar results. The coatings having more reflectance value saves more cooling energy. From the analysis of surface temperature of roof and ceiling of the studied building, the outside roof temperature shows a huge reduction but inside ceiling shows minor reduction of temperature with the studied cool coatings compared to the case of existing bitumen roof. The temperature profile gave different picture for conditioned and non-conditioned options; non-conditioned options have higher inside surface temperature than conditioned one. Even for mechanical and natural ventilation of non-conditioned options are different; inside surface temperature is higher for mechanical ventilation option than natural one. The reduction of cooling energy is not huge but clear on the application of cool coatings on roof for all cool coatings applicable for roof. Sample#4 LANCO Ultra-siliconizer, having the highest reflectance of 80%, saves 7.4% of cooling energy annually. For the studied building, as Sample # 4 LANCO Ultra-Siliconizer having the highest reflectance value can be recommended to use on the roof for efficiency of cooling energy.

A future research can be conducted based on this research as continuation by selecting a cold storage building of supermarket that requires huge cooling energy usage. The surface temperature on roof and ceiling for that selected building can be measured during summer season. The energy model can be validated using the local weather station data of the same year of measurement by comparing the model surface temperature with the measured surface temperature at the same location to make the experiment for closest accuracy. For aging test, the test method and standard to be followed as the same done by the manufacturer to arrive at a solid conclusion. For the other steps, methodology of this study can be followed.

Appendix A

7 SEARCH RESULTS

Selected filters

Keywords: lanco
Primary product type: Field-Applied Coatings

Please note that the CRRC does not set a minimum definition for "cool", the CRRC simply lists the measured radiative property values on our Directory. A product's placement on the Directory does not mean that the product is "cool" as defined by any particular code body or program.

*CRRC Rapid Ratings: These are interim laboratory-aged values that simulate weathered values. These values will be replaced with the measured three-year aged values upon completion of the weathering process. SRI values calculated using Rapid Ratings may change once the aged rating replaces the interim rating.

PRINT EXPORT ALL PRODUCTS

CRRC PROD. ID	MANUFACTURER: BRAND MODEL	PRODUCT TYPE	COLOR	SOLAR REFLECTANCE		THERMAL EMITTANCE		SRI		MORE INFO
				initial	3 year	initial	3 year	initial	3 year	
1026-0006a	Lanco Manufacturing Corp.: Lanco Evershield / RC-947	Field-Applied Coatings: Polyurethane	Bright White	0.86	pending	0.91	pending	109	pending	±
1026-0004	Lanco Manufacturing Corp.: Lanco Siliconizer / RC-200	Field-Applied Coatings: Acrylic	Bright White	0.88	0.75	0.90	0.87	111	92	±
1026-0003	Lanco Manufacturing Corp.: Lanco Siliconizer Plus / RC-797	Field-Applied Coatings: Acrylic	Bright White	0.84	0.76	0.90	0.87	106	94	±
1026-0001	Lanco Manufacturing Corp.: Lanco Ultra Siliconizer / RC-905	Field-Applied Coatings: Acrylic	Bright White	0.84	0.69	0.89	0.90	106	84	±
1026-0002	Lanco Manufacturing Corp.: Lanco Urethanizer / RC-994	Field-Applied Coatings: Acrylic	Bright White	0.83	0.72	0.89	0.90	104	89	±
1026-0005	Lanco Manufacturing Corp.: Lanco White Seal Plus / RC-886	Field-Applied Coatings: Acrylic	Bright White	0.82	0.76	0.90	0.88	103	94	±
1026-0007	Lanco Manufacturing Corp.: Lanco White Seal RC-865	Field-Applied Coatings: Acrylic	Bright White	0.84	0.69	0.90	0.89	106	84	±

KS.112 Kool Seal® PREMIUM ELASTOMERIC ROOF COATING

PRODUCT DESCRIPTION

Kool Seal® Premium White Elastomeric Roof Coating (63-600) is formulated with 100% acrylic elastomeric resin. The coating forms a thick rubber-like blanket of protection that expands and contracts with roofs. It remains flexible from -30°F to 160°F for long-lasting protection and provides superior reflectivity to lower interior temperatures and save energy. **Kool Seal® Premium White Elastomeric Roof Coat** adheres to aged galvanized and pre-painted metal, urethane and polystyrene, aged aluminum coating, pre-cast concrete, flat and barrel cement tiles. For use on built-up roofs, modified bitumen, bonded tar & gravel, most other asphaltic surfaces and in ponding water situations, **Kool Seal® Kool-Lastik™ Primer (34-600)** is required. **Do not use on roofing shingles.** In general, roof coatings, when applied to a structurally sound roof, will extend its life expectancy by protecting the roof from the elements. However, when roofs are badly deteriorated, they may require complete roof replacement instead of coating. If you're not sure, ask a qualified roofing contractor for an evaluation.

FEATURES AND BENEFITS

- Energy saving up to 35%.
- Reflects 90%+ of the sun's rays.
- Designed to be durable in any climate.
- Higher solids for better coverage.
- Forms a thick rubber-like blanket of protection.
- Expands and contracts – clings to your roof in all temperatures.
- Protects against moisture.
- Cured elastomeric film is mildew and algae resistant.
- Helps to absorb sound.
- Environmentally compliant.
- Soap and water cleanup - while wet.

Recommended uses:

- Metal
- Concrete
- Foam
- Brick
- Flat Cement Tile
- Unglazed Barrel Cement Tile
- Aged Aluminum Coatings
- Existing Elastomeric Roof Coatings

When used with Kool-Lastik™ Primer, recommended for:

- Ponding Water Conditions
- Rolled Roofing
- Built-up Roofs
- Modified Bitumen
- Bonded Tar & Gravel
- Most Asphaltic Surfaces

CHARACTERISTICS

Color	White
Vehicle	100% Acrylic
Volume Solids	44% $\pm$ 2%
Weight Solids	58% $\pm$ 2%
VOC:	16g/l

Drying Time:

To Touch	4-6 hours
Recoat:	24 hours
2 coat application	

Coverage per gallon:

(Apply two coats at the rates shown.)
 Metal (corrugated) 80 sq.ft.
 Metal (smooth) 100 sq.ft.
 Foam / Mod. Bit. 50 sq.ft.
 Concrete (depends on porosity) 50 sq.ft.
 Bonded Tar & Gravel / BUR 50 sq.ft.

SURFACE PREPARATION

WARNING! Removal of old paint by sanding, scraping or other means may generate dust or fumes that contain lead. Exposure to lead dust or fumes may cause brain damage or other adverse health effects, especially in children or pregnant women. Controlling exposure to lead or other hazardous substances requires the use of proper protective equipment, such as a properly fitted respirator (NIOSH approved) and proper containment and cleanup. For more information, call the National Lead Information Center at 1-800-424-LEAD (in US) or contact your local health authority.

Testing: Due to the wide variety of substrates, preparation methods, application methods and environments, the customer should test the product in an inconspicuous spot for adhesion and compatibility **prior to full scale application.**

Remove all previous coating that is loose by scraping or wire brushing. Then, scrub the roof with a water and detergent solution to remove all dirt, oil and grease. Mildewed areas must be treated with 1 part chlorine bleach, 3 parts water, then washed with detergent. Rinse surface thoroughly and let dry. Simply sweeping a roof surface to remove dirt is ineffective. **NOTE:** Areas collecting ponding water lasting 2-3 days must be repaired using roof drains or other corrective measures. For less severe ponding areas or to be used on rolled roofing, built-up roofs, modified bitumen, bonded tar & gravel or most other asphaltic surfaces (excluding roofing shingles) you must first prime with **Kool Seal® Kool-Lastik™ Primer.**

Kool Seal® PREMIUM ELASTOMERIC ROOF COATING

SURFACE PREPARATION

Kool-Lastik™ Primer is not required or recommended for metal, coated metal, concrete, flat or barrel cement tile, brick or urethane foam. (See specific instructions listed below). Proceed to prime (if needed), then repair seams, cracks, and flashing as well as around skylights, vents, stacks, and other protrusions with **Kool Seal® Acrylic Patching Cement (61-220)** and **Kool Flexx® Reinforcing Grid (20-840)**.

METAL: Remove rust and treat these areas with a quality metal primer. Tighten or totally replace loose fasteners. Then, top coat with **Kool Seal® Premium White Elastomeric Roof Coating**.

CONCRETE: Repair cracks and any weakened sections of concrete with a good quality masonry cement before coating. Remove all salts of efflorescence (white crystal deposits) with a very mild water and muriatic acid solution. Then top coat with **Kool Seal® Premium White Elastomeric Roof Coating**. Over a period of time these deposits may again work their way through the coating. Should this occur, wash the coating with the mild muriatic acid solution to restore the coating's color.

URETHANE FOAM: Repair cracks, holes, and indentations where water will collect with **Kool Seal® Acrylic Patching Cement**. Apply enough patching cement in several layers to indentations to allow water to drain. Then top coat with **Kool Seal® Premium White Elastomeric Roof Coating**.

SURFACE PREPARATION

BONDED TAR & GRAVEL: Remove all loose stones and scrub the roof with a water and detergent solution to remove all dirt, oil, and grease. Prime the surface with two coats of Kool-Lastik™ Primer completely sealing all of the gravel to prevent moisture from seeping under the coating. Then, top coat with Kool Seal® Premium White Elastomeric Roof Coating.

ROLLED ROOFING & MOD. BITUMEN: Scrub the roof with a water and detergent solution to remove all dirt, oil, and grease. Prime the surface with two coats of Kool-Lastik™ Primer. Then, top coat with Kool Seal® Premium White Elastomeric Roof Coating.

APPLICATION

Do not apply when temperature is below 50°F or if the temperature is expected to drop below 50°F before the coating has completely dried. Drying time will take four to six hours in temperatures above 70°F with low humidity. Drying time will increase as temperature decreases or humidity is high. Humidity of 85% or more will drastically increase drying time. In areas where dew accumulates in early evening, it is best to coat in the morning. **NOTE:** Stop coating by early afternoon (3 p.m.) to prevent wash off, which will occur if dew, fog, or rain arrive before coating dries. For best results apply with a soft brush, 3/4" heavy nap roller, or airless sprayer. Avoid excessive brushing. Spread uniformly. Cover any previous coating. Always apply two coats in different directions. Apply the first coat in a north-south direction; the second in an east-west direction.

APPLICATION

For spray application, an airless pump is recommended. Pump one gallon per minute with at least 2,000 PSI fluid pressure. Suggested tip sizes are .021 with a 10" pattern or .025 with a 12" pattern. This product has excellent suspension and requires minimal stirring to assure uniformity. If roof is hot, spray with water to prevent coating from drying too fast. May be applied over damp, not wet, surface. **DO NOT USE ON RUBBER ROOFS. DO NOT USE ON FLAT ROOFS WITH A SLOPE OF 1/2 INCH OR LESS PER FOOT.** For troublesome roofs and small shallow Ponding water situations, to include modified bitumen, rolled roofing, bonded tar and gravel, built-up roofs and most asphaltic SURFACES (excluding roofing shingles), you must apply two coats of Kool-Lastik™ Primer then top coat with Kool Seal® Premium White Elastomeric Roof Coating. **COVERAGE:** Apply two coats to all surfaces at the rate shown. **DO NOT DILUTE THIS PRODUCT.**

KOOL SEAL® PREMIUM ELASTOMERIC ROOF COATING

CLEAN-UP

Clean hands, tools and spills immediately with soap and warm water. After cleaning, flush spray equipment with mineral spirits to prevent rusting of the equipment.

WARNING

- Use with adequate ventilation
- Keep out of the reach of children
- Use a NOISH approved respirator, when necessary
- Do not take internally
- In case of ingestion, CALL A PHYSICIAN immediately. DO NOT induce vomiting

If splashed in the eyes, flush thoroughly with clean water for a minimum of 15 minutes. CALL A PHYSICIAN immediately. May cause irritation to the skin. If brought into contact with the skin, wash thoroughly with soap and water. Seek medical attention if redness or irritation occurs. Avoid breathing vapors and spray mist. Reseal container after each use. Wear protective clothing, gloves, and goggles. Read MSDS before using product.

ORDERING INFORMATION

Part Numbers

White

Quart KST063600-14
Gallon KST063600-16
Five KST063600-20

SMIS

White

Quart 897-9312
Gallon 166-9860
Five 958-7650

TECHNICAL SERVICES

1-888-321-KOOL(5665)
www.koolseal.com

The information and recommendations set forth in this Product Data Sheet are based upon tests conducted by or on behalf of KST Coatings and The Sherwin-Williams Company. Such information and recommendations set forth herein are subject to change and pertain to the product offered at the time of publication. Consult your KST or Sherwin-Williams representative to obtain the most recent Product Data sheet.

Urethanizer™ RC-994

Urethane Ceramic Rubber Top Membrane

Description

LANCO® Urethanizer™ is a high performance, rubberized, ceramic urethane, elastomeric, roof coating and sealer. A highly durable, fiber reinforced roof coating with superior adhesion properties. The ceramic composition of this product will significantly lower interior temperature of structures by reflecting 79% of the sun's rays and reducing heat by 89%. **Urethanizer™** will not crack, crumble or peel off, withstanding severe weather and total joint movements. It will provide a seamless, waterproof and weather protective seal tightly adhered to the roof surface.

Uses

In laboratory tests, **Urethanizer™** has proven its outstanding properties during adhesion-in-peel testing, exceeding every standard (per ASTM C 794 specifications) over a variety of substrates. This will assure many years of excellent protection over surfaces such as:

- Modified asphalt membranes
- Built-up roofs
- Polyurethane foam
- Concrete
- Aged galvanized metal
- Bonded tar and gravel shingles
- Asphalt shingles & Tile
- EPDM Rubber

Advantages

- Urethane ceramic technology
- Fiber reinforcement
- High UV reflectance
- High ozone resistance
- Insulates and creates a cool roof
- Excellent wind uplift resistance
- Salt spray resistance
- Good vapor permeability (Allows substrate to breathe)
- Low VOC roof coating
- Excellent dirt pick-up resistance
- Ultra fast drying properties
- Mildew and algae inhibitor
- Applies blue – dries ultra white
- Does not usually require a primer

Surface Preparation

Make certain the roof substrate is thoroughly clean and dry. Remove all debris and old loose coatings by means of sandblasting or high-pressure water stream or wire brushing. Remove all mildew, algae or fungus growth with

a 1:3 solution of household bleach, flushing thoroughly with water and allowing to dry completely. Surface should not accumulate water for more than 48 hours. Coat entire roof deck with **Acrylic Primer Sealer AS-210**, if necessary, at a rate of 250 sq.ft./gal.

Application

When used as a stand-alone product, apply the first coat by pouring liquid **Urethanizer™ RC-994** onto roof and spreading it at a rate of 50 sq.ft./gal. Avoid going twice over the same area. Allow 24 hours before applying subsequent coats applying them in the same manner as the first coat. When used in combination with **Polyester Fabric Mesh FM-222** a base coat of **Urethanizer RC-994** insulating membrane must be applied in which to embed to embed the polyester fabric. Please consult technical data sheets for **Urethanizer™ RC-994** for detailed procedures.

Weather

Select a warm clear day for installation. Consult weather bureau if needed to ensure there is no forecast of rain. Do not apply product after 4:00PM. Product must be kept rain free for at least 6 hours after application.

Certified Effective Energy Saving Coating

Urethanizer™ RC-994 is an **Energy Star** certified roof coating that will provide an energy efficient structure for many years, dramatically lowering internal temperature, thus requiring less energy consumption for cooling. Test results in three major US cities show that **Urethanizer™ RC-994** will provide an initial solar reflectance of 79%* with maintained average reflectance after 3 years of 82% (ASTM C 1549)*7 and the elimination of 89% (ASTM C 1371)*3 of all heat received.

Solar Reflectance Test					
Material ID Location	ASTM Test Method	Result, Solar Reflectance, (r)			
		Air Mass = 1.5			
		Avg.	SD	95% CI	
RC-994-1 Orlando	C 1549	0.80	0.006	0.016	
RC-994-2 Orlando	C 1549	0.81	0.003	0.008	
RC-994-3 Orlando	C 1549	0.81	0.009	0.022	
RC-994-1 Miami	C 1549	0.82	0.003	0.008	
RC-994-2 Miami	C 1549	0.83	0.003	0.007	
RC-994-3 Miami	C 1549	0.84	0.002	0.005	

*Initial reflectance values are shown lower than the maintained value due to coating being blue at time of application, turning ultra white after 7 days exposure to sunlight.

Urethanizer™ RC-994 Starts Whiter – Stays Clean Longer

After 3 years of service, side by side comparison shows the superiority of **Urethanizer™ RC-994**, as a white reflective coating, over other acrylic copolymer or elastomeric coatings.

Because of the high content of highly reflective pigments, it will initially reflect 79%*2 of sun's rays and eliminate 89%*3 of heat received. This revolutionary technology allows the finish to remain white for longer periods than other products on the market maintaining an average solar reflectance of 82%*7, three years after initial application (as independently tested, ASTM C 1549). Assures a long term advantage over competing products on the market.

High Performance Elastomeric Coating

MIAMI DADE COUNTY
APPROVED

Urethanizer™ RC-994 surpasses all liquid and physical film properties required by **Miami-Dade County** standards. In using **Urethanizer™ RC-994**, **LANCO® Mfg. Corp.** guarantees that you are using the very best high performance elastomeric roof sealer.

MEETS 100% OF FEDERAL SPECIFICATION TT-C-555B AS AN EFFECTIVE WATERPROOF COATING

Urethanizer™

Urethane Ceramic Rubber Top Membrane

Technical Data

Type:	Reinforced urethane acrylic copolymer		
Drying Time (ASTM D 1640)			
75°F and 50% RH:	Tack free, minutes:	42	
	Finger tack:	48	
	Zapon tack:	75	
	Dry Hard, minutes:	110	
	Dry Through, minutes:	185	
Storage Conditions:	Store between 40°F and 90°F		
Full Cure:	7 (seven) days		
Application Temperature:			
Ambient	Min. + 45°F to 105°F		
Surface	Min. + 40°F to 130°F		
Flash Point:	Non-flammable		
Flame Spread Rate:	Class A		

Disclaimer: This technical data is true and accurate to the best of our knowledge. Published technical data and instructions are subject to change without notice.

M.S.D.S. Available upon request.

Shelf Life: 3 years after date of manufacture when stored out of the sun in unopened buckets at a temperature of less than 100 degrees F. Keep from freezing.

PROPERTY	ASTM TEST METHOD	RESULT	ASTM D 6083 REQUIREMENT
Liquid Requirements (Table 1)			
Brookfield Viscosity @ 73.4°F, cps	D 2196	26,200	12,000 - 85,000
Viscosity @ 73.4°F, KU	D 562	109	85 - 141
Volume Solids, %	D 2697	51.5	>50
Weight Solids, %	D 1644	66.2	>60
Film Properties (Table 2)			
Initial Tensile Strength @ 73°F, psi	D 2370	304	200 min.
Initial Elongation @ 73°F, %	D 2370	185	100 min.
Permeance (20 mil dry film, 73.4°F/50% RH, Inverted), perms	D 1653	30.8	50 max.
Water Swelling, Mass %	D 471	13.9	20 max.
Wet Adhesion to galvanized metal, pli	C 794 / D 903	5.4	
Wet Adhesion to EPDM, pli	C 794 / D 903	4.6	2.0 min.
Wet Adhesion to asphalt shingles, pli	C 794 / D 903	2.9	2.0 min.
Wet Adhesion to concrete, pli	C 794 / D 903	5.2	2.0 min.
Wet Adhesion to SPUF	C 794 / D 903	3.4	2.0 min.
Tear Resistance (Die C), lbf/in	D 624	79.0	>60
Fungi Resistance, rating	G 21	0	0 max.
Film Properties after 1,000 Hrs Accelerated Weathering (Table 2)			
Elongation @ 73°F, %	D 2370	167	100 min.
Low Temperature Flex, 1/2" mandrel, -15°F	D 522	Pass	Pass
Appearance after 1,000 hrs accelerated weathering	D 4798	Pass	No Cracking or Checking

COVERAGE:

Surface	Area	1st coat	2nd coat	3rdcoat	4th coat	Total System
Metal Roofs	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Wood Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Concrete Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Built-up Roofs	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
General Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Polyurethane Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Asphalt Shingles	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	128 wet mils / 65.6 dry

Note: In order to obtain a commercial warranty from **LANCO®** for the application of a **Urethanizer™ RC-994** roof coating system, you must first consult with **LANCO®** in order to have the correct roof coating system recommendation for your particular need.

Note: Asphalt roofing: Prior to application over asphalt roofs the attic area should be very well ventilated (gable vent fan works best) to prevent condensation on the roof or in between the layers of the material or decking. Be sure all tabs are completely adhered and sealed. Areas where the existing material has blistered, buckled or become wet, must be removed and repaired using similar products or system. Be sure all edges and grooves are completely coated to ensure a uniform thickness. If any large holes, dents, grooves or flashing transitions remain, apply Siliconizer Crack Filler and fabric mesh on those areas not properly sealed. Additional coats may be need in order to provide a completely covered and uniform continuous film.

NORTH AMERICA • 600 Mid Florida Drive Airport Industrial Park of Orlando, Florida 32824 • Tel. (407) 240-4000 Fax (407) 240-4046
CARIBBEAN & SOUTH AMERICA • Urb. Aponte #5, San Lorenzo, Puerto Rico USA 00754 • Tel. (787) 736-4221 Fax (787) 736-5313
CENTRAL AMERICA • Zona Industrial Bes, lote #4, El Coyol de Alajuela, Costa Rica • Tel. (506) 2438-2257 Fax (506) 2438-2162

Ultra Siliconizer™ RC-905

100% Acrylic Silicone Top Membrane

Description

This product is a single component 100% acrylic silicone sealer for roofs and walls with outstanding adhesive properties that will provide a thick, high performance, water and weather resistant seal on most surfaces, usually without need of a primer coating. Due to a transition process, **LANCO® Ultra Siliconizer™** normally dries in half the time as other similar products, ensuring a quick and effective installation. It will significantly lower the interior temperature of the structure by reflecting 78% of the sun's rays and reducing heat received by 90%. Product will not crack, peel or blister even under severe weather conditions.

Uses

Ultra Siliconizer™ exceeds every standard (per ASTM C 794) in adhesion-in-peel testing under laboratory conditions, proving its outstanding adhesive properties over a wide variety of substrates, assuring many years of solid protection on surfaces such as:

- Modified asphalt membranes
- Built-up roofs
- EPDM Rubber
- Polyurethane foam
- Concrete
- Aged galvanized metals
- Bonded tar and gravel and/or asphalt shingles

Advantages

- 100% acrylic/silicone technology
- Fiber reinforcement
- High UV reflectance values
- High resistance to ozone
- Insulates and provides a cooler roof
- Excellent resistance to wind uplift
- Salt spray resistant
- Excellent permeability allowing substrate to breathe
- Low VOC roof coating
- Excellent resistance to dirt build up
- Ultra fast drying technology
- High resistance to ponding water*
- Excellent mildew and algae resistance
- Applies blue, ultra white when dry
- Seldom requires a primer coating

Surface Preparation

Ensure that roof substrate is thoroughly clean. Remove all foreign matter and loose previous coatings by sandblasting, high-pressure water stream or wire brushing. Remove all mildew and fungus growth with a 1:3 bleach solution and flush well with water, then allow to dry completely. *Substrate should not pond water for longer than 48 hours. Coat entire roof surface with **Acrylic Primer Sealer AS-210** at a rate of 250 sq.ft./gal. when necessary.

Application

Use a **LANCO® 1/4" Nap Rough Surface Roller PA-568** or airless spray to apply two perpendicular coats of product, allowing 24 hours between each coat. Ambient temperature must not be lower than 50°F (10°C) before applying or during drying process. If roof surface is too hot, spray with cool water to prevent sealer from drying too quickly. Product must never be thinned or diluted. A rubberized base coat of **Aqua-Proof™ MD-863** with embedded **Polyester Fabric Mesh FM-222** may be used. Consult **Aqua-Proof™ MD-863** technical data sheet or **Ultra Siliconizer™ RC-905** roofing systems specifications.

Weather

Select a warm clear day for installation, ensuring there is no forecast of rain for that time frame. Do not apply coating after 4:00 PM. Product must be kept rain free for a minimum of 6-8 hours after application.

Certified Energy Saving Coating

Ultra Siliconizer™ RC-905 is an **Energy Star** certified roof coating that will provide an energy efficient structure for many years. It will dramatically lower internal temperature of the structure thus requiring less energy for mechanical cooling. Tests performed in three major American cities prove that **Ultra Siliconizer™ RC-905** will provide an initial solar reflectance of 78%* and a constant reflectance of 84% after three (3) years (ASTM C 1549) and reduction of 90% of all heat received (ASTM C 1371).

Solar Reflectance Test				
Material ID Location	ASTM Test Method	Result, Solar Reflectance, (r) Air Mass = 1.5		
		Avg.	SD	95% CI
RC-905-1 Orlando	C 1549	0.80	0.006	0.016
RC-905-2 Orlando	C 1549	0.81	0.003	0.008
RC-905-3 Orlando	C 1549	0.81	0.009	0.022
RC-905-1 Miami	C 1549	0.82	0.003	0.008
RC-905-2 Miami	C 1549	0.83	0.003	0.007
RC-905-3 Miami	C 1549	0.84	0.002	0.005

*Initial reflectance values are shown lower than the maintained values because product applies as blue film and then dries to a brilliant white after 7 days exposure to sunlight.

Ultra Siliconizer™ RC-905 Starts Whiter and Stays Cleaner Longer

From the moment of application, this product will provide a strong, thick, monolithic membrane that has been formulated using the most advanced coating technology, incorporating ultra small particles with a tightly bonded molecular structure which prevents dirt from adhering and embedding on the surface. Due to

its high content of highly reflective pigmentation, it will initially reflect 78% of sun's rays and reduce heat received by 90%.

This revolutionary technology allows the finish to remain whiter than similar products on the market, maintaining an average solar reflectance of 84% three (3) years after application (as independently tested ASTM C 1549). This ensures a long-term advantage over similar products on the market.

High Performance Elastomeric Coating

Ultra Siliconizer™ RC-905 surpasses all liquid and physical film properties required by strict **Miami-Dade County** regulations. In applying **Ultra Siliconizer™ RC-905**, **LANCO®** guarantees that you are using the very best high performance elastomeric roof sealing product available.

MEETS 100% OF FEDERAL SPECIFICATION TT-C-555B AS AN EFFECTIVE WATERPROOF COATING

Ultra Siliconizer™

100% Acrylic Silicone Top Membrane

Technical Data

Type:	One Component 100% Acrylic Silicone		
Drying Time (ASTM D 1640)			
75°F and 50% RH:	Tack free, minutes:	45	
	Finger tack:	50	
	Zapon tack:	77	
	Dry Hard, minutes:	112	
	Dry Through, minutes:	188	
Storage Conditions:	Store between 40°F and 90°F		
Full Cure:	7 (seven) days		
Application Temperature:			
Ambient	Min. + 45°F to 105°F		
Surface:	Min. + 40°F to 130°F		

Disclaimer: This technical data is true and accurate to the best of our knowledge. Published technical data and instructions are subject to change without notice.

M.S.D.S. Available upon request.

Shelf Life: 3 years after date of manufacture when stored out of the sun in unopened buckets at a temperature of less than 100 degrees F. Keep from freezing.

PROPERTY	ASTM TEST METHOD	RESULT	ASTM D 6083 REQUIREMENT
Liquid Requirements (Table 1)			
Brookfield Viscosity @ 73.4°F, cps	D 2196	18,000	12,000 - 85,000
Viscosity @ 73.4°F, KU	D 562	102	85 - 141
Volume Solids, %	D 2697	51.4	>50
Weight Solids, %	D 1644	66.5	>60
Film Properties (Table 2)			
Initial Tensile Strength @ 73°F, psi	D 2370	273	200 min.
Initial Elongation @ 73°F, %	D 2370	239	100 min.
Permeance (20 mil dry film, 73.4°F/50% RH, Inverted), perms	D 1653	28.3	50 max.
Water Swelling, Mass %	D 471	19.9	20 max.
Wet Adhesion to galvanized metal, pli	C 794 / D 903	5.4	
Wet Adhesion to EPDM, pli	C 794 / D 903	3.3	2.0 min.
Wet Adhesion to asphalt shingles, pli	C 794 / D 903	2.9	2.0 min.
Wet Adhesion to concrete, pli	C 794 / D 903	6.1	2.0 min.
Wet Adhesion to SPUF	C 794 / D 903	3.8	2.0 min.
Tear Resistance (Die C), lbf/in	D 624	83.5	>60
Fungi Resistance, rating	G 21	0	0 max.
Film Properties after 1,000 Hrs Accelerated Weathering (Table 2)			
Elongation @ 73°F, %	D 2370	169	100 min.
Low Temperature Flex, 1/2" mandrel, -15°F	D 522	Pass	Pass
Appearance after 1,000 hrs accelerated weathering	D 4798	Pass	No Cracking or Checking

COVERAGE:

Surface	Area	1st coat	2nd coat	3rdcoat	4th coat	Total System
Metal Roofs	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Wood Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Concrete Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Built-up Roofs	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
General Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Polyurethane Surfaces	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	-----	-----	64 wet mils / 32.8 dry
Asphalt	50 sq./ft. per gallon	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	32 wet mils / 16.4 dry	128 wet mils / 65.6 dry

Note: In order to obtain a commercial warranty from **LANCO®** for the application of a **Ultra Siliconizer™ RC-905** roof coating system, you must first consult with **LANCO®** in order to have the correct roof coating system recommendation for your particular need.

Asphalt roofing: Prior to application over asphalt roofs the attic area should be very well ventilated (gable vent fan works best) to prevent condensation on the roof or in between the layers of the material or decking. Be sure all tabs are completely adhered and sealed. Areas where the existing material has blistered, buckled or become wet, must be removed and repaired using similar products or system. Be sure all edges and grooves are completely coated to ensure a uniform thickness. If any large holes, dents, grooves or flashing transitions remain, apply Siliconizer Crack Filler and fabric mesh on those areas not properly sealed. Additional coats may be need in order to provide a completely covered and uniform continuous film.

NORTH AMERICA • 600 Mid Florida Drive Airport Industrial Park of Orlando, Florida 32824 • Tel. (407) 240-4000 Fax (407) 240-4046
CARIBBEAN & SOUTH AMERICA • Urb. Aponte #5, San Lorenzo, Puerto Rico USA 00754 • Tel. (787) 736-4221 Fax (787) 736-5313
CENTRAL AMERICA • Zona Industrial Bes, lote #4, El Coyol de Alajuela, Costa Rica • Tel. (506) 2438-2257 Fax (506) 2438-2162

Albedo100®

Permanent Spray

Albedo100 Permanent Metallic is a permanent grey spray with light-reflective properties that sticks to most surfaces, and resists wind and rain. The spray is UV-resistant and is durable on materials such as wood, concrete, metal, stone etc. Albedo100 Permanent Metallic is appropriate for use on wheels on strollers, bicycles, gates, letter boxes, kayaks, garbage cans, tools, metal, painted surfaces, pavements, fences, nylon textiles, bicycle-helmets, etc.

How does it Work?

Albedo100 Light Metallic is a quick-drying lacquer that is grey in daylight and light-reflective in the dark. The spray reflects in the same direction as the light source. This means it is only the person behind the light source that can see the reflection. Test the effect by shining a light, held at eye-level, upon the sprayed surface. Alternatively taking a photo with flash e.g. with your mobile cell phone camera, or watching the object from a car with the headlights on, from a distance. Albedo100 Light Metallic is a permanent spray, however, in some cases it can be removed using mineral spirits. Note: mineral spirits can affect the original paint work

How to Use

1. Always spray outside or in well-ventilated areas. Shake the can vigorously +1 minute (at least 20 sec after you hear the bulb inside). Repeat during application.
2. After shaking, spray immediately from a distance of approximately 1 foot, with even swiping movements. Hold the can upright while spraying. Do not over-apply. Dries in a couple of minutes at normal room temperature.
3. Clean the nozzle after use, by spraying upside down for 1-2 sec.

Important:

Make sure the object to be sprayed is dry, and that dirt, grease and other loose particles are removed before application. The spray attaches to dry surfaces. Some surfaces and certain plastics may need to be treated with a primer before use in order to achieve optimum and durable results over time. Pliable surfaces may stiffen if sprayed with Albedo100 Light Metallic. You can easily create reflective signs and symbols by cutting out, and spraying on stencils.

Figures shown are averages and should not be used for writing specifications. Similar test conducted on any individual sample may vary in results. NOTICE: While we believe them to be reliable, the statements and information herein are only for general guidance and are not warrants or guarantees for accuracy and completeness. The user must by test or otherwise determine suitability for his purpose. THERE IS NO WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, Our standard terms and conditions of sale apply exclusively to all orders, and ALL LIABILITY FOR DAMAGES OF ANY KIND, INCLUDING CONSEQUENTIAL, EXCEEDING PURCHASE PRICE IS EXCLUDED. No one is authorized by us to make oral warranties. We reserve the right to make changes without notice or obligation in our products and publications. 24August2016/pc

Appendix B

Wall and Roof Assemblies Detail

WALL CONSTRUCTION 1

8" ARCHITECTURAL BLOCK
1" AIR SPACE
6" MTL STUDS @16" O.C.
R20 FIBROUS INSULATION
CONT. 6 MIL V.B.
1/2" GYP. BD.

2 HOUR RATED
CONC. BLOCK

WALL CONSTRUCTION 2

PREENGINEERED WALL SYSTEM
10" CONC. BLOCK
6" ST STUDS @16" O.C.
CONT. 6 MIL V.B.
R20 BATT INSUL
1/2" GYP. BD.
2 HOUR FIRE RESISTANCE RATING

WALL CONSTRUCTION 3

10" ARCHITECTURAL. BLOCK
4" PREENGINEERED WALL SYSTEM
R20 BATT INSUL

INTERIOR WALL TYPES

Appendix C

Appendix C: Roof Assembly – Assignment of Material in Design Builder

Roof Assembly showing with Existing Bitumin Roofing Built-up

Assembly coated with Sample#1_Kool Seal 1 (63-600)

Roof Assembly coated with Sample#2_Kool Seal 2 (KS0063600-16)

Edit construction - Roof Sample_2_(KS0063600-16)

Constructions Data

Layers Surface properties Image Calculated Cost Condensation analysis

General

Name: **Roof Sample_2_(KS0063600-16)**

Source: ASHRAE Standard 90.1 (Appendix A)

Category: Roofs

Region: General

Definition

Definition method: 1-Layers

Calculation Settings

Layers

Number of layers: 5

Outermost layer

Material: Sample_2_(KS0063600-16)

Thickness (m): 0.9000

☐ Bridged?

Layer 2

Material: 0.375 in. Roofing, built up

Thickness (m): 0.0095

☐ Bridged?

Layer 3

Material: Board insulation (Glass fiber board)

Thickness (m): 0.1500

☐ Bridged?

Layer 4

Material: Metal deck

Thickness (m): 0.0100

☐ Bridged?

Innermost layer

Material: 0.5 in. (12.7 mm) gypsum board

Thickness (m): 0.0127

☐ Bridged?

Model data

Insert layer Delete layer Help Cancel OK

Help

Construction Layers

Set the number of layers first, then select the material and thickness for each layer.

[Insert layer](#)

[Delete layer](#)

Bridging

You can also add bridging to any layer to model the effect of a relatively more conductive material bridging a less conductive material. For example wooden joists bridging an insulation layer.

Note that bridging effects are NOT used in EnergyPlus, but are used in energy code compliance checks requiring U-values to be calculated according to BS EN ISO 6946.

Energy Code Compliance

You can calculate the thickness of insulation required to meet the mandatory energy code U-value as set on the Energy Code tab at site level.

This calculation identifies the 'insulation layer' as the layer having the highest r-value and requires that no bridging is used in the construction.

[Set U-Value](#)

Roof Assembly coated with Sample#3_LANCO-3 Urethanizer

Edit construction - Copy of Roof Sample_1_Kool Seal 63-600

Constructions Data

Layers Surface properties Image Calculated Cost Condensation analysis

General

Name: **Roof Sample_3_Urethanizer**

Source: ASHRAE Standard 90.1 (Appendix A)

Category: Roofs

Region: General

Definition

Definition method: 1-Layers

Calculation Settings

Layers

Number of layers: 5

Outermost layer

Material: **Sample_3_Urethanizer**

Thickness (m): 0.9000

☐ Bridged?

Layer 2

Material: 0.375 in. Roofing, built up

Thickness (m): 0.0095

☐ Bridged?

Layer 3

Material: Board insulation (Glass fiber board)

Thickness (m): 0.1500

☐ Bridged?

Layer 4

Material: Metal deck

Thickness (m): 0.0100

☐ Bridged?

Innermost layer

Material: 0.5 in. (12.7 mm) gypsum board

Thickness (m): 0.0127

☐ Bridged?

Model data

Insert layer Delete layer Help Cancel OK

Help

Materials

Metal deck

Metal surface

Metals - aluminum

Metals - aluminum cladding

Metals - brass

Metals - bronze

Metals - copper

Metals - duraluminum

Metals - iron

Metals - iron, cast

Metals - lead

Data Report (Not Editable)

General

Metal deck

Source: ASHRAE Standard 90.1 (Appendix A)

Category: Metals

Region: US General

Material Layer Thickness

Force thickness: No

Thermal Properties

Detailed properties: Yes

Thermal Bulk Properties

Conductivity (W/m-K): 45.2800

Specific Heat (J/kg-K): 500.00

Density (kg/m³): 7824.00

Resistance (R-value): No

Vapour Resistance

Vapour resistance definition: 1-Factor

Vapour factor: 150

Vapour resistivity (MNs/m): 1.0

Roof Assembly coated with Sample#4_ LANCO-4 Ultra Siliconizer

Edit construction - Roof Sample 4_LANCO Ultra Siliconizer_RC-905

Constructions Data

Layers Surface properties Image Calculated Cost Condensation analysis

General

Name: Roof Sample 4_LANCO Ultra Siliconizer_RC-905

Source: ASHRAE Standard 90.1 (Appendix A)

Category: Roofs

Region: General

Definition

Definition method: 1-Layers

Calculation Settings

Layers

Number of layers: 5

Outermost layer

Material: Ultra Siliconizer

Thickness (m): 0.0020

☐ Bridged?

Layer 2

Material: 0.375 in. Roofing, built up

Thickness (m): 0.0095

☐ Bridged?

Layer 3

Material: Board insulation (Glass fiber board)

Thickness (m): 0.1500

☐ Bridged?

Layer 4

Material: Metal deck

Thickness (m): 0.0100

☐ Bridged?

Innermost layer

Material: 0.5 in. (12.7 mm) gypsum board

Thickness (m): 0.0127

☐ Bridged?

Model data

Insert layer Delete layer Help Cancel OK

Help

Info Data

Construction Layers

Set the number of layers first, then select the material and thickness for each layer.

[Insert layer](#)

[Delete layer](#)

Bridging

You can also add bridging to any layer to model the effect of a relatively more conductive material bridging a less conductive material. For example wooden joists bridging an insulation layer.

Note that bridging effects are NOT used in EnergyPlus, but are used in energy code compliance checks requiring U-values to be calculated according to BS EN ISO 6946.

Energy Code Compliance

You can calculate the thickness of insulation required to meet the mandatory energy code U-value as set on the Energy Code tab at site level.

This calculation identifies the 'insulation layer' as the layer having the highest r-value and requires that no bridging is used in the construction.

[Set U-Value](#)

Roof Assembly coated with Sample#5_ Albedo 100 Reflective Spray

Edit construction - Roof Sample5_Albedo 100

Constructions Data

Layers Surface properties Image Calculated Cost Condensation analysis

General

Name: Roof Sample5_Albedo 100

Source: ASHRAE Standard 90.1 (Appendix A)

Category: Roofs

Region: General

Definition

Definition method: 1-Layers

Calculation Settings

Layers

Number of layers: 5

Outermost layer

Material: Albedo 100

Thickness (m): 0.0100

☐ Bridged?

Layer 2

Material: 0.375 in. Roofing, built up

Thickness (m): 0.0095

☐ Bridged?

Layer 3

Material: Board insulation (Glass fiber board)

Thickness (m): 0.1500

☐ Bridged?

Layer 4

Material: Metal deck

Thickness (m): 0.0100

☐ Bridged?

Innermost layer

Material: 0.5 in. (12.7 mm) gypsum board

Thickness (m): 0.0127

☐ Bridged?

Model data

Insert layer Delete layer Help Cancel OK

Help

Info Data

Construction Layers

Set the number of layers first, then select the material and thickness for each layer.

[Insert layer](#)

[Delete layer](#)

Bridging

You can also add bridging to any layer to model the effect of a relatively more conductive material bridging a less conductive material. For example wooden joists bridging an insulation layer.

Note that bridging effects are NOT used in EnergyPlus, but are used in energy code compliance checks requiring U-values to be calculated according to BS EN ISO 6946.

Energy Code Compliance

You can calculate the thickness of insulation required to meet the mandatory energy code U-value as set on the Energy Code tab at site level.

This calculation identifies the 'insulation layer' as the layer having the highest r-value and requires that no bridging is used in the construction.

[Set U-Value](#)

Appendix D

Your Veridian Bill

Service Address

SENTINEL SELF STORAGE
AJAX
475 HARWOOD AVE N

Amount Previously Billed

PREVIOUS BALANCE	\$1,807.88
Payment Jun 15, 2016 - Thank You	-\$1,807.88
BALANCE FORWARD	\$0.00

Your Electricity Charges

Electricity		
Summer On-Peak	1,518.41 kWh @ 18 ¢	\$273.31
Summer Mid-Peak	1,374.87 kWh @ 13.2 ¢	\$181.48
Summer Off-Peak	7,266.72 kWh @ 8.7 ¢	\$632.20
SubTotal	10,160.00 kWh	\$1,086.99
Delivery		\$359.96
Regulatory Charges		\$64.17
Debt Retirement Charge		\$71.12
H.S.T. (Registration # 88628-2920-RT0001)		\$205.69
Total Due By Aug 02, 2016		\$1,787.93

Outstanding balances after the due date will be assessed an interest charge of 1.5% per month (19.56% per annum).

Account Details

Service Type	Small Commercial
Your Account Number	60022090-00
Billing Date	Jul 11, 2016
Due Date	Aug 02, 2016
Amount Due	\$1,787.93

Account Status Year To Date

Cost Incurred This Billing	Cost Incurred To Date
\$1,787.93	\$14,464.68

Veridian has received regulatory approval for May 1st, 2016 changes to electricity distribution rates. For details please visit our website www.veridian.on.ca or call our Customer Care Department.

Your Electricity Usage

Meter No	Billing Period	Days	Current Reading	-	Previous Reading	x	Billing Multiplier	=	kWh Used
VC00207467	May 15, 2016 to Jun 15, 2016	31	11361		11234		80		10,160.00

Compare the Electricity You Are Using

Average Daily Electricity Use (kWh)						
Period Start	Period End	Days	On-Peak	Mid-Peak	Off-Peak	Total
May 15, 2016	Jun 15, 2016	31	49	44	234	327
Apr 15, 2016	May 15, 2016	30	45	44	263	352
Mar 15, 2016	Apr 15, 2016	31	54	51	279	384
Feb 15, 2016	Mar 15, 2016	29	63	57	285	405
Jan 15, 2016	Feb 15, 2016	31	68	56	323	447
Dec 15, 2015	Jan 15, 2016	31	68	54	315	437
Nov 15, 2015	Dec 15, 2015	30	71	58	284	413
Oct 15, 2015	Nov 15, 2015	31	55	55	287	397
Sep 15, 2015	Oct 15, 2015	30	53	53	275	381
Aug 15, 2015	Sep 15, 2015	31	52	49	273	374
Jul 15, 2015	Aug 15, 2015	31	52	48	258	358
Jun 15, 2015	Jul 15, 2015	30	51	48	248	347
May 15, 2015	Jun 15, 2015	31	44	42	255	341

Above numbers may be rounded. Please see reverse for time-of-use period details.

24-hour Outage Hotline: 1-866-579-6819

Please detach and return this portion with your payment.

SENTINEL SELF STORAGE
1970-10123 99 STREET
EDMONTON AB T5J 3H1

Your Veridian Bill

Your Account Number	60022090-00
Total Due By Aug 02, 2016	\$1,787.93

Outstanding balances after the due date will be assessed an interest charge of 1.5% per month (19.56% per annum).

Amount Paid	\$
-------------	----

6002209000900178793001787931608020000

Your Veridian Bill

Service Address

SENTINEL SELF STORAGE
AJAX
475 HARWOOD AVE N

Amount Previously Billed

PREVIOUS BALANCE	\$1,787.93
Payment Jul 20, 2016 - Thank You	-\$1,787.93
BALANCE FORWARD	\$0.00

Your Electricity Charges

Electricity		
Summer On-Peak	1,548.14 kWh @ 18 ¢	\$278.67
Summer Mid-Peak	1,345.29 kWh @ 13.2 ¢	\$177.58
Summer Off-Peak	6,946.57 kWh @ 8.7 ¢	\$604.35
SubTotal	9,840.00 kWh	\$1,060.60
Delivery		\$349.00
Regulatory Charges		\$62.14
Debt Retirement Charge		\$68.88
H.S.T. (Registration # 88628-2920-RT0001)		\$200.28
Total Due By Aug 24, 2016		\$1,740.90

Outstanding balances after the due date will be assessed an interest charge of 1.5% per month (19.56% per annum).

Account Details

Service Type	Small Commercial
Your Account Number	60022090-00
Billing Date	Aug 02, 2016
Due Date	Aug 24, 2016
Amount Due	\$1,740.90

Account Status Year To Date

Cost Incurred This Billing	Cost Incurred To Date
\$1,740.90	\$16,205.58

Your Electricity Usage

Meter No	Billing Period	Days	Current Reading	-	Previous Reading	x	Billing Multiplier	=	kWh Used
VC00207467	Jun 15, 2016 to Jul 15, 2016	30	11484		11361		80		9,840.00

Compare the Electricity You Are Using

Average Daily Electricity Use (kWh)						
Period Start	Period End	Days	On-Peak	Mid-Peak	Off-Peak	Total
Jun 15, 2016	Jul 15, 2016	30	52	45	232	329
May 15, 2016	Jun 15, 2016	31	49	44	234	327
Apr 15, 2016	May 15, 2016	30	45	44	263	352
Mar 15, 2016	Apr 15, 2016	31	54	51	279	384
Feb 15, 2016	Mar 15, 2016	29	63	57	285	405
Jan 15, 2016	Feb 15, 2016	31	68	56	323	447
Dec 15, 2015	Jan 15, 2016	31	68	54	315	437
Nov 15, 2015	Dec 15, 2015	30	71	58	284	413
Oct 15, 2015	Nov 15, 2015	31	55	55	287	397
Sep 15, 2015	Oct 15, 2015	30	53	53	275	381
Aug 15, 2015	Sep 15, 2015	31	52	49	273	374
Jul 15, 2015	Aug 15, 2015	31	52	48	258	358
Jun 15, 2015	Jul 15, 2015	30	51	48	248	347

Above numbers may be rounded. Please see reverse for time-of-use period details.

24-hour Outage Hotline: 1-866-579-6819

Please detach and return this portion with your payment.

SENTINEL SELF STORAGE
1970-10123 99 STREET
EDMONTON AB T5J 3H1

Your Veridian Bill

Your Account Number	60022090-00
Total Due By Aug 24, 2016	\$1,740.90

Outstanding balances after the due date will be assessed an interest charge of 1.5% per month (19.56% per annum).

Amount Paid	\$
-------------	----

6002209000900174090001740901608240000

Your Veridian Bill

www.veridian.on.ca

The power to make your community better.

VERIDIAN
CONNECTIONS

Service Address

SENTINEL SELF STORAGE
AJAX
475 HARWOOD AVE N

Amount Previously Billed

PREVIOUS BALANCE	\$1,740.90
Payment Aug 17, 2016 - Thank You	-\$1,740.90
BALANCE FORWARD	\$0.00

Your Electricity Charges

Electricity

Summer On-Peak	1,517.01 kWh @ 18¢	\$273.06
Summer Mid-Peak	1,333.28 kWh @ 13.2¢	\$175.99
Summer Off-Peak	7,709.71 kWh @ 8.7¢	\$670.74
Sub Total	10,560.00 kWh	\$1,119.79
Delivery		\$372.94
Regulatory Charges		\$66.67
Debt Retirement Charge		\$73.92
H.S.T. (Registration # 88628-2920-RT0001)		\$212.33
Total Due By Sep 20, 2016		\$1,845.65

Outstanding balances after the due date will be assessed an interest charge of 1.5% per month (19.56% per annum).

Account Details

Service Type	Small Commercial
Your Account Number	60022090-00
Billing Date	Aug 29, 2016
Due Date	Sep 20, 2016
Amount Due	\$1,845.65

Account Status Year To Date

Cost Incurred This Billing	Cost Incurred To Date
\$1,845.65	\$18,051.23

RECEIVED
AUG 31 2016

Your Electricity Usage

Meter No	Billing Period	Days	Current Reading	Previous Reading	x	Billing Multiplier	=	kWh Used
VC00207467	Jul 15, 2016 to Aug 15, 2016	31	11616	11484		80		10,560.00

Compare the Electricity You Are Using

Average Daily Electricity Use (kWh)

Period Start	Period End	Days	On-Peak	Mid-Peak	Off-Peak	Total
Jul 15, 2016	Aug 15, 2016	31	49	43	249	341
Jun 15, 2016	Jul 15, 2016	30	52	45	232	329
May 15, 2016	Jun 15, 2016	31	49	44	234	327
Apr 15, 2016	May 15, 2016	30	45	44	263	352
Mar 15, 2016	Apr 15, 2016	31	54	51	279	384
Feb 15, 2016	Mar 15, 2016	29	63	57	285	405
Jan 15, 2016	Feb 15, 2016	31	68	56	323	447
Dec 15, 2015	Jan 15, 2016	31	68	54	315	437
Nov 15, 2015	Dec 15, 2015	30	71	58	284	413
Oct 15, 2015	Nov 15, 2015	31	55	55	287	397
Sep 15, 2015	Oct 15, 2015	30	53	53	275	381
Aug 15, 2015	Sep 15, 2015	31	52	49	273	374
Jul 15, 2015	Aug 15, 2015	31	52	48	258	358

Above numbers may be rounded. Please see reverse for time-of-use period details.

24-hour Outage Hotline: 1-866-579-5819

Please detach and return this portion with your payment.

VERIDIAN
CONNECTIONS

SENTINEL SELF STORAGE
1970-10123 99 STREET
EDMONTON AB T5J 3H1

Your Veridian Bill

Your Account Number	60022090-00
Total Due By Sep 20, 2016	\$1,845.65

Outstanding balances after the due date will be assessed an interest charge of 1.5% per month (19.56% per annum).

Amount Paid \$ 1,845.65

6002209000900184565001845651609200000

PAID ONLINE
782

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