BENEFITS OF METAL REFLECTIVE SURFACES FOR CONCENTRATING SOLAR APPLICATIONS

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ABSTRACT

Concentrating Solar Power (CSP) is a growing industry in which companies are constantly striving for higher levels of efficiency and a lower levelized cost of energy. Highly reflective metal-based mirrors provide CSP companies with efficiency gains and a number of other compelling advantages over legacy glass mirror solutions. These new metal mirrors have been tested by the National Renewable Energy Laboratory and the German Aerospace Center. In testing, they have maintained their high level of performance over time and have been deemed suitable for CSP applications. These metal mirrors are of lighter weight and a more formable nature than glass, and can provide cost, performance, maintenance, transport, and durability advantages in the field. This paper will examine all of these points of comparison, while reviewing third party performance testing results, and exploring the composition and production of these metal mirrors.

1. INTRODUCTION

From what you will see and hear on the show floor at this and other large solar events, it would seem that concentrating solar applications are mature, commonplace technologies that enjoy market dominance in the renewable sector. However, critics of renewable energy would have you believe that these are still drawing board technologies that will be too complex, costly and unreliable to become a realistic source of everyday energy for the world. The truth – as always – is somewhere in between these two extremes.

Concentrating solar technologies are fast maturing systems and solutions being offered by a wide and diverse range of companies, all of which hold great promise for the future of the solar, renewable energy, and energy industries. The ultimate goal for concentrating solar power companies is proven grid parity with sustained performance over time. To achieve this, they are constantly seeking advancements in efficiency and durability that contribute to gains in lower levelized cost of energy. It is critical that CSP prove it can deliver efficiency at scale, while eliminating concerns over reliability and complexity.

With this goal in mind, CSP companies are seeking to eke out efficiency gains while improving overall reliability, reducing complexity, attracting credible partners, and continually chipping away at system and maintenance costs.

One of the newer ways this can be done is through the use of metal mirrors to replace traditional glass mirrors. Recent advancements in metal reflective surfaces have provided an opportunity for concentrating solar companies to better attain those reliability, performance and cost goals by using aluminum based mirrors. These unbreakable, formable, and lightweight mirrors provide a compelling advantage over legacy glass systems.

This paper will examine the inherent material advantages of aluminum over glass as well as highlight the production process of these metal mirrors. It will also explore recent testing data from the National Renewable Energy Laboratory (NREL) in the United States and the German Aerospace Center (DLR) of metal mirrors. Finally, we will look at some example projects and industries that are already effectively using metal mirrors in their CSP systems.

2. GLASS VERSUS ALUMINUM

For years, glass has been the default choice for mirrors used in concentrating solar applications. These mirrors have performed admirably over time, and are still evident and operable in large desert solar plants from as early as the

1970s. But this has largely been due to the lack of a viable alternative. Until now.

The two most compelling attributes of glass are its high level of performance and its ability to sustain that level of performance over time. Until recently, there were no substitutes for glass in those areas. Now, with advanced techniques, aluminum can be turned into a highly reflective and durable surface that rivals glass on both fronts. In the next section, we will delve further into the techniques that make this possible as well as the NREL and DLR tests that document it.

But glass also has many inherent shortcomings that aluminum mirrors solve. These include:

2.1 Breakability

One of the most obvious drawbacks of glass is its fragility during transport and handling. In order to ship glass, great care and expense must be taken to ensure that it arrives in one piece at its destination. In many cases, this can even mean purchasing or shipping more glass than needed to account for breakage.

Unfortunately, this challenge does not stop with the freight. Take a walk through any large solar installation and notice the amount of broken glass in between rows of parabolic troughs and reflectors. Installation, windstorms, flying debris, and any number of other hazards can lead to broken mirrors. This can significantly add to material and maintenance costs.

Aluminum is an unbreakable material, effectively eliminating all of the concerns associated with glass. In addition, special coatings make it scratch resistant and allow it to be simply and efficiently cleaned in the field.

2.2 Weight

Glass is a very heavy material, especially when transported in bulk as thick sheets. This adds time and cost to the shipping process, and can also have an impact on the amount of breakage per shipment.

Even more problematic, the weight of glass inhibits many of the new modular, solar systems being developed by innovative CSP companies. These technologies use lightweight space frames that can be placed in urban or space constrained areas such as parking garage rooftops for commercial applications. The weight of glass can place stress on these frames and it can be prohibited from use in some locations because of both weight and security concerns.

Aluminum is an inherently lightweight material that operates at a fraction of the weight of glass. It allows for cheaper and quicker shipping and packing methods, while also pairing perfectly with new, space frames that can be placed on rooftops and other challenging locations.

2.3 Formability

Glass is a rigid substance that is difficult to bend or form into certain shapes. Again, this can inhibit shipping and handling processes, making them more difficult, costly and time consuming. In addition, glass cannot be formed into a structural part of certain solar systems.

In contrast, aluminum is highly formable and can actually act as part of the solar system itself. For example, in the new NEP Solar Polytrough collectors, Alanod-Solar's aluminum mirror actually helps form the structure of the parabolic trough to add strength and reduce weight in the overall system.

2.4 Expansion

One of the little discussed drawbacks of glass is that it expands and contracts significantly in weather extremes. This demands an allowance or gap in placement on reflector frames in solar installations. This gap can be as large as one inch between each sheet, or pane, of glass – both vertically and horizontally. Over the course of a trough, a loop, and the entire solar farm, this can lead to a tremendous loss of efficiency.

Aluminum mirrors do not share this characteristic and can be placed much closer together on a reflector frame. This leads to fewer panels, fewer bolt points and more surface area. In combination, this equals less cost, less maintenance, higher performance, and an overall higher level of efficiency.

3. METAL TECHNOLOGY & PRODUCTION

Alanod-Solar high efficiency metal mirrors are produced through a continuous air-to-air physical vapor deposition (PVD) process that applies the super-reflective layer to coil anodized material. This leverages all of the advantages inherent in aluminum plus adds a highly reflective layer with a solar reflectance of up to 95 percent. Additionally, we apply a weather-resistant nano-composite for outdoor protection using a coil-coating process.

The primary advantage of such processing is continuity. By avoiding batch processing, we also enable an extremely high production capacity. Commissioned at the end of last year, Alanod-Solar's first small commercial line is able to produce 30 million square feet (three million square meters) of outdoor mirror material. This is enough to power 300 MW worth of CSP power plants.

4. THIRD PARTY TESTING

The National Renewable Energy Laboratory in the United States and the German Aerospace Center recently announced impressive results from new performance testing on metal mirrors.

NREL tested Alanod-Solar metal-based mirror samples of MIRO-SUN® outdoors at three separate NREL facilities in Golden, Colorado; Phoenix, Arizona; and Miami, Florida over a period of three years. During that time, the mirrors showed an average drop of less than one percent in specular reflectance measured within a 25-mrad cone angle.

These samples were also exposed to NREL accelerated weather tests using both an Atlas Ci5000 Weather-Ometer and a BlueM damp heat oven.

The Weather-Ometer exposes samples to a continuous condition of Xenon-arc light, 60 degrees Celsius, and 60 percent relative humidity. It accelerates weathering by roughly six times, meaning that in this 15-month test, the metal mirrors were exposed to an equivalent of seven and one half years of light. Over that time, the mirror performance declined between less than one and 2.3 percent in specular reflectance.

The BlueM oven applies an even more intense testing protocol, exposing samples to a continuous condition of 85 degrees Celsius and 85 percent relative humidity without light. Over the accelerated test period, which may simulate as much as 25 years of real world exposure, the samples maintained a very high specular reflectance value.

Overall, the test results demonstrated an outstanding degree of consistency and high-level performance during rigorous real world and accelerated weathering tests. There are no known similar results for any other anodized aluminum front surface mirrors, making these metal mirrors the definition of performance for this category.

DLR measured Alanod-Solar metal mirrors for spectral specular reflectance using a Perkin-Elmer Lambda 950 spectrometer with a Universal Reflectance Accessory (URA). Absolute measurements were taken in three positions, rotated each time by 45 degrees. The average and standard deviations of the three measurements was used for further evaluation. The results were weighted with the solar spectrum of ASTM G173-03 at air mass AM 1.5 to produce the solar weighted specular reflectance in the range from 250-2500nm.

According to the DLR report:

"The measured samples show solar weighted direct reflectance values of 0.868 – 0.883 as measured with the [URA within an acceptance angle >25 mrad] in the spectrometer. The optical analysis of the beam spread distributions shows furthermore that most of the reflected energy can be captured within a radius determined by a standard deviation of 0.67 – 1.20 mrad, corresponding to a target radius of 2-4 mrad. This shows that the analyzed materials can be used in [concentrating solar power] applications."

These tests jointly establish new performance benchmarks for aluminum front-sided mirrors for solar applications. Taken together, these tests and reports show that aluminum-based metals mirrors are well suited for CSP applications because of their proven durability and sustained level of specular reflection. In fact, these tests show that Alanod-Solar's metal mirrors have the longest documented sustained durability and performance for aluminum mirrors.

5. CONCENTRATING SOLAR THERMAL

One of the solar industries taking early advantage of these advancements in metal mirrors is Concentrating Solar Thermal (CST), a technology that captures heat from the sun to power industrial applications. This technology has the potential to dramatically impact energy efficiency and large industry's traditional reliance on fossil fuels.

CST primarily serves large industrial applications that require process heat. According to the International Energy Outlook for 2009, the industrial sector uses more energy than any other, accounting for about one-half of the world's total delivered energy. Much of that energy is related to heat, which is needed for production, process and facility heating & cooling. This need is prevalent in a wide range of industries, including dairy, meat and food processing; beverage bottling; textile manufacturing; pharmaceuticals; and many others. Traditionally, most of these applications are driven by fossil fuels. CST provides a compelling and cost effective alternative.

The technology itself borrows from both solar thermal and CSP systems. Like solar thermal, the core of the system is an absorber material that transfers heat to a fluid for use in heating or cooling applications. But unlike the flat plate collectors used in solar thermal, it uses concentrating technology as in CSP. These parabolic troughs capture a large amount of sunlight and then focus it on a very small absorber area. This efficient use of sunlight and heat transfer enables CST to heat fluids beyond the boiling point – normally over 150°C (300F) and sometimes up to 300°C (570F).

Many of the most innovative CST systems in use today employ metal mirrors in their parabolic troughs to increase the overall efficiency of the system. These aluminum mirrors are lighter, less likely to break, and more formable in installation while not sacrificing performance or durability. The documented ability for these mirrors to perform at a high level of reflectivity for many years – even under duress – is also very important.

Examples of CST installations using some combination of these metal mirrors include:

(1) SunChips® facility in Modesto, California built by American Energy Assets
(2) Sopogy's SopoNova 4.0 solar collectors producing cooling for the Southern California Gas Company's Energy Resource Center's air condition system
(3) A number of steam and air conditioning CST systems in Turkey and Jordan built by Solitem Group
(4) NEP Solar's recently announced project as part of the first solar cooling system for a shopping center in Australia.

6. THE FUTURE

Metal mirrors are just beginning their ascension as the preferred material for CSP applications. As more field-testing and durability becomes available, more CSP technologies and companies will begin to incorporate them into their systems. Additionally, many companies are hard at work designing space frames specifically suited to metal mirrors. These technologies will significantly lower the overall cost and increase the performance of CSP systems when paired with metal mirrors.

In short, the future for metal mirrors in CSP is bright indeed. Their lightweight nature, inherent formability, unbreakable composition, and scratch-resistant surfaces make for a mirror that is easier to produce, ship, and install in any almost any physical environment or setting, while exhibiting performance and durability that is on par with the best glass mirror systems.

7. REFERENCES

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