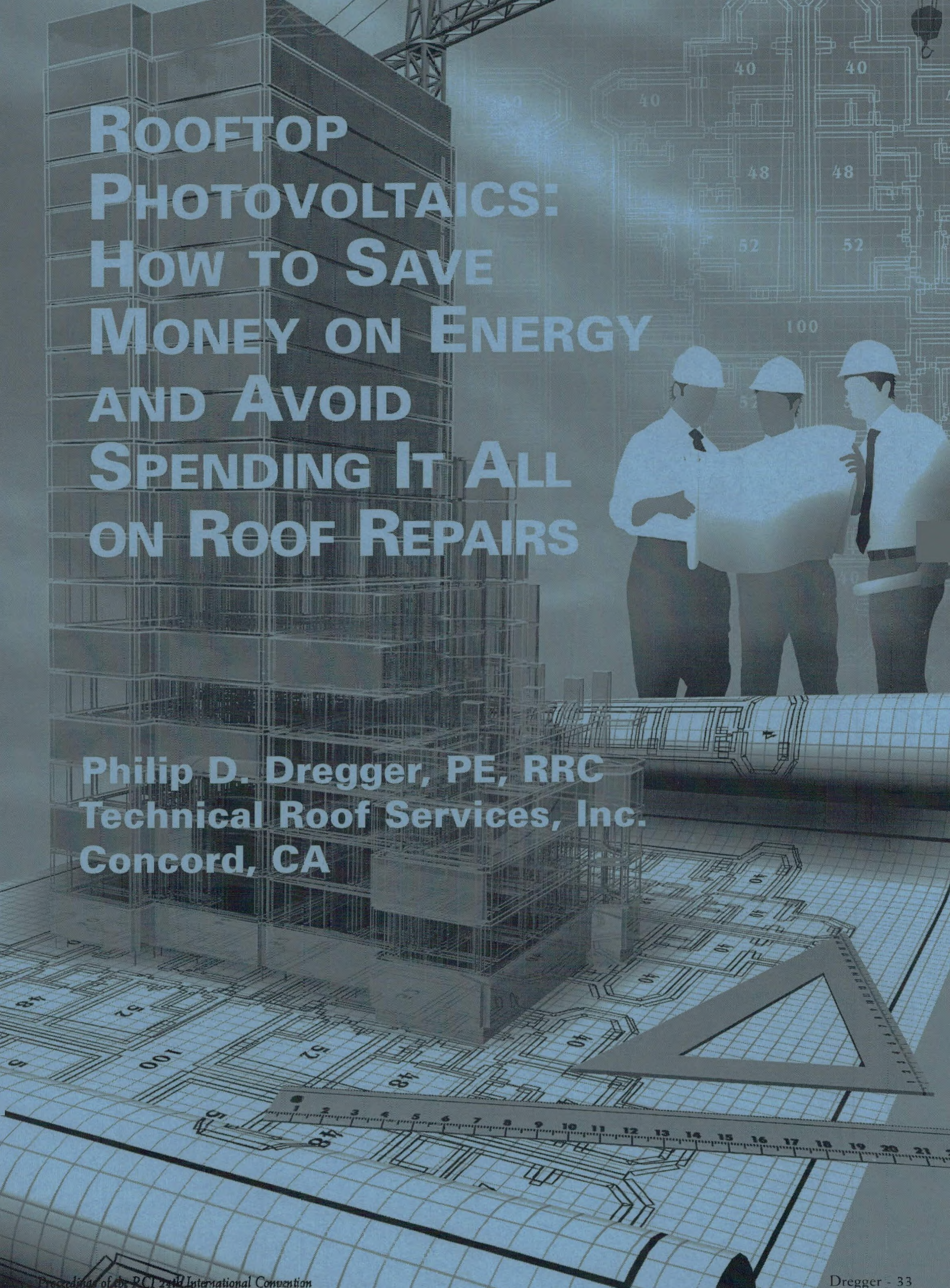
Rooftop Photovoltaics: How to Save Money on Energy and Avoid Spending It All on Roof Repairs



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ABSTRACT

The use of rooftop photovoltaic (PV) panels has increased dramatically and so have problems with the roof coverings over which they are installed. This paper discusses some practical ways that building owners and roof professionals can reap the benefits of conserving energy. It also provides tips to avoid unwelcome surprises associated with nonfire-rated systems, roof leaks, premature roof deterioration, inadvertent voiding of roof covering warranties, compromised access for fire-suppression efforts, and excessive costs associated with temporarily removing and reinstalling PV panels in order to effect needed roof maintenance and repairs.

SPEAKER

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Rooftop Photovoltaics: How to Save Money on Energy and Avoid Spending It All on Roof Repairs

The installation of rooftop photovoltaic (PV) panels such as those pictured in *Figure 1* has increased dramatically over the last few years and so have problems with the roof coverings over which they are installed. This paper discusses some practical ways that building owners and roof professionals can reap the benefits of conserving energy. It also provides tips to avoid unwelcome surprises associated with nonfire-rated systems, roof leaks, premature roof deterioration, inadvertent voiding of roof covering warranties, compromised access for fire-suppression efforts, and excessive costs associated with temporarily removing and reinstalling PV panels in order to effect needed roof maintenance and repairs.

The primary learning objective is to understand some practical considerations related to long-term performance of rooftop photovoltaic systems and the roof coverings on which they are installed:

- Roof covering considerations regarding leak repairs, existing warranties, and durability.
- Future roof access considerations involving maintenance, worker safety, and fire suppression.
- Panel installation considerations for both steep-sloped (greater than 2:12) and low-sloped roofs.
- System design considerations regarding resistance to fire, high winds, and ground motions.

Figure 1 – Large array of photovoltaic panels installed on a roof in San Francisco.

EXISTING ROOFS

Installation of PV panels over an existing roof covering makes good use of some otherwise "unused" space, but can add significant weight to the roof and can make even routine leak repairs prohibitively expensive. Also, if PV arrays are installed over an existing roof covering that is near the end of its life, the panels may need to be temporarily disconnected and moved relatively soon after they are installed to allow roof system replacement, again at significant cost to the building owner.

Questions that merit discussion before undertaking a retrofit PV project include the following:

- How much does the existing roof system weigh?
- How much weight can be safely added?
- How much longer can the existing roof covering be expected to last?

Unless reliable information is available, roof test cuts are usually required to make reasonable estimations of the weight of an existing roof system. Thereafter, even if the PV system is relatively lightweight, it is best to involve a registered structural engineer to determine how much weight can safely be added to the roof structure. Sometimes, this information greatly limits the choices of candidate PV panels.

The remaining life of an individual roof covering is difficult to estimate and depends greatly on the building owner's expectations. Information about the anticipated "average life" of various generic types of roof coverings can be obtained from the paper "2005 Roofing Industry Durability and Cost Survey," by Carl Cash, published in the *Proceedings of the RCI 21st International Convention & Trade Show* in Phoenix, AZ, in 2006.

Due to potentially high costs associated with temporarily disconnecting and moving PV panels to effect roof repairs, the option to replace the existing roof covering as part of a PV project should be seriously considered.

If the existing roof covering is not replaced as part of the PV installation project, it is strongly recommended to investigate and stop roof leaks, make needed repairs, and to perform any "preventive"-type maintenance work, even if it is not scheduled to be performed for a couple of years. Also, consider conducting a nondestructive-type roof moisture survey as a tool to help outline areas of wet insulation, so that openings that may be allowing water intrusion (but have not yet manifested as leaks inside) can be identified and repaired.

Tip 1 – Document roof covering conditions before PV panel installation to provide an objective basis for resolving questions of alleged roof damage.

Tip 2 – Configure PV panel arrays to allow access for future maintenance, anticipated roof repairs, and possible fire-suppression efforts. The California Department of Forestry and Fire Protection recently published the *Solar Photovoltaic Installation Guideline*, which is now available online (see **www://osfm.fire.ca.gov/pdf/reports/solarphotovoltaic guideline.pdf**).

Tip 3 – Consider fall protection provisions if the new PV modules now direct foot traffic to within 6 ft of unprotected roof edges or roof openings such as those shown in *Figure 2*.

Figure 2 – PV arrays can inadvertently direct foot traffic close to unprotected roof edges.

Figure 3 – Seals over fractures in an older fiber-cement roof product.

SLOPED ROOFS

PV panels installed on sloped roofs are often mounted on frames positioned just a few inches above the roof surface. Installation of the frames and panels usually involves workers walking directly on the surface of the existing roof. During installation, a worker's attention is likely to be more on how to carefully handle a glass-like PV panel than on how to carefully step on the underlying roof product. Accordingly, the "walkability" of candidate sloped-roof products should be carefully considered.

Sloped roof products such as asphalt shingles and standing-seam metal roofs have a reasonable measure of durability against damage by foot traffic, without special protection. In the opinion of this author, other roof products such as older fiber-cement shakes (pictured in *Figure 3*), and some lightweight tile products are less resistant to damage by foot traffic and may require special protection or installation methods to avoid damage. Nevertheless, even fairly durable sloped-roof products can be damaged during installation of PV panels.

Supports and Flashings

PV panels can be secured to sloped roofs in several different ways. For many structural standing-seam metal roofs (including those sloped less than 2:12), one handy way is to secure the PV panels to the standing seams using a proprietary, nonpenetrating, metal-clamp assembly. For other types of sloped roofs, a penetrating yet roof-friendly way is to secure the PV panels to frames that are elevated above the roof surface by round posts anchored into the roof-framing members. Although installation of the posts requires cutting holes through the roof coverings, the posts and the openings around them can be readily made weather-tight using standard flanged penetration flashings such as those shown in *Figure 4*.

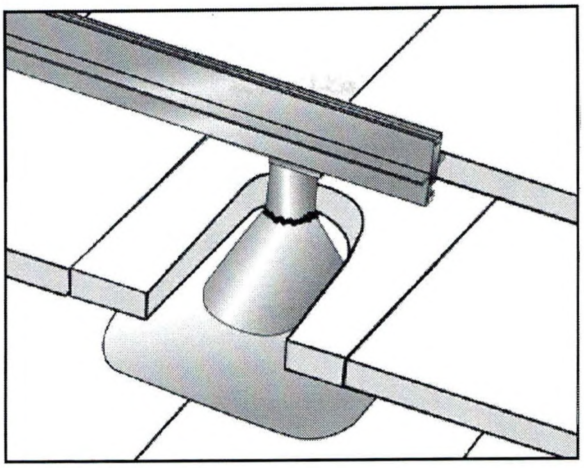

Figure 4 – Premanufactured frame rail "standoff" and flashing. (Source: UniRac.)

Avoid securing support frames and/or panels directly through the roof products (see *Figure 5*), relying on sealants or gasket-type materials for weather protection. These types of in-the-water-plane seals likely will work for a while but do not represent reliable longer-term solutions. Some manufacturers of sloped-roof products provide recommendations for how to install and flash PV panels mounted on their roofs, including recommended accessory products.

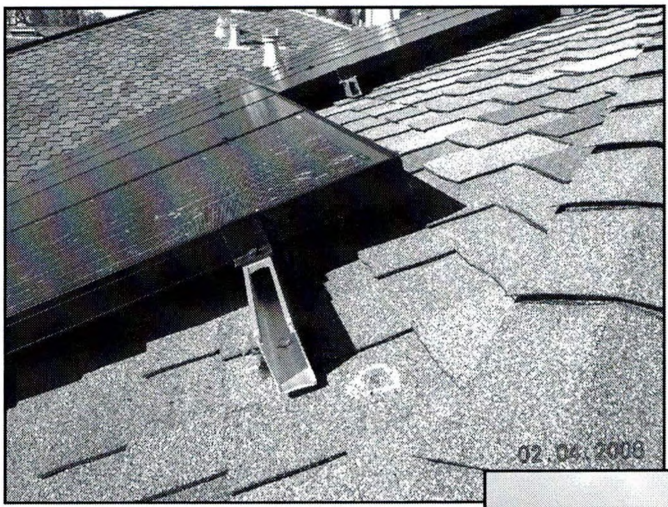

Figure 5 – Rail supports anchored to roof framing directly through asphalt shingles.

Snow Country

PV panels installed on sloped roofs in cold climates have special requirements (see *Figure 6*). Frame-supported PV arrays will likely act like snow retention devices and therefore need to be designed and anchored considering the weight of retained snow and ice. Also, heat generated by PV panels will accelerate melting of snow and ice on the roof. Under some conditions, the melted ice may refreeze immediately down slope of the PV panels, creating conditions similar to ice dams but potentially positioned up-slope from where specialty ice- and water-type waterproofing products, routinely installed along eaves as ice dam protection, may not be installed. Under other conditions, heat generated by PV panels may cause accumulations of ice and snow to unexpectedly slide down and off of the roof.

Figure 6 – Installations in snow country must consider that PV panels can both retain and melt snow.

LOW-SLOPED ROOFS

PV panels are installed on low-sloped roofs in different ways. This paper groups these different ways into three broad categories, depending on how the PV panels relate to the roof covering.

- Integrated – Panels are part of or adhered to the roof covering. *Figure 7* shows an example of an integrated PV panel system.
- Roof-bearing – Panels are independent from but in contact with the roof covering.
- Frame-supported – Panels are elevated above the roof covering.

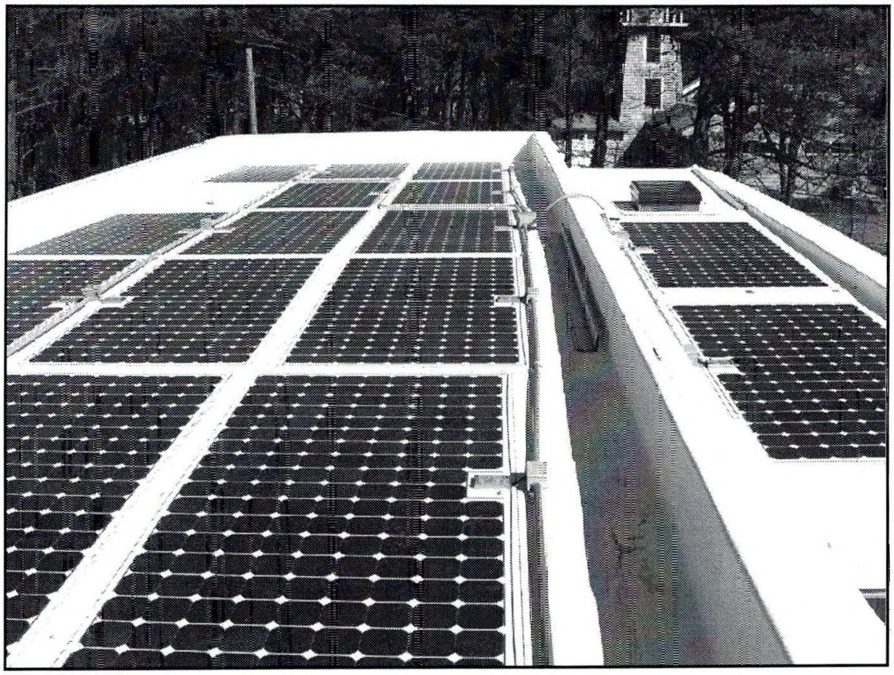

Figure 7 – "Integrated" PV panels. (Source: Open Energy.)

INTEGRATED PV SYSTEMS

Section 1503.1 of the 2006 International Building Code (IBC) states, "...Roof coverings shall be designed, installed and maintained in accordance with this code..." Among other things, the 2006 IBC has requirements for fire, wind, and impact resistance of roof coverings. These code provisions do not specifically address roof coverings combined with PV panels. Nevertheless, in the opinion of this author, roof coverings with integrated PV panels would be intended to meet these requirements as a combined assembly. It is unclear how these provisions are intended to apply to nonintegrated PV panel systems such as some roof-bearing and frame-supported systems. Roof professionals should anticipate special submissions and approvals might be required as part of the permitting process for roof projects involving PV panels.

Fire Classifications

Table 1505.1 in the 2006 IBC lists the required minimum external roof-covering fire classifications for roofs, based on the type of construction and occupancy/use. Construction projects and sometimes owner insurance underwriters require more restrictive roof-covering fire classifications than the code minimums. *The Roofing Materials and Systems Directory* by Underwriters Laboratories is a well-known source of fire classification listings for roof coverings.

For most integrated PV systems, two separate fire classification listings are needed. One fire listing is needed where the roof covering is covered by integral PV panels and another is needed where it is not. And to be applicable, the proposed assembly must comply exactly with the listed assembly and/or optional components and/or allowed substitutions. *Figure 8* shows the burn pattern on a thin-film PV laminate adhered to an EPDM membrane after testing on a 5:12 slope.

For sloped roofs, it is especially important to confirm that the required fire classification is available at the slope required. For example, standing-seam metal roofs routinely qualify as "Class A" fire-resistant on unlimited slopes, whereas the same standing-seam metal roofs covered with thin-film, flexible PV panels have significant slope restrictions.

In the case of integrated PV roof coverings bein installed over existing roof systems, the fire-resistance classification must be listed under the "Maintenance and Repair Systems" category to be applicable. It should be pointed out that gypsum boards are often required to achieve "Class A" fire resistance, especially for slopes greater than ½:12 with combustible decks.

Tip 4 – Confirm the weight of the fire-rated assembly. If ½-in

Figure 8 – Burn pattern on a thin-film PV laminate adhered to an EPDM membrane after testing at 5:12 slope. (Source: 2001 Company.)

gypsum needs to be added to obtain a certain fire rating, this can increase the weight of an integrated PV roof system up to 2 psf.

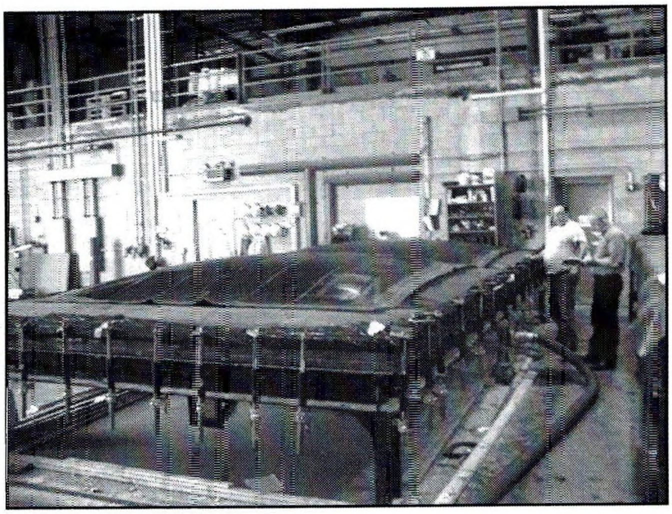

Figure 9 – Billowing of thin-film PV laminate adhered to a mechanically attached EPDM membrane during wind uplift test. (Source: 2001 Company.)

Wind Resistance

Section 1504.1 of the 2006 IBC states, "Roof decks and roof coverings shall be designed for wind loads in accordance with Chapter 16 and Section 1504.2 [tile], 1504.3 [nonballast], and 1504.4 [ballast]." Testing is required to substantiate the required wind resistance in accordance with FM Approval Standards 4450/4470 (utilizing ANSI/FM 4474 wind uplift test procedure) or UL uplift tests 580/1897. These wind-resistance requirements apply to roof coverings with integrated PV panels and should be tested accordingly.

"Billowing" of the mechanically attached single-ply roof membranes as shown in *Figure 9* is an expected and normal response to uplift forces. Roof professionals need to confirm that PV panels, – ones that are for installation as integrated components of mechanically attached roof systems – can accommodate without damage the bending they may be subjected to during high wind conditions.

Tip 5 – For semi-rigid PV panels proposed to be adhered over mechanically attached single-ply roofs, consider installing air retarders and supplemental membrane fasteners around each PV panel.

Impact Resistance

Section 1504.7 of the 2006 IBC states, "Roof coverings installed on low-slope roofs... shall resist impact damage based on the results of tests conducted in accordance with ASTM D3746... or FM 4470 [steel ball]." This requirement is also applicable to integrated PV-panel roof coverings.

Tip 6 – In areas subject to significant hailstorms, confirm that impact-resistance performance (weather protection) is compatible with photovoltaic "power" performance. For example, an integrated PV roof covering that successfully passes tests intended to judge its ability to maintain weather protection after impacts by hail-sized projectiles (e.g., no cracking, splitting, or rupture) may lose its ability to generate power during these same tests.

Standing Water

Power generation is diminished by accumulations of dust and debris on the surface of PV panels. Areas where water stands on low-sloped roofs readily accumulate soil particles. Enhancing surface drainage to avoid standing water conditions or positioning PV panels away from such areas is a prudent consideration.

PV Panels ≠ Cool Roofs

Currently, the state of California has a requirement, as part of a prescriptive compliance approach, to install highly reflective roofs over conditioned spaces of nonresidential buildings. There is no exemption for roofs covered with integrated PV panels. To comply with the CA code in such cases, roof insulation needs to be added below integrated PV panels to compensate for heat absorbed by the panels and transmitted downward into the roof system. The pending 2008 CA Energy Code Update and the currently proposed revisions to ASHRAE 90.1 provide exemptions for building-integrated PV panels.

Highly reflective roof coverings are known to stay tens of degrees cooler than dark-colored roof coverings on hot, sunny days. PV panels, like dark colored roofs, get hot. Integrated PV panels transfer some of that heat downward into the roof systems below them. On one project in the San Francisco Bay Area, during June 2008, average maximum temperatures in excess of 150°F (66°C) were recorded below PV panels adhered over a white thermoplastic roof membrane.

All college chemistry students know heat accelerates reactions. Deterioration or "aging" of most roof coverings consists of an ongoing series of chemical reactions (e.g., oxidation). It seems only logical, then, to ask if roof coverings in direct contact with PV panels are likely to deteriorate at a faster rate than roof coverings not covered by PV panels. The answer, at least in part, depends on how much hotter the roof membrane gets below where it is covered by the PV panels and where it is not.

Black EPDM roof membranes are likely to experience very similar temperatures below areas where PV panels are installed and where they are not. White thermoplastic membranes, on the other hand, are likely to experience much higher temperatures below areas where integrated PV panels are installed than where they are not.

This author is not aware of any published studies relating elevated temperatures of integrated PV panels to decreased service performance of the roof coverings, but, nevertheless, believes it is prudent to consider the possible adverse effects of heat aging of roof coverings below integrated PV panels as part of the roof-covering selection process. It should also be noted that some types of roof insulations (e.g., molded bead, expanded and extruded polystyrenes) begin to soften and deform at much lower temperatures than others, perhaps in the range of temperatures experienced below integrated PV panels in hot climates.

Tip 7 – Consider possible impacts of heat aging and confirm that the existing roof insulation is compatible with the range of elevated temperatures anticipated below the integrated PV panels.

ROOF-BEARING PV SYSTEMS

Roof-bearing PV panels like those shown in *Figure 10* impact the existing roof coverings on which they bear and, in turn, are impacted by the existing roof coverings below them. Another example of a roof-bearing PV system consists of lightweight, individual, sloped PV units, each with four rubber-tipped legs that bear on the roof surface and that snap together in long arrays. Potential impacts associated with roof-bearing systems include these:

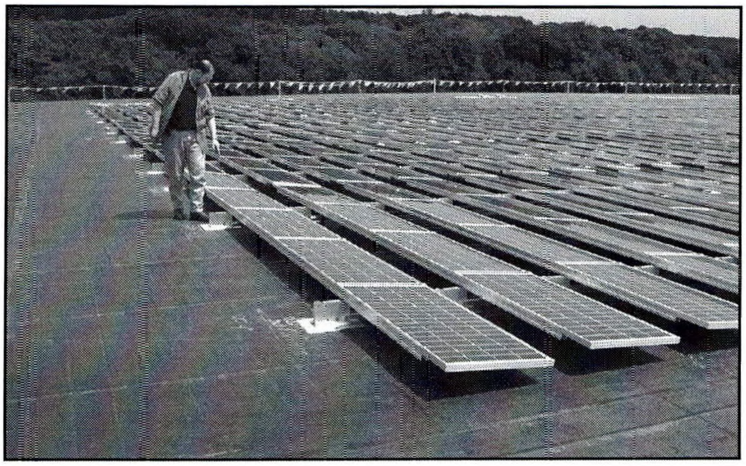

Figure 10 – Roof-bearing PV panels. (Source: 2001 Company.)

- Possible voiding of existing roof warranties, or at least increased owner costs to obtain roof warranty benefits (i.e., move PV panels).
- Changes to roof-service conditions (e.g., less UV, more residual moisture).
- Wind responses of the roof covering possibly damaging the PV panels.

This author is aware of one retrofit PV panel project where stone ballast was removed from an EPDM membrane and replaced with PV panels adhered to cementitious-surfaced insulation boards (a type of ballast). As far as the EPDM membrane was concerned, it had been converted from a ballasted assembly to a protected membrane assembly (PMA). This change may or may not have significant adverse impact on the service performance of the existing roof, depending on project specifics. Roofing professionals must keep in mind that membrane-selection criteria, including warranty requirements, can vary significantly between PMAs and conventionally ballasted roof assemblies.

This author is also aware of a nonpenetrating, loose-laid, and ballasted type of PV panel array that moved about 8 in over a matter of days caused by moderate-wind flutter of the mechanically attached single-ply roof membrane over which it was installed.

Tip 8 – Involve roof-covering materials manufacturers as part of all roof-bearing PV panel projects, especially retrofit projects.

FRAME-SUPPORTED (LOW-SLOPE) PV SYSTEMS

Some PV panels, instead of being integrated with the roof membrane or set loosely on the roof surface, are supported on frames and elevated above the roof surface. Keys to success for these systems are proper flashing of the frame anchorage penetrations and provision of adequate clearance below. To facilitate reliable flashing of anchorage penetrations, frame supports should be constructed of pipe sections rather than angle or channel shapes. Avoid pitch pans. If practical, provide a minimum 18-in clearance below the panels to facilitate future maintenance. Finally, consider installing roof-surface protection along pathways between panels where repeated foot traffic for equipment maintenance and panel cleaning is anticipated. Screening may need to be provided around the frames to discourage nesting of birds and the inevitable soiling of the PV panels by bird excrement. Depending on local conditions, PV panels may need to be washed two or more times a year to maintenance reasonable power generation (see *Figure 11*).

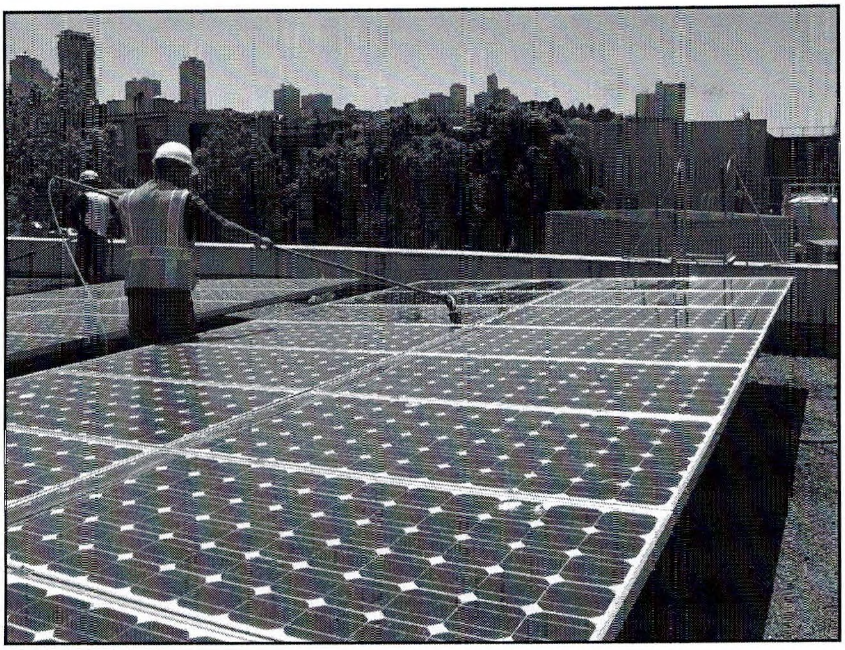

Figure 11 – Cleaning of frame-supported PV panels.

CONCLUSION

The difference between rooftop PV systems that meet owners' expectations and those that do not often hinges not on the amount of power generated, but on how some very common-sense considerations regarding the roof coverings below them are addressed. By asking the right questions and doing the necessary homework up front, roof professionals can help minimize unwelcome surprises associated with questionable fire-rated systems, premature roof deterioration, inadvertent voiding of roof-covering warranties, compromised access for fire suppression, and excessive costs associated with temporarily removing and reinstalling PV panels to perform needed roof repairs.

RETURN ON INVESTMENT (ROI)

Analyzing the expected rate of return on a large investment like rooftop PV panels requires anticipation and valuation of all savings/payback, incentives, and reasonably foreseeable costs. This paper discusses a few foreseeable cost items that are sometimes not considered. Increased costs associated with maintaining and repairing a roof covered by large PV arrays, and especially costs associated with replacing a roof while attempting to maintain operation of a PV system, are examples of two such cost items that need to be included in life-cycle cost and ROI analyses. When these and other types of foreseeable costs are not included, the results of such analyses will be simply inaccurate and potentially also misleading.