GUIDELINES FOR INSTALLATION OF SOLAR COMPONENTS ON LOW-SLOPED ROOFS—A SUMMARY

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This paper presents guidelines for installation of solar collectors and related equipment on low-sloped roofs of commercial, industrial, and multi-family type buildings. The guidelines are concerned primarily with the waterproofing integrity of the roofing system, access to the collectors and roofing, attachment of different types of collector support frames and rooftop safety. Technical information from the literature, building codes, roofing field surveys, and acceptable roofing practice provided the basis for the guidelines. The guidelines include recommendations for design of the solar installation with regard to roofing performance, workmanship during collector installation, and maintenance of roofs with solar components.

Key Words: Collector installation; field survey; guidelines; low-sloped roofs; roofing performance; solar collectors.

INTRODUCTION

The ever-increasing number of solar collector systems on commercial buildings in the United States testifies to solar energy's potential for reducing heating and cooling energy consumption, thus aiding the national effort to conserve precious fossil fuels. On most solar system installations on commercial buildings, collector arrays and other system components are roof-mounted. Roofs of commercial buildings are generally low-sloped and waterproofed with bituminous built-up membranes, though other types of membranes are sometimes used. A slow-sloped roof slopes about ½ in. per ft. or less (40 mm/m),* or about 4 percent.

Low-sloped roofs offer a number of advantages for the installation of solar collectors, notably:

- Readily available and sufficient space.
- Generally unshaded location where the collectors may be mounted at proper orientation toward the sun.
- Normally limited access to restrict unauthorized individuals, including vandals, from interfering with collector operations.

Associated with the installation of solar collectors on low-sloped roofs are several disadvantages:

- Possibly excessive roof deflection from the added dead load of the collector arrays.
- Increased risk of roofing problems that may lead to premature failure. (Experience has shown that roof-system performance is generally inferior for roofs with rooftop equipment compared with roofs without roof-mounted equipment.)
- Increased costs of roofing repair, maintenance, and replacement. (Roofing costs for buildings with roof-mounted solar equipment will generally exceed the costs for buildings without solar equipment, because of the obstacles imposed by the solar components.)

Comprehensive guidelines are needed to assist solar system designers and installers in proper installation of solar components on existing low-sloped roofs. The design of solar systems mounted on low-sloped roofs usually lacks thorough considerations of the interactions of the solar components with the roofing systems and the effect of the solar installation on overall roofing performance. Installation of roof-mounted solar equipment should neither adversely affect nor significantly reduce the roof system's anticipated service life.

This paper presents a summary of the results of a previously reported study on the installation of solar components on low-sloped roofs. [1]* Its objective was to present guidelines for proper installation of solar equipment on existing low-sloped roofing systems. These guidelines are intended to assist solar system designers and installers in providing for adequate performance of roofing systems retrofitted with solar equipment. They are also intended to be incorporated in design manuals and guide specifications for retrofitting low-sloped roofs with solar equipment. Although specifically prepared for the retrofitting of existing roofing systems, many of the guidelines also apply to solar installations on new roofing systems.

SCOPE OF THE STUDY

The guidelines were derived from four main sources:

- A review of the technical literature
- A review of model building codes and related documents
- A field inspection of low-sloped roofs retrofitted with solar equipment

*Values of SI Units given in the report are approximate.

*Numbers in brackets refer to references given in section 8.

- Supplemental information was obtained from roofing contractors, air-conditioning contractors, building owners or their representatives, researchers, solar system manufacturers, and roofing material manufacturers.

The study was limited to the interaction of the solar components and roofing systems; it excludes structural analyses for connecting solar equipment to structural frames and roofs.

THE LITERATURE SURVEY AND CODE-RELATED DOCUMENTS

A literature survey produced relatively few reports, containing little informtion, on the effect of solar collector installation on the performance of low-sloped roofing systems. There were, moreover, no guidelines for proper installation of solar collectors on low-sloped roofs in the United States. Several reports did, however, not specific factors to be addressed during collector installation—e.g. attachment of collectors to the roof, waterproofing of penetrations, roof drainage, clearance between collectors and the roofing, and the design of the installation. (See bibliography of references from the literature survey [1].) One noteworthy source is the French Centre Scientifique et Technique du Batiment (CSTB), which has published general rules for installation of solar collectors on low-sloped roofs for new construction. [2].

The U.S. model building codes were examined to obtain information concerning the effect of the installation of solar components on rooftop safety. The model codes contain provisions applicable to the installation of equipment on roofs, but not specifically for solar components. The Council of American Building Officials (CABO) has prepared a model document for code officials that contains recommended requirements for solar heating, cooling, and hot water systems. [3] The CABO-recommended requirements provide new provisions concerning solar installation for consideration for incorporation into existing codes. Provisions within the CABO-recommended requirements applicable to the installation of solar components on low-sloped roofs included protection against water penetration into the building, protection of pedestrians from sliding snow and ice, structural requirements, and fire safety requirements.

The U.S. Department of Housing and Urban Development has issued the Intermediate Minimum Property Standards (MPS) Supplement for Solar Heating and Domestic Hot Water Systems which, like the CABO document, contains sections dealing with the effect of solar collector installation on the performance of low-sloped roofs. [4] These sections include provisions for water tightness of roofing penetrations, fire safety, clearance of collectors above the roof surface, snow and wind loads, and fungus growth. The provisions within both the CABO recommended requirements [3] and the HUD MPS Supplement [4] were also used in part in support of the guidelines.

THE FIELD SURVEY

A field survey of 17 varied commercial, industrial, and multi-family buildings with solar equipment mounted atop low-sloped roofs had several purposes:

- To inspect the condition of these roofs
- To identify roofing problems attributable to the installation of solar equipment
- To judge whether the solar installation might adversely affect roofing performance
- To determine whether solar-system installation was performed in a manner consistent with acceptable roofing practice

Observations from the survey provided valuable background information in support of the guidelines.

Aggregate-surfaced built-up bituminous membranes provided the waterproofing on 16 buildings. One building had a smooth-surfaced built-up roof with an aluminum coating.

Different types of collector support frames and methods of attachment of the solar components to the roof system were considered in the selection of the buildings. With one exception, the roofs surveyed had flat plate solar collectors. One roof had a concentrating solar collector system. The solar equipment was retrofitted to all roofs inspected and most of the solar systems had been installed for a period of two years or less. For most buildings, the collector frames were attached to the roof system with steel supports that extended through the roofing membranes. In a few cases, wooden frames supporting the collectors were attached to wooden planks (or sleepers) which were secured directly to the roof system by mechanical fasteners.

A number of factors by which the solar installation might affect the performance of low-sloped roofing systems were identified during the survey. Some of the important factors included the following: the condition of the roofing at the time of the solar installation; roof slope and drains; attachment of collector supports and roof penetrations; pipe penetrations; and clearance between collectors and roofing. Most of the surveyed roofs had some installation feature that violated the principles of good roofing practice. The photographs of Figures 1-4 show some observatons made during the survey.

Figure 1 shows heavy steel frames supporting collectors. The frames were supported by steel pipe columns penetrating the roofing. The roof penetrations were waterproofed with pitch pockets, some of which contained cracks and openings in the filler bitumen.

In Figure 2, solar collectors mounted on wooden frames were anchored to the roof with wooden sleepers set directly on the roofing and mechanically fastened in place. The sleepers had partially settled into the flood coat and aggregate surfacing. It was not determined whether membrane damage had occured, but there were no reported leaks.

Inadequate clearance between the roof and steel frames supporting collectors is shown in Figure 3. In this case, a new built-up membrane was applied concurrently with the solar-equipment installation.

Figure 4, another example of solar collectors supported by heavy steel framing members, shows access on the roof and around the collectors restricted by horizontal members connecting adjacent collector arrays.

GUIDELINES

The guidelines for retrofitting existing low-sloped roofing systems with solar-collector systems comprise short statements consistent with good roofing and building practices. In the previous report by Mathey and Rossiter [1], a commentary follows each guideline, including points to consider and steps to be taken to implement the guideline. The relatively long commentaries are omitted here, because their presentation is beyond the scope of this summary report.

The commentaries accompanying the guidelines in the

previous report [1] at times contained reference to roof construction details prepared by the National Roofing Contractors Association (NRCA) [5]. For use in this study, the NRCA details were modified in some cases for specific applications to solar-component installation. Some designers of roof-mounted solar collector systems may prefer other construction details. It was suggested [1] that in these instances, the alternate details be comparable to those prepared by NRCA. Guidelines for retrofitting existing low-sloped roofing systems with solar collector systems are as follows:

Condition of the Existing Roofing—The Roof Components
The condition of the existing low-sloped roofing components including membrane, insulation, and deck should be determined prior to the design and installation of the solar collector system. Solar-system components should be only installed on roofs assessed to be in good condition and expected to provide satisfactory performance (without major repair or reroofing) for 15 years or more.

Condition of the Existing Roofing—Roof Slope and Drainage
Roofs that pond water are considered unacceptable for the installation of solar components. Steps should be taken before solar component installation to assure adequate drainage.

Design—Structural Requirements
The roof structural framing should be checked for its capacity to support the mass of the solar collectors and other roof top system components.

In calculating dead loads for solar systems, the mass of the transfer liquid in the collector, liquid in roof-mounted storage tank, and liquid in other subsystems and components should be included, except when using dead load to resist uplift or overturning.

Design—Wind Loads on Collectors Mounted on Roofs
Collectors mounted on open racks at an angle to the surface of low-sloped roofs should resist any uplift loads caused by wind. Wind loading should be determined according to the provisions given in the HUD Minimum Property Standards (MPS) Supplement [4].

Design—Roof Wind Loads
Roof loading from wind on flat-plate collectors and concentrating collector support structures and/or enclosures should be included in the structural analysis of the roof framing, and any other structural framing affected by these loads.

Rigid board roof insulation applied during solar component installation should be well-adhered or mechanically fastened to the deck so that the roofing system will resist uplift forces from anticipated winds.

Design—Roof Snow Loads
Snow loads should be determined on the basis of local snow conditions and should consider severe drifting between collectors (and under open racks) and accumulation on cover plates. In cases where the collectors are mounted with their cover plates forming steep slopes, shedding or sliding of snow from the collectors may cause snow to accumulate at their bases, additional snow loading should be considered in the analysis of the structural framing.

Design—Fire Safety
The effect of the installation of solar collectors on the fire rating of low-sloped roofs should be considered during the design of the solar system. The installation of solar collectors and other system components on the roof should not reduce the fire retardant classification of the roof covering materials below the collectors. Local building codes should be consulted to ascertain that the installation conforms to fire safety requirements of roof systems.

Design—Roof Plan
A drawing of the roof plan should be prepared during the design of the collector system installation.

Design—Architectural Drawings
Architectural drawings for solar collector installations should include complete, accurate details of penetrations and flashings.

Workmanship During Collector Installation—Membrane Protection
Installation of the solar system components should be accomplished without abuse and damage of the existing roof membrane.

Workmanship During Collector Installation—Water Penetration
The roof system should be protected from the entry of water at all times during collector installation.

Workmanship During Collector Installation—Installation of Roofing
Roofing contractors should apply permanent roof membranes, flashings, and other roofing system components.

Workmanship During Collector Installation—Debris
Debris remaining on the roof from the solar equipment installation should be removed at the completion of the construction.

Workmanship During Collector Installation—Bitumen Application
In conducting bituminous roofing operations such as the flashing of collector supports and repair of accidental membrane damage, care should be exercised to prevent the splatter of hot bitumen on collector cover plates.

Impairment of Drainage
Installation of the solar collectors should not affect the roof system's capacity to drain water completely.

Clearance—Between Collectors and Roofing
Adequate clearance should be provided between the bottom of the solar collectors and/or the collector frames to allow unobstructed inspection, maintenance, repair, and replacement of the roofing system below the collectors. Minimum clearance should generally range between 24 and 30 inches (600-750 mm).

Clearance—Around Collectors
Adequate clearance should be provided between the perimeter of collector arrays and roof perimeters, roof penetrations and equipment. To provide adequate clearance, a minimum distance of 24 inches (600 mm) between the perimeters of the collector arrays and roof perimeter, penetrations and equipment is recommended. Solar collector supports and collector panels should not extend beyond the edge of the building.

Clearance—Between Heat-Transfer Fluid Pipes and Roofing
With the exception of pipe penetrations through the roofing, a minimum clear distance of 14 inches (350 mm) should be provided between the heat-transfer fluid pipes including thermal insulation with its protective covering and the roof surface.

Collector Supports—Attachment of Collector Supports
Supports for solar collector frames should be securely attached to the roof structure and properly waterproofed.

Collector Supports—Stub Columns
Stub columns extending above the membrane surface and allowing for proper flashing may be used as supports for solar collector frames.

Collector Supports—Parapet Walls
Solar collector frames should not be supported by parapet walls, because of inadequate distance between collector arrays and roof perimeter. If it is necessary to support collector frames by parapet walls, structural analysis should demonstrate that damage to walls or roofing will not result from induced horizontal and vertical loads.

Collector Supports—Guy Wires
Guy wires, used to brace solar collector frames against uplift, should not be fastened directly through the roof membrane to the structural deck with eye bolts or other methods of attachment. Guy wires should be connected to properly flashed penetrations; e.g., sealed pipe columns, curbs, or stub columns.

Flashing of Pipe Column Supports, Pipes and Conduit
Pipe-column supports and heat-transfer fluid pipes penetrating the roofing membrane should be flashed with pipe sleeves with rectangular base flanges, extending at least 4 inches (100 mm) from the vertical circular portion of the sleeve.

Supports for Pipes
Heat-transfer fluid pipes should be supported by the collector support frames whenever possible. They should extend along the roof for the minimum practicable distance.

Compatibility of Heat Transfer Fluids With Roofing Membranes
Heat-transfer fluids should be selected and used to avoid damage to the roofing membrane.

Safety—Access to the Roof
Roofs over three stories high should have a means of access to provide for collector cleaning and maintenance.

Safety—Access on the Roof
Solar-collector systems on low-sloped roofs should not unduly obstruct the normal movement of building occupants or emergency personnel.

Safety—Sliding Snow and Ice
In areas with design snow load of 20 pounds per square foot (958 Pa) or greater (as required by local codes), provisions should be made over entrances and locations of pedestrian and vehicular ways to restrain or deflect snow and ice masses that may slide off elevated solar system components.

Maintenance of Roofing—Roof Inspections and Maintenance
Roof inspections and maintenance should be performed at regular intervals.

Maintenance of Roofing—Roofing Repair and Replacement
Needed repairs or replacement of sections of roofing or flashing identified during maintenance inspections should be completed as soon as possible.

Walkways for Protection of Roofing and Piping
Walkways should be provided on roof areas that receive frequent foot traffic due to periodic inspection and maintenance of roof-mounted collector system components.

SUMMARY

This paper summarizes a recently completed study [1] to prepare guidelines for installation of solar equipment on existing low-sloped roofing systems in conformance with good roofing and building practices. The study included a review of the technical literature, model building codes and related documents, and a field survey of low-sloped roofs retrofitted with solar equipment. Information from these sources provided the basis for the guidelines.

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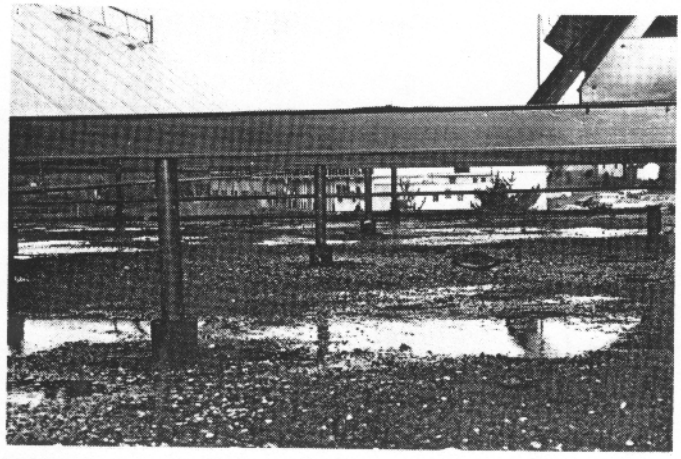

FIGURE 1
Steel Pipe Columns Supporting Collector Frames Penetrate the Roofing

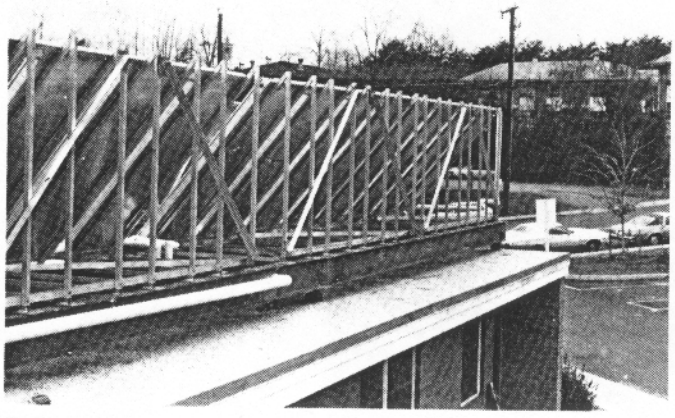

FIGURE 3
Inadequate Clearance Between Roofing and Steel Frames Supporting Collectors

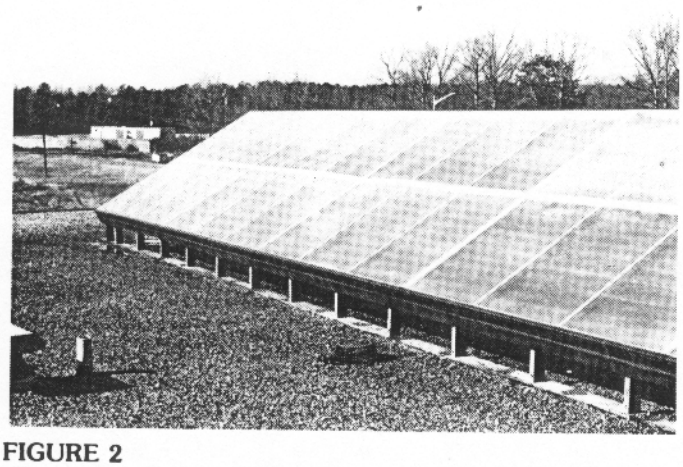

FIGURE 2
Wooden Collector Frames Mounted on Sleepers Which Are Set Directly on the Roofing and Mechancially Fastened in Place

FIGURE 4
Restricted Access on the Roof and Around Collectors Due to Heavy Horizontal Members