Energy Conservation and Solar Energy for Historic Buildings
Guidelines for Appropriate Designs

Prepared for Technical Preservation Services Division
National Park Service
U.S. Department of Interior
By
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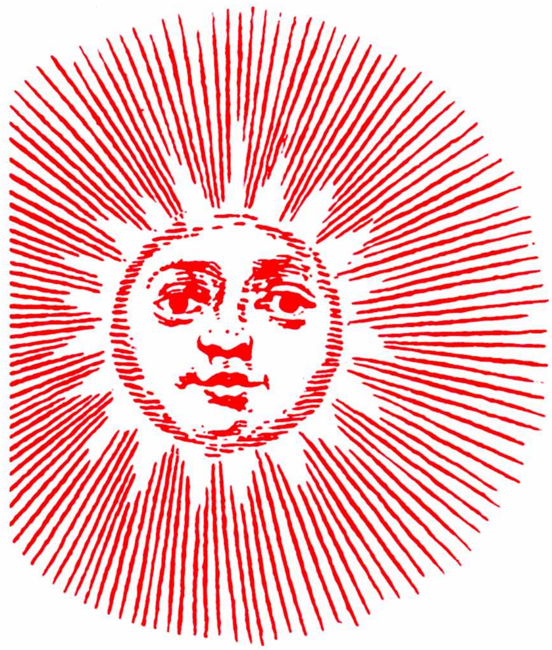

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The National Center for
Architecture and Urbanism
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Washington, D.C. 20009

Acknowledgements

The concept for these guidelines was originated at the Department of Interior, National Park Service, Technical Preservation Services Division and came to fruition through the efforts of Baird Smith, AIA and his colleagues there, including Lee Nelson, AIA, Gary Hume, Ward Jandl and Jean Travers. Three architects, each knowledgeable in historic preservation subjects and at least familiar with energy conservation and solar energy issues, reviewed drafts of these guidelines and offered valuable advice. They are C. Richard Bierce, AIA of the National Trust for Historic Preservation, William Brenner of the National Institute of Building Sciences and C. Stuart White, AIA of Banwell, White and Arnold Architects. The guidelines were conceived and written by Thomas Vonier, AIA and Peter H. Smeallie of Thomas Vonier Associates, Inc. with technical assistance from Françoise Vonier.

The information contained herein has been prepared to be consistent with the *Secretary of the Interior's Standards for Rehabilitation*. Persons utilizing this document in planning and implementing a building rehabilitation to take advantage of the federal tax incentives provided for in the Economic Recovery Tax Act of 1981 must apply for such benefits according to procedures described in 36 CRF 67. Each project is judged on its own merits and all project work must comply with the *Secretary of the Interior's Standards for Rehabilitation*.

Why this Publication Was Developed

In common with owners, managers and users of other buildings, people and organizations associated with historic buildings have become increasingly concerned with the costs and availability of the energy needed to provide convenient and comfortable interior conditions. Historic buildings pose unique challenges and considerations in this regard, beyond those normally encountered in existing buildings.

These special considerations are reflected in the Secretary of Interior's *Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings*, which form the basis for determining whether rehabilitation of an historic building might qualify for certain federal tax benefits.

When the Secretary of Interior's standards and guidelines were developed, energy conservation and solar energy applications were not given detailed or explicit consideration. The purpose of this publication is to elaborate on the Secretary's standards and guidelines with specific regard to energy conservation measures and solar energy applications.

Although these guidelines are intended to cover a complete range of energy considerations, they are not meant to constitute a comprehensive energy primer for historic buildings. References are provided to more complete technical works. This publication is intended to provide guidance on common energy conscious design measures and strategies, in light of important historic characteristics, in order to assure that steps taken are appropriate to the historic buildings in question.

Every effort will be made periodically to update and expand these guidelines as new concepts are developed and new techniques become known. Written comments on these guidelines are welcome and should be addressed to:

Technical Preservation Services Division
National Park Service
U.S. Department of the Interior
Washington, D.C. 20240

Introduction to the Energy Conservation and Solar Energy Guidelines

It is generally acknowledged that in both rehabilitation and new construction, energy conservation measures such as weatherization and insulation must precede the effective use of solar energy systems. Reducing the heating loads to be met by solar energy is an essential first step. This is reflected in these guidelines.

Several general points should be made regarding energy conservation and solar energy measures. First, the economic feasibility of measures depends on factors related to the costs of money, energy and construction, the investment horizon of the building owner, and many other considerations. Economic aspects of these measures deserve careful study in light of the specifics associated with a given building. A number of readily used methods and resources exist for this purpose and are referenced at the end of these guidelines.

Second, the use of solar energy -- by passive or active means -- may not be practical for some historic buildings. Shadows cast by surrounding buildings and objects, the existing building's orientation, configuration or fenestration may all dictate against solar design strategies. These factors would not preclude integration of energy conservation measures, however, and should not discourage their pursuit.

Third, many historic buildings, by virtue of the energy resources available during the era in which they were erected, were designed to make integral use of energy-conserving and passive solar principles. In such cases it may be most desirable to restore these features to their original working order. On the other hand, with active solar systems involving expanses of flat-plate collection equipment and networks of plumbing or ductwork, the challenges posed are largely related to concealment and integration, as these were not part of the original building. Finally, building energy use can be improved by identifying discrepancies between the original design assumptions and the current actual building use. This is particularly true for those historic buildings that have undergone changes in use, e.g., residential buildings into museums. Significant reductions in energy use can result from detailed evaluation of a building's use.

By design these guidelines have concentrated on the architectural aspects of energy conservation and solar energy, leaving out detailed consideration of ordinary heating, ventilating and air-conditioning equipment. In addition, common weatherization and insulation techniques are not addressed on the assumption that these measures are well enough covered in existing literature.

The intent is to give design guidance in determining recommended additions and alterations to historic buildings necessitated by conservation and solar devices, rather than economic, operating or engineering information.

The Secretary of Interior's Standards for Rehabilitation

While not addressed to energy conservation and solar energy, the Secretary of the Interior's standards for rehabilitation are concerned generally with measures having an influence on the character and appearance of historic buildings. The standards, as they appear in Title 36, Part 67 of the Code of Federal Regulations, are as follows:

1. Every reasonable effort shall be made to provide a compatible use for a property which requires minimal alteration of the building, structure, or site and its environment, or to use a property for its originally intended purpose.

2. The distinguishing original qualities or character of a building, structure, or site and its environment shall not be destroyed. The removal or alteration of any historic material or distinctive architectural features should be avoided when possible.

3. All buildings, structures, and sites shall be recognized as products of their own time. Alterations that have no historical basis and which seek to create an earlier appearance shall be discouraged.

4. Changes which may have taken place in the course of time are evidence of the history and development of a building, structure, or site and its environment. These changes may have acquired significance in their own right, and this significance shall be recognized and respected.

5. Distinctive stylistic features or examples of skilled craftsmanship which characterize a building, structure, or site shall be treated with sensitivity.

6. Deteriorated architectural features shall be repaired rather than replaced, wherever possible. In the event replacement is necessary, the new material should match the material being replaced in composition, design, color, texture, and other visual qualities. Repair or replacement of missing architectural features should be based on accurate duplications of features, substantiated by historic, physical, or pictorial evidence rather than on conjectural designs or the availability of different architectural elements from other buildings or structures.

7. The surface cleaning of structures shall be undertaken with the gentlest means possible. Sandblasting and other cleaning methods that will damage the historic building materials shall not be undertaken.

8. Every reasonable effort shall be made to protect and preserve archaeological resources affected by, or adjacent to any project.

9. Contemporary design for alterations and additions to existing properties shall not be discouraged when such alterations and additions do not destroy significant historical, architectural or cultural material, and such design is compatible with the size, scale, color, material, and character of the property, neighborhood or environment.

10. Wherever possible, new additions or alterations to structures shall be done in such a manner that if such alterations or additions were to be removed in the future, the essential form and integrity of the structure would be unimpaired.

The standards are available free of charge through:

Technical Preservation Services Division
National Park Service
U.S. Department of the Interior
Washington, D.C. 20240

A Note on the Format

The energy conservation and solar energy guidelines are organized so that each page addresses a separate issue. Energy conservation guidelines examine environmental considerations, building external features and building internal features. The solar energy system guidelines examine active systems and passive design techniques. Although each guideline covers a specific topic, designers should attempt to integrate the various techniques, realizing that modifications to one area can have effects on the energy and historic aspects of the entire building.

Each page is organized to treat a design issue from a historic and energy-conserving perspective. Historic considerations are based on the Secretary of Interior's *Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings,* and a list of recommendations a designer should consider when undertaking any rehabilitative design on an historic building. Energy considerations point out the energy benefits of certain inherent building features, as well as selected building design modifications and additions. The section entitled "Design Guidance" presents possible design solutions and considerations for energy conservation or solar energy measures for historic buildings.

As a way to amplify the text and provide an additional element of guidance, a number of photographs, diagrams, illustrations and drawings are included. To the degree possible these have been taken from actual buildings and situations. These examples should not be seen as the only or even the definitive possible approaches to a given problem; many variations exist.

Captions provided with the illustrations are intended to amplify the example and to specify the point being emphasized.

Finally, each page includes references that provide more technical and detailed design guidance. Each reference source has been carefully examined for appropriateness, and every attempt has been made to include references that are readily available at most university and public libraries.

Preservation Retrofitting: Some Preliminary Steps

Before design changes are made to historic buildings, the building should be examined carefully for the possibility of retrofitting measures that will not jeopardize the historic character of the building and can be accomplished at a reasonable cost. Preservation retrofitting improves the thermal performance of the building and leads to reduced building energy consumption.

Building designers and owners who undertake preservation retrofitting must take into account certain considerations unique to older and historic buildings. Larger quantities of moisture are present in the interiors of most buildings; designers and owners should assure that retrofitting measures do not create moisture-related deterioration. Materials that are chemically or physically incompatible with existing materials, or that are improperly installed can cause serious damage to historic materials, and can, at times, pose a significant health and safety problem. Finally, the designer and owner should thoroughly investigate the existing physical condition of the building. The basic building components should be checked to determine the methods of construction used and the presence of insulation. The presence of adequate vapor barriers should be checked, sources of air infiltration should be identified, and the condition of the exterior wall materials and roof should be assessed to determine the weather tightness of the building.

Detailed preservation retrofitting measures are presented in the Technical Preservation Services Division's Preservation Brief 3, *Conserving Energy in Historic Buildings,* by Baird Smith, AIA. Copies may be obtained by writing:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

stock number 024-016-00103-6

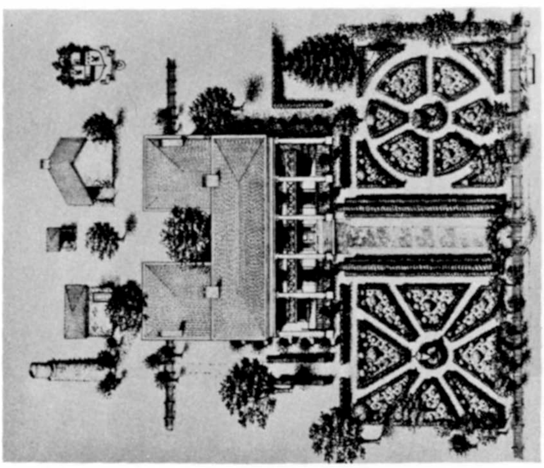
Historic Considerations
based on Secretary's Standards

Distinctive landscape features that link buildings to their environment should be retained. Building features that contribute to the neighborhood's distinguishing character should be retained

Energy Considerations

Existing topographical features e.g., landforms and bodies of water, affect the microclimate of a site. Adjacent buildings and ground surfaces can reflect solar radiation toward the building. Where unwanted solar radiation is reflected toward the building, surfaces can be painted, planted or otherwise altered without damaging the neighborhood's historic character. Topography and existing structures can also provide desirable shading and wind breaks. Parks, gardens and vegetated areas act as thermal buffers against extremes.

Example



Landscaping and careful planting of vegetation have long played an important role in helping to minimize heat gains and losses as seen in this Georgian plantation.

Design Guidance

The presence of water on or near a site has a moderating influence on temperature extremes. Water absorbs excess heat from the environment, cooling it; as temperatures drop, the stored heat is reradiated to the surroundings. Large bodies of water cause diurnal onshore and offshore breezes that can be used for natural ventilation. Vegetation also moderates climatic extremes; vegetated areas tend to be cooler, more humid and thermally more stable than unvegetated areas. The introduction of parks, gardens, ponds and lakes, where appropriate, is encouraged.

Manmade structures should be examined for their desired shading capabilities or, conversely, for reflecting solar radiation, and for their effect on prevailing breezes. Consideration should be given to the removal of obstructions that adversely affect a building's access to light and wind in cases where those obstructions are not historically significant.

References

California Energy Resources Conservation and Development Committee, *Energy Conservation Design Manual for Non-Residential Buildings,* 1977.

Robinette G.O., *Landscape Planning for Energy Conservation,* Reston, VA: Environmental Design Press, 1977.

State of Hawaii, *Saving Energy and Dollars: Choosing a House or Apartment,* Honolulu, HA: State Energy Office, 1981.

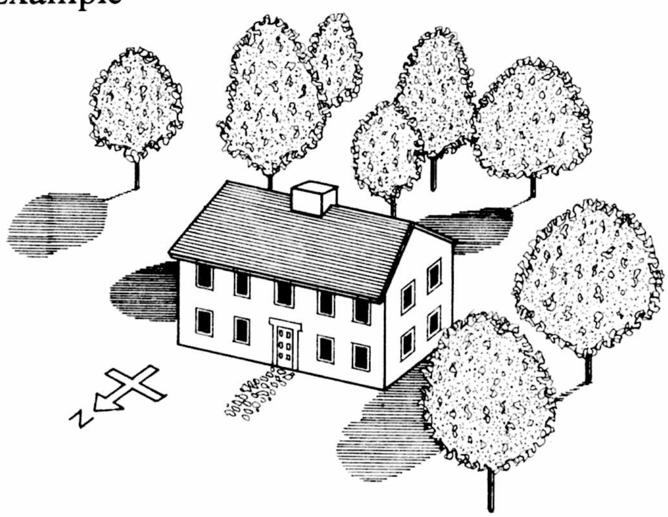
Historic Considerations
based on Secretary's Standards

Site elements -- plants, trees, fencing, signs, benches, walkways, outbuildings -- that might be an important part of the property's history and development should be retained. Modifications to the site should be evaluated in light of the actual knowledge of the past appearance of the property.

Energy Considerations

Modifications to the building's site should take advantage of the energy conservation potential of a properly planned and managed landscape. Where solar radiation is desirable in winter but not in summer, consider planting deciduous trees near the southerly facades so that the building has shading in summer but sun exposure in winter. Consider planting evergreen trees close to the northerly facades in order to minimize the effects of wind and to provide summer and winter shade.

Example



The planting of deciduous trees on south and west sides is a traditional and effective way to provide natural shading. Trees also help to minimize undesired winds adjacent to buildings.

Design Guidance

Before planting trees, consideration should be given to the proper placement of the young trees. Underestimating the size of adult trees can result in trouble with branches, roots and clogged drains. Planting or leaving trees or other plant materials in close proximity to the building, closer than 5 feet, may cause deterioration of the historic fabric, especially to foundations. Shadow patterns should be considered with respect to the time of day and distance of the trees from the building. Since shading is minimal when the sun is directly overhead and maximal when it is closest to the horizon, trees located nearer the east and west facades are more effective at shading and blocking unwanted radiation. Fountains, ponds and sprays can provide a cool area at the building's base. These historic amenities should be retained in working order. Consideration should be given to placing an intake for ventilating air near these pools of water. A significant amount of free pre-cooling can be obtained.

References

Labine C., *The Energy-Efficient Old House,* in The Old House Journal, September 1977, pp 105-107.

Olgyay V., *Design with Climate: Bioclimatic Approach to Architectural Regionalism,* Princeton, NJ: Princeton University Press, 1963.

Robinette G.O., *Plants/People/and Environmental Quality,* Washington, D.C.: U.S. GPO, 1972.

Historic Considerations
based on Secretary's Standards

The original roof shape should be preserved. All architectural features that give the roof its essential character should be preserved or replaced in kind.

The original roofing material should be retained whenever possible. Replacement materials should match the old in composition, size, shape, color and texture.

Energy Considerations

The configuration of the roof can provide energy saving opportunities. Overhangs shield windows below from the high, hot summer sun, yet admit lower winter sunlight. High parapet walls shade adjacent roof areas. Color and texture influence the roof's reaction to solar radiation. The physical design of the roof can enhance internal ventilation, and influence heat gain and loss.

Example

The materials and shapes of the roofs on these modest woodframe residences impart a distinct character to the neighborhood and play an important part in adapting the buildings to their climate. Major changes to the roof configurations and materials would detract from these qualities and would be inappropriate.

Design Guidance

Modifications to the roof should respect the importance of the roof to the building as a whole and to the surrounding environment. A flat roof, not visible from view, offers more possibilities for modifications than a prominent hipped or gabled roof. A dark, flat roof can collect warm air and radiate it down to the floor beneath. A gable roof with overhangs provides sun control on two sides. A hip roof offers sun control on four sides. Gable vents can flush heat out of the attic space. To minimize heat gain in summer, roofs can be finished with a light-colored surface having high emissivity or can employ reflective surfaces. Dark, rough surfaces absorb solar radiation. In many older buildings roofs were designed to be inherently energy conserving. Repairing and replacing the architectural elements such as overhangs, cornices, parapets, dormer windows, cupolas and chimneys can improve the energy performance of the building.

References

AIA Research Corporation, *Energy Conscious Redesign of Existing Buildings: Workbook and Design Manual,* Washington, D.C.: AIA Research Corporation, 1976, p 19.

State of Hawaii, *Saving Energy and Dollars: Choosing a House or Apartment,* Honolulu, HA: State Energy Office, 1981.

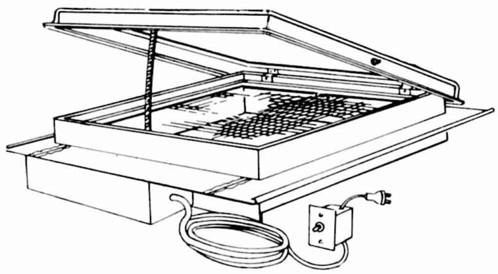
Historic Considerations
based on Secretary's Standards

The essential character of the roof should be preserved. Adding inappropriate features such as new skylights is not recommended unless their appearance is concealed from principal views. When skylights are an essential part of an existing roof, they should be preserved and repaired.

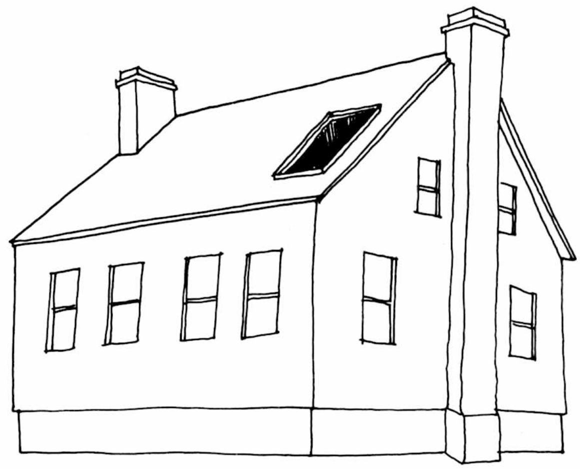
Energy Considerations

Skylights make direct use of sunlight and reduce the demand for electric lighting. They can also function as passive solar collectors. Thermally efficient skylights reduce heat gain in summer. Skylights that open and close induce natural ventilation and cooling, in addition to providing daylighting benefits.

Examples



Skylights are easily installed and often unobstrusive from the exterior. Venting skylights, if properly placed, will help to promote physiological cooling.



Skylights should be placed out of view from main elevations and care should be taken to avoid large, conspicuous bubbles or domes when these are inconsistent with historic period features.

Design Guidance

The addition of new skylights to roofs should be undertaken after careful consideration of the potential energy benefits as well as the contribution of the roof to the character of the building as a whole and to the surrounding environment. New skylights should be added in places of the roof where they will not cause irreversible damage to the roof or the interior ceiling. Skylights and skylight systems are frequently found in older buildings, especially industrial buildings. While many are decorative, many were designed as important elements for lighting and ventilation. If replacement is required, the framing grid of the new skylights should retain the pattern of the original system. However, the glazing may take advantage of new products such as translucent plastic sandwich panel glazing containing light transmissive insulation. Many older buildings also contain clerestories which were designed to admit light and provide for natural ventilation. These should be preserved, restored and made operable where appropriate. Dormers are a common way, historically, of providing light and air into or under roof spaces. In some cases, on non-significant facades, the addition of dormers would be architecturally appropriate.

References

Architectural Aluminum Manufacturers Association, *Shedding Light on Energy Savings with Skylights*, 1980.

U.S. Department of the Interior, Heritage Conservation and Recreation Service, *Rehabilitation: Claremont 1978*, Washington, D.C.: U.S. GPO, 1978.

Historic Considerations
based on Secretary's Standards

In the event replacement of architectural features is necessary, new material should match material being replaced in composition, design, color, texture and other visual qualities. Historic paint colors and finishes of the structure should be discovered and reused.

Energy Considerations

Exterior wall color affects the energy efficiency of the building. Light colors reflect more of the sun's heat, keeping the walls cooler. Darker colors absorb more of the sun's heat. Lighter colors are generally more appropriate in southern or warmer climates, while darker colors work best in northern or colder climates.

Example

Dark exterior wall surfaces can become 60°F warmer than surrounding air temperatures, while lighter-colored surfaces tend to reflect both heat and light.

Design Guidance

In many older buildings, the choice of wall materials and colors were often a response to site and climatic conditions. Dark colors absorb heat; light colors reflect heat. Masonry and stone materials retain heat, reradiating it at a slower rate than many other materials. When considering the effectiveness of radiant heat transfer, the material properties which affect the energy flow are absorbance, emissivity and reflectance. In general, as the absorptivity and emissivity of a material increase, the reflectivity decreases. In any replacement of or modification to exterior walls, the importance of the facade to the building as a whole and to the surroundings should be considered.

References

Stein R., *Architecture and Energy,* Garden City, NY: Anchor Press/Doubleday, 1977.

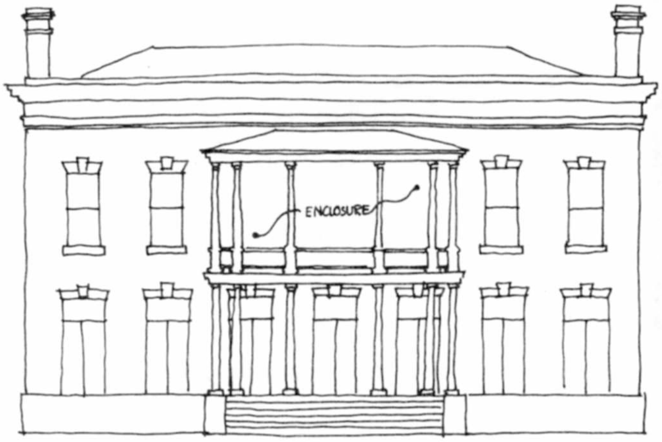
Historic Considerations
based on Secretary's Standards

Porches should be retained and repaired if they are of a distinguished original quality, or if they are a change which may have taken place over time, and are evidence of the history and development of the building.

Energy Considerations

Porches act as buffers between the building and the weather. In summer, porches can screen out unwanted sunlight while letting cooling breezes enter the building. The use of demountable panels or jalousies can make porches usable in colder months. Enclosed porches, when properly oriented, can act as sun pockets on clear winter days.

Examples



The fixed glass enclosure behind the column plane of this porch was approved by the National Park Service. It is unobstrusive and sensitively preserves the character of the original.

Enclosure of porches on this house by clapboarding is inappropriate because a distinctive feature is altered significantly.

Design Guidance

Enclosing previously open porches can provide both energy benefits and additional interior space at relatively low costs. Enclosing such areas should be undertaken with careful consideration of the porch's relationship to the building's character and neighborhood. Especially important is the position of the porch with respect to major facades. In most cases, porches which are an integral architectural or historic feature should not be enclosed. Alterations to or enclosure of rarely viewed rear porches may be more appropriate than changes to a front porch. The materials and treatments used in the enclosure should retain the porch's historic nature, assuring its continued compatibility with the whole building and context.

References

Neblett N., *Energy Conservation in Historic Homes,* Washington, D.C.: Historic House Association of America, 1980.

U.S. Department of the Interior, Heritage Conservation and Recreation Service, *Porch Enclosures,* in Interpreting the Secretary of the Interior's Standards for Historic Preservation Projects, number 80-001, Washington, D.C., April 1980.

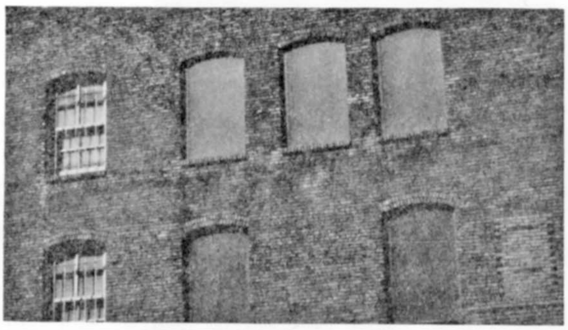
Historic Considerations
based on Secretary's Standards

Window and door openings, frames, sash, glass, doors, lintels, sills, pediments, architraves, hardware, awnings and shutters should be retained and repaired where they contribute to the architectural and historic character of the building. The thermal performance of existing windows and doors should be improved through techniques which are compatible with the character of the building and which do not damage window and door frames.

Energy Considerations

Existing windows and doors, either wood or metal, frequently receive attention only as an energy liability. Besides providing protection against the environment, windows and doors admit light, sun and air. Heat loss, heat gain and air infiltration should be carefully studied to determine if window or door modifications should be undertaken. Windows and doors are often the principal decorative element of a facade; any modification should respect the importance of the window or door to the building.

Examples



The original character of this facade has been destroyed by the placement of opaque panels over window openings, presumably in the name of security and energy conservation. Other treatments are possible and would retain the original character.

The large expanse of glass on this facade is not necessarily an energy liability. By retaining the operable features and avoiding inappropriate treatments, the historic and energy-conserving properties of the original windows can also be retained.

Design Guidance

Heat transfer through glass is affected by solar radiation, outdoor/indoor temperature difference (thermal conduction), and velocity and direction of air flow across interior and exterior glass surfaces. Heat loss and heat gain are also a function of orientation -- heat loss usually is greatest on northern exposures, heat gain highest on southern exposures. Air infiltration, the passing of air through cracks and openings in windows and doors, is a major energy factor in most older buildings. There are many methods by which heat loss and gain and air infiltration from glass areas can be reduced. Each method should be evaluated in terms of its energy effectiveness, cost and impact on the appearance of the building. Where modifications are made to windows, it is important to consider matching color and dimensions of frame and sash, especially on the significant facades. In general, reflective or tinted glass, while possibly an energy saving alternative, is not recommended on historic facades, unless the reflectivity and color of the glass are compatible with the existing historic fabric. New windows and doors should respect original shadow reveals and relation to the wall plane.

References

California Energy Resources Conservation and Development Committee, *Energy Conservation Design Manual for Non-Residential Buildings,* 1977.

Myers J., *The repairs of Historic Windows,* in Preservation Brief 9, published by the Technical Preservation Services Division, U.S. Department of the Interior, 1981.

U.S. Department of the Interior, Heritage Conservation and Recreation Services, *Rehabilitation: Claremont 1978,* Washington, D.C.: U.S. GPO, 1978, pp 52-53.

Historic Considerations
based on Secretary's Standards

The thermal performance of existing windows and doors should be improved through techniques which are compatible with the character of the building and which do not damage window or door frames. Missing or irreparable windows on significant facades should be replaced with new windows that match the original in material, size, muntin and mullion proportion and configuration, and reflective qualities of the glass.

Energy Considerations

Double (or triple) glazed windows serve as insulating agents to reduce heat transfer through glass. Double glazed windows can reduce heat loss in winter (while still admitting much of the solar radiation) and reduce heat gain in summer.

Examples

This Washington, D.C. hotel had windows with a multiple pane configuration before rehabilitation.

While the pane configuration was not retained in the rehabilitation, the character of the facade as a whole was not significantly changed, making these replacement windows an appropriate solution. Decisions about window replacement must be made on a case-by-case basis.

Design Guidance

Many existing single glazed windows can be converted permanently to double glazed windows by the addition of a new glazing frame to accept the additional pane of glass. Where the existing window frame is in good condition and the glazing system permits, a glazing sheet of glass may be replaced by a sealed double glazing unit. Where the existing window frame is in poor condition and is scheduled for renovation or replacement, a double glazed should be considered. Any repair or replacement of windows should match the original in the appearance of the window style, from the interior of the building as well as the exterior. The replacement of existing windows with any type of thermal glass should recognize the architectural and historic character of the windows, the building and its surroundings, particularly when the window is located on a significant facade.

References

Hastings R., Crenshaw R., *Window Design Strategies to Conserve Energy*, Washington, D.C.: National Bureau of Standards, 1977.

U.S. Department of Energy, Federal Energy Management Program, *Architects and Engineers Guide to Energy Conservation in Existing Buildings,* Washington, D.C.: U.S. GPO, 1980, p 225.

U.S. Department of Energy, *Windows for Energy Efficient Buildings*, periodical produced by Lawrence Berkeley Laboratory, University of California, Energy and Environment Division.

Historic Considerations
based on Secretary's Standards

The thermal performance of existing windows and doors should be improved through adding storm windows and doors which are compatible with the character of the building and which do not damage window or door frames. The installation of new exterior storm windows and doors which are inappropriate in size or color, which are inoperable, or which require removal of historic window elements should be avoided.

Energy Considerations

Properly designed and installed storm windows and doors reduce heat loss caused by conduction and infiltration. Storms are often the most appropriate solution for historic buildings because they generally do not damage the existing window or door and they can be removed with little difficulty.

Example

Triple track storm windows improve the thermal performance of existing windows and may be compatible with the building's appearance.

Design Guidance

Storm windows should be compatible in design and construction with the original window and with the character of the building in general. This includes frame color, frame configuration, craftsmanship and general glass proportion and reflective qualities. Wooden storm windows are increasingly hard to find and expensive if custom-made. If aluminum is to be used, it should be in a color compatible with the original window and trim. Removable interior storms may be easier to install but can result in significant moisture damage if not properly vented.

References

Labine C., *The Energy-Efficient Old House,* in The Old House Journal, September 1977.

Neblett N., *Energy Conservation in Historic Homes,* Washington, D.C.: Historic House Association of America, 1980.

U.S. Department of Energy, Federal Energy Management Program, *Architects and Engineers Guide to Energy Conservation in Existing Buildings,* Washington, D.C.: U.S. GPO, 1980, p 225.

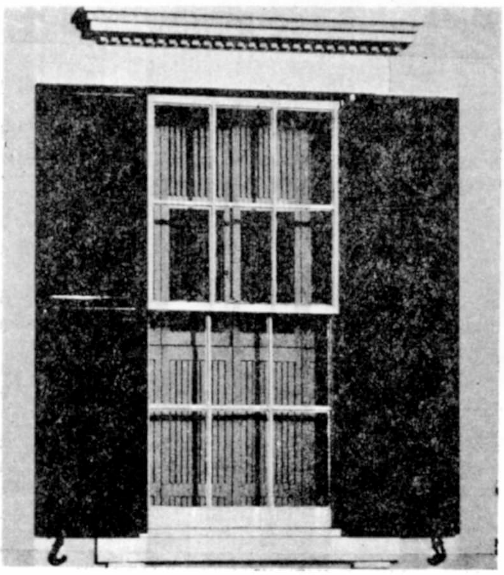
Historic Considerations
based on Secretary's Standards

Awnings and shutters should be repaired and retained where they contribute to the architectural and historic character of the building. While the improvement of the window and door's thermal performance is encouraged, the installation of shutters, screens, blinds, security grills and awnings which are historically inappropriate and which detract from the character of the building is not recommended.

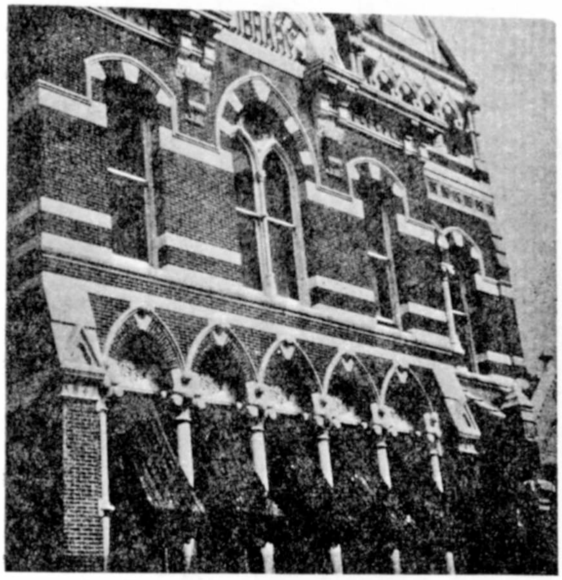
Energy Considerations

Solar heat gain through glass can be reduced through the use of external shading devices at the glass areas. Ideally designed shading devices can be used to reduce radiant heat gain in an overheated period without reducing radiant gain significantly in an underheated period. Shading devices include awnings, shutters, screens, rolling blinds, and horizontal and vertical fins.

Examples



Exterior shutters minimize nighttime heat loss in winter when closed. The interior shutters reduce summer heat gain by filtering direct sunlight.



Lowered awnings on this Indiana library reduce heat gain in summer. They can be raised in winter to admit the sun's direct rays.

Design Guidance

Well designed external shading devices can prevent up to 95 percent of the incident radiation from reaching the building's interior. Shading devices can take the form of vertical or horizontal projections or they can be part of the building structure. Awnings and shutters are the most common devices on older buildings. Both are operable shading devices and can be manually adjusted according to the season and time of day. Awnings, shutters and other shading devices should be used where their placement is historically accurate. In general, fixed, metal awnings and aluminum, inoperable shutters are inappropriate. The use of contemporary shading devices may be appropriate if their design is compatible with the building and if their installation creates no irreversible damage.

References

Olgyay V., *Design with Climate: Bioclimatic Approach to Architectural Regionalism,* Princeton, NJ: Princeton University Press, 1963.

U.S. Department of Energy, Federal Energy Management Program, *Architects and Engineers Guide to Energy Conservation in Existing Buildings,* Washington, D.C.: U.S. GPO, 1980, p 226.

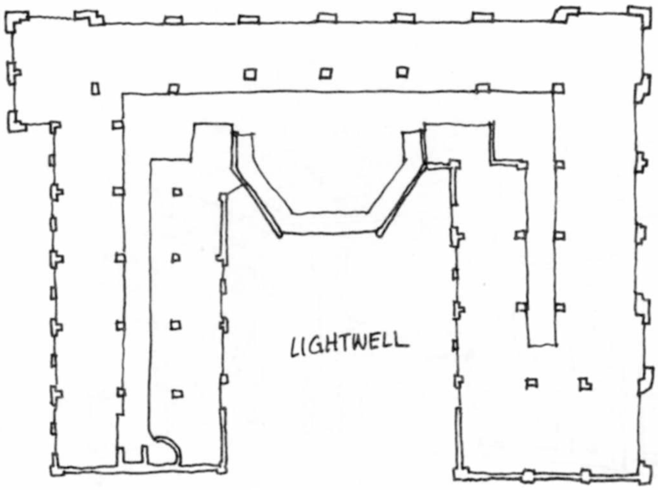
Historic Considerations
based on Secretary's Standards

Windows, doors and other openings should be retained and repaired where they contribute to the architectural and historic character of the building. Introducing or changing the location or size of windows, doors and other openings that alter the architectural and historic character of the building is not recommended.

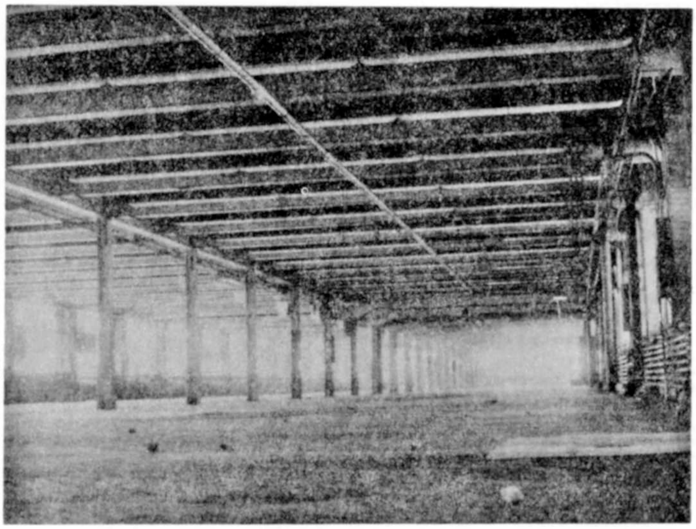
Energy Considerations

The introduction of natural light into buildings can be an effective source of primary illumination. Many older buildings were designed to take advantage of daylighting, but through the years the introduction of artificial illumination and changes in the building's functional layout have diminished the potential for the use of natural light. Windows, doors and other openings in the building envelope should take advantage of the benefits of natural light.

Examples



The floor plan of the Monadnock Building shows the degree to which the search for natural illumination influenced the building's design. Offices were placed close to the perimeter of the building, nearest sources of daylight.



The large open expanses of roof and floor areas in this historic machine shop at Claremont, New Hampshire are part of the approach to natural lighting, as are the large areas of glazing.

Design Guidance

Natural light can be an effective source of illumination particularly in perimeter spaces. The amount of available daylight in a building is a function of operating hours, latitude, weather, time of year, window size and location, shading and glazing details, reflectivity of interior surfaces, and furnishings. Emphasis should be placed on the proper control of daylight; otherwise the heat gain imposed on the cooling system may outweigh the energy savings from natural lighting. Effective use of daylighting can save energy by reducing the cooling load caused by heat generated from electric lights and can reduce the amount of electricity needed for illumination. Natural lighting can be improved through better use of skylights, windows and reflectors. Adding windows and other openings should be undertaken only on secondary facades.

References

Lawrence Berkeley Laboratory, *Daylighting/Window Design Resource Package,* Energy Efficient Buildings Program, 1981.

U.S. Department of Energy, Federal Energy Management Program, *Architects and Engineers Guide to Energy Conservation in Existing Buildings,* Washington, D.C.: U.S. GPO, 1980, pp 200-202.

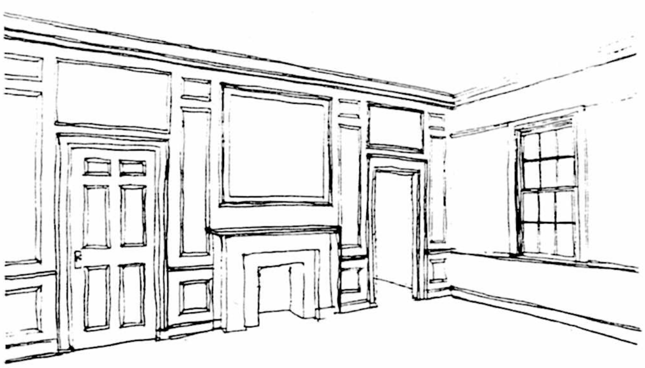
Historic Considerations
based on Secretary's Standards

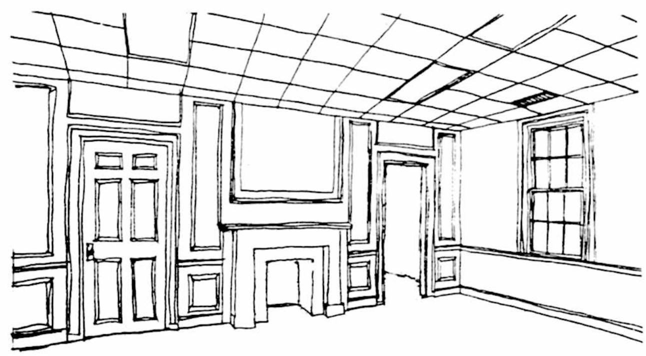
Interior original material and architectural features should be retained wherever possible. Deteriorated material should be repaired or replaced, where necessary, with new materials that duplicate the old as closely as possible. The original sizes of rooms, including floor to ceiling heights, should be maintained.

Energy Considerations

In many older buildings the floor to ceiling height is greater than in contemporary buildings. Dropped ceilings are often added to cut down on the amount of conditioned space. In many cases, this negates natural convection patterns inherent in older buildings. The addition of features such as ceiling fans, where appropriate, can help cool and circulate air in a room.

Examples





Lowering of ceilings generally is inappropriate and rarely produces the energy savings that might have been expected because of changes in circulation patterns.

Design Guidance

In many older buildings the ceilings are an important historic element. Alterations should be undertaken only after careful consideration to the importance of the ceiling to the room and to the building in general. Room air stratification is beneficial in the summer as hot air rises. Old-fashioned ceiling fans can be used to circulate air enhancing room cooling. In winter, ceiling fans can help warm a high ceilinged room by circulating the stratified hot air back to the floor level.

References

Labine C., *The Energy-Efficient Old House,* in The Old House Journal, September 1977.

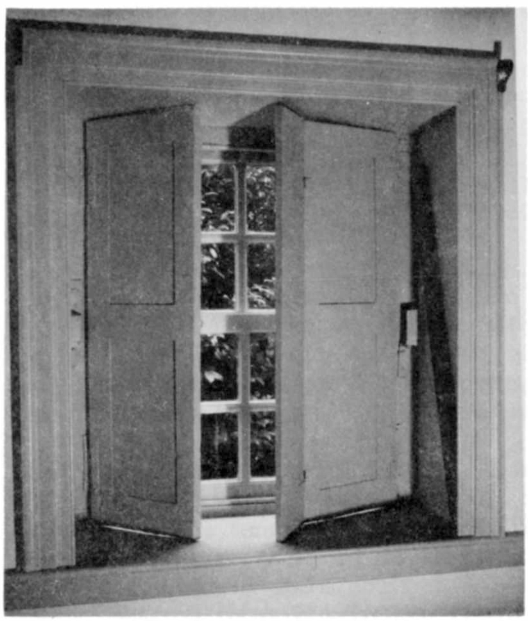
Historic Considerations
based on Secretary's Standards

The thermal performance of windows and doors should be improved through strategies and techniques which are compatible with the character of the building and which do not damage windows or door frames. The basic interior plan of a building including the relationship and size of rooms, corridors and other spaces should be retained.

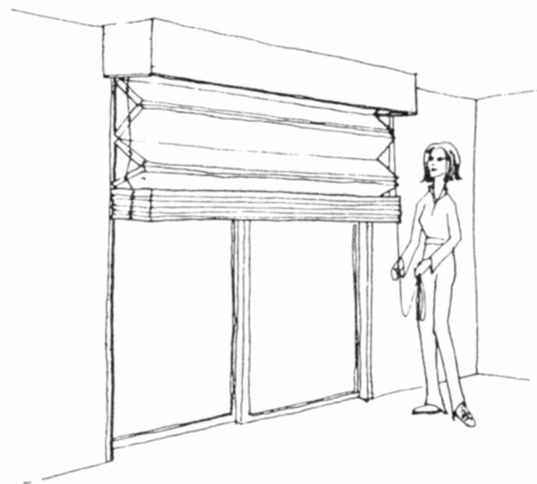
Energy Considerations

Internal shading devices can be found in many older buildings, e.g., blinds, drapes, portieres. The use of these devices can help reduce solar gain in summer and heat loss in winter. The installation of shading devices should be consistent with the historic integrity of the room.

Examples



Originally designed for security purposes, folding wood panels on the interior also provide insulation and block the sun's rays. These interior shutters may provide a design precedent for contemporary insulating panels.



Insulating shutters present opportunities for integration with existing architectural interior features. The shutters must be well sealed around all edges in order to produce maximum benefits.

Design Guidance

Internal shading devices are generally less efficient than external devices because the solar radiation enters the building and is trapped, causing interior heat gain. Shading efficiency with internal devices increases with the use of lighter colors due to their reflective properties. One advantage of internal shading devices is the ability of people to operate them, opening and closing as needed. Blinds are most effective in reducing solar heat gain while still admitting natural light, when used in combination with clear glass. Roller shades also reduce heat gain but have the disadvantage of eliminating natural light and outward vision when drawn. The ability of draperies to reduce solar heat gain depends on the texture of the weave and the reflective properties of the materials from which they were woven. Light-colored draperies made from tightly woven fabric are most effective in reducing solar heat gain.

References

Olgyay V., *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, Princeton, NJ: Princeton University Press, 1963.

Several Definitions of Solar Terminology

In order to provide readers unfamiliar with solar energy systems with at least a rudimentary knowledge of various elements, features and alternative configurations, a few definitions are being provided here. They are drawn from materials developed for the U.S. Department of Housing and Urban Development's solar residential demonstration programs and are generally accepted in the building community.

Active Solar Systems can be characterized as one in which an energy resource, in addition to solar, is used for the transfer of thermal energy. This additional energy, generated on or off the site, is required for pumps, blowers, or other heat transfer medium moving devices necessary for system operation. Generally, the collection, storage and distribution of thermal energy is achieved by moving a transfer medium (often water) throughout the system.

Collector. The collector subsystem is the assembly used for absorbing solar radiation, converting it into useful thermal energy, and transferring the thermal energy to a heat transfer fluid. Collectors vary in configuration to include flat plate, concentrating, and tracking collectors. They can be mounted directly to a finished roof, integrated with the roof structure, or mounted to racks on the roof or at a location separate from the building.

Storage. The component of the solar energy system which stores the collected solar heat. It may be a rock bed, a water tank, or a solid mass wall.

Auxiliary Energy Systems. These systems consist of equipment using conventional energy sources both to supplement the output provided by the solar energy system as required by the design conditions and to provide full energy back-up requirements when the solar heating or domestic hot water systems are inoperable.

Passive Solar Systems can be characterized as those in which solar energy alone is used for the transfer of thermal energy. This system requires no pumps, blowers, or other heat transfer medium moving devices which use energy other than solar. The major component in a passive solar system generally utilizes a mass with high thermal capacitance, where heat is collected, stored, and distributed to the building without additional pumping power. Collection, storage and distribution are achieved by natural heat transfer phenomena employing convection, radiation and conduction in conjunction with the use of thermal capacitance as a heat flow control mechanism.

Historic Considerations
based on Secretary's Standards

New construction should use contemporary designs compatible with the character of the building and the neighborhood. Mechanical equipment should be placed in an inconspicuous location. Adding new height to the building that changes the scale and character of the building is not recommended and in many areas may be expressly forbidden by Historic District Review Boards. Additions in height should not be visible when viewing the principal facades.

Example

Parapet walls and building height help to conceal collectors from view. Positioning to the rear of this building helps to restrict visibility from the street and sidewalk.

Energy Considerations

Most active collectors are located on the roof of a building in order to obtain maximum access to sunlight. A roof also provides a solid, flat surface for anchoring collectors, permitting piping and ductwork to be run inside the structure and reducing heat loss. Roof-mounted collectors offer the possibility of compatible integration with the existing roof, as well as concealment of the collector if the roof configuration and its importance warrant it.

Design Guidance

The most important factor concerning roof-mounted collectors is the size of the installation in relation to the affected roof area. Small installations such as two panels for water heating offer greater possibility for inconspicuous placement, while larger installations such as those used for space heating in cold climates, may cover an entire roof. The decision to use roof-mounted collectors depends also on the shape and orientation of the roof itself. Flat roofs allow collectors to be positioned almost anywhere on the roof and tilted up on a mounting to capture the sun's rays. Collectors may also be mounted on sloping roofs. On buildings where the roof peaks run east/west, a south-facing area of the roof may be available if it is free from shadows. When a roof is improperly oriented (generally not within 30 degrees of south) the collector can still be mounted so that it faces south, but the visual problems are such that this method is not recommended. Collectors can also be mounted on the roof of an accessory building (such as sheds or outbuildings), on secondary roofs or on lower elevation ells or wings that are oriented in the correct direction. This method is often preferable on historic buildings since these roof locations are usually less conspicuous than the primary roof area.

The principal issues concerning the installation of roof-mounted collectors are the following:

1) The collectors should be designed and installed to be compatible with the configuration, color and texture of the roof. This is of primary importance if the roof area is visible when viewing the facade. The collectors should not add noticeable height to the building or change the slope of the roof in any significant way. Collectors that lie flat on the surface of a sloped roof should consist of panels and materials that are consistent in color and appearance with the original roofing materials.

2) In cases where the collectors cannot lie flat against the existing sloped roof, the system design should be consistent with the character of the building and the neighborhood. As such, the support structure and exposed piping should be compatible in materials, size, color and texture with the building and neighborhood.

3) Roof-mounted collectors add significant weight to the building's roof support system. Careful study should be made to assure that the weight of the collectors and support system structure do not exceed the bearing limits of the roof.

In cases where the installation of roof-mounted collectors must be concealed in order to retain the historic integrity of the building, there are a number of design alternatives.

1) Buildings that have south-facing roofs on the backside of the building may be appropriate for placement of the collector, if the rear facade and roof are not significant.

2) Buildings with roof peaks running east/west may have unobstructed south-facing roofs. If this roof is not visible when viewing the facade, placement of the collectors here may be appropriate.

3) Collectors may be located on buildings that have flat roofs by locating them near the back of the roof especially in taller buildings. Buildings with parapets may be particularly appropriate, since the added height of the parapet may help conceal the collector.

References

AIA Research Corporation, *Solar Dwelling Design Concepts,* U.S. Department of Housing and Urban Development, Washington, D.C.: U.S. GPO, 1976.

American Planning Association, *Residential Solar Design Review: A Manual on Community Architectural Controls and Solar Energy Use,* Washington, D.C.: U.S. GPO, 1980.

National Trust for Historic Preservation, *New Energy from Old Buildings,* Washington, D.C.: Preservation Press, 1981, pp 93-99, 128-179.

Historic Considerations

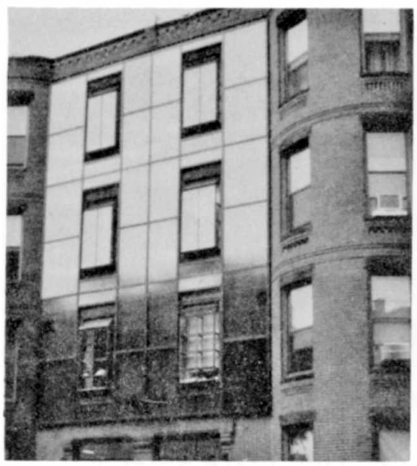
based on Secretary's Standards

New construction should use contemporary designs compatible with the character of the building and the neighborhood. Mechanial equipment should be placed in an inconspicuous location. Adding new height to the building that changes the scale and character of the building is not recommended and in many areas may be expressly forbidden by the Historic District Design Review Boards. Additions in height should not be visible from the facade.

Energy Considerations

Wall-mounted collectors can be installed on the south side of a building in cases where it may be inappropriate to install the system on the roof. A south wall installation generally works best in northern climates at high altitudes where the winter sun is low in the sky and strikes the vertical walls directly.

Example



The front elevation of these Boston rowhouses was fitted with a system of flat plate solar collectors designed to trap and redistribute air warmed by the sun's rays. The total effect alters significantly the original character and materials of the elevation. Reflective glare is a major problem with such glazing approaches, here made especially severe by placement toward the street. This concept, if applied to a non-principal facade, might be more successful.

Design Guidance

Active solar collectors mounted on wall surfaces should be considered in cases where roof surfaces are inappropriate (because of incompatible design considerations, or where existing roof features prevent new construction) or where the energy efficiency of the solar system is improved by vertical mounting. Wall-mounted collectors on historic buildings present nearly insurmountable problems on facades that have historic significance.

The principal issues concerning the installation of wall-mounted collectors are similar to those for roof-mounted collectors. Wall-mounted collectors should be designed and installed to be compatible with the character and texture of the external wall surface. The collector should not detract from the historic character of the facade, and should not cause irreversible damage to the existing wall surface. In cases where the installation of wall-mounted collectors must be concealed in order to retain the historic fabric of the building or the neighborhood, the collectors must be installed on surfaces that are not easily visible when viewing the principal facades. Wall-mounted collectors should also be installed on portions of walls that are shielded from view by other building features.

References

AIA Research Corporation, *Solar Dwelling Design Concepts*, U.S. Department of Housing and Urban Development, Washington, D.C.: U.S. GPO, 1976.

American Planning Association, *Residential Solar Design Review: A Manual on Community Architectural Controls and Solar Energy Use*, Washington, D.C.: U.S. GPO, 1980.

Historic Considerations
based on Secretary's Standards

New construction should use contemporary designs compatible with the character of the building and the neighborhood. Mechanical equipment should be placed in an inconspicuous location. Distinctive features of the building site and environment should be retained.

Energy Considerations

Collectors can also be mounted on the ground adjacent to buildings. Ground-mounted collectors should be tilted on south-facing frames or mounted on natural earth mounds (berms) which have been sloped at the proper angle. The major disadvantage of ground-mounted collectors is that they must be located close to the building to avoid heat loss during transport. In addition, ground-mounted collectors are susceptible to shading, may present safety problems, or may be vulnerable to ground maintenance equipment.

Examples

These ground-mounted collectors are unacceptable because they are inappropriate in scale, material and form to the period of the house and its surroundings.

This collector design has flat plate solar collectors placed on a side elevation, out of view, to resemble cellar doors. This is an acceptable approach for active systems.

Design Guidance

Ground-mounted collectors can be used near buildings where they do not detract from the historic relationship of the site to the building and its surroundings. Proper placement of low shrubs or other planting materials appropriate to the site can conceal ground-mounted collectors. This strategy is effective when the collector is visible from the street. Care must be taken not to decrease the amount of sunlight falling on the collector by improper planting. Ground-mounted collectors must be adequately shielded from access by the public for safety reasons. Finally, ground-mounted collectors must be located near the building they serve in order to minimize heat loss during transport.

Ground-mounted collectors can be concealed through the use of earth berms built up around the collector. Berming can make the appearance of the collector less obtrusive than mounting on a separate collector frame. A berm can be built between a roadway and the front of the building to hide the solar installation yet leave the building visible. The use of berming is limited by the character and existing topography of the site. Berming most likely would be inappropriate on predominantly flat sites, but can be appropriate for large sites with diverse topography or rolling terrain.

References

AIA Research Corporation, *Solar Dwelling Design Concepts,* U.S. Department of Housing and Urban Development, Washington, D.C.: U.S. GPO, 1976.

American Planning Association, *Residential Solar Energy Design Review: A Manual on Community Architectural Controls and Solar Energy Use,* Washington, D.C.: U.S. GPO, 1980.

Historic Considerations
based on Secretary's Standards

New work should be designed to be compatible in materials, size, color and texture with the earlier building and the neighborhood. Introducing or changing the location or size of windows, doors and other openings that alter the architectural and historic character of the building is not recommended. The basic plan of a building, the relationship and size of rooms, corridors and other spaces should be retained.

Energy Considerations

Direct gain designs collect heat by allowing solar radiation to pass through south-facing windows into the interior of the building. The walls and floor are used as thermal storage masses either by intercepting radiation directly or by absorbing reflected or reradiated energy. At night the heat flow into the storage masses is reversed and reradiated. Control of overheating is provided by shading or by an insulating glass area.

Example

Many historic buildings are suited ideally to applications of direct solar gain principles. The window openings -- solar apertures -- in this historic facade are perfectly sized and oriented for such an approach.

Design Guidance

Unlike add-on mechanical collectors in active solar systems, collectors in passive solar systems are generally an integral part of the building they serve. Many older and historic buildings have passive features incorporated into their design -- large south-facing windows, skylights, clerestory windows, greenhouses. The design challenge is to reuse these features properly to take advantage of ambient natural energy. Direct gain systems generally use large expanses of south-facing glass. In historic buildings, the redesign of a facade to increase the amount and type of glazing should be undertaken only on walls that are not principal facades, or if the modifications do not destroy the historic fabric. In such buildings there may be overriding considerations not to use large expanses of south-facing windows. One major reason may be that the interior room layout is not suited to adequate thermal storage mass. Also, direct sunlight discolors certain fabrics and may adversely affect other decorative materials and finishes as well. Finally, surrounding structures and vegetation may impede direct sunlight to the point that a south-facing collecting surface becomes infeasible. Clerestory windows and skylights may also be used in direct gain designs. Both admit sunlight through the roof of a structure and direct sunlight to a particular interior surface.

References

AIA Research Corporation, *Regional Guidelines for Building Passive Energy Conserving Homes,* U.S. Department of Housing and Urban Development, Washington, D.C.: U.S. GPO, 1980.

Mazria E., *The Passive Solar Energy Handbook: Expanded Professional Edition,* Emmaus, PA: Rodale Press, Inc., 1979.

National Trust for Historic Preservation, *New Energy from Old Buildings,* Washington, D.C.: Preservation Press, 1981.

Western Sun Utilization Network, *Passive Solar Heating and Cooling Design Manual,* Emmaus, PA: Rodale Press, Inc., 1980.

Historic Considerations

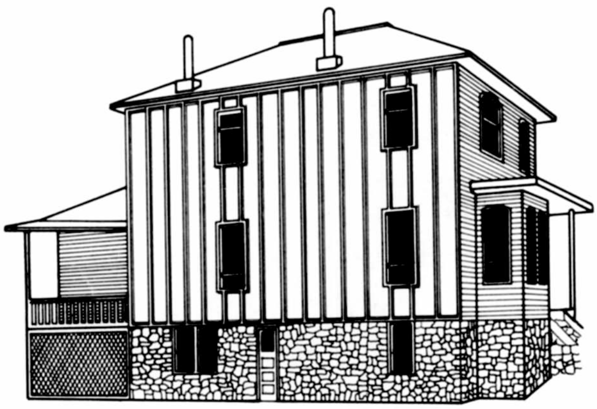
based on Secretary's Standards

New work should be designed to be compatible in materials, size, color and texture with the earlier building and the neighborhood. Introducing or changing the location or size of windows, doors and other openings that alter the architectural and historic character of the building is not recommended. The basic plan of a building, the relationship and size of rooms, corridors and other spaces should be retained.

Energy Considerations

Indirect gain systems allow sunlight to enter south-facing glazing and strike a storage mass (either masonry or water) behind the window. The mass wall is located behind the glazing and is vented to allow warm air to enter the interior of the building. In summer, the warm air is vented to the outside through the glazing vents. Construction of an internal mass wall which disturbs the interior is not recommended. Indirect gain systems for historic buildings will usually involve installing glazing on an existing south-facing wall.

Examples



Glazing the south-facing masonry wall is not appropriate in this proposed design. The glazing is out of character for the materials of the period and obscures a significant portion of the building's original material. Also, because glazing can be seen from many points in the surrounding historic district, it would detract from the character of the neighborhood.

Design Guidance

Buildings with masonry walls facing south may lend themselves to indirect gain passive system design. By attaching one or two layers of glazing to an existing wall and properly venting the system, existing windows can be used to vent air to and from the interior space.

The principal issues concerning the use of indirect gain systems are the appropriateness of new glazing materials to the facade and the potential destruction of historic fabric. Indirect gain systems may be appropriate on south-facing facades when they are not visible from the street. However, if the glazing disturbs the vista of surrounding buildings, it may be considered inappropriate. The introduction of a new material such as glazing must not be obscure or cause irreversible damage to the building's historic material.

References

AIA Research Corporation, *Regional Guidelines for Building Passive Energy Conserving Homes,* U.S. Department of Housing and Urban Development, Washington, D.C.: U.S. GPO, 1980.

Mazria E., *The Passive Solar Energy Handbook: Expanded Professional Edition,* Emmaus, PA: Rodale Press, Inc., 1979.

National Trust for Historic Preservation, *New Energy from Old Buildings,* Washington, D.C.: Preservation Press, 1981.

Western Sun Utilization Network, *Passive Solar Heating and Cooling Design Manual,* Emmaus, PA: Rodale Press, Inc., 1980.

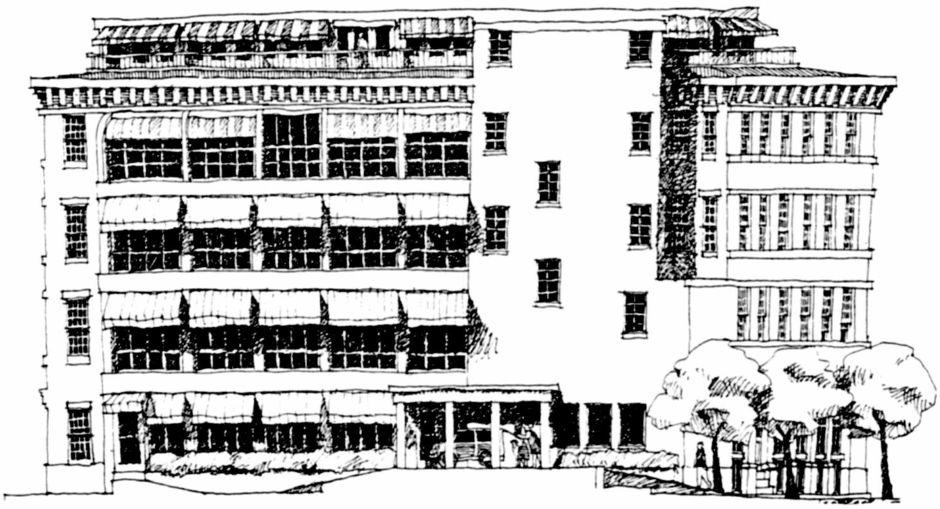
Historic Considerations
based on Secretary's Standards

New additions and adjacent new construction should be kept to a minimum, and should be compatible in scale, building materials, and texture. The use of contemporary designs should be compatible with the character of the building and neighborhood.

Energy Considerations

Sun spaces, or isolated gain passive systems, collect solar radiation in a room thermally separate from the building's interior spaces. The glazing and storage mass are outside of the building when needed. At night, glazing is covered by insulation, reducing heat loss. A solar greenhouse is an example of this type of system. A sun space can also be thermally connected to the building by use of a mass wall for radiant heat transfer.

Examples



Awnings shade a passive solar greenhouse that was built to add heat to residences and provide additional floorspace. The greenhouse addition is to the rear and does not detract from the building's character.

Design Guidance

A solar sun space, or greenhouse, is a popular and effective mean of increasing square footage (especially in commercial buildings) and providing energy benefits. Glass-enclosed additions are aesthetically acceptable to most people and when properly located and built of compatible materials that do not damage historic fabric, can add significantly to the appearance and utility of many buildings. However, their application to historic structures must be carefully evaluated in terms of the location and size of the structure and its overall effect on the appearance of the historic building. There have been some successful, and many unsuccessful applications of greenhouse additions to historical buildings. In general, the principal issues designers should address when contemplating the addition of sun spaces, greenhouses, glass arcades, or any new glass-enclosed additions are as follows:

1) Glass-enclosed sun spaces should be located where they provide maximum energy benefits, generally on the south side of a building, and where they do not obstruct or visually impair the appearance of the building. Consideration must be given to locating the sun space on a non-significant elevation, such as the south-facing backside of a townhouse. The glazing surfaces should be on a plane compatible with the building's facades and lines. Tilting a sun space at an angle inconsistent with the building is generally not recommended.

2) The size and scale of the sun space should be compatible with the scale of the building and neighborhood. Large additions that obscure significant parts of historic buildings or that draw attention away from the historic appearance of the building are not recommended.

3) Materials used in construction of the sun space should match as nearly as possible buildings' original materials. Framing, trim details and glazing panel proportions should be compatible with other elements of the historic building.

4) The addition of sun spaces should be undertaken with minimal alteration to the building. Ideally, sun spaces should be attached to the building in a manner such that their removal would cause no irreversible damage to the historic fabric and/or obscure significant architectural details or features.

Sun spaces can assume a variety of uses consistent with the character of the building and neighborhood. For example, glass-enclosed arcades to connect separate buildings may combine traditional use with a solar greenhouse for heating. Solar greenhouses on residential structures can provide heat, as well as added space for gardens, plants and other uses.

References

Mazria E., *The Passive Solar Energy Book: Expanded Professional Edition*, Emmaus, PA: Rodale Press, Inc., 1979.

Schnur S., *Two-Story Glory,* in Rodale's New Shelter, July/August 1981, pp 66-74.

U.S. Department of the Interior, Heritage Conservation and Recreation Services, Technical Preservation Services Division, *Greenhouse Additions,* in Interpreting the Secretary of the Interior's Standards for Historic Preservation Projects, August 1981.

Western Solar Utilization Network, *Passive Solar Heating and Cooling Design Manual,* Emmaus, PA: Rodale Press, Inc., 1980.

Additional References

American Institute of Architects, *Life-Cycle Cost Analysis: A Guide for Architects,* Washington, D.C.: American Institute of Architects, 1977.

This publication presents the basics of life-cycle cost analysis, provides some guidance on its use for architects and gives a number of examples. Written for the designer with little or no experience with life-cycle costing, this manual explains how life-cycle costing fits into the processes of planning and design.

General Services Administration, *Energy Conservation for Existing Office Buildings,* Washington, D.C.: GPO, 1975.

This manual analyzes the energy performance of existing buildings and suggests a series of design guidelines for site, building envelope, HVAC, lighting and other power systems.

Mazria E., *The Passive Solar Energy Book: Expanded Professional Edition,* Emmaus, Pennsylvania: Rodale Press, 1979.

This comprehensive work covers a wide range of passive solar concepts and information -- from general solar theory and applications to systems design, sizing and performance calculations. It is organized around 27 patterns for the application of solar energy systems to building design; these patterns are presented from large to small scale and are cross-referenced.

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Page 11 Left: Upper floor plan of the Monadnock Building in Chicago, Illinois. Sketch by Thomas Vonier Associates, Inc.
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Right: Lawton House in East Haddam, Connecticut. Photo by Wilson H. Brownell, courtesy of the National Trust for Historic Preservation.

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