NBSIR 78-1532

Environmental and Safety Considerations for Solar Heating and Cooling Applications

David Waksman
John Holton

Solar Criteria and Standards Program
Building Economics and Regulatory Technology Division
Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

September 1978

Prepared for

Department of Energy
Office of Conservation and Solar Applications
Washington, D.C.

and

Department of Housing and Urban Development
Division of Energy, Building Technology and Standards
Washington, D.C. 20410

NBSIR 78-1532

ENVIRONMENTAL AND SAFETY CONSIDERATIONS FOR SOLAR HEATING AND COOLING APPLICATIONS

David Waksman
John Holton

Solar Criteria and Standards Program
Building Economics and Regulatory Technology Division
Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

September 1978

Prepared for

Department of Energy
Office of Conservation and Solar Applications
Washington, D.C.

and

Department of Housing and Urban Development
Division of Energy, Building Technology and Standards
Washington, D.C. 20410

U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*

Dr. Sidney Harman, *Under Secretary*

Jordan J. Baruch, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

TABLE OF CONTENTS

ENVIRONMENTAL AND SAFETY CONSIDERATIONS FOR SOLAR HEATING AND COOLING APPLICATIONS

1. INTRODUCTION

The "Intermediate Minimum Property Standards" (MPS) [1]* and the residential and commercial "Interim Performance Criteria" (IPC) [2, 3] prepared by the National Bureau of Standards (NBS) address many health and safety considerations that need to be considered by system designers. For example, factors such as the flammability and toxicity of heat transfer fluids are often not considered in the design of systems. These problems are compounded by the lack of clear guidelines as to which fluids constitute hazards that warrant special consideration.

This report is intended to create an increased sense of awareness of the health and safety aspects of solar heating and cooling applications by extracting and amalgamating pertinent provisions of the MPS and IPC documents. Additional discussion of their rationale and other considerations are presented. Emphasis is placed on the safety provisions in the MPS document which are consistent with those in the commercial IPC document. The provisions in these two documents which were prepared in November 1976 and March 1977 represent an update of the provisions in the residential IPC document which was prepared in January 1975. The provisions in the MPS document are somewhat more prescriptive than those in the performance based IPC document. Safety related issues related to both active and passive solar energy systems are addressed by both documents.

In applying the MPS and IPC standards, recognition must be given to the type of project under consideration; single family, multi-family, institutional or commercial. Though very few of the requirements note any difference in treatment for a specific hazard (for example, a safe potable water system is considered essential in any type of occupancy) they often include standards by reference that do embody significantly different treatment for different types of buildings. For example, fire resistance requirements vary with different occupancies and solar components which form part of a fire resistant building element must be able to meet these various requirements.

Some of the areas that are discussed include: structural safety, heat transfer fluid toxicity and flammability considerations including the protection of potable water, effects of solar equipment on the fire resistance of buildings, mechanical system protection, and protection from physical hazards.

2. GENERAL PROVISIONS

The overall philosophy of the MPS and IPC documents with regard to safety is to prevent the creation of a hazard, due to the presence of solar equipment, which is greater than that which would be found in a non-solar building.

> The incorporation of solar systems into the living unit shall not create an environment which is more hazardous to the occupants than that of a conventional living unit. Materials and the construction used in installation of solar systems shall be in accordance with the fire protection provisions of S-405.
>
> (S-600-6.1)**

In keeping with this philosophy, frequent reference is made throughout these documents to nationally recognized codes and standards.

> Except as modified herein, materials, equipment and installation shall be in accordance with the standards and nationally recognized model codes cited within the body of this document, the current applicable editions and titles of referenced standards and codes are contained in Appendix E. State and local codes which deviate from nationally recognized codes or standards in order

*Numbers in brackets [ ] indicate references given at the end of this report.

**Indented paragraphs are taken from the MPS [1]; designations in parenthesis ( ) are references to specific MPS sections. References in MPS paragraphs are given as footnotes in this report.

to satisfy local conditions may be accepted by HUD if such deviations are identified and substantiated with satisfactory engineering data.

(S-500-1)

3. FIRE SAFETY PROVISIONS

These provisions include considerations such as the flammability of materials used in solar equipment, the influence of solar installations on the fire resistance of the building and the provision of space for access and emergency egress in the event of a fire.

3.1 FLAMMABLE MATERIALS

These provisions are primarily concerned with heat transfer fluids and insulation materials. The remainder of the materials used in solar installations are similar to those used in conventional installations and are covered by reference to nationally recognized codes.

> Assemblies and materials used in the solar systems shall comply with the nationally recognized codes for fire safety under all anticipated operating and no flow conditions.
>
> (S-515-1.1)

> The storage, piping and handling of combustible liquids shall be in accordance with the Flammable and Combustible Liquids Code NFPA No. 30.
>
> (S-600-6.2)

3.1.1 Heat Transfer Fluids

Some of the heat transfer fluids that are used in solar installations are combustible and/or toxic. A number of installations have used a fluid having a flash point of about 140°F under conditions where the fluid could be heated under normal operating conditions to about 200°F and, under "no flow" (stagnation) conditions, to temperatures of 350°F or higher.

The solar MPS has several provisions related to the flammability of heat transfer fluids.

Detailed labeling requirements are specified to identify potential hazards.

> The provisions of the Federal Hazardous Substances Act (1971) shall apply to heat transfer fluids. In addition, heat transfer media classified as combustible shall be labeled as such.
>
> Emergency first aid instructions shall be included on the label of toxic heat transfer fluid containers. A technical data sheet shall be provided with all heat transfer fluids which contains the following information.
>
> Service temperature range
> Viscosity over service temperature range
> Freezing point
> Boiling point
> Flash point
> Auto ignition temperature
> Specific heat
> Vapor pressure over service temperature range
> Instructions for inspection, treatment and disposal of fluid
> Emergency first aid instructions.
>
> For toxic fluids, a list of the chemical components of the fluid shall be available expressed in mg./liter. This list shall include any substances which comprise more than 0.10% of the medium.
>
> (S-515-8.1.1)

Requirements are placed on systems using combustible liquids. The system must be designed to eliminate the hazard and limitations are placed on the flash point of such fluids.

Heat transfer fluids which require special handling (e.g., toxic, combustible, corrosive, explosive, etc.) shall not be used unless the systems in which they are used are designed to avoid unnecessary or unreasonable hazards; see Section S-615-10.1.

(S-515-8.2.1)

Temperatures attained by fluids in solar systems under operating and no flow conditions shall not exceed a temperature which is 100 F below the flash point of the fluid. In no case shall a liquid with a flash point below 100 F or a flammable gas be used. Flash point shall be determined by the methods described in NFPA No. 321, Basic Classification of Flammable and Combustible Liquids.

Commentary: NFPA No. 321 (1973) defines Flammable Liquids as those with flash points below 100 F and Combustible Liquids as those with flash points at or above 100 F. This section prohibits the use of flammable liquids (flash point below 100 F) and permits the use of combustible liquids (flash point at or above 100 F) under prescribed conditions. In common, non-technical usage, the term flammable liquid frequently refers to any liquid with a flash point, including liquids classified as combustible.

(S-515-8.2.2)

It is anticipated that the flash point requirement may be changed by the Department of Housing and Urban Development (HUD) to the less stringent provision given below recognizing the differing levels of hazard presented by different types of installations. However, before such changes to the MPS can be made, HUD procedures require public review and comment.

Proposed Revision*

"The Flash Point of a liquid** heat transfer fluid shall equal or exceed each of the following temperatures:

A. 100 F;

B. 50 F above the maximum design operating temperature of the solar system;

C. 1) 200 F below the maximum stagnation temperature attained by the collector during the test required by Section S-515-2.1.2, provided that the collector manifold assembly is located outside the building and exposed to the weather;

2) the maximum stagnation temperature, as defined above, in all other manifold configurations."

The rationale for the different values in item C is that a system leak under no-flow conditions is most likely to occur in the collector or in the collector manifold assembly. A lower flash point liquid will be acceptable when the manifold assembly is external to the building, since there is a significant lower hazard of ignition under such conditions. Where a leak could occur in an enclosed area which might have an ignition source (attic-located heater, fan, or other electrical device, for instance), there is a higher hazard justifying a higher safety standard.

Provisions are also specified in the solar MPS for the detection of toxic and/or combustible fluids and for the identification of points from which such fluids can be discharged.

---

* Memorandum to Solar Transfer Fluid Manufacturers from David C. Moore, HUD, December 19, 1977.

**A "liquid heat transfer fluid" is defined as the operating fluid including water or other liquid base and all additives at the concentration used under operating conditions.

If toxic or combustible heat transfer fluids are used, means shall be provided for the recognition of leaks and thus the warning of occupants when leaks occur.

Commentary: These substances may be treated in a manner similar to antifreeze and gases when providing for tell-tale indicators. For instance, antifreeze agents, such as ethylene glycol, may be treated with non-toxic dyes which distinguish them clearly. Furthermore, if any such materials are to be stored on the premises, they should be stored in containers which are labeled in accordance with the Federal Hazardous Substances Act and be protected from easy opening by children e.g., childproof lids. Safe storage locations should be provided.

(S-615-8.1.2)

Drains and other designated fluid discharge or fill points in solar systems at which toxic, combustible, high temperature or high pressure fluids may be discharged shall be labeled with a warning describing the identification and hazardous properties of the fluid, instructions concerning the safe handling of the fluid, and emergency first aid procedures.

Commentary: The original fluid containers will frequently be discarded after the system is charged which could result in no record of the fluid's properties being retained. The system drain is the point at which the owner or service personnel are most likely to contact the heat transfer fluid and permanent labeling should be retained at that point. Identification may be provided by attaching a tag containing the required information such as may be supplied by the heat transfer fluid manufacturer.

(S-615-8.1.3)

Another important provision is concerned with the warning of maintenance personnel about hazards that can occur during system maintenance. A number of fires have occurred as a result of workmen trying to repair leaks with a soldering torch. In automobile fuel systems, one automatically expects gasoline to be present; however, in solar equipment the heat transfer fluids present an unfamiliar hazard.

The manual shall completely describe the H and/or DHW systems, their breakdown into subsystems, their relationship to external systems and elements, their performance characteristics and their required parts and procedures for meeting specified capabilities.

The manual shall list all parts of the systems, by subsystem, describing as necessary for clear understanding of operation, maintenance, repair and replacement, such characteristics as shapes, dimensions, materials, weights, functions, and performance characteristics. The manual shall include a tabulation of those specific performance requirements which are dependent upon specific maintenance procedures. The maintenance procedures including ordinary, preventive and minor repairs, shall be crossreferenced for all subsystems and organized into a maintenance cycle. The manual shall fully describe operating procedures for all parts of the system including those required for implementation of specified planned changes in mode of operation. The instructions shall provide warning against hazards that could arise in the maintenance of the system and shall fully describe precautions that shall be taken to avoid these hazards.

(S-600-3.2)

The disposal and containment of toxic and/or flammable fluids are discussed on pages 11 and 12 of this report.

3.1.2 Insulation Materials

There are a number of fire safety provisions in the solar MPS related to insulation. For passive systems in particular there is concern over the use of large areas of combustible insulation material to provide thermal control.

These requirements apply to both fixed and movable insulation installed in conjunction with or as an integral part of the solar system. Materials used for insulation shall be of sufficient proven effectiveness and durability under the expected operating conditions to assure that required design conditions concerning heat losses, sound control and fire rating are attained. Insulation in contact with the ground shall not be adversely affected by soil, vermin or water. Insulating materials shall be in accordance with 507-3 of the MPS and S-607-3. Insulating materials for air ducts shall be in accordance with Section 507-1 of the MPS. Materials used for vapor barriers shall be in accordance with Section 507-2 of the MPS.

Commentary: When movable insulation is used in passive systems, design consideration should be given to ensure protection of the insulation from structural damage, degradation due to weather or other degrading factors.

(S-515-11.1)

The flame spread classification index for all insulation materials shall not exceed the following values:

Plastic Foam	25
Loose Fill Insulation	50
Other Insulation Material	150

The ASTM E 84 flame spread test method shall be the basis for evaluating the surface burning characteristics of the insulation materials. Where fibrous blankets with facings are to be used, the surface burning characteristics of the complete faced insulation blanket shall be measured.

*Commentary: No single test is sufficient to provide a full estimate of performance of a product in a fire. Plastic foams and loose fill insulation are difficult to evaluate in ASTM E 84. The requirement of flame spread classification of 25 maximum for plastic foams and 50 for loose fill insulation will provide as much safety assurance as is possible with current test methods. Such a classification shall not be construed as the equivalent of "noncombustible," Many insulation materials, including those consisting of celluose, plastic foam and fibrous glass (containing organic binder) are combustible materials which will burn and release heat, especially when exposed to continuous large fire sources.**

(S-515-11.1.1)

Chemical retardant insulations shall retain their flame resistance throughout their service lifetime. The procedures and equipment specified in ASTM C739-73, Section 10.4, "Flame Resistance Permanency," shall be used in judging the effect of aging on the permanence of any flame retardants used during manufacture.

(S-515-11.1.2)

Materials used for thermal insulation shall be in accordance with S-515-11 and may be applied to the following areas: walls, roofs, ceilings, floors, pipes, ducts, vessels, and equipment exposed to the external environment.

Exposed plastic foam (untreated or fire-retardant treated), Kraft-asphaltic vapor barrier on mineral and organic fiber insulations, and non-fire-retardant treated

---

*A Consumer Product Safety Commission regulation for cellulose insulation becomes effective on September 8, 1978. Modifications, including institution of radiant panel testing, are currently under consideration.

loose fill insulation shall not be permitted in habitable areas unless fully protected from the interior of the building by a thermal barrier of 1/2 inch gypsum wallboard having a finish rating of not less than 15 minutes or other approved material having an equivalent finish rating as determined by ASTM E 119. Thermal barriers shall be installed in a manner such that they will remain in place for a minimum of 15 minutes under the same test conditions.

Installed insulation and vapor barriers shall not make contact with recessed light fixtures, motors, fans, blowers, heaters, flues and chimneys. Thermal insulation shall not be installed within 24 inches of the top or within 3 inches of the side of a recessed electrical fixture enclosure, wiring compartment or ballast unless labeled for the purpose. To retain loose fill insulation from making contact with other energy-dissipating objects, a minimum of 2 inches of air space should be provided and assured by the use of blocking.

Commentary: Although a degree of material combustibility is allowed, the intent is to allow insulating materials which are not more combustible (or flammable) than existing construction and insulation materials, and to preclude any increased fire hazard due to the retention of heat from energy dissipating objects. In areas where occupants are likely to be engaged in normal activities, the insulation should perform its intended function without the increased risk of ignition, rapid flame spread and heat and smoke generation. Insulation in concealed spaces may be a particular fire problem due to its susceptibility to smoldering and its inaccessibility for fire fighting.

(S-607-3.1)

An important consideration is that insulation used inside air collectors may give off harmful substances that can enter a building's air duct system. The selection of materials which comply with existent standards for air handling systems should prevent a hazard from occurring by this means.

Design of all warm air heating systems shall be in accordance with the recommendations of the ASHRAE Guide or applicable manuals of NESCA, SMACNA, and ARI. Installation shall comply with NFPA Standards 31 and 54 and either NFPA 90A or 90B, as applicable.

(S-515-3.3)

A number of air collector designs utilize types of plastic foam materials that are not capable of meeting these standards.

3.2 FIRE RESISTANCE OF BUILDING ASSEMBLIES

Safety concerns include the effects that the presence of solar components will have on the fire resistance of building assemblies. Passive solar energy systems may utilize large expanses of glazing which may be flammable, or may employ large air plenums throughout the building. Such configurations need to be considered in addition to those used in the more conventional active systems.

The incorporation of solar subsystems shall not reduce the fire resistance ratings required by 405.4 of the MPS.

Commentary: Roof-mounted collectors which are an integral part of the roof construction shall not reduce fire resistance rating of the roof assembly.

(S-405-4.1)

Penetrations through fire-rated assemblies shall not reduce the fire-resistance ratings required by 405-4 of the MPS.

(S-405-4.2)

Major solar system components that are integral parts of assemblies which normally require firestopping shall be firestopped on all sides. Firestopping shall be wood blocking of minimum 2 inch nominal thickness or of noncombustible materials providing equivalent protection. Firestopping may be included as an integral part of the component where the component as installed provides equivalent protection.

Commentary: It is the intent of the section to prevent solar system components from reducing the effectiveness of firestopping. For example, in the case where a solar collector is an integral part of a wood framed wall which would normally be firestopped between studs, firestopping shall be required in the wall above and below the solar collector.

(S-405-7)

Installation of solar collectors or system components on or as an integral part of the roof shall not reduce the fire retardant characteristics of the roof covering below the level specified in 405-12 of the MPS.

(S-405-12)

The elevated temperatures that can arise in solar equipment can also create a hazard if adequate clearance is not provided.

Combustible solids adjacent to solar equipment or an integral part of a solar component shall not be exposed to elevated temperatures which may cause ignition.

Commentary: Heating of cellulosic materials as well as other combustible materials over an extended period of time may result in the material reaching and surpassing its autoignition temperature. The most commonly accepted ignition temperature of wood is 392 F. However, studies have indicated that wood may ignite when exposed to a temperature of 212 F for prolonged periods of time. The ignition temperature of plastics may be above or below those of cellulosic materials. Clearances for HVAC equipment, ducting and piping are discussed in NFPA No. 89M. When applicable, clearances specified by a nationally recognized testing laboratory may be used.

(S-600-6.4)

3.3 EMERGENCY ACCESS AND EGRESS

A final consideration with regard to fire safety is ease of access and the provision of adequate means for egress in the event of an emergency.

Components of the solar system shall not impinge on the requirements of Section 304-3 of the MPS.

Commentary: Reasonable outdoor open space must be maintained for livability, service, emergency access, isolation of fire and protection of adjacent property.

(S-304-2)

The design and installation of the solar heating and domestic hot water systems shall not impair the normal movement of occupants of the building or emergency personnel.

***COMMENTARY: SPECIAL CONSIDERATION SHOULD BE GIVEN TO THE EFFECT OF THE CONFIGURATION OF ROOF-MOUNTED COLLECTORS ON FIRE EXITING, FIRE FIGHTING OR EMERGENCY RESCUE.**

(S-402-1.1)

Components of the solar system shall not be located in such a way as to interfere with the primary means of occupant egress.

---

*Bold-faced type is used in the MPS to indicate provisions applicable to multi-family dwellings only.

Commentary: The location of solar equipment on a roof shall not reduce the usability of that roof for access or egress. Solar system components located remote from the building but near a means of egress shall not block the means of egress if a fire occurs in the solar system component.

(S-405-6)

Piping and equipment shall be located so as not to interfere with normal operation of windows, doors, or other exit openings and so as to prevent damage to piping, equipment, or injury to persons.

(S-615-10.12)

Although it is not anticipated that problems will arise in this area because of previous experience with building codes, it is an important consideration especially in retrofit situations where limited space is available.

4. PROTECTION OF AIR AND POTABLE WATER

Serious health hazards can occur in solar installations as a result of contamination of air or water. The potential for leakage of toxic heat transfer fluids in liquid systems is ever present where such liquids are used. In addition, mold, mildew, fungi, or chemicals given off from the materials used in solar components can cause health hazards in both air and liquid systems. We recently became aware of a health problem which may have been caused by the thermal decomposition of the materials in an air system and the subsequent entry of decomposition products into the building's air system. The following general provisions address these problems:

No material, form of construction, fixture, appurtenance or items of equipment shall be employed that will introduce toxic substances, impurities, bacteria or toxic chemicals into potable water and air circulation systems in quantities sufficient to cause disease or harmful physiological effects.

Commentary: This situation is of concern not only as it pertains to ducts, piping, filters and joints but also to storage areas, such a rock beds. In addition, the growth of fungus, mold and mildew is possible when collectors are applied to a roof surface over the water tight membrane. If the collectors are in contact with the membrane or held away from the membrane to allow for drainage, the shaded membrane area can support the growth of mildew and other fungus in some warm, moist climates. Special design consideration should be included to avoid this problem in climates where it can occur.

(S-501-3.1)

Components and materials used in the H and DHW systems shall not promote the growth of fungi, mold or mildew in accordance with applicable codes, the test specification of UL 181-74, Section 10 and MPS, Appendix D, Section E.

Commentary: Special consideration should be given to the presence of fungi in air handling systems since such micro-organisms are frequently allergenic.

(S-600-6.7)

Thermal storage tank materials, including any interior protective coatings and the heat storage medium used, shall not impart toxicity, undesirable tastes, or odors to either air or water intended for human consumption. For liquid systems, the requirements of the U.S. Public Health Service Drinking Water Standards shall apply.

(S-515-7.4.1)

4.1 PROTECTION OF POTABLE WATER

It is very difficult for the system designer to assess the safety of the heat transfer fluids that are currently on the market. It is also very difficult for the designer to determine the safeguards that must be taken to ensure safe system operation. Data are available in the literature that rank various heat transfer liquids on the basis of their relative toxicity. However, these data do not indicate the cut-off points at which various degrees of protection must be taken. For example, a number of the toxicity tables list propylene glycol as slightly toxic. A substance with such a ranking most likely does not fit under the definition of potable; if it did no safety precautions need to be taken, yet it is not as hazardous as many other substances that are used in heat transfer fluids. This problem is compounded by factors such as: (1) the use of additives to modify fluid properties; (2) the possible formation of harmful decomposition products, e.g., by thermal degradation; (3) the fact that liquids are generally available in varying grades of chemical purity; (4) the possibility that the system will be refilled in the future with a hazardous liquid; and (5) the possibility that circulation in a closed loop system for prolonged periods of time will even result in the contamination of potable liquids, e.g., by metal ion buildup.

The MPS and IPC documents do not present standards to determine the degree of toxicity presented by various liquids. They are primarily concerned with the provision of adequate protection when potentially hazardous substances are used.

The provisions for the detection of toxic and/or combustible fluids (S-615-8.1.2) and for the identification of discharge points for such fluids (S-615-8.1.3) have already been presented in Section 3. Another important consideration is the heat exchange interface that may exist between a non-potable liquid and potable water.

> When nonpotable liquid is used in a solar energy system to transfer heat to domestic (potable) hot water, the design of the heat exchanger shall be such that either a minimum of two walls or interfaces are maintained between the nonpotable liquid and the potable water supply or protection is provided in such a manner that equivalent safety is provided.
>
> *Commentary: Double wall heat exchanger designs are one way of meeting the intent of this criterion. When double wall heat exchanger designs consisting of two single wall heat exchangers in combination with an intermediary potable heat transfer liquid are used, leakage through one of the walls would result in a single wall configuration. Although this design is considered to meet the intent of this criterion, there are several other designs that avoid this problem.*
>
> *The use of single wall configurations which solely rely upon potable water pressure to prevent contamination is not considered to be an acceptable solution. Similarly, extra thick single walls are not considered to meet the intent of this requirement.*
>
> *For approval of other than double wall designs, the procedures described in S-101 should be utilized.*
>
> (S-515-9.1)

This problem is complicated by the lack of definitive standards as to what constitutes acceptable double wall or equivalent protection.

Other provisions relating to the handling of non-potable liquids are as follows. The second of these provisions parallels the previous requirement for heat exchangers.

> Potable water supply shall be protected against contaimination in accordance with the prevailing model plumbing code having jurisdiction in the area, as well as the requirements which follow.
>
> (S-615-10.1)
>
> Circulation loops of subsystems utilizing nonpotable heat transfer fluids shall either be separated from the potable water system in such a manner minimum of two walls or interfaces is maintained between the nonpotable liquid and the potable water supply or otherwise protected in such a manner that equivalent safety is provided.
>
> *Commentary: Double wall heat exchanger designs are one way of meeting the intent of this criterion. When double wall heat exchanger designs consisting of two single wall heat exchangers in combination with an intermediary potable heat transfer liquid are used, leakage through one of the walls would result in*

a single wall configuration. Although this design is considered to meet the intent of this criterion, there are several other designs that avoid this problem.

The use of single wall configurations which solely rely upon potable water pressure to prevent contaimination is not considered to be an acceptable solution. Similarly, extra thick single walls are not considered to meet the intent of this criterion.

For approval of other than double wall designs, the procedures described in S-101 should be utilized.

(S-615-10.1.1)

In buildings where dual fluid systems, one potable water and the other non-potable fluid, are installed each system may be identified either by color marking or metal tags as required in ANSI A13.1-1956 [1] or other appropriate method as may be approved by the local administrative code authority. Such identification may not be required in all cases.

(S-615-10.1.2)

Backflow of non-potable heat transfer fluids into the potable water system shall be prevented in a manner approved by the local administrative code authority.

Commentary: The use of air gaps and/or mechanical backflow preventers are two possible solutions to this problem. The following are some recognized standards that may be acceptable to the local administrative code authority: Complete titles are given in Appendix E.

Air gaps	*- ANSI-A112.1.2*
Backflow preventers	*- FCCCHR Chapter 10*
	IAPMO PS 31-74
	AWWA C506-69
	A.S.S.E. 1011
	A.S.S.E. 1012
	A.S.S.E. 1013
	A.S.S.E. 1015
	A.S.S.E. 1020
	ANSI-A112.1.1

(S-615-10.1.3)

The design and installation of the solar system, its subsystems and components shall be accomplished in such a manner as to provide complete protection of the potable water supply. Such installations shall be in accordance with Chapter 10 of the National Standard Plumbing Code and other applicable codes (see Section S-615-10).

(S-600-6.9)

Protective measures that should be taken when potable make-up water is added to tanks containing non-potable water are addressed in the following provision:

Tanks of large capacity should have an indicator or other means for determining that the tank is full. Tanks shall have overflows with outlets located so that spillage will not run into the building structure or damage the premises. Tanks that do not contain potable water but require make-up water from the potable water system shall be filled by way of an air gap or other means acceptable to the administrative authority having jurisdiction.

(S-615-7.5)

4.2 PROTECTION OF AIR QUALITY

Provisions for the protection of air quality from mold, mildew and fungi (S-600-6.7) and for protection from contamination of air by system components (S-501-3.1) have already been presented in Section 4. The importance of these provisions cannot be overemphasized, especially with regard to the possibility of having mold and fungi in rock bed storage and the possibility of using materials in air collectors that decompose at "no flow" (stagnation) temperatures and give off harmful substances that subsequently get into building air handling systems. This latter phenomenon, outgassing, is thus not only a problem when condensates build up on cover plates but also when potentially harmful substances are given off.

[1] Scheme for the Identification of Piping Systems, ANSI A13.1-1956.

Other important provisions are concerned with protection from dust and dirt in air systems and with the build up of vapors from heat transfer media.

Duct and fan systems shall be protected against accumulation of deposits of dust or dirt that could reduce flow and efficiency in addition to creating a potential health hazard when admitted into occupied spaces. Air filters are required on the outlet side of rockbed storage in active systems.

Commentary: The gravel used for rock bed storage with air systems is selected for size and freedom from dirt and dust. Therefore, smooth and washed material combined with the use of filtered air is desirable to provide a maintenance free, clean distribution system. Fan grilles should be removable or hinged to permit access to the fan and motor for cleaning, servicing, replacement or repair.

(S-615-13.2)

The concentration of the vapor of the heat transfer medium in the building's interior atmospheric environment shall not exceed 1/10th the threshold limit value (TLV) for that particular medium in an 8-hour period.

Commentary: The TLV is primarily concerned with industrial exposure. Because routine household exposure could be for much longer time periods, the 1/10th value of the TLV is recommended. TLV's are under continuous review; a list of currently adopted values is published by the American Conference of Government Industrial Hygienists.

(S-515-8.2.3)

5. COLLECTION AND DISPOSAL OF HAZARDOUS FLUIDS

Adequate consideration is seldom given to the safe disposal of hazardous heat transfer liquids. The general rule of thumb appears to be that leakage and liquids released from pressure relief valves should be allowed to go where them may. In addition to being hazardous, many of these liquids can cause severe deterioration of building materials, e.g., roofing materials. Consideration is given in the MPS and IPC documents to the intentional disposal of such hazardous liquids as well as the catchment and disposal of liquids inadvertently released from the system. The temperature of the fluids being released also needs to be considered.

Leakage from assemblies or subassemblies which contain heat transfer fluids shall not significantly impair the function of other components which may come in contact with the leaking heat transfer fluid or create a safety hazard.

(S-515-1.10)

Systems utilizing other than air or potable water as a heat transfer fluid shall provide for the catchment and/or harmless removal of these fluids from vents, drains or re-charge points as approved by local administrative code authority. Potable water shall be discharged to suitable drainage systems connected to the building or site drains. See MPS Section 615-9.

(S-615-9.1)

Adequately sized and protected receptacles shall be provided when toxic and/or combustible fluids are used in order to collect and store the overflow from: pressure relief valves, liquids drained from the system when it is being serviced, and identifiable leakage. Provisions of MPS Section 615-4.4 (Section 615-4.5 in MPS 4920.1) shall be applied.

Commentary: When a toxic heat transfer fluid is used (see Section S-515-8.2), a catch basin must be provided. It must be sufficiently large to accept dilution as required by MPS Section 615-9 before disposal.

If the diluted medium is biodegradable through conventional sewage treatment, the diluted medium is to be flushed into the sanitary sewer system (not the storm sewage system). Consideration should be given to the effect of flushing solar systems on the "Basic Design Loading" for sewage treatment, Section CS 603, HUD Handbook 4940.3, "Minimum Design Standards for Community Sewage Systems."

(S-615-9.2)

Relief valves shall be piped to discharge to locations acceptable to the local administrative code authority having jurisdiction.

(S-615-10.11)

The following additional provisions related to the safe disposal of waste liquids were contained in a draft version of the HUD solar MPS [4] which was released for public comment. These provisions were later deleted as being virtually impossible to enforce when dealing with a small homebuilder.

Fluid Disposal - Biodegradability and Aquatic Quality

a. A list of the chemical components of the heat transfer medium must be provided in mg/liter. This list must include any substances which comprise more than 0.10% of the medium.

b. The organic constituents of these substances must have a five-day Biochemical Oxygen Demand (BOD), using sewage seed, of at least 70% of the theoretical oxygen demand. This test shall be in conformance with the Standard Methods for the Examination of Water and Waste Water, American Public Health Association (1971).

c. The concentration of chemical constituents must be compared with the 96 Hour LC-50* bioassay value for protection of aquatic life. This comparison is to be made in accordance with the Water Quality Criteria 1972.

Using the gallon/day capacity of the local sewage treatment plant, approximate the concentration at the treatment plant. If the dilution of the chemical constituents is 1/10th the LC-50 value or greater at the sewage treatment plant, the heat transfer medium must be diluted before emptying into a public sewer.

Commentary: Means for the disposal of heat transfer fluids are discussed in Section S-615-9 of this document. Consideration should also be given to the effect of flushing solar systems on the "Basic Design Loading" for sewage treatment, Section CS 603, HUD Handbook 4940.3, Minimum Design Standards for Community Sewage Systems. A preliminary draft of the Environmental Protection Agency's Quality Criteria for Water, October 10, 1975, is currently under review. After its publication in the Federal Register, EPA's criteria will supercede those currently listed

(S-515.8.2.4)[4]

6. TEMPERATURE AND PRESSURE PROTECTION

There are a number of provisions in the MPS and IPC documents concerned with the provision of adequate temperature and pressure relief. Additional provisions are concerned with the testing of systems at pressures greater than those anticipated in actual service, and with the labeling of components as to allowable operating conditions (e.g., maximum and minimum allowable operating temperatures and pressures). Another provision is concerned with the protection of collectors that are not designed to withstand cold filling while at stagnation temperatures. This has been known to result in potentially hazardous failures in at least one design of evacuated tube collector. The following provisions for the temperature, pressure, and vacuum protection of various solar hardware elements are given in the solar MPS.

The control subsystem shall be designed so that in the event of a power failure, or a failure of any of the components in the subsystem, the temperatures and/or pressures developed in the H and DHW systems will not be damaging to any of the components of the systems and the building or present a danger to the occupants. The safety devices shall meet the requirements of Section 515-6.4

*LC = Lethal Concentration.

of the MPS and be demonstrated to be adequately safe and protected for the intended application.

(S-615-14.1)

Adequately sized and responsive pressure relief devices shall be provided in those parts of the energy transport subsystem containing pressurized fluids. A pressure release device shall be provided in each portion of the system where excessive pressures can develop. Each section of the system shall have a pressure relief device so that no section can be valved off or otherwise isolated from a relief device. Automatic pressure relief devices shall be set to open at not more than the maximum pressure for which the subsystem is designed.

Relief devices shall drain to locations in accordance with Section S-615-9.1.

Commentary: Care should be taken in the design and layout of the fluid transport system to prevent conditions in which locally excessive pressures are developed as a result of flow restrictions. Precautions must be taken to assure that heat transfer liquids do not discharge on asphalt base roofing materials or other types of roofing or locations which may be hazardous, cause structural damage, building finish discoloration, or damage to plant materials. (S-615-14.1.1)

The importance of taking into account the effects of flow restrictions on pressure relief can't be overemphasized. Air locks can result in catastrophic failures.

Those portions of heating systems which contain liquid heat transfer fluids and are not directly connected to the potable water supply shall not leak when pressures of not less than 1-1/2 times their design pressure are imposed for a minimum of 15 minutes [1]. The pressure shall be gradually applied and sustained for a sufficient length of time to permit examination of all pipe joints for leakage. Those portions of the system using domestic hot water shall not leak when tested in accordance with the code having jurisdiction in the area where the system is used. In areas having no building code, a nationally recognized model code shall be used [1].

(S-615-10.10.1)

Collectors shall be labeled to show the manufacturer's name and address, model number, serial number, and collector weight (dry). Technical data sheets shall also be provided which include collector efficiency as measured according to S-615-2.2, maximum allowable operating and no-flow temperatures and pressures, minimum allowable temperatures, and the types of fluids which can and cannot be used.

Commentary: Other data related to the installation and operating conditions or characteristics is desirable such as the pressure drop across the collector.

(S-515-2.1.1)

The solar energy system, including collectors, pipes, tanks, and heat exchangers shall be protected against possible collapse by design or by provision of vacuum relief valves.

Commentary: System components may be subjected to collapse if heating system leakage were to occur or if the system were drained without venting.

(S-615-14.1.2)

Automatic flow control valves shall be provided for collectors unable to withstand temperature shock.

(S-615-14.1.3)

---

[1] "The BOCA Basic Plumbing Code," "Southern Standard Plumbing Code," "The Uniform Plumbing Code," and "The National Plumbing Code."

Recognizing that solar energy cannot be shut off in the same manner as a conventional fuel supply, provisions are included to cover heat dumping where necessary.

Provisions for dumping excess thermal energy shall be provided during the off-peak heating season when required for safe operation of the system.

Commentary: For systems in which it is not practical to shut the collection system down, the excess energy can be transfered to the external environment using a heat exchanger or alternate methods.

(S-615-1.9)

Also, so that solar installations do not adversely effect the conventional heating and hot water system and vice versa, provisions are included for safe interconnection.

The interconnections of the auxiliary energy system to the solar energy system shall be made in a manner which will not result in excessive temperature or pressure in the auxiliary system or in bypassing of safety devices of the auxiliary system.

(S-615-11.2)

7. STRUCTURAL SAFETY

The MPS and IPC documents address the various types of structural loads that can be imposed on solar hardware. In addition to the loads that would normally be expected on a building, consideration must be given to the possibility of wind uplift loads on collectors mounted at an angle to or parallel to roofs. Other important considerations are the weakening of structural members by penetrations, especially in retrofit situations and the possibility of cover plates falling off collectors and unusual snow loads caused by solar component configurations. Where structural analysis cannot be performed, testing may be required.

GENERAL

This section contains those supplemental requirements to Chapter 6 of the MPS needed to cover solar systems which utilize conventional structural materials (materials covered by the current MPS edition). Unless specifically modified herein, the requirements of MPS Chapter 6, apply in addition to the supplemental requirements in this section.

All structural design for solar systems and their mounting structures shall be based on generally accepted engineering practice. All loading shall be in accordance with ANSI A58.1 except as shown otherwise in this document or MPS.

(S-601-1)

DESIGN DEAD LOADS

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

Commentary: Liquids are normally present in systems in which they are the heat transfer medium and thus are a long term sustained load where creep is a consideration. They also effect seismic forces in a fashion similar to any other dead load. However, it is possible to remove liquid, thus they should not be counted on to resist uplift.

(S-601-2)

DESIGN LIVE LOADS

Roof Mounted Solar Systems

Resistance to design live roof loads prescribed in Table 6-1.2 of MPS 4900.1 (Table 6-1.3 of MPS 4910.1 and 4920.1) shall not be required for collector panels that are mounted on roofs but do not form an integral part of the roof if adequate access is provided for service and maintenance personnel. For collectors which form an integral part of the roof, resistance to the design live roof loads listed in Table 6-1.2 (or 6-1.3) shall be required.

Commentary: The design live loads contained in Table 6-1.2 of MPS 4900.1 constitute minimum loading requirements needed primarily for human safety. The roof will need to be repaired from time to time; therefore, it must support the workman making the repairs, regardless of the wind and snow loading requirements. This is not the case for accessible roof-mounted collectors; they do not need to support workmen when being repaired. Hence, they need only sustain the required environmental loading (wind, snow and hail).

(S-601-3.1)

Maintenance Loads

All components of the solar energy systems which must support maintenance personnel shall resist a single concentrated load of 250 lbs. distributed over a 4 sq. in. area, acting on the installed component in the most critical locations. Special allowance shall also be made for heavy maintenance equipment, if used.

(S-601-3.2)

WIND LOADS

Flat Plate Collectors Mounted on Roofs and Walls

Wind loads on flat plate solar collectors shall be those specified for roofs and walls in Section 601-6 of the MPS or as modified in paragraphs S-601-4.1.1, .2, .3, and .4 below.

(S-601-4.1)

Flat plate collectors that are mounted with their cover plates and back surfaces flush with the surface of the roof shall resist the wind loads that would have been imposed on those areas of the roof covered by the collectors.

(S-601-4.1.1)

Flat plate collectors mounted at an angle or parallel to the surface of the roof on open racks shall resist any uplift load caused by the impingement of wind on the underside of the collector. This wind load is in addition to the equivalent roof area wind pressure and suction loads, and shall be determined by utilizing accepted engineering procedures which may include wind tunnel testing. Equivalent roof area wind loads are those wind loads that would have been applied to the areas of the roof occupied by the collectors. Equivalent roof area wind loads shall be applied to the outer cover plate of the collectors.

(S-601-4.1.2)

In calculating design wind loads for flat plate collectors mounted on roofs, the internal pressure coefficients, C_{pi}, listed in Table 11, ANSI A 58.1, shall be taken as zero for the wind pressure within a collector. Collectors that form an integral part of the roof structure shall resist the internal pressures from the inside of the building just as any other roof member.

(S-601-4.1.3)

Wind loads on flat plate collectors mounted at an angle to a vertical wall shall be the same as those required for equivalent roof eave area as stipulated in section 6.5.3.2.4 of ANSI 58.1. Wind loads on flat plate collectors mounted parallel to, or integral with vertical walls shall be the same as those required for exterior walls.

(S-601-4.1.4)

Other Types of Solar Collectors Mounted on Roofs and Walls

Wind loading on other types of solar collectors shall be determined using the results of accepted engineering procedures including the MPS and ANSI A58.1 or physical simulation which may include wind tunnel testing.

(S-601-4.2)

Roof Wind Loads

Roof loading due to wind effects on flat plate collectors and concentrating collector support structures and/or enclosures must be included not only in the design of the roof support framing, but also in the design of all structural elements influenced by these loads.

(S-601-4.3)

Ground Mounted Collectors

Wind loading on ground-mounted flat plate collectors and their support structures shall be determined in the same manner as that for roof-mounted flat plate collectors. Where flat plate collectors are mounted on open racks, equivalent roof area wind loads shall be those given for nonenclosed structures as given in Section 6.6, ANSI A58.1, taking into account local terrain characteristics.

(S-601-4.4)

Exposed Storage Tanks

Wind loads on exposed storage tanks shall be determined in accordance with ANSI A58.1.

(S-601-4.5)

SNOW LOADS

Flat Plate Solar Collectors Mounted on Roofs and Walls

Snow loads acting on flat plate solar collectors or caused by their installation shall be those required for roofs as specified in Section 601-5 of the MPS or as modified in paragraphs S-601-5.1.1, .2, and .3 below.

(S-601-5.1)

Flat plate collectors that are mounted with their cover plates and back surfaces parallel to the surface of a roof, and those that are mounted at an angle to the surface of a roof, on open or closed racks in a saw-tooth arrangement shall support the snow loads that would otherwise have been imposed on areas of the roof covered by the collectors. Where collectors are mounted with their cover plates forming steep slopes, shedding of snow from the collector may cause snow to accumulate at the base of the collector or other hazardous conditions which shall be considered in the design of the roof.

(S-601-5.1.1)

Flat plate collectors mounted at an angle to the surface of a wall, and supported by the wall, shall be designed to support the same snow loads as an equivalent roof eave area.

(S-601-5.1.2)

Consideration shall be given to the potential local accumulation of snow under flat plate collectors.

(S-601-5.1.3)

Roof Loading

A single or multiple saw-tooth array of collectors may cause severe drifting between each mounted collector (and under open racks) in addition to the snow load on the cover plates. These unusual snow loads must be determined on the basis of local snow conditions.

(S-601-5.2)

Other Types of Solar Collectors

Snow loads on other types of solar collectors shall be determined as specified in the applicable portions of ANSI A58.1 and by accepted engineering procedures.

(S-601-5.3)

A particular concern in structural design for seismic loads on solar system components is that new and possibly quite heavy elements may be located in elevated positions in buildings. Collector arrays on roofs, water tanks in attics, thermal storage masses in walls or roofs (in passive systems) all present potential seismic hazards which are somewhat unusual for residential construction.

SEISMIC LOADS

General

Seismic design requirements for the mechanical and electrical components of solar energy systems are covered in this section. Architectural and structural components shall be designed in accordance with MPS Section 601-9. The requirements of this section shall apply to the erection, installation, relocation, or replacement of, or addition to any mechanical or electrical component of a solar system. If elements of the solar energy system are attached to any existing structural element, or if parts of any existing structural element are modified or replaced with parts different in size and weight, the element, as well as its connections to the building shall be redesigned to comply with the seismic design requirements of Section 601-9 of the MPS.

(S-601-6.1)

Mechanical and Electrical Components

For those buildings required to be designed for earthquake by Section 601-9 of the MPS, mechanical and electrical components of solar energy systems shall resist seismic forces as specified for parts and portions of buildings in the latest edition of the "Uniform Building Code" (UBC) [1]. The value of C_p used in the UBC to establish the seismic force shall be taken from Table S-601-6.

The design of all connections between the mechanical or electrical components and the structural frame shall allow for anticipated movements of the structure. The details of the connections shall be made a part of the contract documents.

Commentary: Mechanical or electrical components of a solar system are subjected to seismic forces generated by their mass and may also be influenced by interaction with elements of the structural system.

(S-601-6.2)

Hail impact represents another potential hazard from flying glass. With the exception of that portion of the U.S., the central hail belt, the criterion which follows establishes a level of performance essentially comparable to that desired for conventional roofing. In the hail belt, where hazard is greater, the performance level is somewhat increased.

HAIL LOADS

The cover plates, lenses, and reflector surfaces of solar collectors shall be protected against or resist the perpendicular impact of a single hailstone of the magnitude stipulated below falling at its terminal velocity.

---

[1] The "Uniform Building Code" is published by the International Conference of Building Officials, Whittier, California.

TABLE S-601-6

Part of System	Direction of Force	Value of C_p 1/ 2/
Storage tanks, pressure vessels, boilers, furnaces, absorption air conditioners, other equipment using combustible or high temperature energy sources, electrical motors and motor control devices, heat exchangers	any direction	0.12 when resting on ground 0.20 when connected to, or housed, elsewhere in the building.
Flat plate and concentrating solar collectors	any direction	0.20
Transfer liquid pipes larger than 2-1/2 in. diameter	any horizontal direction	0.12

1/ For flexible and flexibly mounted equipment and machinery, appropriate values of C_p shall be determined by a properly documented dynamic analysis, or by dynamic testing, using appropriate excitation spectra approved by HUD. Consideration shall be given to both the dynamic properties of the equipment and machinery and to the building or structure in which it is placed.

2/ WHEN LOCATED IN THE UPPER PORTION OF ANY BUILDING WHERE THE H_N/D RATIO IS 5:1 OR GREATER THE C_P VALUE SHALL BE INCREASED BY 50%

WHERE H_N = HEIGHT IN FT. OF THE PART OF THE SYSTEM ABOVE THE BASE LEVEL OF THE BUILDING

D = THE DIMENSION OF THE STRUCTURE IN FEET IN A DIRECTION PARALLEL TO THE APPLIED FORCE.

Hail size: D = 0.3d

in which D = hailstone diameter, inches

d = mean annual number of days with hail taken from Figure S-601-7 [1].

Terminal velocities for various hail sizes are given in Table S-601-7 [2]. Compliance with this provision shall be based on documented past hail loading performance or NBS Building Science Series BSS 23 [3] or analytical procedures acceptable to HUD.

Commentary: The correlation of hail size with mean annual number of days with hail was determined using data relating the probability of occurrence of hail particle size to the number of days with hail (tabulated in Ref. [4]), and limited statistical information relating the local area covered by hail-storm, and the regional area for which statistical data are compiled. The hail size indicated has a 5% probability of being exceeded in any one year (estimated 20 year recurrence interval). The hail requirements in this section are based on available information which does not contain physical test data. Therefore, local hailstone loading performance should be considered in implementing the requirements of this section.

The impact from the vertical terminal velocity is used as a measure of the effect of hail falling with or without horizontal wind. It is possible that a larger impact could occur on surfaces sloped from 30° to 60° if the maximum particle diameter occurred simultaneously with high horizontal wind velocity. perpendicular to the surface. It may be overly conservative for particles over 1.5" impacting on near vertical surfaces. However, due to the lack of information on this phenomenon and the low probability of its occurrence, it is assumed that the terminal velocity gives the best measure of impact force consistent with the present state-of-the-art.

The loadings specified in this section to determine collector performance closely parallel those that conventional asphalt shingles and built up roofing are expected to withstand for all but the mid-continent hail belt.

DYNAMIC LOADS

Dynamic loads resulting from sun tracking solar collectors or other moving equipment shall be taken into account in the design of the dwelling frame.

(S-601-8)

---

[1] Baldwin, J. L., "Climates of the United States," U.S. Dept. of Commerce, Washington, D.C. (1973).

[2] Mathey, R. C., "Hail Resistance Tests of Aluminum Skin Honeycomb Panels for the Relocatable Lewis Building, Phase II," NBS Report 10193, National Bureau of Standards, Washington, D.C. (1970).

[3] Greenfield, H., "Hail Resistance of Roofing Products," Building Science Series 23, National Bureau of Standards, Washington, D.C. (August 1969).

[4] "Storm Data," U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service (monthly periodical).

TABLE S-601-7

Values of weight and terminal velocity in free fall computed for smooth ice spheres.

Diameter in	Weight gm	Weight lb	Terminal Velocity ft/sec.
1/2	0.98	0.002	51
3/4	3.30	0.007	62
1	7.85	0.017	73
1 1/4	15.33	0.034	82
1 1/2	26.50	0.058	90
1 3/4	42.08	0.093	97
2	62.81	0.138	105
2 1/4	89.43	0.197	111
2 1/2	122.67	0.270	117
2 3/4	163.28	0.360	124
3	211.98	0.467	130

from: Mathey, R.C., "Hail Resistance Tests of Aluminum Skin Honeycomb Panels for the Relocatable Lewis Building, Phase II," NBS Report 10193, National Bureau of Standards, Washington, D.C., 1970.

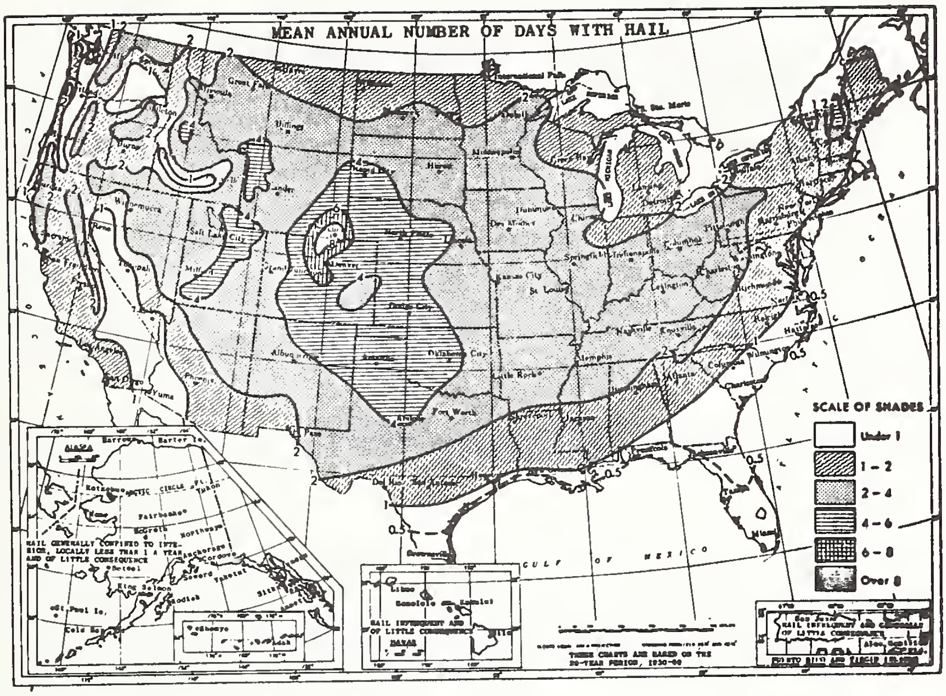

FIGURE S-601-7

from: Baldwin, J. L., Climates of the United States, U.S. Department of Commerce, Washington, D.C., 1973.

THERMAL DISTORTION

Thermal distortion of the mechanical or structural components of the solar system shall not cause premature failure or degradation in system performance greater than the design limits.

Thermal distortion of the solar system, including that occurring during periods of stagnation, shall not cause damage to the system or the supporting dwelling structure.

Commentary: Expansion coefficient data for cover and absorber plate materials are listed in Appendix Tables B-1 and B-3.

(S-601-9)

COLLECTOR COVER PLATES

Deflection or local distress of cover plates resulting from the maximum design loading shall not allow the cover plate to become separated from the unit nor result in degradation in collector performance greater than the design limits. This shall be demonstrated by analysis or physical simulation.

Commentary: Since wind can come from any direction, there will be maximum pressure (inward) loading for units mounted on the windward side of an installation and maximum suction (outward) loading for those mounted on the leeward side (unless shielding is provided). Depending on the installation, suction loading can, and often does exceed pressure loading, hence, cover plate retainers must be adequately designed to prevent them from being separated from the collector frame or induce failure of the cover plate by suction loading.

(S-601-10)

CONNECTIONS OF COLLECTOR FRAMES AND/OR OTHER SUPPORT STRUCTURES

When collector frames and/or other support structures are mounted on walls, roofs, or other weather resistant surfaces, distortion of the frame from imposed loading shall not cause penetrations or separations of these surfaces such that moisture leaks occur through the weather resistant surfaces.

(S-601-11)

STORAGE TANKS

Design and Fabrication

Storage tanks shall be designed and fabricated to standards embodying principles recognized as good engineering design and fabrication practice for the materials used. These standards shall include those listed in Appendices C and E of the MPS and others as approved by HUD.

Tanks containing soil or rock like materials shall be designed for lateral pressures in accordance with accepted principles of soil mechanics.

(S-601-12.1)

Testing

Each liquid storage tank shall be tested in accordance with section S-615-10.10 to prove that leakage does not occur. Storage tanks designed to contain only dry heat storage material need not be leak tested unless a safety hazard can result from a storage tank failure.

(S-601-12.2)

Environmental and Vehicular Loading

In addition to meeting the design, fabrication and test requirements, stipulated in the preceding paragraphs of this section, storage tanks shall meet the following loading requirements.

(S-601-12.3)

Above Ground

Unsheltered storage tanks shall resist loads resulting from snow, wind, hail, thermal, and seismic loading. Sheltered (completely enclosed) tanks need only resist seismic loading.

(S-601-12.3.1)

Underground

Underground tanks shall resist soil and hydrostatic loads and foundation loads transmitted to them and they shall be anchored to prevent flotation resulting from flooding or high ground water level when the tanks are empty. For sites subject to commercial traffic or heavy truck traffic, storage tanks shall resist the wheel loads transmitted to them as specified in AASHTO H20-44, with no impact. For areas subject to other vehicular or human traffic, the pertinent loads stipulated in section 601-4.3 of MPS 4910.1 or 4920.1 shall be resisted.

Commentary: The criterion specifies the level of vehicular traffic for which buried components should be designed in cases where heavy vehicular traffic is anticipated to occur in service for purposes of access. The H20-44 truck is considered to be representative of load levels associated with heavy vehicles such as trucks for repair, maintenance, moving, and delivery of fuel.

(S-601-12.3.2)

8. PROTECTION FROM PHYSICAL HAZARDS

The MPS and IPC documents contain a number of other provisions concerned with protection from heated surfaces, protection from scalding, protection from ice and snow fall, glazing safety, protective measures for maintenance personnel, and solar glare. Interference with access and circulation has already been discussed with regard to fire safety in section 3. In many cases solar components may present physical hazards that are greater than those ordinarily found in buildings, e.g., the presence of heated surfaces that are readily accessible and the build up of ice and snow on collectors. Relevant provisions that have not already been discussed are as follows:

> Components of solar systems which are accessible, located in the areas normally subjected to occupant traffic and which are maintained at elevated temperatures shall either be insulated to maintain their surface temperatures at or below 140 F at all times during their operation or be suitably isolated. Any other exposed accessible components that are maintained at temperatures above 140 F shall be identified with appropriate warnings.
>
> (S-600-6.3)

> All domestic hot water systems shall be equipped with means for limiting temperature of the hot water for personal use at fixtures of 140 F.
>
> (S-615-10.6)

In a companion document developed specifically for solar domestic hot water installations [5] storage tank overheating is addressed. Solar heated hot water tanks can reach temperatures much higher than those that would normally occur with conventional tanks, e.g., under low use conditions.

> Thermal storage shall be protected against maximum temperature, pressure and vaccum in accordance with the provisions of S-615-7.4.1.
>
> *Commentary: During extended periods with no draw, solar DHW systems can supply thermal energy to such an extent that dangerously high temperatures may be reached in storage tanks. To avoid this, thermostatically controlled valves or other methods may be used to prevent undesired collector heat from entering storage. Such provisions may require collectors to be stagnation tolerant or provide heat dumping capability in the collector circulation loop. In any case, maximum tank temperature should be limited to 180°F*

Personal hazard and system impairment due to snow and ice condition can be created by solar installations.

> In areas which have a snow load of 20 pounds per square foot or greater required by local codes, provision shall be made over entrances and locations of pedestrian and vehicular ways to restrain or deflect sliding snow and ice masses which may slide off elevated solar system components.
>
> *Commentary: Solar system components may often include smooth slippery surfaces located in elevated positions at steep angles. These elements may heat up rapidly and loosen masses of snow or ice which may slide-off. Means should be provided to prevent a hazard to people or property. Methods such as deflectors, restraints, low friction materials or design of "safe fall" areas (pedestrain or vehicular ways spaced away from the building) should be considered*
>
> (S-304-3)

> The design of solar buildings and systems shall provide for the possibility of formation of ice dams and snow build up.
>
> *Commentary: In very cold climates, water flowing off a warm collector may freeze on cold surfaces immediately below it (such as exposed eaves), thereby forming an ice dam which can cause water to back up under roofing or into the collector itself. This may be moderated by methods such as elimination of the cold surface or provision of an impervious surface such as continuous flashing. Snow sliding off a collector may pile up at the bottom and cover part of the collector. This would have a tendency to reduce the efficiency of the collector and increase the possibility of thermal breakage of glass in the collector. This may be moderated by methods such as the provision of space below the collector for snow pile up or by the installation of heating cables.*
>
> (615-2.1.6)

Glazing safety is an important consideration, especially in the case of passive installations where large expanses of glazing are used.

Glazing may be located in elevated and exposed positions increasing the potential hazard from falling glass. The glazing may also be located adjacent to pedestrian traffic areas and in passive direct gain installations, glazing unbacked by a readily visible absorber presents a risk similar to that found in the glazing used in conventional window walls.

The materials used as glazing for cover plates must meet the following requirements based on materials properties as well as safety considerations. The safety requirements are made with respect to the physical location of the glazing and the exposure risk of persons nearby.

Commentary: Appendix Table B-1 lists properties of a number of materials that have been used for cover plates.

(S-515-2.2.1)

All glazing materials shall be of adequate strength and durability to withstand the loads and forces required by Section S-601 of this document.

(S-515-2.2.1.1)

Applications include windows which act as cover plates for solar collectors, both integral with dwelling construction and as freestanding components.

a. Glazing materials other than those specified in b or c below, shall meet the intent of the requirements for glazing in MPS Section 508-8.3.

   Commentary: Consumer Product Safety Act, Part 1201, was published in the Federal Register January 6, 1977 and will become effective on July 6, 1977 (except for fire retardant glazing required by ordinance for which the effective date is January 6, 1980). This standard contains mandatory safety standards for architectural glazing materials.

   Film-type glazing materials for the outermost cover plate, if unsupported, may be unacceptable if they can be deflected under load, e.g., a person's hand pushing against the glazing may present an opportunity for exposure of the film (and the person's hand) to hot surfaces such as the asborber plate. Also there is a probability of exposure to impact which may result in tearing of the film.

b. Glazing materials with slopes less than 45° which extend below 6' 0" (from ground level) shall be safety glazed or otherwise protected against impact of falling bodies.

   Commentary: This commonly refers to glazing on which children may climb or against which a passerby may fall.

c. Glazing panels which are an integral part of a roof or rack-mounted system on a roof, not routinely accessible by the occupant, shall meet the requirements of Section S-601.

   Commentary: Annealed glass or films may be acceptable.

(S-515-2.2.1.2)

Protective measures for maintenance personnel include the following:

Where access for service or cleaning of solar subsystems requires a person to balance on a narrow or (steeply) sloping surface, provisions shall be made for securing a life-line, guard-rail, or other personal protective device.

(S-600-6.6)

Solar energy components located on the site shall be accessible for cleaning, adjusting, servicing, examination, replacement or repair without trespassing on adjoining property.

Commentary: Components should not be located unnecessarily under buildings or roads or in other places which are difficult to reach. Storage tanks in particular are large and may need periodic replacement or inspection.

SOLAR COLLECTORS ON ROOFS OVER 3 STORIES MUST HAVE ACCESS PROVIDED FOR CLEANING AND MAINTENANCE.

COMMENTARY: THE USE OF PORTABLE LADDERS IS NOT CONSIDERED TO BE ADEQUATE UNDER THESE CIRCUMSTANCES.

(S-309-1)

Personal hazard mav also result where blinding reflections, sharp edges, and heavy traffic situations are present. These are noted in the following:

Special considerations must be given to assure that elements of the solar system do not create unnecessary safety hazards to users.

Commentary: Hazards which require special attention include the reflection of sunlight which creates visual distraction, the projection of sharp edges which influence the movement of people near free-standing collectors and the proximity of solar components to recognized architectural hazards such as exterior overhangs, stairs, ramps, landings, doors, etc.

(S-303-2)

9. OTHER PROVISIONS

A number of other provisions are directly related to health and safety, e.g., protection against vermin and rodents, location and identification of emergency controls and provision of 100 percent back up with auxiliary energy.

Solar energy systems (including piping, fixtures, appliances, and other equipment) should not contribute to the entry or growth of vermin or rodents. Maintenance of physical barriers, minimization of concealed spaces conducive to harboring vermin or rodents, provisions of access for cleaning should be in accordance with applicable codes such as Section 2.13 of the National Standard Plumbing Code.

(S-600-6.8)

Main shutoff valves and switches shall be conspicuously marked and placed in a readily accessible location, in the same manner as electrical service panels, in accordance with Section 240.24 of NFPA 70, and MPS, Section 616.

(S-615-14.2)

The thermal energy contribution provided by solar energy shall be backed up 100 percent with an auxiliary thermal energy subsystem which will provide the same degree of reliability and performance as a conventional system.

Commentary: The uncertainty in the availability of solar energy during inclement weather requires complete back up of the solar energy contribution to meet comfort and hot water standards.

(S-615-1.2)

There are many other provisions, too numerous to mention, related to the durability/reliability of materials that have health and safety implications should a failure occur. In addition, reference to applicable standards is used in the MPS and IPC documents as a means of ensuring safety. A list of those standards referenced in the solar MPS document, many of which are related to safety, is attached as an appendix to this report.

10. REFERENCES

1. "Intermediate Minimum Property Standards Supplement - Solar Heating and Domestic Hot Water Systems," 4930.2, 1977 Edition, prepared for HUD by NBS.

2. "Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings," January 1, 1975, prepared for HUD by NBS.

3. "Interim Performance Criteria for Solar Heating and Cooling Systems in Commercial Buildings," prepared for ERDA by NBS, NBS Report NBSIR 76-1187, November 1976.

4. "Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems," prepared for HUD by NBS, NBS Report NBSIR 76-1059, April 1976 (Draft for comments; no longer available in print).

5. "Intermediate Standards for Solar Domestic Hot Water Systems/HUD Initiative," prepared for HUD by NBS, NBS Report NBSIR 77-1272, July 1977.

APPENDIX E

REFERENCED STANDARDS

AASHTO H20-44 Standard Specification for Highway Bridges

ANSI A13.1 (1956) Scheme for the Identification of Piping Systems

ANSI A58.1 (1972) Building Code Requirements for Minimum Design Loads in Buildings and Other Structures

ANSI A112.1.1 (1971) Performance Requirements, Methods of Test for (ASSE 1001-1970) Pipe-Applied Atmospheric-Type Anti-Siphon Vacuum Breakers

ANSI A112.1.2 Air Gaps in Plumbing Systems (Reaffirmation and redesignation of A40.4-1942)

ANSI B9.1 (1971) Safety Code for Mechanical Refrigeration

ANSI B15.1 (1972) Safety Standard for Mechanical Power Transmission Apparatus

ANSI B16.18 (1972) Cast Bronze Solder Joint Pressure Fittings

ANSI B31.1, Section I (1973) Power Piping

ANSI B96.1 (1973) Specification for Welded Aluminum-Alloy Field-Erected Storage Tanks

ANSI B124.1 (1971) Safety Standard for Air Filter Units (UL 900 April 1971)

ANSI B137.1 (1971) Steel Underground Tanks for Flammable and Combustible Liquids (UL 58-July 1971)

ANSI B191.1 (1976) Standard for Heat Pumps (UL 559)

ANSI S2.8 (1972) Guide for Describing the Characteristics of Resilient Mountings

ANSI Z95.1 (1974) Oil Burning Equipment (NFPA 31-1972)

ANSI Z97.1 (1975) Performance Specifications and Methods of Test for Safety Glazing Material Used in Buildings

ARI Standard 240 (1975) Standard for Unitary Heat Pump Equipment

ARI Standard 260 (1967) Standard for Application, Installation, and Servicing of Unitary Systems

ARI Standard 410 Forced Circulation Air-Cooling and Air-Heating Coils

ARI Standard 760 (1975) Standard for Solenoid Valves for Use with Volatile Refrigerants and Water

ASHRAE 37-69 Method of Testing for Unitary Air Conditioning and Heat Pump Equipment

ASHRAE 55-74 (1974) Thermal Environmental Conditions for Human Occupancy

ASHRAE 90-75 (1975) Energy Conservation in New Building Design

ASHRAE 93-77 (1977) Methods of Testing Solar Collectors Based on Thermal Performance

ASHRAE 94-77 (1977) Method of Testing Thermal Storage Devices Based on Thermal Peformance

ASHRAE Handbook of Fundamentals

ASME SA-53, Section VIII Boiler and Pressure Vessel Code

ASSE 1011 Performance Requirements for Hose Connection Vacuum Breakers

ASSE 1012 Performance Requirements for Backflow Preventers with Intermediate Atmospheric Vent

ASSE 1013 Performance Requirements for Reduced Pressure Principle Back Pressure Backflow Preventers

ASSE 1015 Performance Requirements for Double Check Valve Type Back Pressure Backflow Preventers

ASSE 1020 Performance Requirements for Vacuum Breakers, Anti-Siphon, Pressure Type

ASTM A53-75 Specification for Welded and Seamless Steel Pipe

ASTM C739-73, Section 10.4 (1973) Flame Resistance Permanency

ASTM D471-75 Test for Rubber Property - Effect of Liquids

ASTM D660-44 (1970) Evaluating Degree of Resistance to Checking of Exterior Paints

ASTM D661-44 (1975) Evaluating Degree of Resistance to Cracking of Exterior Paints

ASTM D714-56 (1974) Evaluating Degree of Blistering of Paints

ASTM D750-68 (1974) Recommended Practice for Operating Light-and-Weather Exposure Apparatus (Carbon-Arc Type) for Artificial Weather Testing of Rubber Compounds

ASTM D772-47 (1975) Evaluating Degree of Flaking (Scaling) of Exterior Paint

ASTM D822-60 (1973) Recommended Practice for Operating Light-and-Water-Exposure Apparatus (Carbon-Arc Type) for Testing Paint, Varnish, Lacquer, and Related Products

ASTM D1081-60 (1974) Test for Evaluating Pressure Sealing Properties of Rubber and Rubber-Like Materials

ASTM D1149-64 (1970) Test for Accelerated Ozone Cracking of Vulcanized Rubber

ASTM D1308-57 (1973) Test for Effect of Household Chemical on Clear and Pigmented Organic Finishes

ASTM D1384-70 Corrosion Test for Engine Antifreeze in Glassware

ASTM D2247-68 (1973) Testing Coated Metal Specimens at 100 Percent Relative Humidity

ASTM D2570-73 Simulated Service Corrosion Testing of Engine Antifreeze

ASTM D2776-72 Tests for Corrosivity of Water in the Absence of Heat Transfer (Electrical Methods)

ASTM E72-74a Conducting Strength Tests of Panels for Building Construction

ASTM E84-70 (1970) Surface Burning Characteristics of Building Materials

ASTM E108-75 (1975) Methods of Fire Tests of Roof Coverings (NFPA 256-1970)

ASTM E154-68 Testing Materials for Use as Vapor Barriers Under Concrete Slabs and as Ground Cover in Crawl Spaces

ASTM E424-71 Test for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials

ASTM F146-72 Test for Fluid Resistance of Gasket Materials

ASTM G1-72 Recommended Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens

ASTM G16-71 Recommended Practice for Applying Statistics to Analysis of Corrosion Data

ASTM G46-76 Recommended Practice for Examination and Evaluation of Pitting Corrosion

AWWA C203-73 Standard for Coal-Tar Protective Coatings and Linings for Steel Water Pipelines

AWWA C506-69 Backflow Prevention Devices-Reduced Pressure Principle and Double Check Valve Types

AWWA D100 (1967) Steel Tanks -Standpipes, Reservoirs and Elevated Tanks for Water Storage

AWWA D102 Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage

BMC, Section M302 (1975) Specific Requirements for the Materials, Design, and Fabrication of Ductwork

CPSC 16 CFR, Part 1201 (1976) Architectural Glazing (Code of Federal Regulation)

Federal Hazardous Substances Act, Code of Federal Regulations, Title 16, Part 1500

FCCCHR, Chapter 10 Manual of Cross-Connection Control (Foundation for Cross Connection Control Research)

FS-DD-G-451C (1972) Glass, Plate, Sheet, Figured (Float, Flat, for Glazing, Corrugated, Mirrors and Other Uses)

FS-TT-C-00598C(1) Caulking Compound, Oil and Resin Base Type (For Building Construction) (18 March 1971)

FS-TT-S-001543A Sealing Compound: Silicone Rubber Base (For Caulking, Sealing, and Glazing in Buildings and Other Structures) (9 June 1971)

FS-TT-S-001657 Sealing Compound: Single Component, Butyl Rubber Based, Solvent Release Type (for Buildings and Other Types of Construction) (8 October 1970)

FS-TT-S-00227E(3) Sealing Compound Elastomeric Type, Multi-compound (For Caulking, Sealing and Glazing in Buildings and Other Structures) (9 October 1970)

FS-TT-S-00230C(2) Sealing Compound: Elastomeric Type, Single Component (For Caulking, Sealing and Glazing in Buildings and Other Structures) (9 October 1970)

FS-TT-P-95A(3) Paint, Rubber: For Swimming Pools and Other Concrete and Masonry Surfaces, 27 May 1966

FS-WW-U-516B Unions, Brass or Bronze, Threaded Pipe Connections and Solder-Joint Tube Connections

FS-WW-U-531D Unions, Pipe, Steel or Malleable Iron; Threaded Connection, 150 lbs. and 250 lbs.

FS-WW-V-35B (1973) Valve, Ball

IAPMO PS 31-74 Specification for Backflow Prevention Devices

IAPMO PSI Prefabricated Concrete Septic Tanks (1966)

NACE TM-01-69 (1972) Laboratory Corrosion Testing of Metals for the Process Industries

NACE TM-02-70 Method of Conducting Controlled Velocity Laboratory Corrosion Tests

NACE TM-01-71 Autoclave Corrosion Testing of Metals in High Temperature Water

NACE TM-02-74 Dynamic Corrosion Testing of Metals in High Temperature

National Primary Drinking Water Regulation - Federal Register, 24 December 1975

NFPA 30 (1973) Flammable and Combustible Liquids Code

NFPA 31 (1974) Standard for the Installation of Oil Burning Equipment

NFPA 54 (1974) National Fuel Gas Code

NFPA 70 (1976) Section 240.24, National Electrical Code

NFPA 89M (1971) Clearances for Heat Producing Appliances

NFPA 90A (1976) Standard for the Installation of Air Conditioning and Ventilating Systems

NFPA 90B (1973) Standard for the Installation of Warm Air Heating and Air Conditioning Systems

NFPA 21 (1972) Standard for Chimneys, Fireplaces and Vents

NFPA 321 (1973) Basic Classification of Flammable and Combustible Liquids

NFO 8 National Forest Products Association, The Wood Tank

NRCA - A Manual of Roofing Practice 1970 (71)

NSPC, Section 2.13 Ratproofing

MIL-T-52777 21 February 1974 Military Specifications for Tanks: Storage, Underground, Glass Fiber Reinforced Plastic

MSS SP-73 Silver Brazing Joints for Cast and Wrought Solder Joint Fittings

SAE J447e(1964) Prevention of Corrosion of Metals

SAE J20e(1974) Coolant System Hoses

Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes, 1975 - American Conference of Governmental Industrial Hygienists

UL 58 (1973) Standard for Steel Underground Tanks for Flammable and Combustible Liquids (ANSI B137.1-1971).

UL 174 (1972) Standard for Household Electric Storage-Tank Water Heaters (ANSI C33.87-1972)

UL 181-74, Section 10 Factory-Made Air Duct Materials and Air Duct Connectors

UL 296 (1974) Standard for Oil Burners

UL 573 (1972) Standard for Electric Space-Heating Equipment (ANSI C33 12-1972)

UL 726 (1973) Standard for Oil-Fired Boiler Assemblies

UL 727 (1973) Standard for Oil-Fired Central Furnaces (ANSI Z96.1-1973)

UL 730 (1974) Standard for Oil-Fired Wall Furances

UL 732 (1974) Standard for Oil-Fired Water Heaters

UL 900 (1971) Safety Standard for Air Filter Units (ANSI B124.1-1971L)

UL 1042 (1973) Standard for Electric Baseboard Heating Equipment (ANSI C33.95-1973)

Water Quality Criteria 1972, National Academy of Science and National Academy of Engineering

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO.	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE	5. Publication Date
Environmental and Safety Considerations for Solar Heating and Cooling Applications	6. Performing Organization Code
7. AUTHOR(S) Waksman, David; Holton, John K.	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234	10. Project/Task/Work Unit No. 7446500 & 7446505 11. Contract/Grant No. IAA-H-38-76 EA-77-A-01-6010
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Dept. of HUD Div. of Energy, Bldg. Tech. & Stds. 451-7th Street, SW Washington, DC 20410 Dept. of Energy Office of Cons. & Solar Appl. 20 Massachusetts Avenue, NW Washington, DC 20545	13. Type of Report & Period Covered 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The HUD Minimum Property Standards (MPS) and the "residential" and "commercial" interim performance criteria (IPC) prepared by the National Bureau of Standards address many health and safety considerations that need to be considered by solar heating and cooling system designers. For example, factors such as the toxicity and flammability of heat transfer fluids are often not considered in the design of systems. Similarly, attention is seldom paid to the safe disposal of these fluids. These problems are compounded by the lack of clear guidelines as to which fluids constitute hazards that warrant special consideration. This report is intended to create an increased sense of awareness of the health and safety aspects of solar heating and cooling applications by extracting and amalgamating pertinent provisions of the MPS and IPC documents. Some of the areas that are addressed include: structural safety, heat transfer fluid toxicity and flammability considerations including the protection of potable water, effects of solar equipment on the fire resistance of buildings, and protection from physical hazards.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Fire safety; health; physical hazards; safety; solar heating and cooling; structural performance; toxicity.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[XX] Unlimited [ ] For Official Distribution. Do Not Release to NTIS [ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13 [XX] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED 20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	32 22. Price

USCOMM-DC 29042-P74