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ACTIVE SOLAR HEATING SYSTEMS

INSTALLATION MANUAL

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PREFACE

These guidelines for the installation of large commercial-scale hot water and space-heating solar energy systems represent years of cooperative effort by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, the Solar Energy Industries Association, and Department of Energy contractors. The challenge of creating a single manual to satisfy the specific needs of designers, installation contractors, and owners for a variety of locations, applications, and system types called for the talents and experience of specialists in many different areas.

This manual describes procedures that cover all the major steps in installing large solar energy systems. Following these procedures will significantly enhance the success of solar installations in buildings.

The manual was developed in conjunction with the ASHRAE Active Solar Heating Systems Design Manual and the ASHRAE Guide for Preparing Active Solar Heating Systems Operation and Maintenance Manuals. These three books are provided to give installation contractors an effective means to use the collective knowledge of government and industry for improving the installation of solar energy systems.

It is industry's responsibility to design, build, and maintain state-of-the-art solar energy systems that satisfy a wide variety of markets and requirements. The Department of Energy has assumed the role of supporting industry in the development of a technology base that would accelerate the acceptance of solar energy systems in the marketplace. During preparation of this manual, great effort was made to collect information from sources with widely varied experiences and to organize it into a usable document.

This manual, as the final product of that effort, is presented to industry with the expectation that it will take its place as a useful and significant part of that solar energy technology base.

Abbreviations and Acronyms for Installation Manual

°C	Degrees Celsius
°F	Degrees Fahrenheit
I-P	Inch-Pound
SI	Systeme International
Btu	British Thermal Unit
hp	Horsepower
k	Kilo
M	Mega
J	Joule
W	Watt
h	Hour
s	Second
yr	Year
ft	Foot
in.	Inch
mm	Millimeter
m	Meter
mph	Miles Per Hour
Pa	Pascal
g	Gram
lb	Pound
psig	Pounds Per Square Inch Gauge
psi	Pounds Per Square Inch
WG	Water Gauge
cfm	Cubic Feet Per Minute
gal	Gallon
gpm	Gallons Per Minute
L	Liter
Dia	Diameter
ppm	Parts Per Million
TDS	Total Dissolved Solids
% RH	Percent Relative Humidity
N/S or N-S	North/South
E/W or E-W	East/West
A/E	Architect/Engineer

U	Overall Heat Transfer Coefficient
UA	Overall Heat Transfer Coefficient (for specific area or device)
R	Thermal Resistance Rating (for thermal insulation)
UV	Ultraviolet
Vac	Voltage-Alternating Current
elev	Elevation
horiz	Horizontal
FC	Fail Close (close on loss of power)
FO	Fail Open (open on loss of power)
ETC	Evacuated Tube Collector
HX	Heat Exchanger
Max	Maximum
Min	Minimum
NC	Normally Closed
NO	Normally Open
DP	Double Pole
ST	Single Throw
DT	Double Throw
DHW	Domestic Hot Water
SHW	Service Hot Water
IPH	Industrial Process Heat
TC	Cold Temperature Sensor
TH	Hot Temperature Sensor
RTD	Resistance Temperature Detector
T Stat	Thermostat
DAS	Data Acquisition System
PRV	Pressure Relief Valve
NPSH	Net Pump Suction Head
P & ID	Piping and Instrumentation Diagram
SDD	System Design Description
SH	Space Heat
EPDM	Ethylene Propylene Diene Monomer
PVC	Polyvinyl Chloride

Abbreviations and Acronyms for Installation Manual

(continued)

Organizations

ACEC	American Consulting Engineers' Council
ACI	American Concrete Institute
ANSI	American National Standards Institute, Inc.
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BOCAI	Building Officials and Code Administrators International
CSI	Construction Specification Institute
DOE	U.S. Department of Energy
ETEC	Energy Technology Engineering Center
IAPMO	International Association of Plumbing and Mechanical Officials
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry
NBS	National Bureau of Standards
NWS	National Weather Service
OSHA	Occupational Safety and Health Administration
SEIA	Solar Energy Industries Association
SFBP	Solar In Federal Buildings Program
SMACNA	Sheet Metal and Air-Conditioning Contractors' National Association
SRCC	Solar Rating and Certification Corporation
TVA	Tennessee Valley Authority
UL	Underwriters Laboratories

EXECUTIVE SUMMARY

PURPOSE

This manual was prepared to provide industry's consensus of the best available installation procedures for large, commercial-scale solar service water and space-heating systems. It incorporates experience from the solar industry and from government-sponsored programs that have demonstrated and advanced the technology of active solar heating systems.

SCOPE

This manual discusses the installation of large commercial and industrial solar energy systems for water heating and space heating. The types of systems discussed are those covered in the ***Design Manual*** *: liquid collector systems (drainback, antifreeze, or recirculation) and air collector systems requiring a minimum storage of 1,000 gal (3,800 L) of water or equivalent or at least 700 ft^2 (65 m^2) of collector area.

Much of the information in this manual also applies to smaller systems. A complete and correct installation procedure is as important for small solar energy systems as for the large ones, and following this manual's procedures, where they apply to smaller systems, will ensure that no critical installation procedure is left out.

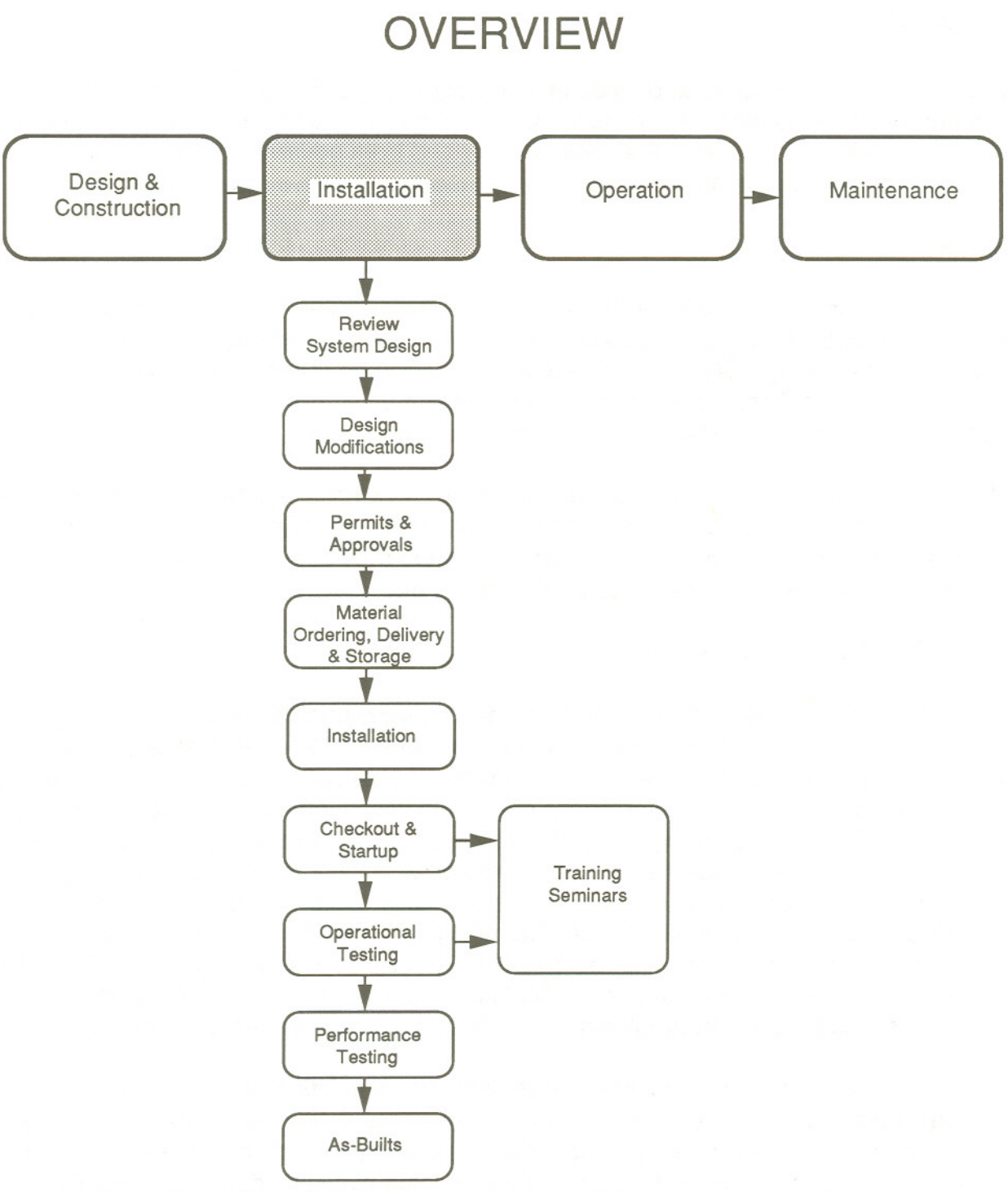
HOW TO USE THIS MANUAL

This manual can be used by architects/engineers (A/Es) and design/build contractors of large active solar heating systems to prepare the construction specification package, by installation contractors to supplement construction specifications, and by owners to inspect their systems. The installation practices discussed include pre-construction, construction, system checkout, and startup recommendations presented in a systematic and standardized approach for the installation of commercial solar heating systems. The installation contractor need not have experience with solar energy systems, nor have been involved in the system design work, but is expected to be experienced in, and licensed for, installation of commercial heating, ventilating, air-conditioning, and/or plumbing systems. Following these procedures will ensure that no critical procedure is left out of the installation and checkout process, and that problems unique to solar energy systems are avoided.

Data from the construction package are used by the installation contractor to make the manual specific to the project so that no other reference is needed. Where data are incomplete (e.g., a component make or model has not been specified), it is expected that the installation contractor will fill in the data as they become available during the installation process.

* In this manual, "***Design Manual***" refers to the companion ASHRAE volume, *Active Solar Heating Systems Design Manual*, 1988, ISBNO-910110-54-9.

The flow of work in a system installation, as illustrated by the following diagram, is presented in the manual with the major procedures identified and discussed in sequence.



1.0 INTRODUCTION

This manual is written for the contractor who will be installing a large commercial solar heating system for service hot water or space heating. The manual will also help a contractor prepare a bid for installation of such a system.

The bidding procedure followed by the contractor varies depending on who has designed the system. Generally one of the following two procedures applies:

1. Architect/Engineer Design: The system has been designed by an independent architect/engineer (A/E). You receive a construction package of bid documents for review and bid on the installation contract, either as primary contractor or as a subcontractor. If your bid is accepted, you then construct in accordance with the construction package specifications. You do not design the system and may not perform some of the checkout.

2. Design/Build: You solicit the opportunity or are asked to bid on the design and installation of a proposed solar project, either as primary contractor or as a subcontractor. You design the system in-house and prepare the construction package (the ASHRAE ***Design Manual*** will help you with the design procedures and bid preparation). If your bid is accepted, you then construct in accordance with your design and specifications, using the manual for help with the installation procedures. You generally perform the checkout.

Most of the information in this manual applies to both situations, although the emphasis may vary depending on whether the installation contractor designed the system. In general, throughout this manual the term "designer" refers to whomever designed the system, no matter whether the designer is an independent A/E or the installation contractor.

This manual covers the installation of systems in new and existing buildings. Most of the information applies in both cases; where critical information applies only to new building installations or only to retrofit installation, that will be indicated.

2.0 REVIEW SYSTEM DESIGN

The bid preparation process begins with a detailed review of the construction package prepared and provided by the designer. Even when the contractor (as designer) has prepared the package, a final reading for mistakes or omissions is advisable before the bid is prepared or equipment ordered. The construction package should include:

- A general system description.
- Design and installation drawings.
- Construction specifications.
- Component specifications (may be in construction cpecifications).
- An operation and maintenance manual.

Contact the appropriate person (designer, general contractor, or owner) if any item is missing, incomplete, or in error.

Once the package is complete, begin a detailed review using this manual's checklists to keep a record of the review. This review will show if all the information needed to bid and install the system has been included; any missing information is noted at the bottom of each checklist as it is completed.

When the detailed review of the design package is complete, make a site survey to become familiar with the building, to answer any questions arising from the review of the construction package, and to get any additional information you will need to bid and install the system. Again, contact the appropriate person to provide any information that is still missing, incomplete, or in error after the detailed review and site survey.

2.1 REVIEW GENERAL SYSTEM DESCRIPTION

The general system description provides an overview of the system to be installed. An example of such a system description is as follows:

System Description: Drainback System for Service Hot Water System Retrofit.

Gross Collector Area:	700 ft² (65 m²)
Storage Volume:	1,000 gal (3,800 L)
Collector Fluid:	Water
Application:	Service Hot Water (SHW)

Hot water is required for showers, lavatories, and minor laundry facilities. Present hot water heating is accomplished with conventional natural gas heating. A solar heating system is desired to reduce the overall fossil fuel energy consumption of the facility.

The solar energy system for this project is a drainback type, (see Figure 1). Water circulates through flat plate collectors where it is heated by solar energy. The energy is transferred to the solar energy storage tank via a heat exchanger. Upon demand for hot water, solar-heated water is transferred from the solar storage tank to an existing hot water storage tank. The system is designed so that the collectors and all exposed piping drain back to the drainback tank when the primary pump is off, providing positive freeze protection.

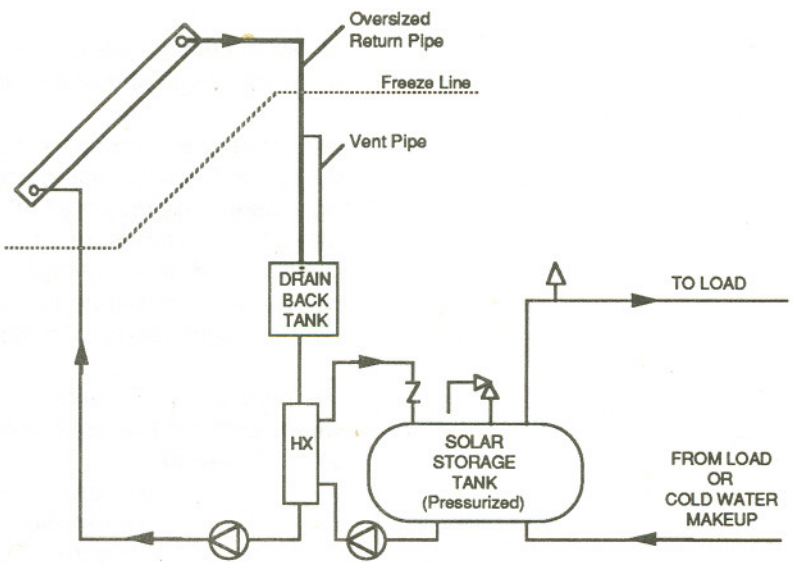


Figure 1. Basic Drainback and Storage System for Service Hot Water Heating

Control of fluid circulation within the collector and solar storage loops is based on the temperature differential between the collectors and storage. When the collector temperature exceeds the storage temperature by 20°F (11°C), the collector and solar storage loop pumps are turned on. The pumps are deactivated when the collector temperature drops to less than 5°F (3°C) above the storage tank temperature. For overheat protection, the pumps are shut off when the solar storage tank water temperature exceeds 200°F (93°C). Backup protection is provided by a high-temperature limit switch that shuts off both pumps if water in the storage tank exceeds 205°F (96°C).

As part of the review, the contractor should also find out the purpose of the project (e.g., maximize cost-effective energy savings, provide a showpiece demonstration project, etc.) and the underlying design assumptions (e.g., why a drainback system, why multiple tanks used for storage, etc.).

2.2 REVIEW DESIGN AND INSTALLATION DRAWINGS

The contractor reviews for completeness the design and installation drawings from the construction package.

Design and installation drawings for large solar system construction projects can be divided into five categories – general, architectural/civil, structural, mechanical, and electrical. The size and complexity of the project determine the number of drawings in each category. In a new building, the solar system (e.g., for structures) can be shown on the building drawings instead of on a separate sheet. For a small retrofit project, details for two or more solar system categories can be shown on the same sheet. Drawings that can be included in each category are listed in a checklist in Appendix A.

An equipment schedule may also be provided as a table on the system schematic or as part of the component specifications.

Be sure that all necessary drawings are present. There may be only two sheets (generally a piping and control schematic and a structural drawing) needed to present all this design information, or there may be ten. Generally, the structural drawing will have been prepared (or reviewed) and stamped by a professional engineer (PE). Note whether the drawings have been stamped by a PE where a stamp has been specified, and whether engineering calculations are provided.

The minimum information and detail to be provided by these drawings are indicated in the eight Drawing Review Checklists provided in Appendix B. These are:

1. System Schematic (liquid)
2. System Schematic (air)
3. Collector Layout and Installation
4. Collector Piping (liquid)
5. Collector Ducting (air)
6. Mechanical Layout and Piping (liquid)
7. Mechanical Layout and Ducting (air)
8. Controls, Instrumentation, and Electrical.

Select the applicable checklists and cross out any items in the checklists not applicable to your system.

Review a complete set of drawings, using these modified drawing review checklists, to determine whether all the information you will need to bid and install the system has been included. Note any questions for the site survey to follow.

2.3 REVIEW CONSTRUCTION SPECIFICATIONS

Information that cannot be easily or explicitly included on design and installation drawings must be described in the construction specifications. This information is usually divided into various categorical subsections, such as mechanical, electrical, concrete, painting, etc. The Construction Specification Institute (CSI) format often is followed. Typical information that can be described in its various subsections includes:

- Part 1 – General
  - Scope
  - Standard tests and performances
  - Related work
  - Definition
- Part 2 – Product
  - Overall description
  - Physical description
  - Material requirements and limitations
  - Environmental conditions
  - Operational conditions
  - Operational performance
  - Special requirements (codes, standards, tests, etc.)
  - Warranty
- Part 3 – Execution
  - General requirements
  - Special conditions
  - Handling and storage
  - Applicable codes and standards
  - Workmanship
  - Inspection and tests
  - Finishing
  - Personnel training requirements.

Construction specifications may consist solely of CSI Section 13980: Solar Energy Systems, with "General," "Materials," and "Execution" subsections, or may be in a form similar to the example construction specifications in Appendix 4B of the ***Design Manual***.

The contractor should review the construction specifications, in conjunction with the design and installation drawings and manufacturers' literature and specifications, to determine whether all the information needed to bid, install, and check out the system has been provided.

Note, in particular, the following items in the construction specifications:

- Applicable codes and other publications.

  Note: Subsection 3.0 of Section 01000 of the sample construction specifications (***Design Manual*** pp. 4B-5 to 4B-7) includes most, if not all, of the codes and publications with which you are likely to be asked to comply.

- The scope of the work and what is included and not included, especially regarding other trades.

  Note: As solar systems are a relatively new specialty, one or more of the contractors performing work related to yours may have no solar experience.

- Restrictions on and modifications of your standard work procedures.

- "Materials" and "Execution" different from your standard work experience.

- "Materials" and "Execution" that do not correspond to what is shown in the design and installation drawings or that cannot be done.

- Safety requirements (e.g., see p. 4A-16 of the sample installation checkout procedure in the ***Design Manual***).

- "Inspections and Tests-" This subsection should include the required installation checkout procedure. (See Section 7.0 of this manual.)

2.4 REVIEW COMPONENT SPECIFICATIONS

During the design process, the designer determined the physical parameters and performance characteristics required of each major component in the solar system and prepared component specifications listing the critical data. (Sample component specification worksheets for most solar components are included in Table 4-1 [liquid] and Table 4-2 [air] of the ***Design Manual***.) Components specified are given in the equipment schedule. If there is no equipment schedule provided, prepare one by doing a material takeoff from the drawings.

Review the component specifications to determine the following:

a. Is there a specification for each component on the equipment list?

   See component specification checklists 1 (Liquid) and 2 (Air)in Appendix C. If any components were not specified, check with the designer. A typical component specification sheet is included in Appendix C.

b. Do the component specifications list a specific manufacturer and model or do they list physical parameters and performance characteristics?

If a specific component manufacturer and model are listed:

- Can you get it? If not, are adequate specifications provided, in addition to the manufacturer's name and model, for you to get an equivalent? Is the use of an "equal" model permitted?
- Has it been approved by the local building department?
- Is there a clearly better alternative available (higher performance and lower maintenance at an equal or lower cost)?
- If any changes are necessary, see Section 3.0.

If you are given only physical/performance data:

- Be aware that more work is involved on your part and the bid process will take longer than if the designer has listed specific manufacturers and models.
- Determine whether enough data are given for you to select and order a component that will meet the specified performance; notify the designer of missing or insufficient data.
- Determine whether the components you typically use for a similiar application comply with the specifications.

  Like other types of mechanical systems, one solar water heating installation, for example, may use similar components as another solar water heating installation. After a short time in the industry, you will know which manufacturers' makes and models are the best choices for each component. Collect manufacturers' literature and other data on each of these components and keep it together in a solar component manual. Record your experience with the use of these components and your "standard" component probably will fit the component specification.
- Consult with your suppliers– they generally have in-house personnel who can recommend an appropriate product. With respect to the major solar components (collectors and controls), however, it is sometimes quicker and more reliable to work directly with the manufacturer's in-house technical personnel or a manufacturer's representative.

  Note: There may be wholesalers in your area who specialize in solar energy equipment. If so, use them.
- Be sure that the components you choose will be approved by the local building department. (Sometimes building departments require special submittals or approvals for solar components because they are unfamiliar with the component or its use in a solar energy system.)

- Select and list your component choices and send them to the designer for approval.

- If possible, use collectors and tanks from local manufacturers, all other things being equal.

2.5 REVIEW OPERATION AND MAINTENANCE MANUAL

The construction package should also include an Operation and Maintenance manual (O&M manual) prepared by the designer for the specific system. If this manual has not been prepared, or if the installation contractor is required by that contract to write the O&M manual, refer to the guidance manual published by ASHRAE.*

The "operation" section should include a complete procedure for empty system filling, initial pressurization of closed loops, automatic (normal) startup, operation and shutdown, manual operation, and emergency operation, using specific valve numbers and component identifications. Mode matrices should be used as applicable to describe the operation of controls. Emergency procedures should specify specific shutdown and recovery steps to be followed by system operators. Procedures for performance monitoring (short-term) and evaluation (long-term thermal performance) should be provided.

The "maintenance" section should include specific routine and corrective maintenance procedures to ensure reliable operation of the solar energy system and troubleshooting procedures and solutions to typical solar system problems with complete checklists (for example, see Appendix 2A of the ASHRAE guidance manual*) and manufacturers' recommendations.

The installation contractor will be required to fill in any gaps in the O&M manual where the designer did not list specific component manufacturers or model numbers. The contractor will also provide "as-builts" for the O&M manual (see Section 10). If the contractor is required to provide any training to operation/maintenance personnel, the designer should have noted that in the O&M manual.

2.6 SURVEY THE SITE

If it is an existing building, walk through the entire system.

If it is a new building, "walk through" the installation on paper.

Based on a review of the construction package, determine whether the system can be installed, as designed and specified, in the space allocated to it in the building. Gather the information needed to bid and install the system. Use the Site Survey Checklist in Appendix D as a guide and a record so that critical information is not omitted.

Note, in general:

- Is the existing building constructed as shown on the drawings you reviewed, especially the roof structure and areas indicated for location of the collectors and tank/pebble bed?

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* ***Guidance for Preparing Active Solar Heating Systems Operation and Maintenance Manuals***, 1990, ISBNO-0-910110-72-7.

- Can the specified components be installed in the space allowed?
- Can the system be laid out as shown?
- What tools and equipment will be required for handling and installation during each aspect of the job?
- What is the safest and most cost-effective way to install the specified system?
- Is the required electrical power available and accessible?
- Is the interconnection with load and auxiliary heating equipment feasible?
- How much personnel coordination will be required?
    - For an existing building: Note the coordination required with building occupants, the plant manager, and the owner regarding interruption of service and access to the site and equipment.
    - For a new building: Note the coordination required with other trades during construction.

Note, in particular, the following critical aspects of the installation where problems have often arisen with respect to solar heating systems.

- Possible interference of existing structures with grading and foundation work required for the new system.
- Type and condition of roof.
    - Is reroofing necassary.
    - Roof is prestressed concrete and no accurate plans showing cable locations are available, requiring roof to be x-rayed to find cables.
- Access to roof framing.
    - There is no access to framing, requiring holes to be cut in the roof to see what is there.
    - Specifications call for through-bolting and there is no access to rafters.
- Collector layout.
    - Collectors fit on roof, but there no room for staging.
    - Collectors won't fit on roof without self-shading.

- Collector layout blocks access to fire escape or other roof-mounted equipment.
- Roof slopes in opposite direction from required piping slope.

- Access for delivery trucks and cranes.
  - Overhead wires prevent use of crane.
  - Concrete truck cannot get to tank footing, so pumper must be used.
  - Delivery truck with tank can't get through narrow alley to tank location at rear of building.
  - Doorways are too narrow or ceilings too low enroute to tank location inside the building.

- Pipe/duct runs from collectors to storage to load.
  - A vertical pipe run up the side of a 10-story building could be easily installed from an existing fire escape.

If any problems are noted, or changes required in the design, because of this site survey, contact the designer for resolution (see Section 3).

Note: If the project calls for a design/build contract, a site survey will have been made **before** design started to gather the information needed to design, specify, bid, and install the system, using the site survey checklist of Appendix D. The installation contractor should repeat this site survey before construction starts to pick up any building changes.