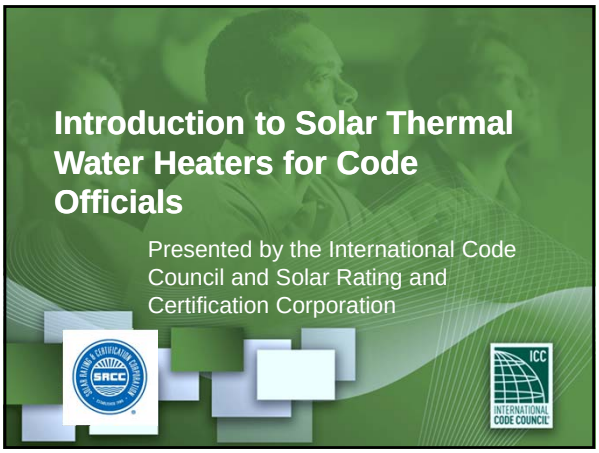

Accreditation

IACET
The Standard for Lifelong Learning

- The International Code Council has been accredited as an Authorized Provider by the International Association for Continuing Education and Training (IACET).
  - As a result of their Authorized Provider accreditation status, ICC is authorized to offer IACET CEUs for its programs that qualify under the ANSI/IACET Standard.
- You will obtain full CEUs for this course, if you actively participate in the training activities and stay for the entire session. Evidence of this will be the sign out sheet.

2

Description

- This seminar is designed to provide a basic introduction to solar water heaters, geared to code officials and inspectors.
  - Participants will gain a foundational knowledge of these systems and the relevant codes and standards.
  - Presentation material will provide real-world examples of installations with areas where code officials should focus.
  - Unique requirements in SRCC standards will be covered.

3

Objectives

- Upon completion, participants will be better able to:
  - List the basic function and components of a solar water heater.
  - Describe the main types of solar thermal systems.
  - Locate solar thermal provisions in the I-Codes and common inspection issues with these systems.
  - Describe the role and use of SRCC design and product standards

4

Prerequisite information

- The participant should have basic knowledge of:
  - General code enforcement principles
  - Working knowledge of the International Building Code, International Residential Code, International Mechanical Code and International Plumbing Code.
  - Water heaters, piping, fittings, joining methods, backflow prevention, cross connection control
  - Plan review and the use of design standards

5

Instructors

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Solar Rating & Certification Corp.

Shawn Martin
Director of PMG Activities
International Code Council

6

Module #1

Introduction to Solar Water Heater Systems and Technology

Introduction to Solar Water Heaters 7

FAQ about Solar Water Heaters

- How does it work?
- What are the different types?
  - Which one works better?
  - How do I determine which one is best for me?
- What subsidies are available?
- What is the difference between solar thermal and solar PV
- Are solar water heaters appropriate for use in all climates? Do they work in the winter?
- Where can solar collectors be mounted?
- What direction should solar collectors face?
- How much do these systems cost?
- How big are the solar thermal collectors? Will they cover the roof of a single family home?
- How long will the collectors last?
- What happens when the roof material itself needs to be replaced?
- What items on a solar thermal system require maintenance?

Solar Water Heating Applications

- Pool and spa heating
- Domestic water heating
- Space heating
- Combination domestic/space heating
- Snow melting systems
- Industrial processes

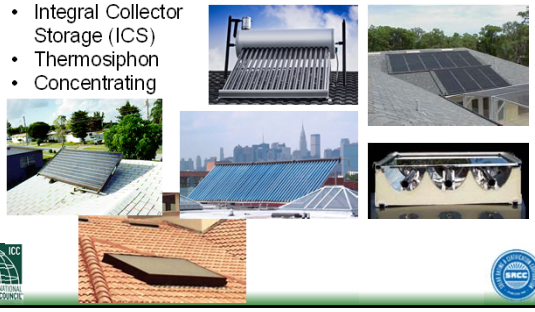
Wide Range of Sizes

Wide Range of Configurations

SOLAR WATER HEATING COLLECTORS, SYSTEM TYPES AND COMPONENTS

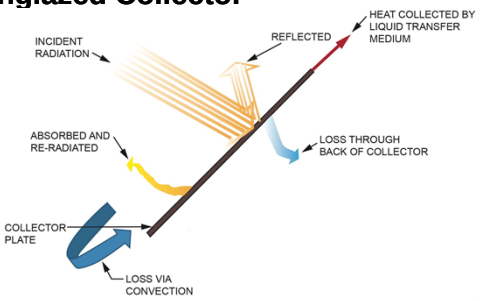
Solar Thermal Collectors

- Flat Plate – glazed and unglazed
- Tubular
- Integral Collector Storage (ICS)
- Thermosiphon
- Concentrating



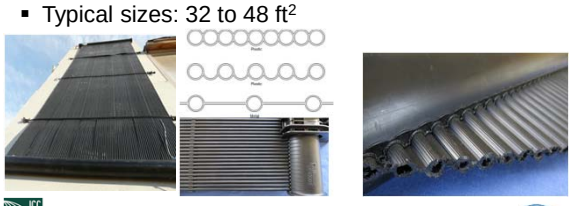
Solar Heating Mechanism Basics

Unglazed Collector



Unglazed Collector

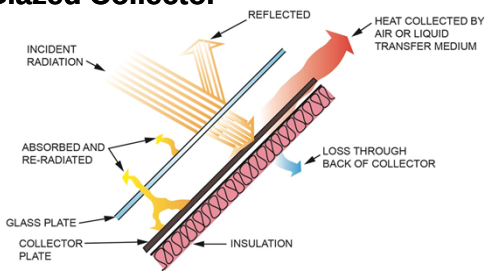
- Converts solar radiation to heat energy
- Operates close to ambient air temperature
- Maximum temperature 30°F above ambient
- Typical sizes: 32 to 48 ft^2



Unglazed Collector

Solar Heating Mechanism Basics

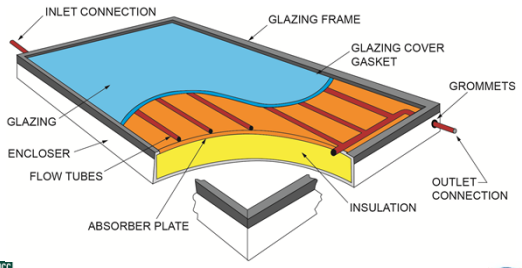
Glazed Collector



Flat Plate Collector

- Converts Solar Radiation to Heat Energy
- Hot box (greenhouse effect)
  - Car with windows up in summer
- Temperatures can exceed 350°F in stagnant collector (no flow)
- Commonly used in warm climates
- Typical sizes: 21 to 48 ft^2

Flat Plate Collector Components

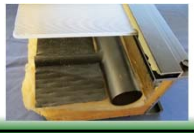


Flat Plate Collector: Enclosure

- Box or frame that holds all components together
  - Well-sealed, but vented
- Environmental durability
- Structural characteristics
  - Wind loads, local codes
- Typical materials:
  - Aluminum
  - Steel, Stainless Steel
  - Fiberglass
  - Copper

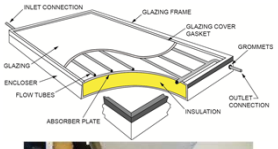
Flat Plate Collector: Glazing

- Usually glass (low-iron) – also sheet and film polymers
- Allows sun's rays to pass to absorber
  - Pass as short waves – heat re-radiates as long wave and prevented from passing back out by glazing
- Blocks air motion across collector – reduces heat loss from convection
- Frame attaches glazing to the enclosure
- Glazing gasket prevents leakage and allows for contraction and expansion



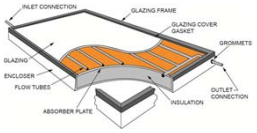
Flat Plate Collector: Insulation

- Placed between absorber and surfaces absorber touches to prevent heat loss by conduction
  - Reduces heat loss from the enclosure
  - Must withstand very high temperatures
  - High temperature binders
  - Closed cell foam
- Evacuated tubes use vacuum as insulator



Flat Plate Collector: Absorber

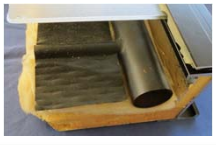
- Absorbs and transfers high levels of solar energy
- Flat metal surface inside the enclosure
- Black Coating:
  - Non-selective: absorptivity = emissivity ~ 95%
  - Selective coating for higher temperatures

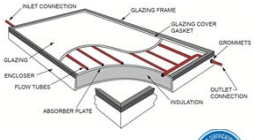


- High absorptivity (~ 96%)
- Low emissivity (~ 5 %)
- Increases collection by preventing heat from re-radiating from the absorber

Flat Plate Collector: Flow Tubes

- Fluid flows through flow tubes, Heat transfers from absorber to fluid
- Conductive metal tubes attached to the absorber
- OD and ID vary - ~3/8" to ½"
- Remove heat from the absorber
- Headers – inlet and outlet tubes, Larger diameter than riser tubes – ~ ¾"



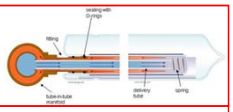


Evacuated Tube Collector

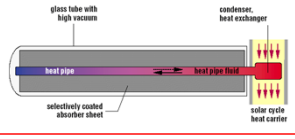
- Cylindrical glazing protects absorber
- Absorber surrounded by vacuum to reduce loss
- Temperatures can exceed 450ºF with no flow
- Used in cold climates or for high temperatures
- Typical sizes: 20 to 60 tubes

Tubular Flow Configurations

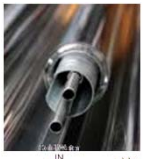
- Flooded

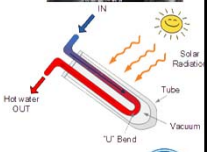


- Heat pipe

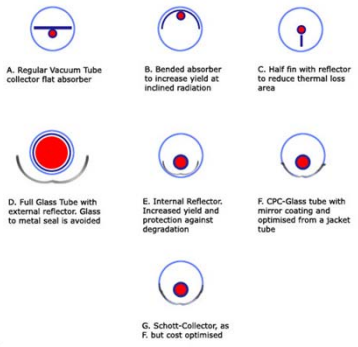


U-tube





Position Within Tube

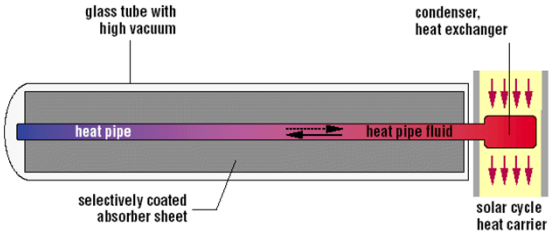


Failed Tube (lost vacuum)

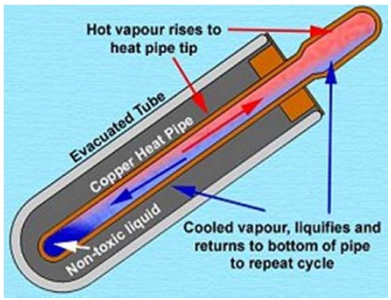
"Heat Pipe" Collector

- Absorber tube is sealed at both ends to create a closed chamber that can be evacuated
- Chamber is filled with a fluid that evaporates at collector operating temperature
- Vapor rises to top of tube to a heat exchanger
- Transfers heat to water in a manifold
- Condensed heat collection fluid then returns by gravity to bottom of the tube
- Starts over again

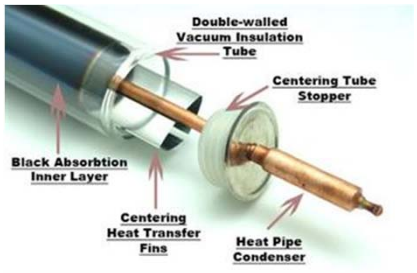
Heat Pipe



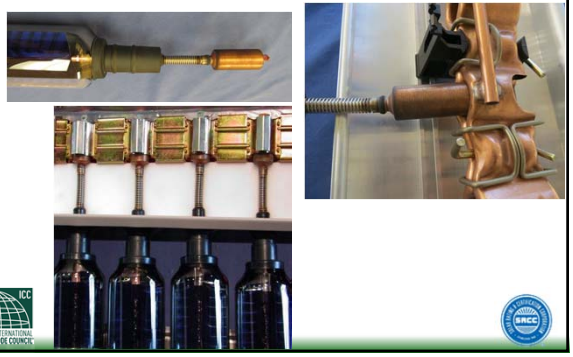
Heat Pipe Operation



Evacuated Tube with Heat Pipe



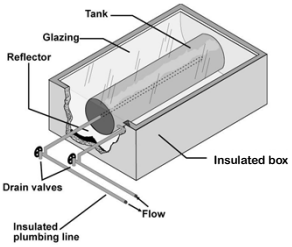
Condenser Inserted in Header

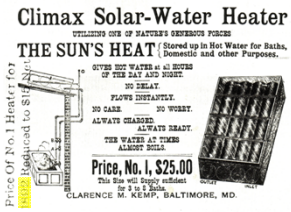


Evacuated Tube Collector

Integral Collector Storage Concept

- aka: Breadbox, Batch Heater, Tank-in-a-box

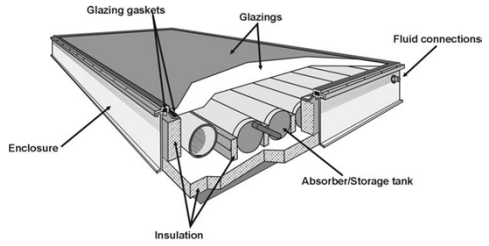




Integral Collector Storage (ICS)

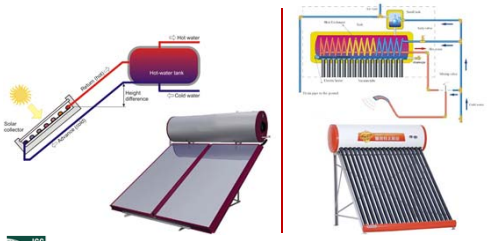
- Combines collector and storage in one unit
- Very simple design – can be homemade or factory built
  - No moving parts - extension of plumbing system
- Uses tanks or large tubes within the collector unit
- Larger and heavier than flat plate collectors
- Internal materials are generally the same as flat plate collectors
- Incorporate 4” diameter tubes or large tanks
- Tanks coated with selective or moderately selective absorber coatings
- Multiple glazings to reduce heat loss
  - Glass and plastic

Modern ICS

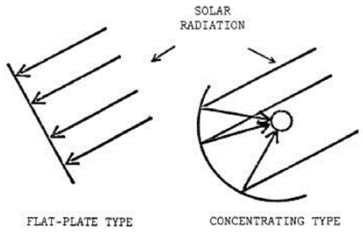


Thermosiphon Collector

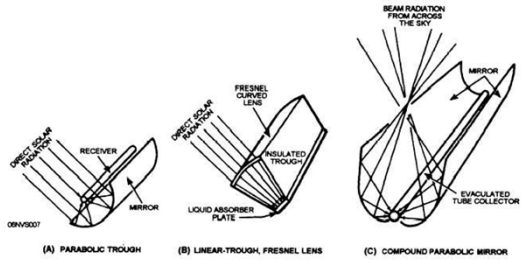
- Natural convection resulting from buoyancy
- Integrates storage with collection



Concentrating Collector



Concentrating Mechanisms



(A) PARABOLIC TROUGH (B) LINEAR-TROUGH, FRESNEL LENS (C) COMPOUND PARABOLIC MIRROR

Concentrating Mechanisms

Parabolic Mirror

Fresnel Lens

Compound Parabolic

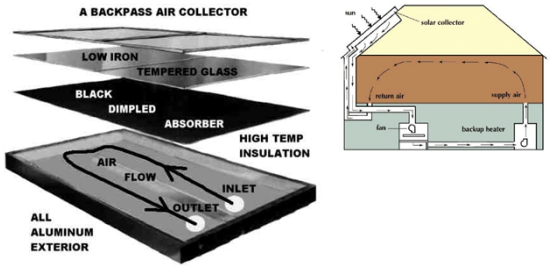
Concentrating Collectors

- Non-tracking:
- Tracking:

Air-Heating Collectors

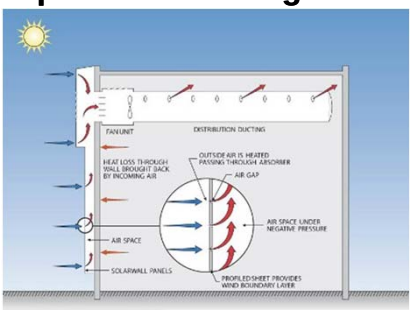
- Conventional flat plate collectors
  - Space heating
  - Water heating
- Transpired collectors
  - Space heating

Conventional Air-Heating Collector



Air-Heating Collectors

Transpired Air-Heating Collector



Transpired Collector Installations

Solar Water Heating Systems

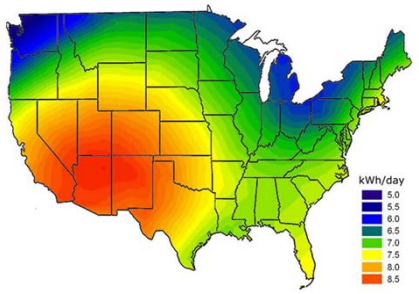
Passive

Direct

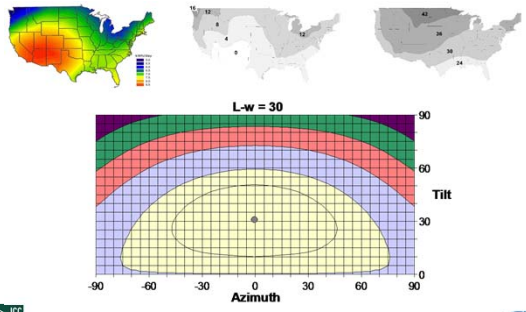
Active

Indirect

Solar Resources



Orientation



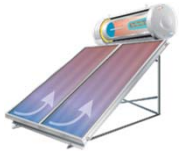
Solar Water Heaters

- Active
  - Direct Active
  - Indirect Active
- Passive
  - Direct Passive
  - Indirect Passive

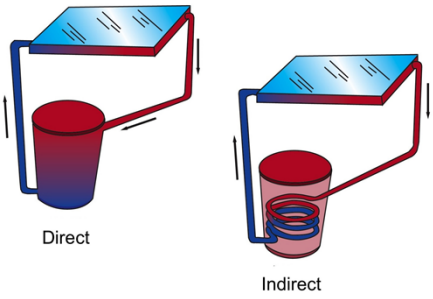
Circulation Types

Distinguished by mechanism used to circulate water through the system:

- ACTIVE
  - Uses one or more pumps
- PASSIVE
  - Uses natural convection via gravity and density



System Heating Categories

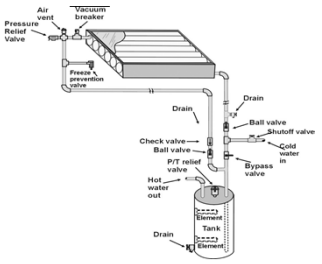


Passive Direct and Indirect Systems

- Passive systems use no pump or controller
- Rely on convection
  - Moves water between collector and storage tank in thermosiphon system
  - Stratify heated water within an ICS system
- Most passive systems are direct
  - Thermosiphon, ICS
- A few incorporate a heat exchanger
  - Thermosiphon (mantle type)

Integral Collector Storage (ICS)

- Pre-heater: feeds solar heated water to conventional water heater
- ICS are plumbed to an auxiliary back up (gas or electric)
- Minimal components – no moving parts: a few valves (pressure, isolation, drain)
- Warm climate or seasonal system



Commercial ICS Systems

Thermosiphon System

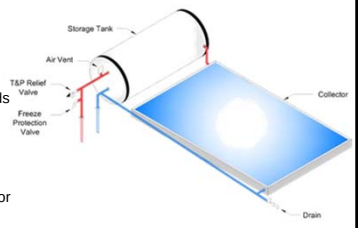
Thermosiphon System Components

Water storage is above the collector

Cold water from bottom of thermosiphon storage tank flows through a pipe to bottom of collector

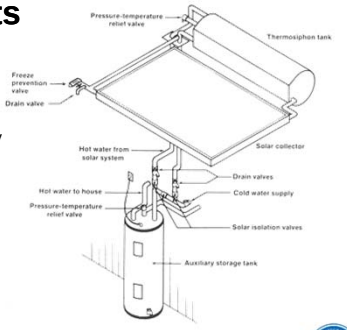
Heated water in collector expands and becomes lighter than cold water

Heavier, denser cold water from tank falls down to the inlet of the collector and pushes the lighter, heated water through the collector outlet and into the top half of the storage tank

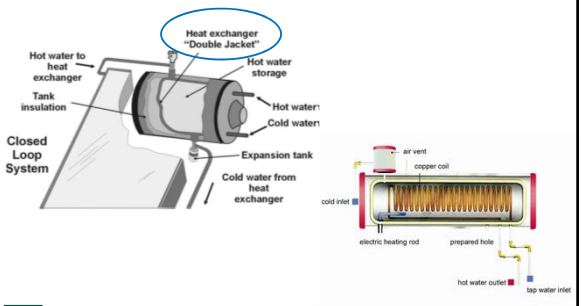


Thermosiphon System Components

- Process continues throughout the day
- Heated water in the thermosiphon tank is moved to the auxiliary tank when a faucet or shower is opened
- Backup heating by electric element in thermosiphon tank or electric or gas in auxiliary storage tank



Indirect Thermosiphon System

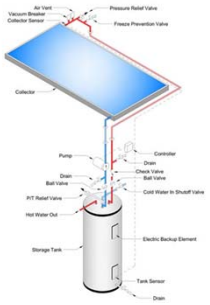


Tubular Thermosiphon System

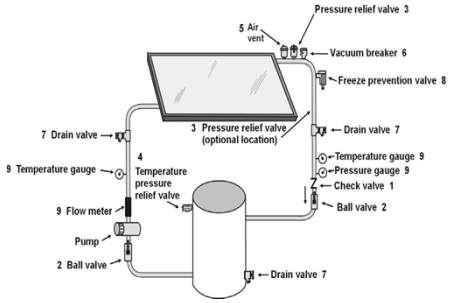
Active Direct Systems

Freeze protection

Pump control strategies:
- Differential
- Photovoltaic

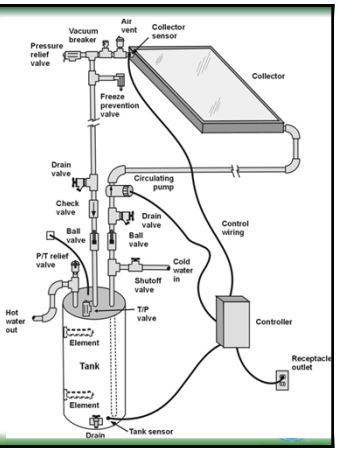


Active Direct System Components



Active System Differential Temperature Control

- Controller is constantly comparing two sensor temperatures
- Water circulates only when sufficient solar energy is available to increase the water temperature
- Circulation pump operates when sensors located at top of collector (hot) and bottom of tank (cold) indicate a 15ºF temperature difference
- Pumps shuts off when temperature difference is 4ºF



Active Direct System Freeze Protection

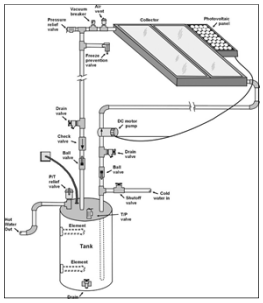
Differential Control

- Recirculation
  - Freeze sensor actuates the pump
  - Water is circulated through the collectors
  - Continuous action (on/off) during freeze conditions
  - Requires power
- Freeze prevention valve
  - Allows flow through the collector during freezing conditions
  - Requires water pressure
  - Backup for recirculation freeze protection
- Manual draining
  - Piping must slope to drain
  - Requires owner action

Active System Photovoltaic Control

- A photovoltaic (PV) module is used to regulate pump operation
- PV module generates power for a DC pump to circulate water through the collector and back to storage tank
  - Pump speed is proportional to solar radiation level
- PV module and pump must be matched properly
  - Pump operates when sufficient solar energy is available for heating water
  - Stops when sun goes down or behind clouds

Active Direct System
Photovoltaic Control

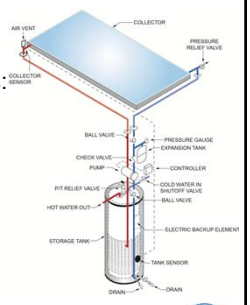


Active System
Photovoltaic Control

- **Freeze Protection Options**
- Freeze prevention valve
  - Allow flow through the collector during freezing conditions
- Manual draining

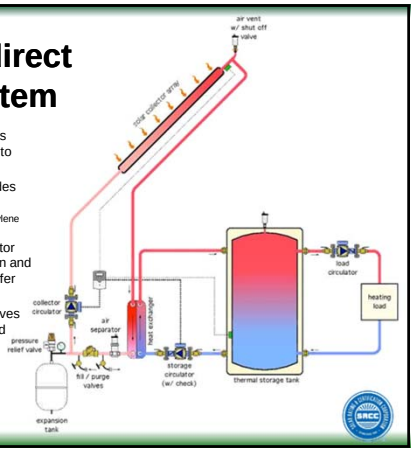
Active Indirect System

- Heat exchanger separates solar loop from potable
- Heat exchanger configurations:
  - External (2 pumps)
  - Wrapped around tank (1 pump)
  - Coil inside tank (1 pump)
- Fluid loop configurations:
  - Filled
  - Drain-back



Active Indirect Filled System

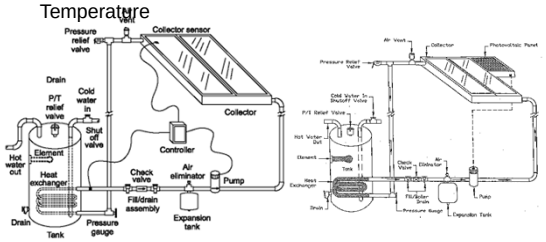
- Heat exchanger transfers heat from the solar loop to the water loop
- Heat transfer fluid provides freeze protection
  - mixture of water and propylene glycol
- Expansion tank in collector loop allows for expansion and contraction of heat transfer fluid
- Specific fill and drain valves required for charging and servicing the system



Active Indirect Filled System Controller

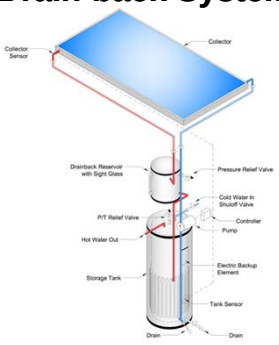
Differential Temperature

PV module



Active Indirect Drain-back System

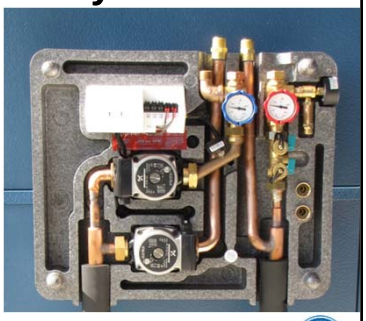
- Fluid in collector loop drains back to a separate tank when pump is turned off by controller
  - Uses gravity
  - Provides freeze protection
  - High-temperature limit protection
- Drain-back tank in conditioned (warm) space
- Water typically used in collector loop



Active Indirect Drain-back System

- Drain-back tank - Sized to hold all fluid in collectors and exposed pipe
- Sight glass to view fluid level
  - Flow meter can also be used
- Fixed volume of air and fluid that does not require air vent, expansion tank, or check valve
- Pump must be sized to overcome a head created by gravity plus friction losses
  - Must lift water from the bottom of the drain-back reservoir to the top of the collector

Active Indirect System

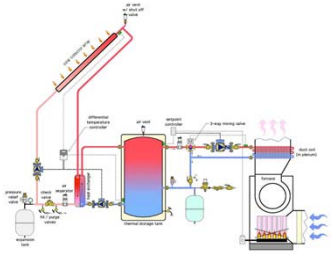


Maintenance Considerations

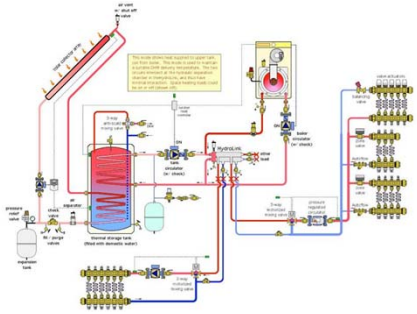
- Active
  - Pumps (bearings, seals)
  - Control sensors (sensor/PV failure, wire damage, lightning strikes)
  - Valves (air vent, P and P&T, freeze)
  - Fluid - indirect systems (pH, viscosity)
- Passive
  - Fluid - indirect systems (pH, viscosity)

Combined Hot Water & Space Heating Systems (Combi Systems)

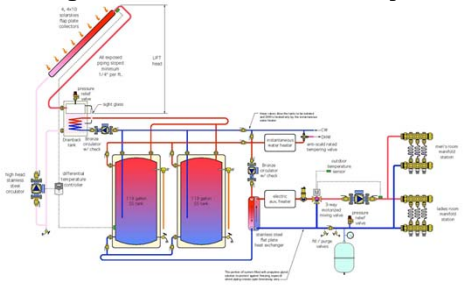
- Forced Air Heating



Combi-systems – Hydronic heating



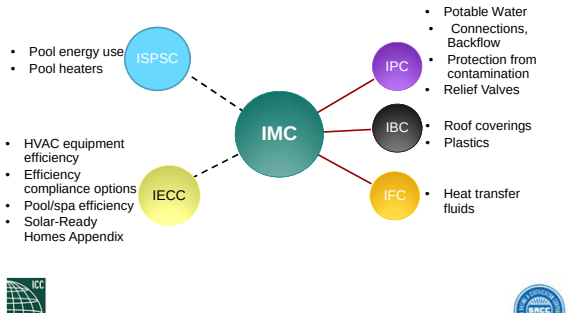
Combi-systems – Hydronic heating with a drain-back system



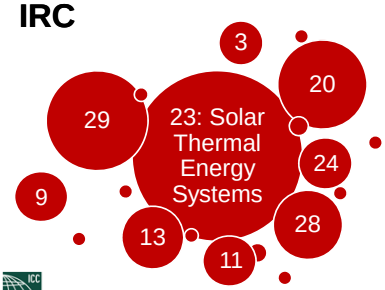
Module #2

Codes and Standards for Solar Water Heating Systems

Solar Thermal in the 2015 I-Codes: Commercial Systems



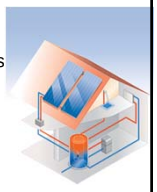
Solar Thermal in the Chapters of the 2015 IRC



Chapters and Sections
3: Building Planning
9: Roof Assemblies
11: [RE] Energy Efficiency
13: General Mechanical System Requirements
20: Boilers & Water Heaters
24: Fuel Gas
28: Water Heaters
29: Water Supply & Distribution
Part VIII - Electrical

SRCC Solar Thermal Standards

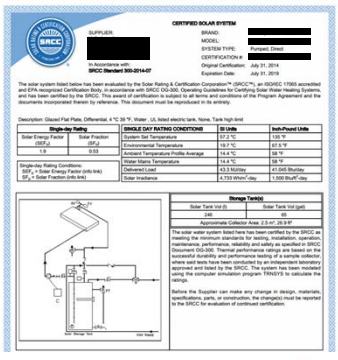
- IRC 2015 References SRCC standards
  - SRCC Standard 100-2013 – Solar Collectors
  - SRCC Standard 300-2013 – Solar Water Heating Systems
  - SRCC Standard 600-2013 – Solar Concentrating Collectors
- New ICC/SRCC standards under development through ICC's ANSI-approved process



Using Systems Certified to SRCC 300

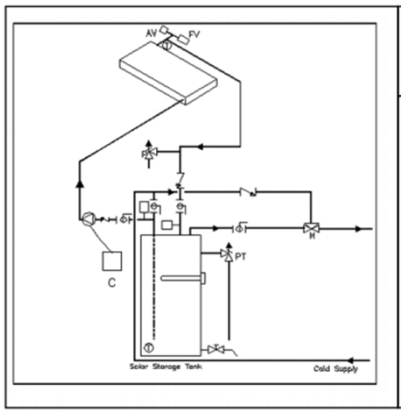
- Verify that the system is installed per design:
  - Compare the installed piping configuration with the one provided by the certifier
  - Installation sections in SRCC 300
- Download the SRCC certificate and standard on the SRCC website: http://www.solar-rating.org/

Example: SRCC 300 Certification



Common Schematic Symbols

—	Plumbing*		Heat Exchanger
	Ball Valve		Coiled Heat Exchanger*
	Three-Way Ball Valve*		Wrap Around Heat Exchanger*
	Gate Valve		Pressure Gauge/Cock*
	Three-Way Gate Valve		Pump
	Tempering Valve*	DB	Drain Back Tank*
	Check Valve	EX	Expansion Tank*
	Pressure Regulator Valve		Liquid Storage Tank*
	Pressure Relief Valve *		Thermometer
	Temperature Relief Valve*	TW	Thermometer Well
P/T	P/T Relief Valve*	C	Electrical Controller*
	Expansion Valve		Temperature Sensor*
	Freeze Valve		Dip Tube*
AV	Automatic Air Vent		Electric Heating Coil*
VB	Vacuum Breaker		Shut-Off and By-Pass Valve Assembly*
	Flow Meter		Strainer
	Drain Down Valve		



Incentive and Rebate Programs

- Performance ratings are provided by some product certifiers and required by many incentive programs in most states.
  - Federal IRS Incentive Tax Credit
  - California Solar Initiative
  - Massachusetts Commonwealth Solar Hot Water
  - New York Solar Thermal Incentive Program
- DSIRE Database provides good source of information

Module #3

Inspecting Solar Water Heating Systems to the 2015 I-Codes

Key Learning Topics

- Access
- Potable water protection
- Pressure and temperature control
- Protection of structure and equipment
- Installation of equipment
- Heat transfer fluids
- Labeling

Access

- Access is a fundamental concern with solar thermal systems.
  - Equipment and components require access for installation, servicing, maintenance.
  - Access must be preserved for emergency responders, especially on roofs
- Requirements differ significantly between residential (IRC) and commercial (IMC)

Access: General Residential

- IRC M1305.1: Access required for HVAC components and appliances for inspection , service, repair, replacement
  - 1305.1.2: Rooms
  - 1305.1.3: Attics
  - 1305.1.4: Under floors

M2301.2.1 Access. Solar energy collectors, controls, dampers, fans, blowers and pumps shall be accessible for inspection, maintenance, repair and replacement.

Rooftop Collector Access: Residential

Rooftop access points:
- IRC R324.7,
- IFC 605.11.1.1

IRC R324.7.1 Roof access points. Roof access points shall be located in areas that do not require the placement of ground ladders over openings such as windows or doors, and located at strong points of building construction in locations where the access point does not conflict with overhead obstructions such as tree limbs, wires or signs.

Access: General Commercial

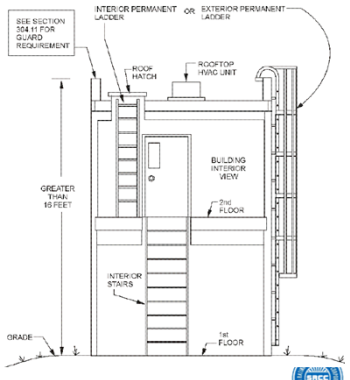
- **IMC 306.1**: Access required for HVAC components and appliances for inspection , service, repair, replacement
  - 306.2: Rooms
  - 306.3: Attics
  - 306.4: Under floors
  - 306.5: Roofs or elevated structures

IMC 1402.1 Access. Access shall be provided to solar energy *equipment* and appliances for maintenance. Solar systems and appurtenances shall not obstruct or interfere with the operation of any doors, windows or other building components requiring operation or access.

Access for Roof-Mounted Equipment: Commercial

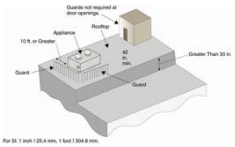
- **IMC 306.5 – Equipment and appliances on roofs or elevated structures**
  - Intends to prevent portable ladders from being the only means of access to equipment ≥ 16' above grade or roof surface.
  - Addresses permanent ladders and catwalks
  - Prohibits walking on slope > 4/12 (33%) or over obstructions > 30" (without a ladder)

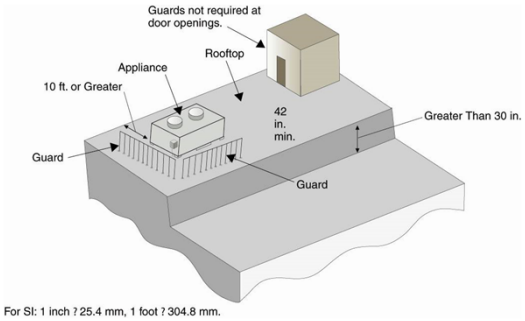
This means that just about every two story building with roof-mounted equipment or appliances will require a permanent means of access.



Access for Roof-Mounted Equipment: Commercial

- **IMC 304.11 – Guards**
  - Protection for personnel servicing rooftop equipment
  - Applies within 10' of a roof edge or surface ≥ 30" above a lower surface





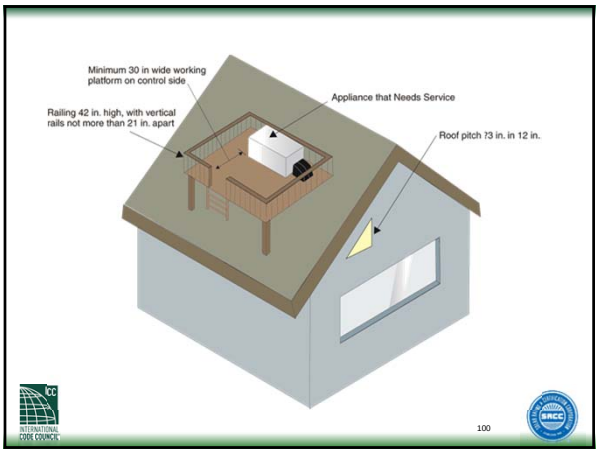
Fall-Arresting Restraint Systems

- **IMC 304.11 Fall Arresting Systems**
  - Exception allows for fall-arresting restraint systems to be employed instead of guards on roofs.
  - Roofs with slope ≤ 3/12 (25%)
  - ANSI/ASSE Z 359.1 systems
  - 10' maximum spacing

NEW for 2015!

Service Platforms for Roof-Mounted Equipment: Commercial

- IMC 306.5.1 – Sloped roofs
  - Level platform required on each side of roof-mounted equipment
    - > 30" size in any direction, with > 42" guards
  - For roofs with slope > 3/12 (25%) with an edge > 30" above grade



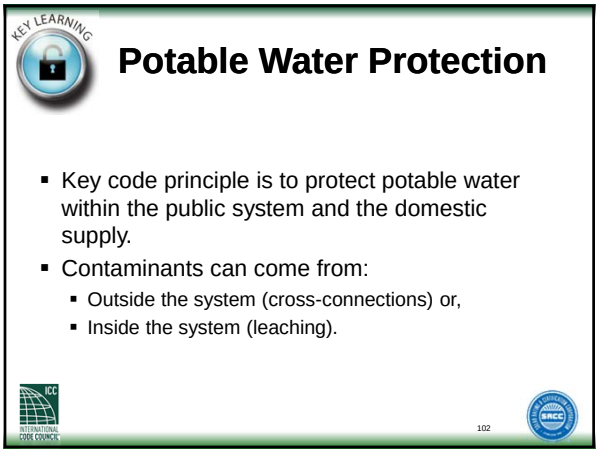
Proximity to other Roof-Mounted Equipment

Ensure that the operation critical roof-mounted components is not impeded by solar collectors.

- Fire dampers
- Smoke vents
- Chimneys
- Plumbing vents
- Doors, windows

IMC 1402.1 Access. ... Solar systems and appurtenances shall not obstruct or interfere with the operation of any doors, windows or other building components requiring operation or access.

IECC Appendix RB103.4 Obstructions. Solar-ready zones shall be free from obstructions, including but not limited to vents, chimneys, and roof-mounted equipment.



What are Cross-Connections?

2015 IPC Definition

CROSS CONNECTION. Any physical connection or arrangement between two otherwise separate piping systems, one of which contains potable water and the other either water of unknown or questionable safety or steam, gas or chemical, whereby there exists the possibility for flow from one system to the other, with the direction of flow depending on the pressure differential between the two systems (see "Backflow").

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Where is there a potential for cross-connections in SWH systems?

- Makeup water valves

- Heat exchangers

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Supply/Makeup Cross-Connection Control

IRC

- Potable supply connection requirements differ for direct/indirect systems in P2902.5.5
  - Indirect: Direct connection to solar loop prohibited
  - Direct:
    - Potable: Connection permitted per Chapter 29.
    - Non-potable: Connection only with ASSE 1012 or 1013 backflow prevention assembly.

IMC

- Requires protection per the IPC in 1401.2.
- No cross-connection protection required where:
  - Part of potable water distribution system
  - All components are listed for potable water use.

Backflow Preventers

- Used to control contamination of public or domestic potable water systems.

IRC P2902.5.5.3 Direct systems for other than potable water distribution systems. ASSE 1012 (potable) or ASSE 1013 (chemically treated water) backflow preventers required.

IPC 608.6 Cross connection control. Cross connections shall be prohibited, except where *approved* backflow prevention assemblies, backflow prevention devices or other means or methods are installed to protect the potable water supply.

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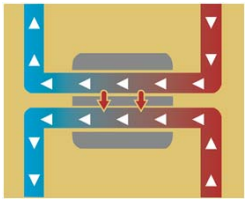
Heat Exchangers - Defined



SRCC 300 -2013 Definition

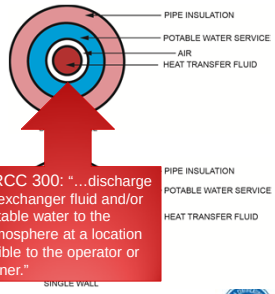
Double Wall Heat Exchanger - A heat exchanger design in which a single failure of any fluid barrier will not cause a cross connection or permit back siphonage of heat transfer fluid into the potable water system.

IMC Definition

Heat Exchanger. A device that transfers heat from one medium to another.

Heat Exchanger Cross-Connection Control

- **1401.3 Heat exchangers** …The system shall have adequate protection to ensure that the potability of the water supply and distribution system is properly safeguarded.
- **IPC 608.16.3, SRCC 300** requires double-wall heat exchangers for where toxic heat transfer fluids are used in Section 6.1.3.6.



SRCC 300: "…discharge of exchanger fluid and/or potable water to the atmosphere at a location visible to the operator or owner."

Contamination Through Leaching

- Materials in contact with potable water can release chemicals and compounds into that water leading to contamination.
- To control this, the codes rely on established standards that set out tests for materials to ensure that they do not contaminate potable water.

IPC 303.4 Third-party certification. All plumbing products and materials shall be listed by a third-party certification agency as complying with the referenced standards. Products and materials shall be identified in accordance with Section 303.1.

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NSF 61 in the IPC

- NSF 61 is cited in the IPC for components supplying drinking water to prevent contamination.
- NSF 61-2012 compliance required for:

- Faucets & fixture fittings (424.1)
- Water service pipe (605.3)
- Distribution pipe (605.4)
- Fittings (605.5)
- Ball, gate, globe valves (605.7)
- DWTU tubing (611.3)
- Fountains and coolers (410.1)

Note: Water heaters are not specifically required to be listed and labelled to NSF 61.

Lead in the IPC

NEW for 2015!

- Previous section on 8% lead remains.

*"**605.2 Lead content of water supply pipe and fittings.** Pipe and pipe fittings, including valves and faucets, utilized in the water supply system shall have a maximum of 8-percent lead content."*

- New section added to address Reduction of Lead in Drinking Water Act:

*"**605.2.1 Lead content of drinking water pipe and fittings.** Pipe, pipe fittings, joints, valves, faucets, and fixture fittings utilized to supply water for drinking or cooking purposes shall comply with NSF 372 and shall have a weighted average lead content of 0.25 percent lead or less."*

Pressure and Temperature Control

- Both pressure and temperature within the system must be controlled within appropriate ranges to prevent unsafe conditions or system damage.
  - Pressure
    - Excessive pressure
    - Vacuum
  - Temperature
    - Excessive temperature
    - Freeze protection

Temperature and Pressure Control

- Protection required in IRC M2301.2.3, IMC 1402.5
  - BUT, per SRCC 300 all solar loops (direct/indirect) should have no temperature relief valves

IMC 1402.5.1 Pressure and temperature. Solar energy system components containing pressurized fluids shall be protected against pressures and temperatures exceeding design limitations with a pressure and temperature relief valve.

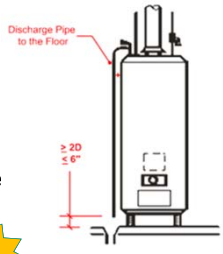
- Residential: Maximum temperature in the dwelling limited to 180°F (IRC M2301.2.12)

Temperature and Pressure Relief Valves

- Relief valve discharge: IRC P2804.5-7, IRC M2301.2.2.2, IMC 1402.5.1
  - Discharge may not be “a hazard or potential cause of damage”

Temperature and Pressure Relief Discharge Piping

- IPC 504.6: Relief valve discharge pipe termination must have a suitable air gap
  - 2012 IPC only limited the maximum height to 6”
  - 2015 IPC also limits the minimum height to > 2XD off the floor or waste receptor flood level rim



NEW for 2015!

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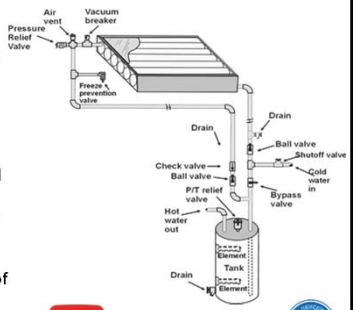
Combi Systems- Temp Control

- Thermostatic mixing valve required for combination domestic/space heating above 140ºF.
- IMC, IPC, SRCC 300: Master thermostatic mixing valve complying with ASSE 1017 shall be provided.

Pressure: Vacuum

- Negative pressures can develop in some system types, especially when draining volumes on the roof.
  - Air must be permitted to enter the system when drained or high vacuum levels can develop.
  - Can cause collapse of components.



2015 Template

YouTube

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Pressure: Vacuum Relief Valves

- Vacuum relief valve can be used to relieve negative pressures.

IRC M2301.2.4 Vacuum relief. System components that might be subjected to pressure drops below atmospheric pressure during operation or shutdown shall be protected by a vacuum-relief valve.

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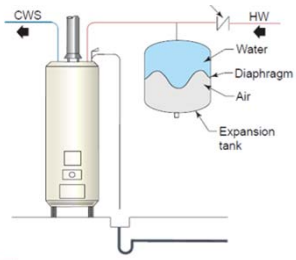
Pressure: Expansion Tanks



- Expansion tanks provisions in IRC M2301.2.8 – references SRCC 300.
  - Not required for drain-back systems in IRC
- Expansion tanks required in IMC 1402.5.4 (per Section 1009) for single-phase liquid systems.
  - Also required in IMC 607.3

Temperature: Freeze Protection

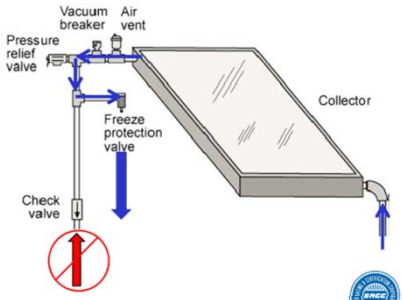
- Freeze protection is required for all systems except in non-freezing climates
  - Recirculation
  - Freeze protection valve
  - Drain-back
  - Indirect System (e.g. Propylene glycol)
- SRCC requires freeze protection described on a label

IRC M2301.2.6 Protection from freezing. System components shall be protected from damage resulting from freezing of heat-transfer liquids at the winter design temperature provided in Table R301.2(1). Freeze protection shall be provided by heating, insulation, thermal mass and heat transfer fluids with freeze points lower than the winter design temperature, heat tape or other *approved* methods, or combinations thereof.

Exception: Where the winter design temperature is greater than 32°F (0°C).

IMC 1402.5.3 Protection from freezing. System components shall be protected from damage by freezing of heat transfer liquids at the lowest ambient temperatures that will be encountered during the operation of the system.

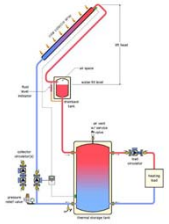
Freeze Protection Valves

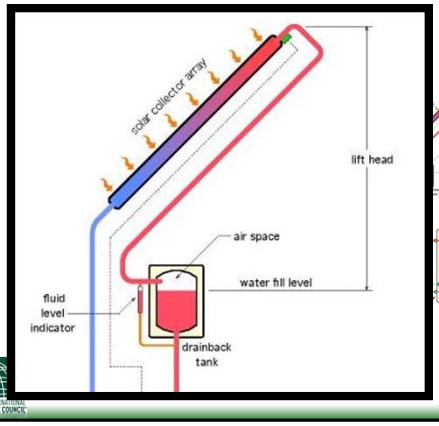


Freeze Protection – Drain-back Systems

- Allows fluid to drain to a tank within conditioned space when pump is not activated.
- Not required to have expansion tanks under IRC M2301.2.8
- May not drain to roof where rainwater harvesting – IRC P2912.2

2015 IRC: DRAIN-BACK SYSTEM. A solar thermal system in which the fluid in the solar collector loop is drained from the collector into a holding tank under prescribed circumstances.





Drain-back tanks

- May be closed or vented
- Needs a pressure relief valve,
  - Should not have a temperature relief valve.
- Should not have expansion tank per IRC M2301.2.8

Freeze Protection Draining Mistakes

For more information on freeze protection visit: http://www.solar-rating.org/facts/overheat_freeze_mechanisms.pdf

Protection of Structure

- **IMC Section 302**. Installation of mechanical systems must not adversely affect:
  - structural
  - fire-resistance
- Specific guidance on cutting, notching boring in 302.3 for wood, 302.5 for steel framing
- Alterations to trusses, engineered wood products prohibited in 302.4

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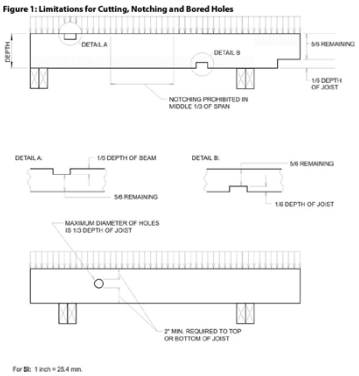
Wood Framing Notching and Boring - Joists

IMC 302.3

- Holes ≥ 2"of the top or bottom of the wood joist.



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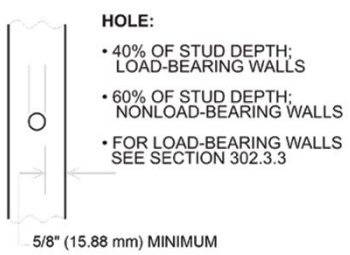
Wood Framing Notching and Boring - Studs

IMC 302.3

- Holes ≥ 5/8" from face of the stud.
- Bored holes should not be in same section as a cut or notch.
- Notches ≤ 25% of depth for load-bearing, ≤ 40% for non-load bearing.



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KEY LEARNING

Installation of Equipment

- To this point we've addressed the following topics:
  - Access
  - Potable water protection
  - Pressure and temperature control
  - Protection of structure and equipment
- These have touched on the installation of the equipment but only partially. The following section will fill in the gaps.

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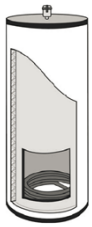
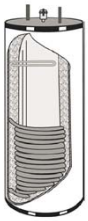
Heat Exchangers - Types



Internal Coil Type



Wrap-Around Type

Flat Plate Type

Heat Exchangers - Code

IRC M2301.4 Heat transfer gasses or liquids and heat exchangers.
…Heat exchangers used in solar thermal systems shall comply with Section P2902.5.2 and SRCC 300. …

IECC C403.2.3 requires plate-type liquid to liquid heat exchangers to be tested and certified to AHRI 400 for commercial applications

Collectors

- Prefabricated collectors can be considered a system component.
  - IRC M2301.3.1 requires solar thermal collectors to comply with SRCC Standard 100 or 600.
  - IMC 1404.1: Label must show manufacturer's name, model number, serial number, collector weight, max allowable temp and pressure, heat transfer fluids.
- Site-assembled collectors can also be design certified.
- Label provides certified performance rating.

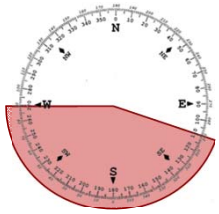
Photo by Joe Ryan, NREL 19690

Orientation

- Orientation of solar collectors plays a critical role in their performance, as noted earlier.
- Code, however, is interested primarily in health and safety, and says little about orientation for performance.
  - Local incentive programs (which are more concerned about performance) may have orientation and shading requirements.
  - Exceptions:
    - IECC Appendices on Solar-Ready Construction.
    - SRCC 300

Orientation – Solar-Ready Provisions

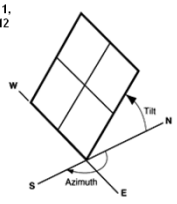
IECC RB 103.1



IECC Appendix RB - RB103.1 General. New detached one- and two-family dwellings, and multiple single-family dwellings (townhouses) with not less than 600 square feet (55.74 m^2) of roof area oriented between 110 degrees and 270 degrees of true north shall comply with Sections RB103.2 through RB103.8.
Exceptions:
1. New residential buildings with a permanently installed on-site renewable energy system.
2. A building with a solar-ready zone that is shaded for more than 70 percent of daylight hours annually.

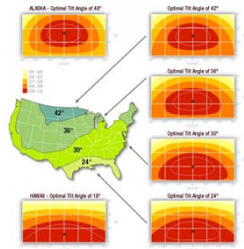
Orientation – SRCC 300

SRCC 300 305.11, 305.12



305.1.11 Tilt and azimuth. Collectors shall be installed on a mount capable of maintaining tilt and azimuth to design conditions.
305.1.12 Shading of collector. The location and orientation of collectors shall be such that they are not shaded by external obstructions or each other more than the specified period allowed in the design.

Tilt and Latitude



- Path of the sun varies with latitude and the time of year.
- Optimal tilt approximately equal to latitude

Introduction to Solar Water Heaters 136

Tilt – Snow Shedding

- Most collectors shed snow easily as they warm in the sun.
- Exception: Evacuated tube
  - Low thermal conductivity reduces heating
  - Added tilt, roofing separation may be needed
  - Follow manufacturer's recommendations.

Introduction to Solar Water Heaters 137

Shading

What are some potential sources of shading of solar collectors?

Preventing Entrapped Air

- Automatic for open loop (direct) circulating systems using potable water as the heat transfer fluid
- Manual or automatic for closed loop (indirect) systems
- Not required for integral collector storage (ICS) and open loop thermosiphon systems
- At high points of system and where air can accumulate

Common Automatic Air Vents

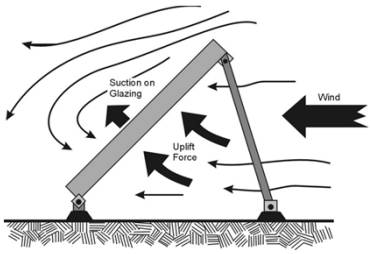
Air Vent Orientation

Air vents are typically required to be oriented true vertical – follow manufacturers' installation instructions.

Mounting Structures and Practices

IRC M2301.2.2.1 Roof-mounted collectors. The roof shall be constructed to support the loads imposed by roof- mounted solar collectors. Roof-mounted solar collectors that serve as a roof covering shall conform to the requirements for roof coverings in Chapter 9 of this code. Where mounted on or above the roof coverings, the collectors and supporting structure shall be constructed of noncombustible materials or fire-retardant- treated wood equivalent to that required for the roof construction.

Wind Uplift on Collectors



Structural Loading

- Loads imposed by collectors differs by type based on the volume of water contained.
  - Storage type collectors (ICS, thermosiphon) have significantly more weight than other types.
- Ensure roofing structures can withstand the additional loading.
  - Consider seeking structural analysis if unclear.

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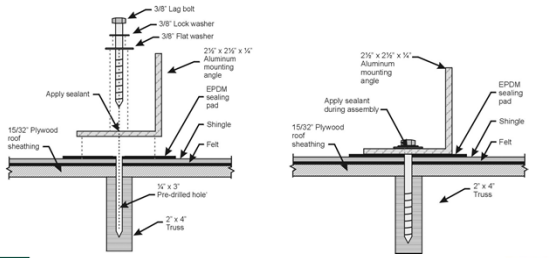
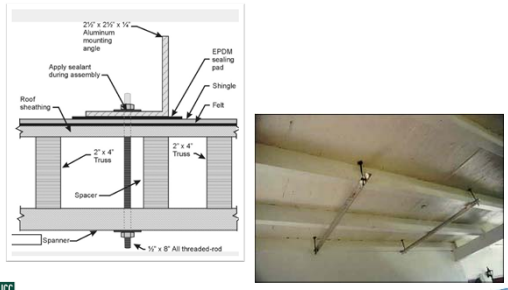
Roof Attachment Methods

- Common mounting methods
  - Spanner mounting
  - Lag bolts
  - J bolts
- Other mounting techniques available – follow manufacturers' instructions
- Considerations
  - Ensure proper fastener engagement
  - Ensure structural integrity of roofing is maintained.
  - Galvanic interaction between dissimilar metals.

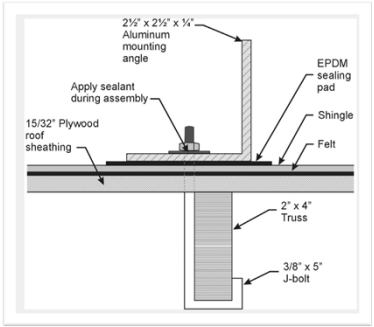
Lag Bolt Example



Spanner Example



J Bolt Example



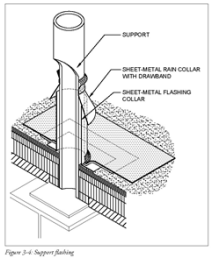
Roofing Penetrations

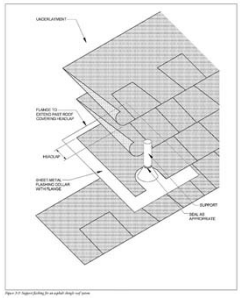
- IRC M2301.2.9, IMC 1402.6
  - Weatherproofing
  - Rodents/insects
- Preserve structural integrity
- Maintain fire rating





Roofing Penetration Flashing Details - Mounts





Source: NRCA Guidelines for Roof Systems with Rooftop Photovoltaic Components (Used with permission)

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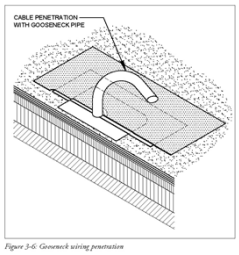
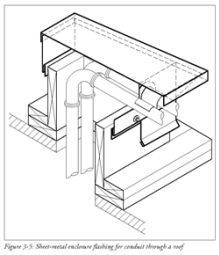
Roofing Penetration Flashing Details – Wiring and Piping





Source: NRCA Guidelines for Roof Systems with Rooftop Photovoltaic Components (Used with permission)

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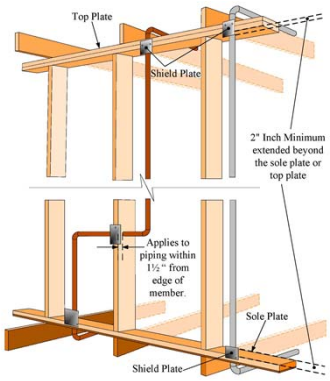
Piping – Key Considerations

- Materials suitable for system temperature/pressure
  - Appropriate transitions between materials
  - Ensure grounding maintained where piping is used.
- Contamination prevention through NSF 61, 372 for domestic water systems for potable systems
- Insulation entire solar loop (IRC M2301.2.5)
- Pipe supports (IMC 305.1)
- Notching and boring (IMC 302.3)
- Protection against damage (IMC 305.5)



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Piping Insulation

- Insulation entire solar loop (IRC M2301.2.5, SRCC 300 301.8.8)
  - Exceptions: Sections used to prevent overheating, used to collect additional energy, or unglazed for pools.
- Protect outdoor insulation from damage.
  - UV Protection (IRC M2301.2.5)
  - Corrosion, degradation
- Ensure pipe hangers do not compress or damage insulation (SRCC 300 305.1.13)

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IECC C403.2.1 for Pipe Insulation

TABLE C403.2.1[a]
MINIMUM PIPE INSULATION THICKNESS (in inches)[c]

FLUID OPERATING TEMPERATURE RANGE AND USAGE (°F)	INSULATION CONDUCTIVITY		NOMINAL PIPE OR TUBE SIZE (inches)				
	Conductivity Btu · in./h · ft² · °F	Mean Rating Temperature, °F	< 1	1 to < 1¼	1¼ to < 4	4 to < 8	≥ 8
> 350	0.32 – 0.34	250	4.5	5.0	5.0	5.0	5.0
251 – 350	0.29 – 0.32	200	3.0	4.0	4.5	4.5	4.5
201 – 250	0.27 – 0.30	150	2.5	2.5	2.5	3.0	3.0
141 – 200	0.25 – 0.29	125	1.5	1.5	2.0	2.0	2.0
105 – 140	0.21 – 0.28	100	1.0	1.0	1.5	1.5	1.5
40 – 60	0.21 – 0.27	75	0.5	0.5	1.0	1.0	1.0
< 40	0.20 – 0.26	50	0.5	1.0	1.0	1.0	1.5

For SI: 1 inch = 25.4 mm, °C = [(°F) - 32]/1.8.

a. For piping smaller than 1½ inches and located in partitions within conditioned spaces, reduction of these thicknesses by 1 inch shall be permitted (before thickness adjustment required in footnote b) but not to a thickness less than 1 inch.

b. For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:

$T = r\{(1 + t/r)^{(K/k)} - 1\}$

where:

T = minimum insulation thickness,

r = actual outside radius of pipe,

t = insulation thickness listed in the table for applicable fluid temperature and pipe size,

K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu · in/h · ft² · °F) and

k = the upper value of the conductivity range listed in the table for the applicable fluid temperature.

c. For direct-buried heating and hot water system piping, reduction of these thicknesses by 1½ inches (38 mm) shall be permitted (before thickness adjustment required in footnote b but not to thicknesses less than 1 inch (25 mm).

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Controls and Wiring

- Low and high voltage types
  - Collector and storage tank sensors
  - Pumps, controls and heaters
- Support, install and protect in accordance with the NEC.

SRCC 300 Wiring Language

- 301.6 Controller subsystem
  - Controls and wiring to be labeled per NEC
  - Sensor wire to be temperature rated per NEC
  - Disconnect switch required for pumps and controls per the NEC
  - Protect from exterior degradation and false signals.
- Grounding for lightning protection in accordance with NEC and mfgs instructions

Backup Heaters and Storage

- Various types of water heaters with/without separate hot water storage tanks and drainback tanks.
- Drip pans are required for supplemental water heaters and storage tanks (P2801.6, IPC 504.7)
- M2301.2.13 Seismic bracing for tanks used in some areas.
- Relief valve discharge must be managed.

Outdoor Tanks

- SRCC 300:
  - Storage tanks and heating equipment installed outdoors must be designed specifically for outdoor installation
  - Unsheltered tanks must be waterproofed.

Heat Transfer Fluids

- Key issues are flammability and toxicity.
- Addressed differently for residential and commercial construction.
  - Storage of flammable materials governed by the IFC.
- Fluids must be compatible with materials in contact.
- SRCC 300 requires containment of toxic discharge from indirect solar loops relief valves

6.4.4 Waste Disposal
Systems utilizing a toxic heat transfer fluid or thermal storage fluid shall provide for the catchments and harmless removal of these fluids from vents where fluid may be automatically discharged.

Heat Transfer Fluids – IRC

- **IRC M2301.4 Heat transfer gasses or liquids and heat exchangers.** *Essentially toxic transfer fluids*, ethylene glycol, flammable gases and flammable liquids shall not be used as heat transfer fluids.
  - Rated for system temp/pressure.
  - Flashpoint ≥ 50°F above stagnation temp.

ESSENTIALLY TOXIC TRANSFER FLUIDS. Soil, water or gray water and fluids having a Gosselin rating of 2 or more including ethylene glycol, hydrocarbon oils, ammonia refrigerants and hydrazine.

Heat Transfer Fluids – IMC & SRCC 300

- **IMC 1403 Heat transfer fluids.**
  - 1403.1: Flashpoint ≥ 50°F above stagnation temp.
  - 1403.2: Flammable liquids and gas use as heat transfer fluids prohibited.
- SRCC 300 does not utilize Gosselin Rating for toxicity – instead uses terms 'toxic' and 'non-toxic'.

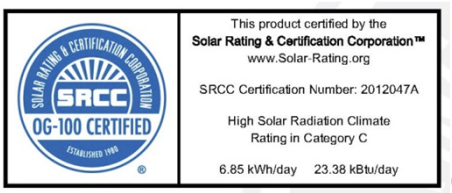
Non-Toxic Fluids - Additives to the heat transfer medium which are listed on the Code of Federal Regulations, Title 21, Food and Drugs; Chapter 1, Food and Drug Administration; Part 182, Substances Generally Recognized as Safe; Part 184, Direct Food Substances Affirmed as Generally Recognized As Safe.

System Labels & Marking

- Drain and fill valve labels and caps (IRC M2301.2.11)
- Thermal storage units (IRC M2301.3.2, IMC 1404.2)
- Solar collectors (IMC 1404.2, IRC M2301.3)
- Maintenance instructions (IRC N1101.12)

Collector Labeling

- IMC 1404.1: Label must show manufacturers' name, model number, serial number, collector weight, max allowable temp and pressure, heat transfer fluids.
- Label provides certified performance rating.



Local Codes

- Training focused on the model codes produced by ICC.
- Local codes may vary.
  - Earlier version of I-Codes may still be in use.
  - Local amendments may omit or change provisions.
- Local incentive programs may add additional requirements.

Important: Know your local codes!

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Solar-Ready Construction

- **IECC Appendix RB, IRC Appendix U: SOLAR-READY PROVISIONS—DETACHED ONE- AND TWOFAMILY DWELLINGS, MULTIPLE SINGLE-FAMILY DWELLINGS (TOWNHOUSES)**
- Optional unless specifically adopted.
- Does not require installation of any solar system – only prepares a suitable area for future installations.

SOLAR-READY ZONE. A section or sections of the roof or building overhang designated and reserved for the future installation of a solar photovoltaic or solar thermal system.

Performance

- Code is primarily concerned with life, health and safety aspects – does not assure highest levels of performance.
  - Exception: Solar-Ready Construction Appendices
- SRCC Standards – address health and safety AND performance minimums, but may or may not be required for a given jurisdiction. Examples:
  - Shading from vegetation, adjacent buildings
  - Orientation
  - Sizing
  - System type
- Know what you are required to enforce locally.

Summary

- Solar systems can be divided into basic types and sub-types (direct/indirect, passive/active)
- I-Codes provisions based in IMC Chapter 14, IRC Chapter 23; references to other codes/sections.
- SRCC 300 and 100 standards provide key product requirements.
- Cross connection, contamination prevention; penetrations, pressure/temp control; freeze protection are key code issues.

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