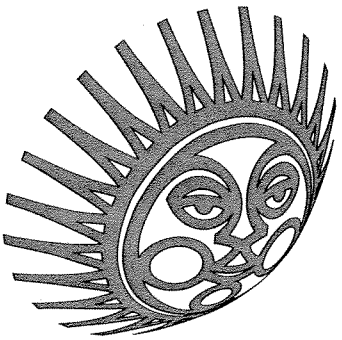

STUDENT HANDBOOK
for the
INSTALLATION AND MAINTENANCE
of the
"ANTI-FREEZE" FREEZE PROTECTION
Domestic Solar Water Heating System

Sponsoring Institution _____

Instructor _____ **Phone Number** _____

NATIONAL SOLAR WATER HEATER WORKSHOP
RESEARCH AND SERVICE FOUNDATION
COLLEGE OF ARCHITECTURE ARIZONA STATE UNIVERSITY
TEMPE, ARIZONA 85287 602•965•5380

PREFACE

Arizona State University is carrying out its mission of education and community service through the National Solar Water Heater Workshop (NSWHW). The scope of the program will include establishing do-it-yourself solar water heater workshop classes in cities representing every state in the Union.

The philosophy behind the workshop program, which had its humble beginnings in 1978, has been to assist the average citizen in exercising his right to alleviate the need for non-renewable forms of energy. This program enables an individual to exercise that right, as endowed by our Creator and insured by our society, to participate in an effort directed at correcting a critical energy situation. The likely consequence of anything less than an all out effort at changing the current pattern of energy use will be economic and social difficulties far severe than any of us has ever experienced.

Based upon the enthusiastic acceptance of the program and the successful installation of thousands of solar water heaters, it is believed the NSWHW will contribute to both individual and general welfare and will be of assistance in avoiding a situation which could seriously affect our level of domestic tranquility and liberty.

The University is proud to be able to join you, the citizens of this land, in this important effort which is already reducing our dependence on imported fuels.

Stanley A. Mumma, Ph.D., P.E.
Professor and Director
of Environmental Research

REPRODUCTION AND USE POLICY

The reproduction of this material is prohibited, and its use is limited to participants in the National Solar Water Heater Workshop for the following reasons:

1. This limitation permits maintaining contact for essential revisions, updating of technical information, and routing of other presentation material.
2. Energy savings achieved by solar water heaters will be accurately documented.
3. System uniformity and quality will be maintained.

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NOTICE

SECTION 1

INTRODUCTION

This handbook and related taped slide lecture is designed to be a complete guide to the installation of the NSWHW solar water heater system designed by Arizona State University. The handbook will follow the taped lecture portion of the NSWHW course by outlining specific points and by further expanding other information presented in the taped lecture. Your instructor will assist you with specific questions relative to your installation and to local considerations, such as tax credits, building or safety codes and professional installation assistance.

Each of the ten steps in this handbook is subdivided into five headings as follows: OVERVIEW, MATERIALS, NOTES, PROCEDURE, and ADDITIONAL INFORMATION. The "PROCEDURE" heading provides step-by-step instructions for your assembly and installation. If you need additional information you may find it under the other headings. You are invited to re-attend the lecture at any convenient time should review be necessary to successfully complete and operate your domestic solar water heating system.

The anti-freeze protection system consists of two separate fluid loops, thermally connected by a double walled heat exchanger. An anti-freeze/water solution is circulated through the collector loop; it is heated by solar energy at the collectors and transfers this heat to the potable water at the heat exchanger. Potable water is circulated from the bottom of the storage tank through the heat exchanger and returned to the top of the storage tank where it is available for household use.

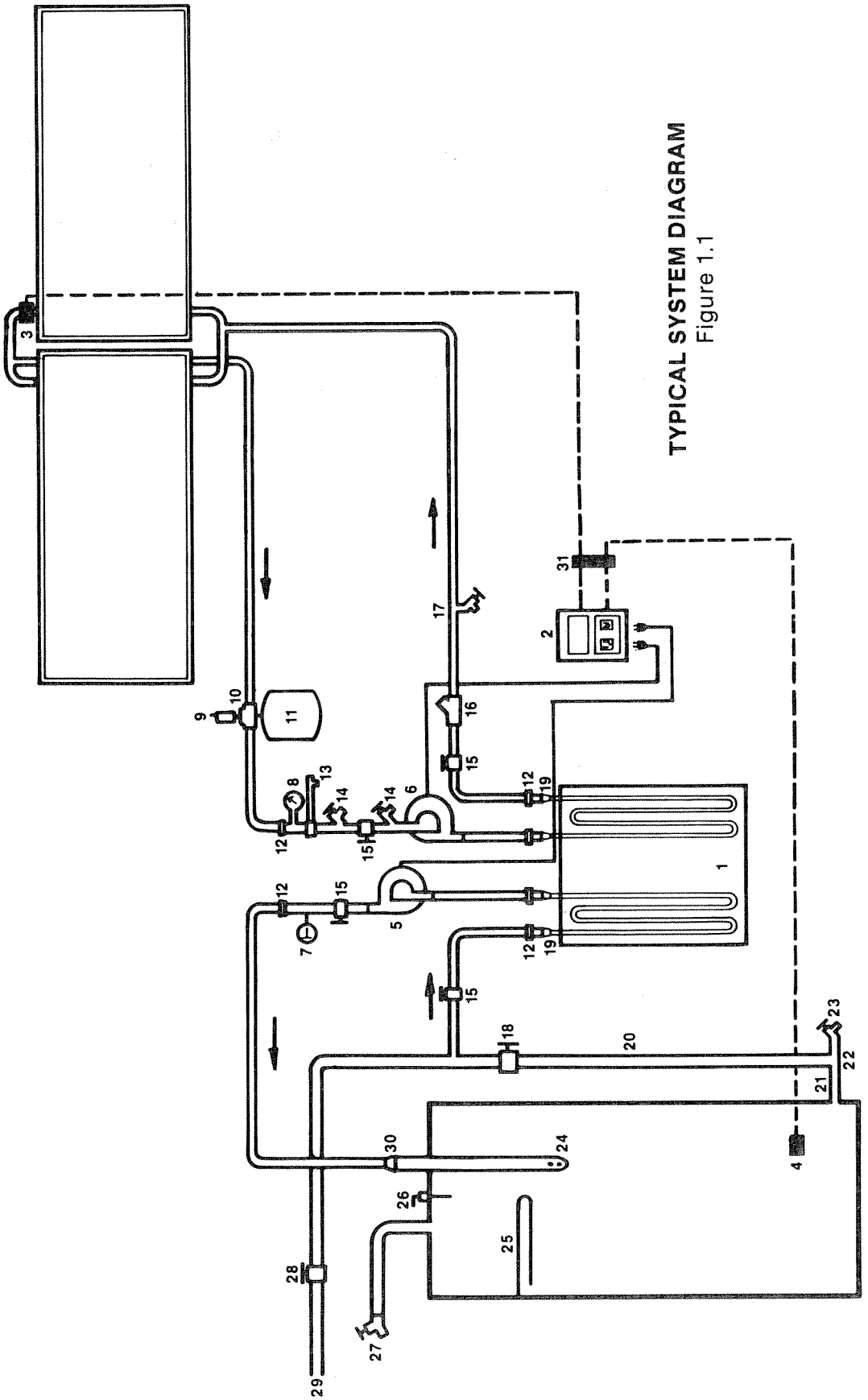
Safety Precautions

Safe work practice can reduce the possibility of property damage and/or personal injury. THINK SAFETY: Avoid dangerous Shortcuts.

1. Wear safety glasses when appropriate.
2. Wear heavy gloves when soldering or working with hot or sharp material.
3. Wear proper foot gear to ensure good footing on roofs and to protect feet from nail punctures and falling objects.
4. Keep roof area as clean as possible and never work on a wet roof, nor **any** roof when thunderstorms are near.
5. All power tools should be properly grounded and have necessary safety equipment.
6. Use a ladder properly. Face it when climbing or descending. Use a footer or safety shoe at the bottom when leaning it against a structure. Avoid electrical power lines, especially when using a metal ladder.
7. Keep a properly charged fire extinguisher handy.
8. Never solder in the attic or under eaves.
9. Be certain the electricity or gas supply is off when working with storage tanks.
10. Keep a first aid kit handy.

Tools

The following tools will be necessary to complete the installation:
Soldering torch, striker, tubing cutter, electric drill and bits, extension cord, level, angle finder, 8 ft. tape measure, square, caulking gun, putty knife, ladder, pipe wrenches, adjustable or open-end wrenches, hammer, screwdrivers, hacksaw, snips, pocket knife, wire cutter, voltage tester, pliers, flux brush, tire pump, 5 gallon bucket, tire pressure gauge. (Necessary supplies are outlined in the Shopping List.)



TYPICAL SYSTEM DIAGRAM
Figure 1.1

SPECIFICATIONS

Collector
- Dimensions - 35 1/8" x 97 1/8" x 4 1/8"
- Gross Area - 23.7 sq. ft.
- Operating Weight - 96 lbs. each
- Absorber Plate - All Copper with selective surface. 3/8" O.D. waterways, 0.013" min. wall thickness.
- Glass - 5/32" tempered low iron
- Box - Extruded aluminum, alloy 6063 T6
- Back - Aluminum sheet - 0.025" thick
- Insulation - 2 1/2" glass fiber - low binder.

Circulating Pumps
- Storage
- Collector

Charging Pump

Controller - with 2 differential sensors

Control Wire - 22 gauge two-conductor jacketed cable

Heat Exchanger - double walled

LEGEND

1. Heat Exchanger
2. Differential controller
3. Collector differential sensor
4. Storage differential sensor
5. Storage circulation pump
6. Collector circulation pump
7. Thermometer
8. Pressure gauge
9. Air vent
10. Air purger
11. Expansion tank
12. Union (6)
13. Pressure relief valve
14. Hose bibb fill valve w/cap
15. Gate valve 1/2" (4)
16. Check valve
17. Drain coupling
18. Gate valve 3/4"
19. Reducer 1/2" x 3/8" (4)
20. 3/4" External Riser
21. Close nipple, dielectric union, 3/4" elbow.
22. 3/4" brass tee
23. *Hose bibb drain valve
24. Modified dip tube
25. *Upper heating element
26. *Temp. pressure relief valve
27. *Hot water faucets in house
28. *Cold water supply valve
29. *Cold water supply
30. 1/2" x 3/4" adapter and *dielectric union
31. Terminal block

*Not included in kit.

Shopping List

1. 50/50 - Tin/Lead solid wire solder, (1/4 pound)
2. 96.5/3.5 - Tin/silver solder (2 feet)
3. Organic soldering paste or flux
4. Flux brush
5. Medium grade emery cloth
6. 1/2" wide teflon tape (not pipe joint compound)
7. 3/4" Copper tubing - type 'L' (1' longer than tank height)
8. Copper tubing - as required for pipe runs to and from collectors
   - Use 3/4" tubing if required by pipe run lengths or system size (see step #3 - size and locate pipe)
   - Type 'L' pipe may be required for all outdoor runs (check with your building department)
9. Pipe insulation - for all hot water carrying pipes
   - 1" thick high density glass fiber, or 3/4" closed-cell polyurethane buy according to outside diameter of pipe and thickness of insulation
   - Armaflex, Rubitex or similar insulation types are not recommended for exterior applications.
10. Pipe insulation cover - to protect insulation from moisture
    - U.V.-Resistant duct tape
    - Aluminum tape
    - Corrugated aluminum pipe cover
11. Storage tank insulation jacket - 3" thick, or R-11, should cover entire tank. 2" water-proof, high density, rigid insulation for base of tank
12. Clear silicone sealant - one caulking gun size cartridge
13. "Liquid Steel" or silicone - for tank sensor
14. 22 Gauge, two conductor - jacketed wire for controller sensors
15. Roof cement - sealant for pipe penetrations and mounting holes
16. Roof jacks - for pipe penetrations
17. Collector mounting brackets and fasteners
18. Prestone II or Dowtherm SR-1 antifreeze and distilled water

SECTION 2

SYSTEM ASSEMBLY AND INSTALLATION

Step 1 Size System

Overview:

- Determine the storage tank size, the number of collectors, the percent of solar contribution and the number of heat exchangers with appropriate pumps.

Materials:

- Tables and Figures

Notes:

- In tailoring your system, consider the number of bedrooms in your house. A change in family size or resale consideration may determine expansion requirements of your system.
- Systems with 3 or 4 collectors require a larger heat exchanger and expansion tank.

Procedure:

- The procedure is essentially an economic evaluation and examples are included for both obtaining a loan and paying cash.

Economic Evaluation (Assuming Money is Borrowed at 19% Interest)

1. Average monthly savings with Solar System

$$= \frac{\text{annual kWh saved (from Table 2.1)}}{12} \times \$/\text{kWh}$$

2. First cost = (cost of system + special tools + classroom instruction + instrumentation + new storage tank, if necessary).
3. Net cost = (First cost) x (1.0 - Federal Tax Credit - State Tax Credit).
   Note: 40% Tax Credit = 0.4.
4. See Table 2.2 for monthly payment if money is borrowed with no down payment.
5. If monthly savings exceed the monthly payments from the beginning you have made a very favorable investment. To be sure, the monthly savings will increase with time and inflation.
6. If you will be using natural gas as the auxiliary energy source for water heating, multiply the annual kilowatt hours saved (from Table 2.1) by .057 to obtain the annual therms or 100 cu. ft. units saved, assuming a gas heating efficiency of 60%.

Example: Dayton, Ohio

1. Family of 4 using 2 collectors.
   From Table 2.1: kWh's saved = 2520.
   If electricity costs $0.06/kWh, then

   $$\text{Monthly savings} = \frac{2520}{12} \times \$0.06 = \$12.60$$

2. If: cost of system = $900
   installation cost = $200
   instruction cost = $80
   Ohio State tax credit = 10% (0.1)
   Federal tax credit = 40% (0.4)

   Then: net cost = (900 + 200 +80) (1 - 0.1 - 0.4)
   = $590.00

3. With a system net cost of $590 and a monthly savings of $12.60, from Table 2.2 a $600 loan for just over 7 years will cost less than the average monthly savings, resulting in a positive cash flow.

Would it be more cost effective to add a third collector?

1. From Table 1: kWh's saved = 3420.
   $\frac{3420}{12} \times \$0.06 = \$17.10$ per month saved.

2. If the additional collector costs $220 and the required additional heat exchanger $60 and the large expansion tank is an additional $10,

   then, net cost = (900 + 290 + 290 + 200 + 80) (1 - 0.1 - 0.4)
   = $735.00

3. From Table 2.2, by interpolation, a $750 loan for six years will cost approximately $17.50 per month to repay. Therefore, 3 collectors are a better investment than 2 because of the shorter payback period.

What about 4 collectors?

1. Average monthly savings $= \frac{3950}{12} \times \$0.06 = \$19.75$

2. The addition of a fourth collector doesn't require another heat exchanger.

   Net cost = (900 + 290 + 220 + 200 + 80) (.5)
   = $845.00

3. From Table 2.2, a 6 year loan is still needed. Therefore, little economic benefit is realized by adding a fourth collector.

Economic Evaluation (Assuming Cash Payment)

1. Accumulated annual savings =

   (1st year savings) × $[1 + (1 + A) + (1 + A)^2 + (1 + A)^3 + \ldots + (1 + A)^n]$
   where A = inflation over payback period minus average interest you could earn.

   n + 1 = # of years.

2. When accumulated savings = net cost
   n + 1 = break even point.

3. **Example:** Dayton, Ohio

   If: First year savings (2 collectors) = $151 (12.60×12 = $151.20)
   Interest that could be earned = 8%
   Inflation = 15%
   Net cost = $590
   A = 0.07 (0.15 - 0.08)

   After 4 years, the accumulated savings =
   (151) $[1 + 1.07 + (1.07)^2 + (1.07)^3]$ = $670.43
   year 1, year 2, year 3, year 4

   Therefore break even point = 3+ years.

Additional Information:

- This sizing procedure is based on the following:

  Orientation = True South
  Collector Tilt = Latitude
  Hot Water Set Temperature = 125F

- Varying collector orientation or tilt from these ideals will result in lower system performance. To get actual solar contribution, divide the annual percent solar from table 2.1 by the appropriate number from figure 2.1 and/or figure 2.2. If the hot water set temperature is above 125F system performance will decrease. However, if it is set below 125F system performance will increase.

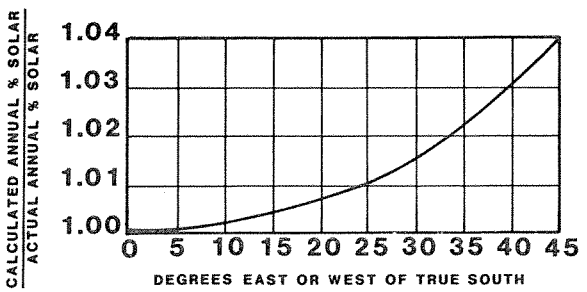


Figure 2.1

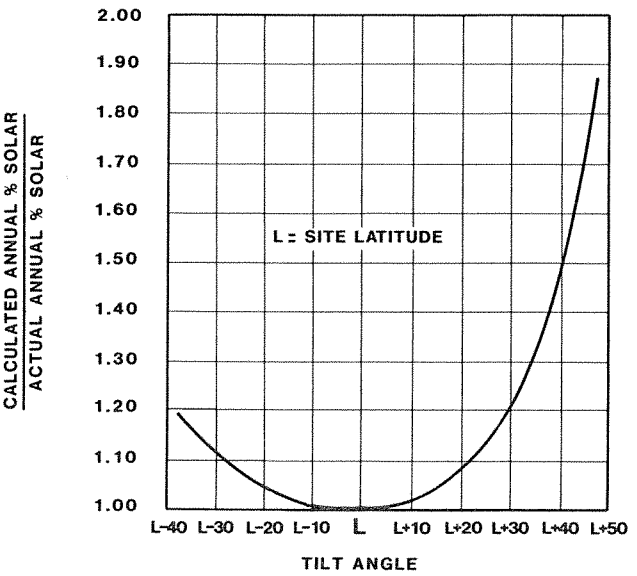


Figure 2.2

TABLE 2.1

ANNUAL PERCENT SOLAR — ANNUAL KILOWATT (kWh) SAVINGS

Number of Collectors - Storage Size (Gallons)		2-66						3-82						4-120					
Family Size		2		4		6		2		4		6		2		4		6	
State	City	%	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%	kWh
Alabama	Birmingham	88	2020	64	2840	48	3160	96	2230	84	3780	67	4430	98	2300	90	4040	79	5240
	Huntsville	88	2020	64	2840	48	3160	96	2230	84	3780	67	4430	98	2300	90	4040	79	5240
Alaska	Fairbanks	46	1460	31	1930	24	2220	59	1900	42	2230	33	3060	66	2140	49	3070	39	3750
Arkansas	Little Rock	87	2130	64	3070	48	3410	95	2380	83	4000	67	4780	98	2470	89	4310	79	5660
Colorado	Denver	90	2570	65	3580	49	4010	98	2800	86	4760	68	5580	100	2880	93	5170	80	6590
Connecticut	Hartford	65	1840	43	2370	33	2700	82	2340	59	3270	46	3780	88	2530	68	3780	54	4440
D.C.	Washington	77	1910	53	25.40	40	2850	89	2230	71	3430	56	4000	93	2350	81	3920	66	4730
Delaware	Wilmington	78	1930	53	2540	40	2850	90	2250	71	3430	56	4000	94	2370	81	3920	66	4730
Florida	Jacksonville	95	2010	73	2980	56	3380	100	2140	93	3820	77	4670	100	2170	97	4010	90	5480
Georgia	Atlanta	89	1880	66	2690	50	3020	96	2060	86	3530	69	3530	99	2150	92	3800	82	5000
	Savannah	93	1970	69	2820	53	3200	99	2130	90	3690	73	4430	100	2170	95	3930	86	5340
Idaho	Boise	83	2350	62	3420	47	3850	91	2600	79	4370	65	5340	94	2700	85	4720	75	6180
Illinois	Chicago	74	2090	50	2760	38	3110	86	2460	67	3710	53	4350	90	2590	77	4280	62	5100
	Peoria	78	2210	54	2970	41	3350	89	2550	72	3980	57	4680	93	2680	81	4500	67	5520
Indiana	Fort Wayne	70	1860	47	2420	36	2750	83	2220	64	3370	50	3840	88	2380	74	3850	59	4540
	Indianapolis	73	1940	49	2520	37	2830	85	2280	66	3420	52	3990	90	2430	76	3950	61	4690
Iowa	Des Moines	78	2210	54	2970	41	3350	88	2520	72	3980	56	4600	93	2690	81	4500	67	5520
Kansas	Wichita	89	2210	67	3210	51	3630	97	2430	85	4100	71	5070	99	2490	91	4410	82	5870
Kentucky	Covington	73	1940	50	2580	37	2830	86	2310	67	3470	52	3990	90	2430	77	4000	62	4770
	Louisville	77	2050	52	2680	40	3050	88	2360	70	3630	55	4230	92	2480	80	4160	65	5000
Louisiana	Baton Rouge	92	1950	70	2860	53	3200	98	2100	89	3660	74	4490	100	2170	94	3880	86	5340
	Shreveport	91	2090	69	3060	52	3420	98	2280	87	3890	72	4760	100	2350	94	4220	85	5630
Maine	Portland	58	1750	38	2230	29	2530	79	2400	56	3300	43	3760	86	2630	65	3840	52	4560
Maryland	Baltimore	77	2050	53	2730	40	3060	90	2410	71	3680	55	4220	94	2540	81	4210	65	5000
Massachusetts	Boston	68	1920	46	2530	35	2870	84	2410	62	3430	48	3940	89	2560	72	4000	57	4690
Michigan	Detroit	68	1930	46	2530	35	2870	82	2340	62	3430	48	3940	88	2530	72	4010	57	4690
	Grand Rapids	67	1890	46	2530	34	2780	81	2320	61	3380	48	3940	86	2480	71	3950	57	4690
Minnesota	Minn/St. Paul	68	2050	46	2700	35	3050	82	2490	62	3650	49	4290	88	2690	72	4260	57	4990

Missouri	Kansas City	82	2070	59	2840	43	3070	92	2300	78	3760	63	4300	96	2420	86	4160	74	5300
	Springfield	84	2080	61	2920	46	3270	94	2350	80	3860	64	4570	97	2450	87	4210	75	5370
	St. Louis	82	2030	59	2830	45	3210	92	2300	78	3760	62	4430	95	2390	85	4120	74	5300
Mississippi	Jackson	90	2070	67	2970	51	3350	97	2250	87	3890	71	4690	99	2320	92	4130	83	5490
Montana	Billings	76	2290	54	3170	41	3580	88	2680	71	4180	56	4900	92	2920	80	4730	66	5790
	Great Falls	74	2230	51	2990	39	3400	87	2640	69	4070	54	4720	91	2780	77	4550	64	5610
Nebraska	Lincoln	78	2210	54	2970	41	3350	89	2550	72	3980	57	4680	94	2710	81	4500	67	5520
Nevada	Las Vegas	99	2270	89	3950	72	4730	100	2320	97	4330	91	6010	100	2350	100	4480	95	6290
	Reno	94	2160	80	3550	61	4010	99	2300	92	4110	83	5480	100	2350	96	4310	90	5970
New Hampshire	Concord	63	1780	43	2370	32	2620	80	2290	58	3210	45	3690	86	2480	67	3720	53	4360
New Jersey	Newark	73	2070	49	2960	37	3030	87	2490	66	3650	52	4270	92	2650	77	4280	61	5020
New Mexico	Albuquerque	97	2400	82	3930	63	4480	100	2500	95	4580	85	6070	100	2520	98	4750	92	6590
New York	Buffalo	63	1670	42	1920	32	2450	77	2200	56	3100	43	3530	83	2390	65	3610	52	4280
	New York City	73	2070	49	2960	38	3110	87	2490	66	3650	52	4270	92	2650	77	4280	61	5020
North Carolina	Charlotte	89	2050	64	2840	48	3160	97	2250	85	3790	67	4230	99	2320	91	4080	79	5240
	Raleigh	88	2020	63	2800	48	3160	96	2230	84	3750	66	4360	99	2320	91	4080	78	5170
North Dakota	Fargo	69	2010	47	2760	36	3140	82	2490	64	3770	50	4370	87	2660	72	4260	59	5170
	Minot	69	2080	47	2760	35	3050	82	2490	63	3710	49	4290	87	2660	72	4260	58	5090
Ohio	Cleveland	65	1960	43	2520	33	2880	79	2400	58	3420	45	3940	85	2600	68	4020	54	4330
	Columbus	68	1920	46	2530	35	2870	83	2370	62	3430	48	3940	88	2530	72	4000	57	4690
	Dayton	72	1910	49	2520	37	2830	85	2280	66	3420	51	3910	89	2410	76	3950	61	4690
Oklahoma	Oklahoma City	90	2290	67	3210	51	3630	97	2430	86	4150	70	4990	99	2500	92	4460	81	5800
	Tulsa	87	2150	63	3020	48	3410	96	2400	82	3960	66	4710	98	2470	90	4360	78	5540
Oregon	Medford	78	2070	57	2940	43	3290	88	2360	74	3830	60	4610	92	2480	81	4210	70	5390
	Portland	69	1830	46	2370	35	2680	83	2220	62	3210	49	3760	89	2410	72	3740	58	4470
Pennsylvania	Philadelphia	75	1990	51	2630	38	2910	88	2360	68	3520	53	4070	93	2510	79	4110	63	4850
	Pittsburgh	65	1840	44	2420	33	2700	81	2320	59	3270	46	3780	86	2480	69	3840	54	4450
Rhode Island	Providence	69	1830	47	2420	35	2680	85	2280	63	3260	49	3760	90	2430	73	3790	58	4460
South Carolina	Columbia	91	2010	66	2930	50	3290	98	2280	87	3890	70	4630	100	2350	93	4170	83	5500
South Dakota	Pierre	79	2260	56	3100	43	3520	89	2550	74	4100	59	4860	93	2680	82	4560	70	5770
	Sioux Falls	75	2130	52	2870	40	3270	87	2490	70	3870	53	4520	91	2620	79	4390	63	5350
Tennessee	Chattanooga	82	2030	56	2680	43	3060	92	2280	76	3670	59	4210	96	2420	85	4120	70	5020
	Memphis	86	2130	63	3020	48	3410	94	2350	82	3960	66	4710	97	2450	89	4310	78	5590
	Nashville	81	2000	57	2730	43	3060	90	2260	76	3670	60	4280	94	2370	84	4070	71	5090
Texas	Amarillo	93	2380	73	3620	37	4070	100	2500	93	4490	79	5640	100	2520	97	4700	90	6450
	Dallas/Ft. Worth	93	1970	75	3060	57	3440	99	2120	91	3740	78	4740	100	2170	95	3930	87	5300
	Lubbock	97	2400	80	3840	61	4340	100	2500	94	4530	83	5930	100	2520	98	4750	92	6590

TABLE 2.1 (Continued)

ANNUAL PERCENT SOLAR — ANNUAL KILOWATT (kWh) SAVINGS

Number of Collectors - Storage Size (Gallons)		2-66						3-82						4-120					
Family Size		2		4		6		2		4		6		2		4		6	
Utah	Salt Lake City	87	2310	68	3500	52	3980	94	2520	84	4350	72	5530	97	2620	89	4630	81	6230
Vermont	Burlington	61	1730	41	2260	31	2540	77	2180	56	3100	43	3530	84	2420	65	3610	51	4190
Virginia	Norfolk	87	2150	62	2970	47	3340	95	2380	81	3910	63	4500	98	2470	88	4260	75	5370
	Richmond	83	2050	58	2780	43	3060	93	2330	76	3670	59	4210	96	2420	85	4120	70	5020
West Virginia	Charleston	72	1910	48	2470	37	2830	86	2310	65	3370	51	3910	90	2430	76	3950	60	4620
Washington	Seattle	68	1680	46	2210	35	2490	82	2050	62	2990	49	3490	88	2220	71	3440	58	4150
	Spokane	74	1960	52	2670	40	3060	86	2310	69	3570	55	4220	90	2430	77	4010	65	5000
Wisconsin	Eau Claire	70	1980	48	2640	36	2940	84	2400	64	3540	50	4100	89	2570	74	4390	59	4860
	Milwaukee	70	1980	48	2640	36	2950	84	2400	64	3540	50	4100	89	2560	74	4110	59	4860
Wyoming	Casper	87	2460	64	3520	49	4010	96	2750	83	4590	68	5580	98	2820	90	5000	79	6500
	Cheyenne	87	2460	61	3360	47	3850	97	2770	82	4540	64	5260	100	2880	91	5060	76	6260

Table 2.1 was generated by f-Chart version IV with the following assumptions: 20 gal/person/day, 125F auxiliary set point, tilt = latitude, orientation = true south, localized average ground water temperature, $F_R(\tau\alpha) = 0.75$, $F_R U_L = 0.65$, heat exchanger $\varepsilon = 0.25$. f-Chart version IV is a computer simulation program developed by the Solar Energy Laboratory, University of Wisconsin-Madison.

TABLE 2.2

MONTHLY PAYMENTS BASED ON A 19% INTEREST LOAN

Period of Loan (Years)

Loan	1	2	3	4	5	6	7	8	9	10
600	55.30	30.25	22.00	17.95	15.57	14.03	12.96	12.20	11.63	11.21
700	64.51	35.29	25.66	20.94	18.16	16.36	15.13	14.23	13.57	13.07
800	73.73	40.33	29.33	23.93	20.76	18.70	17.29	16.27	15.51	14.94
900	82.95	45.37	33.00	26.92	23.35	21.04	19.45	18.30	17.45	16.81
1000	92.16	50.41	36.66	29.91	25.95	23.38	21.61	20.33	19.39	18.67
1100	101.42	55.55	40.33	32.90	28.55	25.71	23.77	22.37	21.33	20.54
1200	110.64	60.60	44.00	35.90	31.14	28.05	25.93	24.40	23.26	22.40
1300	119.86	65.65	47.66	38.89	33.74	30.39	28.09	26.43	25.20	24.27
1400	129.08	70.70	51.33	41.88	36.33	32.73	30.25	28.47	27.14	26.14
1500	138.30	75.75	55.00	44.87	38.93	35.07	32.41	30.50	29.08	28.00

You may contact a lending institution for other interest-rate amortization tables.

TABLE 2.2

Step 2 Locate Collectors

Overview:

- Determine the location of the solar collectors considering: 1. Good solar exposure, 2. Proximity of collectors to storage, 3. Aesthetics, 4. Installation and maintenance ease, 5. Roof surface material.

Materials:

- As required to inspect your site.

Notes:

- No more than 5% of the collector area should be shaded between 9 a.m. and 3 p.m. Standard Time (Solar Time if known) throughout the year. One of the major sources of shading is trees, so the homeowner should be aware of the effect of future growth. Chimneys, dormers, other buildings, new construction and even fences may shade the collector array, especially in the winter when the sun angles are low and shadows are long.
- Avoid tile or slate roofs or other types which are difficult to seal.
- Collectors should be installed with the long dimension horizontal.
- On sloped roofs, **do not** locate your collectors over or in line with exterior doorways or walkways.
- Where frequent snowfall is prevalent and collectors are not parallel to the roof slope, locate your collectors close to the ridge of your house. This decreases snow accumulation under the collectors.

Procedure:

1. Determine where you will locate your collectors using the examples provided.
2. Check your intended location for shading.

   Imagine the sky as a transparent dome with its center at the solar collector array. The path of the sun during the year can be etched (projected) on the dome, as can the outline of surrounding houses and trees. The sun's path during the optimum hours between 9 a.m. and 3 p.m. Standard or Solar Time throughout the year scribes a solar window on the dome. Almost all of the useful sunlight that reaches the collector array must come through this window.

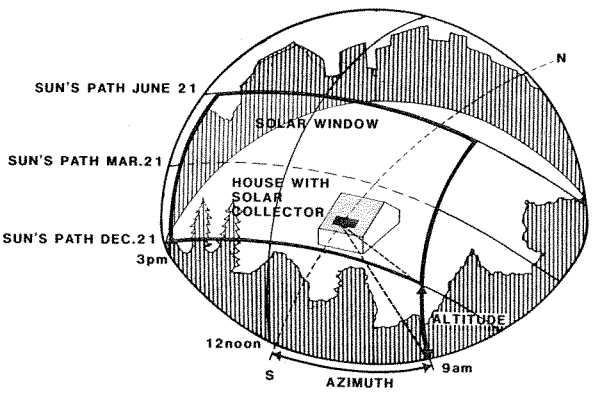


Figure 2.3

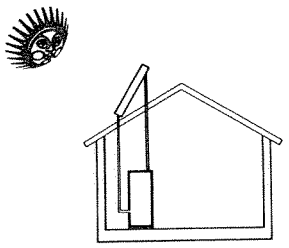


Figure 2.4 SOUTH FACING ROOF

Typically Best Suited:

Advantages
- simple bracket design.
- minimal wind loading.
- ideal collector location is close to storage.

Disadvantages
- roof surface must be pierced.

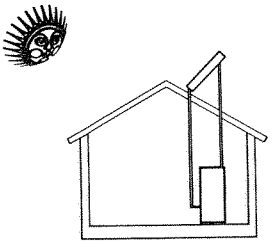


Figure 2.5 NORTH FACING ROOF

Advantages
- reduced visibility from street.

Disadvantages
- increased wind loading.
- roof surface must be pierced.

NOTE: roof peak should not shade collectors in winter.

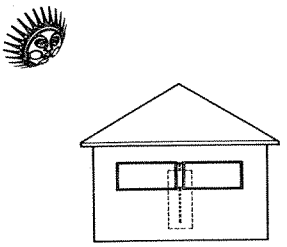


Figure 2.6 WALL MOUNT

Advantages
- minimal wind loading.
- roof surface is not disturbed.
- easy access for cleaning.

Disadvantages
- eaves may shade collectors during summer.
- more susceptible to accidental breakage.

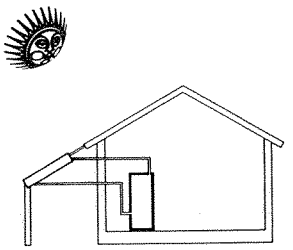


Figure 2.7 EAVE MOUNT

Advantages
- roof surface is not disturbed.
- additional shading is provided to wall.

Disadvantages
- extensive structural supports; costly.
- ice damming will be a problem in areas of heavy snowfall; not recommended.

EAST OR WEST ROOF

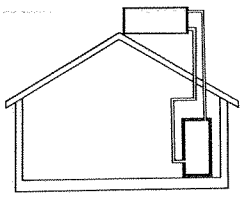


Figure 2.8 EAST OR WEST ROOF

Advantages
- collectors face south.

Disadvantages
- roof surface must be pierced.

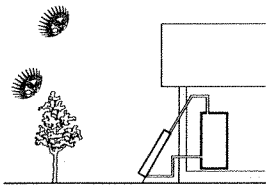


Figure 2.9 GROUND MOUNT

Advantages
- no roof penetrations.
- minimal wind loading.
- easy access for cleaning.

Disadvantages
- collectors may be shaded by surrounding objects.
- high potential for accidental breakage.
- snow buildup.
- requires footings.
- must meet zoning requirements.

To determine true south, solar noon must be found first. Solar noon is exactly halfway between sunrise and sunset on any given day. Consult the local newspaper or weather broadcast. Drive a post vertically into the ground the mark the shadow at solar noon.

Example: Sunrise 6:06
Sunset 6:54

$$\text{Solar Noon} = \frac{(12:00 - 6:06) + 6:54}{2} + 6:06$$

Answer: Solar Noon = 12:30

Use the table below to forecast the angular height of the sun above the horizon at 9 a.m. and 3 p.m. Standard Time on December 21st when the sun is lowest in the sky. Stand at the location of your collectors facing solar south.

The azimuth is the angular distance along the horizon left or right of true south. The altitude is the angular distance above the horizon at the 9 a.m. or 3 p.m. azimuth position. See figure 2.9.

Latitude	Solar Position at 9 a.m. & 3 p.m. on 21 Dec.		Spacing(s) See Add'l Information	Altitude at Solar Noon on 21 Dec.
	Azimuth	Altitude		
24	46°	25°	4′	43°
32	44°	20°	4½′	35°
40	42°	14°	6′	27°
48	41°	8°	8′	19°
56	40°	2°	14′	11°
64	—	—	52′	3°

Table 2.3

Additional Information:

- If you mount your collectors behind one another on a flat surface, the "spacing" column above shows the *minimum* distance ("S" in the figure) between them to ensure that one collector does not shade the other. Obviously, at higher latitudes, the spacing becomes prohibitive. If collectors are mounted on a south-sloping roof, they may be mounted closer together. Use the "Solar Noon Altitude" column to determine the sun's highest position on December 21 and, using your angle finder, determine the minimum collector-to-collector spacing which will avoid shading.

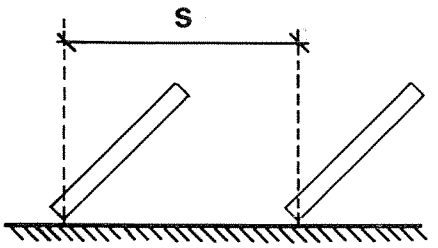


Figure 2.10

- If you have unique problems consult your instructor for additional help.

Step 3 Size and Lay Out Pipe

Overview:

- Consider the number of collectors in your system, determine the pipe diameter and length, as well as the balancing method you will use.

Materials:

- Pipe Sizing Chart, Figure 2.11.

Notes:

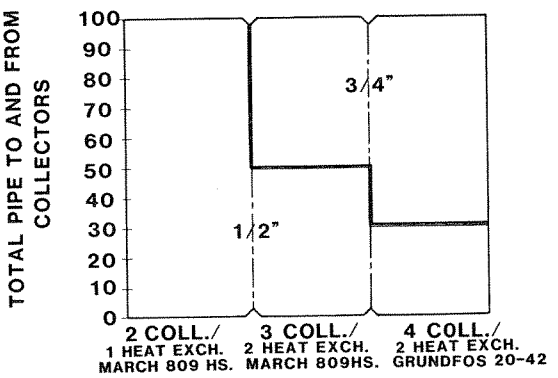
- Collectors must be plumbed in parallel to perform most efficiently.
- Locate pipe runs adequate distances from obstructions to allow for easy assembly and for installing the insulation.
- Consider future expansion and size pipes accordingly; if in doubt, choose the next larger pipe diameter.
- Use only copper pipe. Plastic pipe is not an acceptable substitute.

Procedure:

1. Figure 2.12 indicates some piping layouts for 2, 3 and 4 collectors. It is desireable that flow be equal in each collector. This may be accomplished by equalizing pipe lengths to each collector or by using balancing valves.
2. Once you have determined your collector arrangement and balancing method, plan the path of copper tubing from the collectors to your storage tank.
3. To determine the proper pipe diameter, measure the **total** length of supply and return runs and consult figure 2.11. For example, with three collectors, 1/2" tubing can be used if the total distance from the tank to the collectors and back is less than 50 feet; 3/4" tubing should be used if the total distance is greater than 50 feet.

NOTE: If a third or fourth collector is used, a larger heat exchanger and expansion tank will be required. See Step 7 — "Additional Information" for plumbing details.

NOTE: If four collectors are needed the March 809 HS should be exchanged for a Grundfos UPS 20-42.



Pipe Sizing Chart
Figure 2.11

Additional Information:

- Consult your building code official for pipe wall thickness and other code requirements.

COLLECTOR ARRANGEMENTS

LEGEND

- SENSOR
- BALANCE VALVE
- RETURN
- SUPPLY
- DIRECTION OF FLOW

CONSULT YOUR INSTRUCTOR IF YOUR COLLECTOR ARRANGEMENT IS NOT SHOWN

Full port balancing valves must be used; acceptable units are: Amtrol Br-1 or Milwaukee 1350. Do not use gate or globe valves.

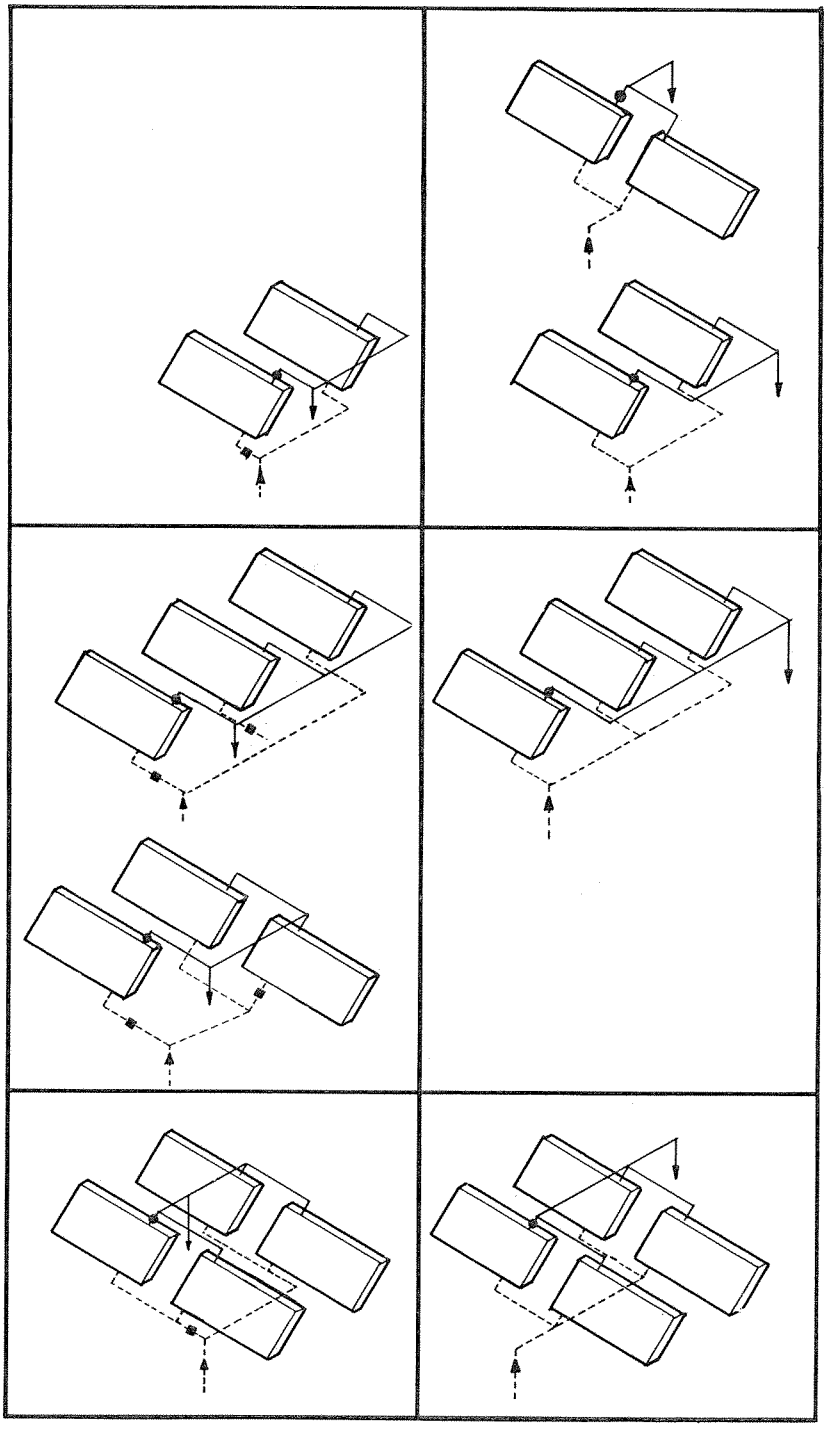


Figure 2.12

Step 4 Mount Collectors

Overview:

- Mount your collectors by one of the following methods:

  1. Parallel to the plane of the roof on redwood or pressure treated lumber spacers, or
  2. On aluminum brackets tilted up, out of the plane of the roof.

  Either method may be fastened to the roof with lag bolts or threaded rods and spanners. Lag bolts should not be used in areas where the design wind load is greater than 180 mph or where 2×4's are used as roof support members.

Materials:

- 7/16" lag bolts or 3/8" threaded rods with nuts and washers.
- 2×4 redwood or pressure treated lumber spacers and/or spanners or aluminum brackets.
- Collector mounting clips and fasteners.

Notes:

- Always mount the collectors with the long dimension horizontal thereby:
  — reducing overturning moment on mounting structure
  — reducing hydrostatic head to keep collector from air locking
  — improving appearance.
- Make sure there is at least 3" of clearance between the roof and collectors to avoid buildup of debris, leaves and water. Mount all spacers parallel with the slope of your roof.
- On flat roofs where winter snowfall is frequent, mount the base of the collectors at least 12" above the roof surface.
- On sloped roofs, install a snow belt at the base of your collectors. Use any smooth aluminum sheet to prevent snow dams in front of the collectors.
- All roof penetrations must be properly sealed to avoid leaks.
- Be careful not to damage the roof. Do not walk on the roof when it is either very hot or very cold.

Procedure:

1. **Collector Preparation**
   - If collectors are to be stored outside before installation, be sure they are covered.
   - Mark collector cover and box pairs to avoid mixing.
   - Drill two 1/4" weep holes in the lower mounting clip groove of each collector box and cover with an aluminum or nylon screen to prevent insects from entering. Hold screen in place with a dab of silicone.

- Install fiber thermal breaks where absorber plate might contact box or glass frame.
- Install box cover-gasket without stretching.
- Enlarge holes in cover glass frame to 3/16".
- Clean the inside of the glass cover with denatured alcohol and fasten cover to box.

1. **Collector Mounting:** If you have determined that mounting your collectors parallel to the roof plane will provide an acceptable collector tilt angle, follow METHOD 1; if brackets are required, follow METHOD 2. Size your bracket members from Part 4 at the end of this section.

   Lag Bolts (Figure 2.14) are used to anchor collector supports directly into roof rafters. Drill 5/16" pilot hole into the rafter and fill the pilot hole with roof cement. Insert 7/16" bolt and washer. Be sure the bolt penetrates the rafter 5". Once secure, coat the top of the bolt and washer with a quality roof cement.

   Threaded Rods (Figure 2.15) are the most secure anchoring technique if the underside of the roof directly beneath the collectors is accessible. Drill a 7/16" clearance hole. 3/8" all-threaded steel rods and 2×4 spanners are used to anchor the collector supports to the underside of the roof rafter. Be sure to force roof cement into roof penetration from above and below. Finally, coat the exposed rods and nuts with quality roof cement.

2. **Collector Mounting Clip:**

   Four aluminum mounting clips are furnished in your kit for securing each collector to the aluminum brackets or 2×4 spacers. If you choose the brackets, use 1"×1/4" high tensile (SAE Grade 8) strength bolts to secure the clips to the brackets. However, if you use 2 x 4 spacers, secure the clips to the spacers with 3" x ¼" lag bolts. Do not locate mounting clips to block weep holes.

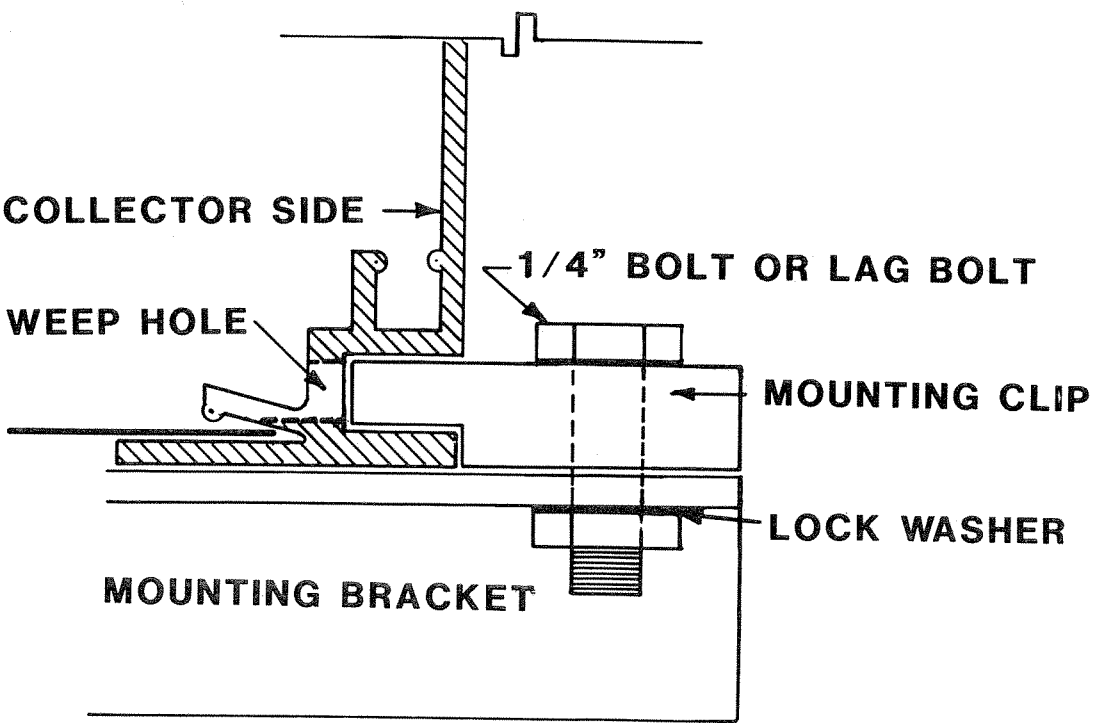


Figure 2.13

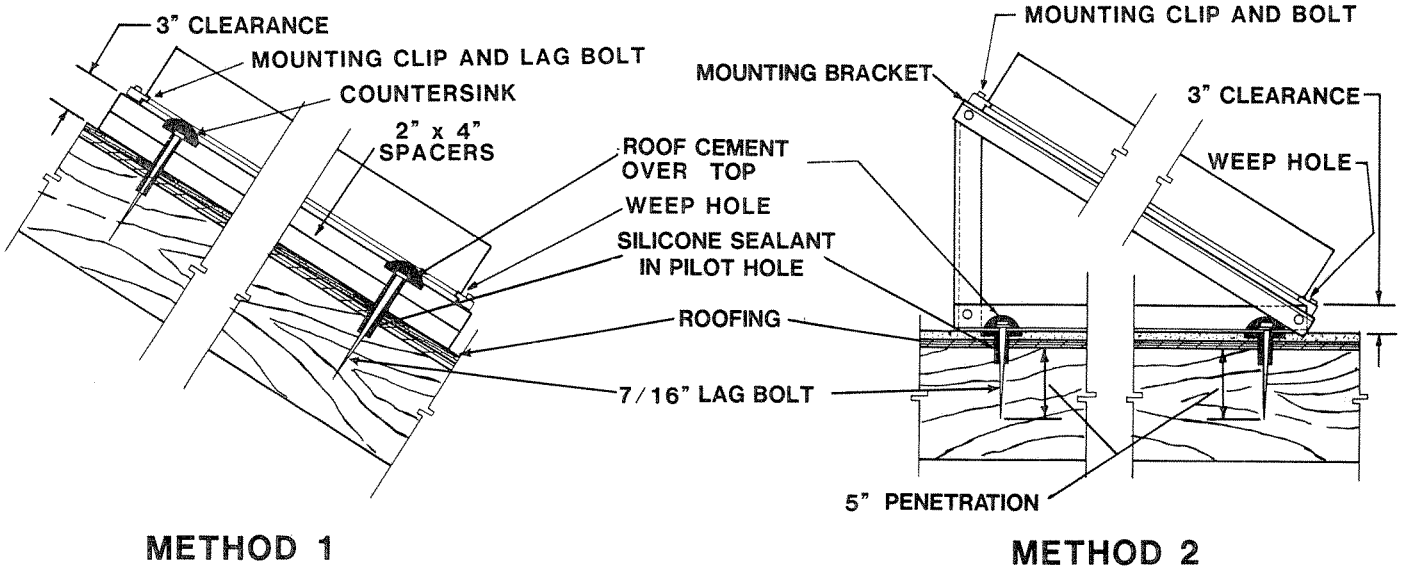


Figure 2.14

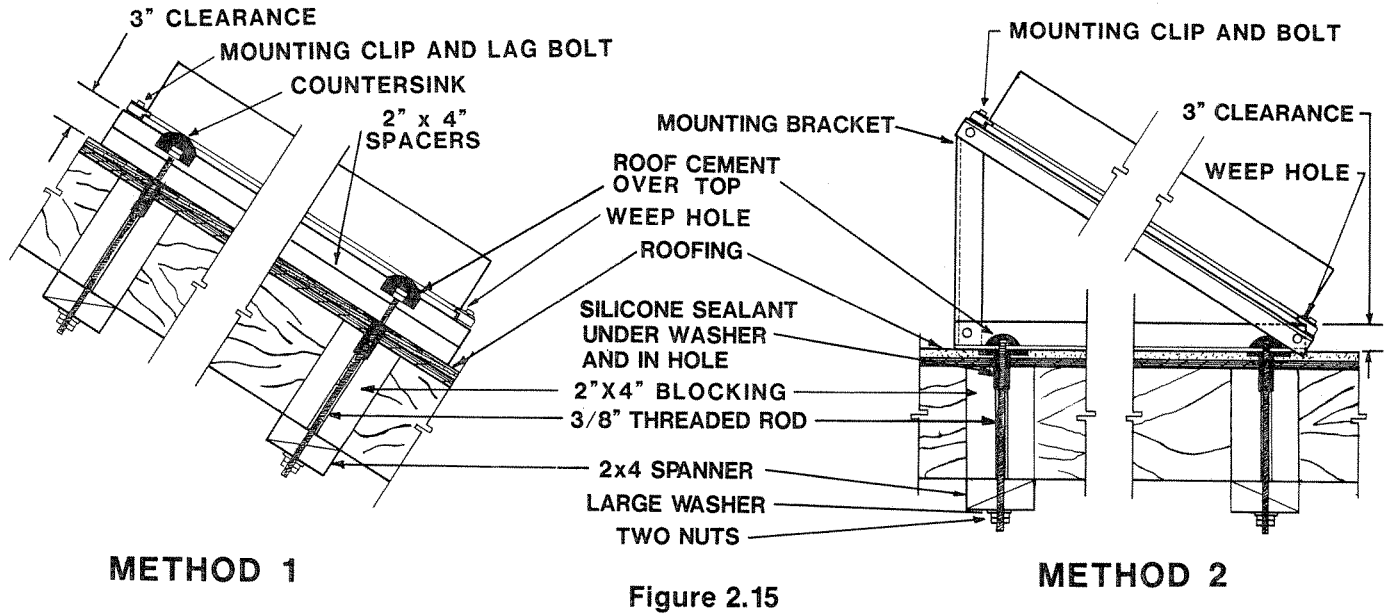


Figure 2.15

4. **Bracket Member Length Details for METHOD 2**

Brackets can be fabricated for any sloped roof or purchased from the hardware supplier and modified as necessary. Use two brackets per collector. Note that brackets should be mounted approximately 2 feet from the end of each collector, however, this may vary slightly depending on rafter location.

In general, the collector tilt angle (the angle between the collector and the horizon) should be the same as your latitude; although a tilt angle of to 10° greater or less than the latitude will have little affect on performance.

All bracket members shall not be less than 1-1/2" × 1-1/2" × 1/8" aluminum angle. Member "A" is 37-3/4" long (the width of the collectors plus room for the mounting clips). For installation on flat roofs in areas of frequent winter snow fall Member "A" should be 52" long. All bolts used for mounting collectors must be SAE Grade 8 with a tensile strength of 150,000 p.s.i.

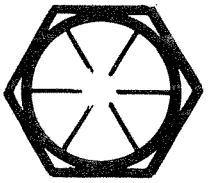


Figure 2.16

Markings on the head of a SAE Grade 8 bolt are shown in Figure 2.16.

At your collector location, use an angle finder to locate Member "A" at the proper tilt angle. Measure the lengths of Members "B" and "C". Size Member "C" so that Member "B" is vertical. Remember, it is not important that the collectors be mounted exactly at the specified tilt angle; a slight variation will not significantly affect performance.

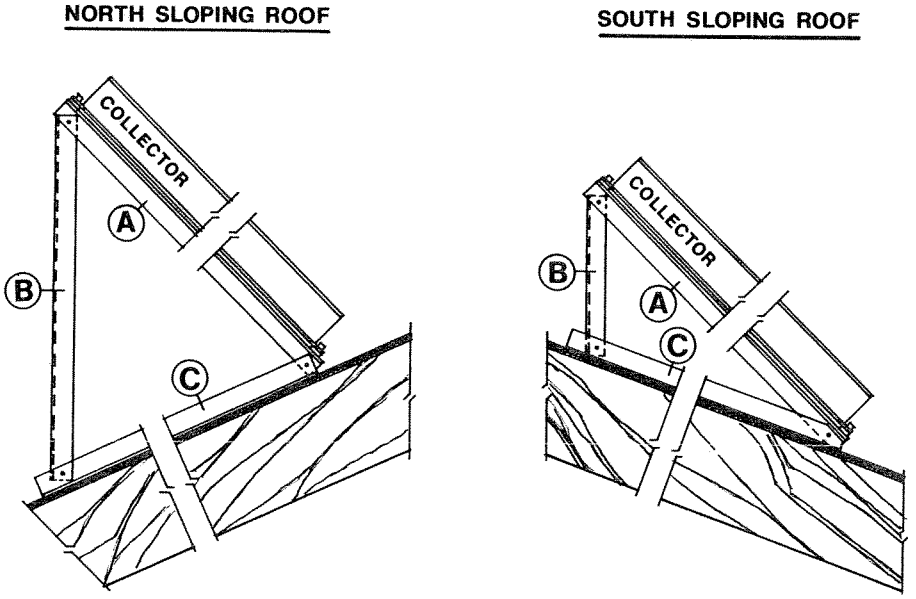


Figure 2.17

- If you wish to determine bracket member lengths arithmetically, the general formulas are:

$$C = \frac{A \cos (T.A.)}{\cos(s)}$$

$$B = \sqrt{A^2 + C^2 - 2AC (\cos a)}$$

where the various members are chosen from the following figures and "A" is the collector back, "T.A." is the tilt angle, and "S" is the roof slope taken from the "angle" column of the table below. For greatest structural strength member "B" should be attached to the end of member "A" and oriented approximately vertically.

ANGLE/ROOF PITCH CONVERSION TABLE	
ANGLE (DEGREES)	ROOF PITCH
5	1/12
10	2/12
14	3/12
18	4/12
23	5/12
27	6/12
30	7/12
34	8/12
37	9/12
40	10/12
43	11/12
45	12/12
47	13/12
49	14/12
51	15/12
53	16/12

Table 2.4

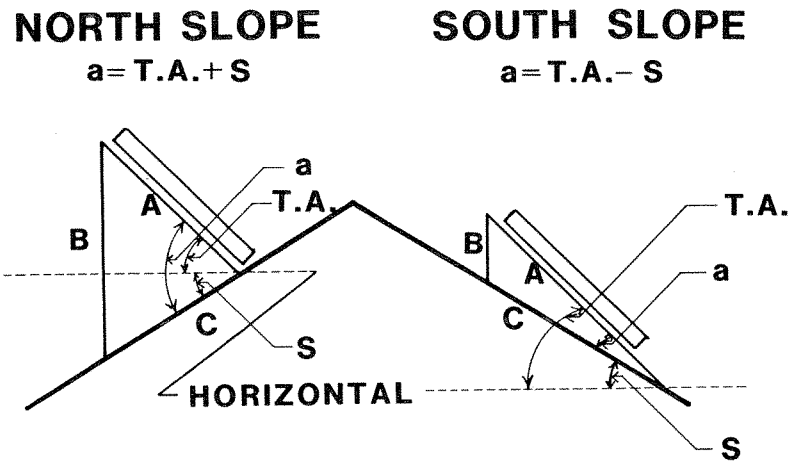


Figure 2.18

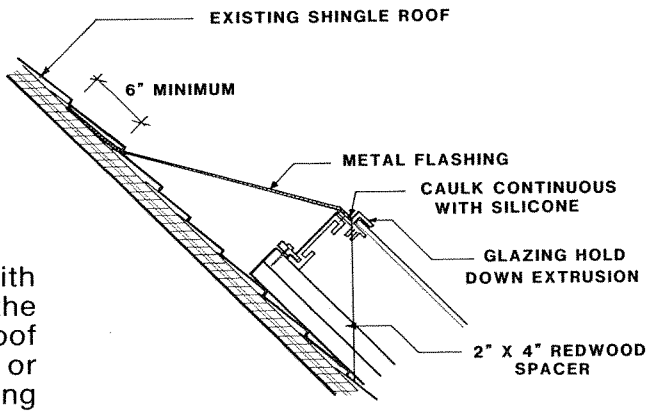


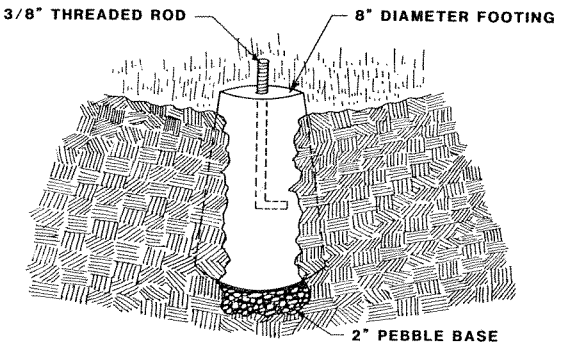
Figure 2.19

- If the slope of your roof is compatible with the collector tile angle, you may flash the upper end of the collectors to keep the roof surface under the collector dry and free or debris. Refer to Figure 2.19 for flashing installation.

- Consult your building code official for wind loading and structural requirements.

- Ground Mountings
  - — ZONING: Before starting construction of a ground-mounted collector array, check local zoning ordinances. The ground-mounted unit may have to conform with local requirements for setback, density, classification of structure and aesthetic requirements.
  - — FOOTINGS: Collectors are mounted on a rack or frame that must be securely attached to footings extending below the local frost line. There should be at least four pier footings, 8" square or in diameter. Footing holes should be dug below the frost line and the bottoms filled with an inch or two of dry, washed pebbles. The footings should be poured with a frame member or a threaded rod protruding from the concrete.

    If the frame is embedded, make a temporary jig so that the rack holds shape while the concrete sets. If the frame member is wood, it must be treated to slow deterioration. If you are using a threaded rod, it must be at least 3/8" in diameter. Instead of pouring four footings, you might want to pour two parallel walls.
  - — FRAMEWORK REQUIREMENTS: In addition to proper evaluation and orientation, the bottom edge of the collectors must be a minimum of 18 inches off the ground to prevent mud splashing and snow drifting up to cover the bottom of the panels. It is wise to attach a small gutter below the collectors to prevent excessive erosion of the soil directly in front of the collector array. A pebble bed in front of the collectors will also help prevent erosion.



PIER FOOTING

Figure 2.20

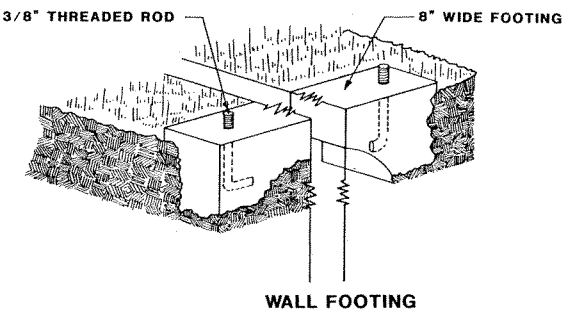


Figure 2.21

Step 5 Penetrate and Seal Roof

Overview:

- Locate and drill holes to allow piping and sensor wires to penetrate the roof. Then install and seal roof jack(s) to prevent water infiltration.

Materials:

- Roof jack(s), roof cement, short piece of copper tubing, roofing nails.

Notes:

- Be sure to purchase roof jack(s) with holes large enough to accept the copper tube and insulation.
- To avoid malfunction of the control system, do not use the same hole for both tube and control wire. Be certain control wire has ample clearance through the jack and roof.
- Apply roof cement beneath the jack and under the roof shingle.
- If separate roof jacks are used for the supply and return tubes, locate the holes far enough apart to avoid overlapping of the roof jacks.

Procedure:

1. Locate and drill piping and control wire holes if pipes are to be routed through your roof. The pipe holes should be at least 1/8" larger than the outside pipe diameter and the control wire hole at least 1/4" in diameter.
2. On shingled roofs, trim the shingle for the radius of the jack's cone. Apply roof cement to the entire area under the jack. Thread the control wire through the roof's surface and then through the jack.
3. Insert the jack under the shingle and firmly press out all the entrapped air under the jack. Then direct a short insulated tube through the roof to verify alignment.
4. Finally, nails can be driven through the jack beneath the shingle and into the roof. Apply roof cement over the nail heads.
5. For flat roofs, be sure to apply a generous coat of roof cement over the top of the jack as shown. Otherwise the method for sealing penetrations is similar to that for shingled roofs.

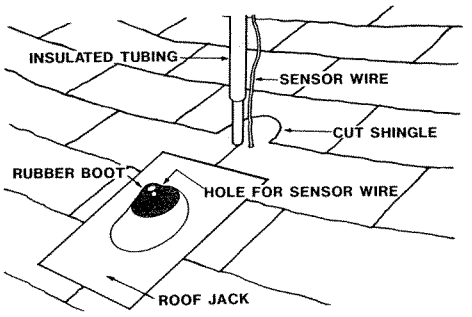


Figure 2.22

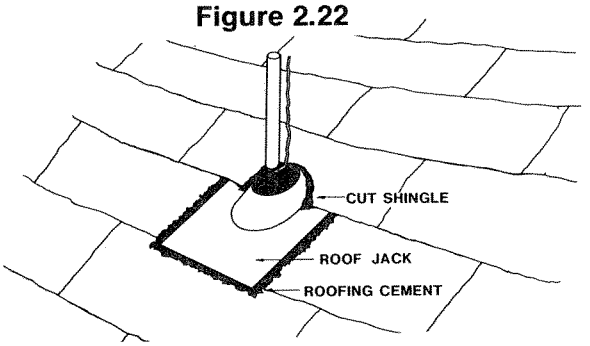


Figure 2.23

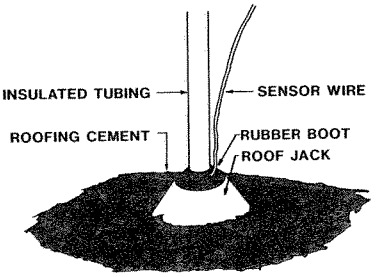


Figure 2.24

Step 6 Prepare Storage Tank

Overview:

- Whether you are modifying your existing hot water heater or installing a new solar tank, prepare your tank for incorporation into the system.

Materials:

- New sacrificial anode if necessary.
- New dielectric unions if necessary.
- New temperature/pressure relief valve recommended.

Notes:

- WARNING: Be sure electricity or the gas supply to the storage tank is off before any work is started. To verify disconnected power, check the pilot light in gas systems. For electric tanks, test for voltage at the tank thermostat.

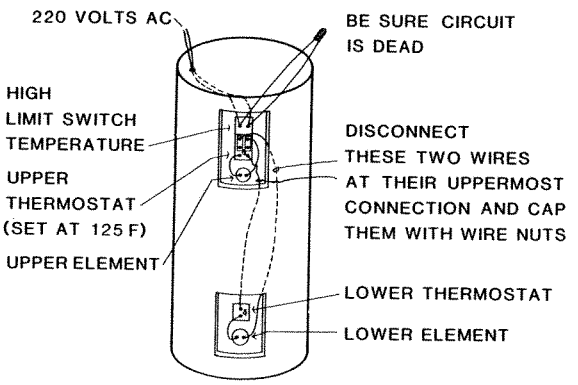


Figure 2.25

Procedure:

1. Shut off the power supply to existing tank.
2. Close cold water city supply valve to the tank.
3. Open the temperature/pressure relief valve.
4. Attach a garden hose to the bottom hose bibb fitting and drain the tank.
5. Remove hot, cold, temperature/pressure and drain valve connections.
6. Move the tank outdoors and examine it carefully to determine remaining tank life expectancy. Check for the following:
   - Excessive corrosion or rust at the top ports.
   - Extreme material buildup on internal tank walls and bottom.
   - Sacrificial anode (fully deteriorated rod indicates minimal service life remains).
   - If you decide to use your existing tank, continue with PROCEDURE 7;
     if you install a new standard tank go to PROCEDURE 8;
     if you choose a new solar tank skip to PROCEDURE 12.
7. Clean the inside of the storage tank thoroughly with a wet and dry shop vacuum or garden hose.

8. At the upper thermostat disconnect the two wires which extend downward to the lower heating element and cap with wire nuts.
9. Set the thermostat for the upper heating element no higher than 140F. **An ideal setting would be 125F.**
10. Remove the cold water supply dip tube from the tank interior. Two different dip tube designs are typical and therefore require different removal techniques.

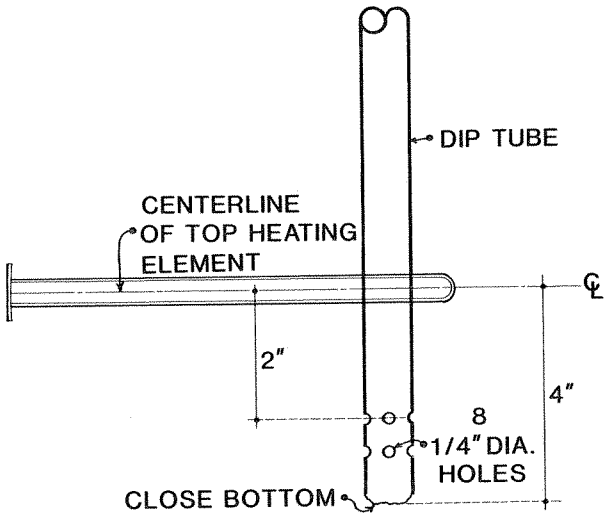
    Flared dip tube — remove external fittings then insert finger or long nosed pliers into the tube and work loose.

    If dip tube is an integral part of the exposed fitting, then raise the tank cover and remove fitting with a pipe wrench. Be careful not to damage the fitting.
11. Cut and modify the dip tube. Drill 1/4" holes (four thru holes) no closer than 2" below the center or the top of the heating element. If a gas tank is to be used as primary solar storage, cut the dip tube 14" long and modify as shown. Re-install the modified dip tube in your tank.
12. Install your modified and/or new tank. Set the tank on a piece of 2" waterproof, rigid, high density insulation to reduce bottom losses.
13. Be sure the temperature/pressure relief valve outlet is piped to a safe place per local building codes.

    NOTE: If you install a solar tank, put a brass or steel cap into the lower port labelled "Solar Supply." Then install the system using the upper port labelled "Cold Supply." See Additional Information in Step 7.

Additional Information:

- The large accumulation of debris in your tank is a result of minerals separated from the water during boiling heat transfer on the surface of the heating elements. Since boiling heat transfer does not occur in the heat exchanger, the tank will stay cleaner and require less service in the future. Flush the tank once each year.



(HEAT WITH TORCH AND PINCH CLOSED)

DIP TUBE MODIFICATION DETAIL

Figure 2.26

Step 7 Install Hardware

Overview:

- Assemble and install all necessary hardware.

Materials:

- Copper tubing and fittings
- Solder (solid wire, 50/50, tin/lead)
- Solder (96.5/3.5, Tin/silver) for use near collectors
- Kit hardware
- Teflon tape
- Flux (organic)
- Emery cloth

Notes:

- If the vertical distance from heat exchanger to collector exceeds 35', the hose bibb fill valves and the gate valve between them must be relocated. Install this portion of the assembly near the collectors and fill the system from this high point according to procedures outline in Step 9.
- See "The Fine Art of Soldering," Section 5.
- Install heat exchanger according to labels applied in the laboratory.
- Consult code officials to determine tubing wall thickness minimums and other specific details regarding building and safety procedures.
- Use teflon tape on all threaded intersections — not plumber's pipe joint compound.
- Use 50/50 solid wire solder — not acid or rosin core — and organic flux. Use silver solder near the collectors.
- Use a dielectric union wherever copper piping joins to galvanized piping.
- Do not overtighten dielectric unions.
- Do not solder in attic or where fire potential exists; instead use soft copper tubing where it is accepted by your local code.
- All valves and fittings are supplied in the hardware kit unless otherwise indicated. See Table 2.5 for small fitting use.
- Route the tubing for ease of installation and insulation. Specifically, locate the horizontal piping high enough above the roof so the pipe insulation does not touch the roof surface.
- Support piping where necessary, particularly near the heavier components such as the air separator and expansion tank.
- Cut all copper nipples from a longer copper tube which you must supply.
- Be sure not to bend soft copper tubing too sharply, the minimum radius should be 3" for 1/2" tubing Use a tubing bender or spring coil to make the job easier.

Procedure:

1. Rigid board insulation and aluminum tape is provided in the kit. Apply this material to the heat exchanger before installation of the kit hardware.

   NOTE: Be careful not to plug heat exchanger tubing with insulation.

2. Tank drain port modification: Remove the hose bibb drain if necessary and install the kit hardware as shown in Figure 2.27.

   NOTE: Remove the dielectric washer while soldering. Use teflon tape on all pipe threads.

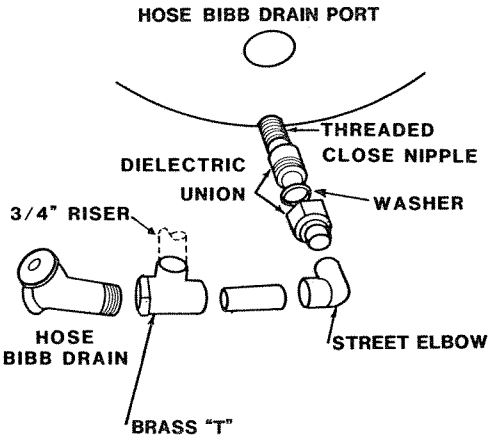


Figure 2.27

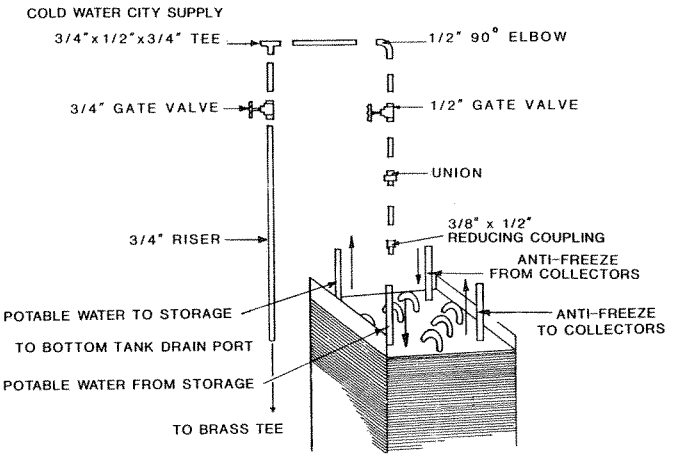


Figure 2.28

3. From brass tee upward to 3/4" gate valve. Install 3/4" riser of rigid copper tubing (supplied by homeowner).

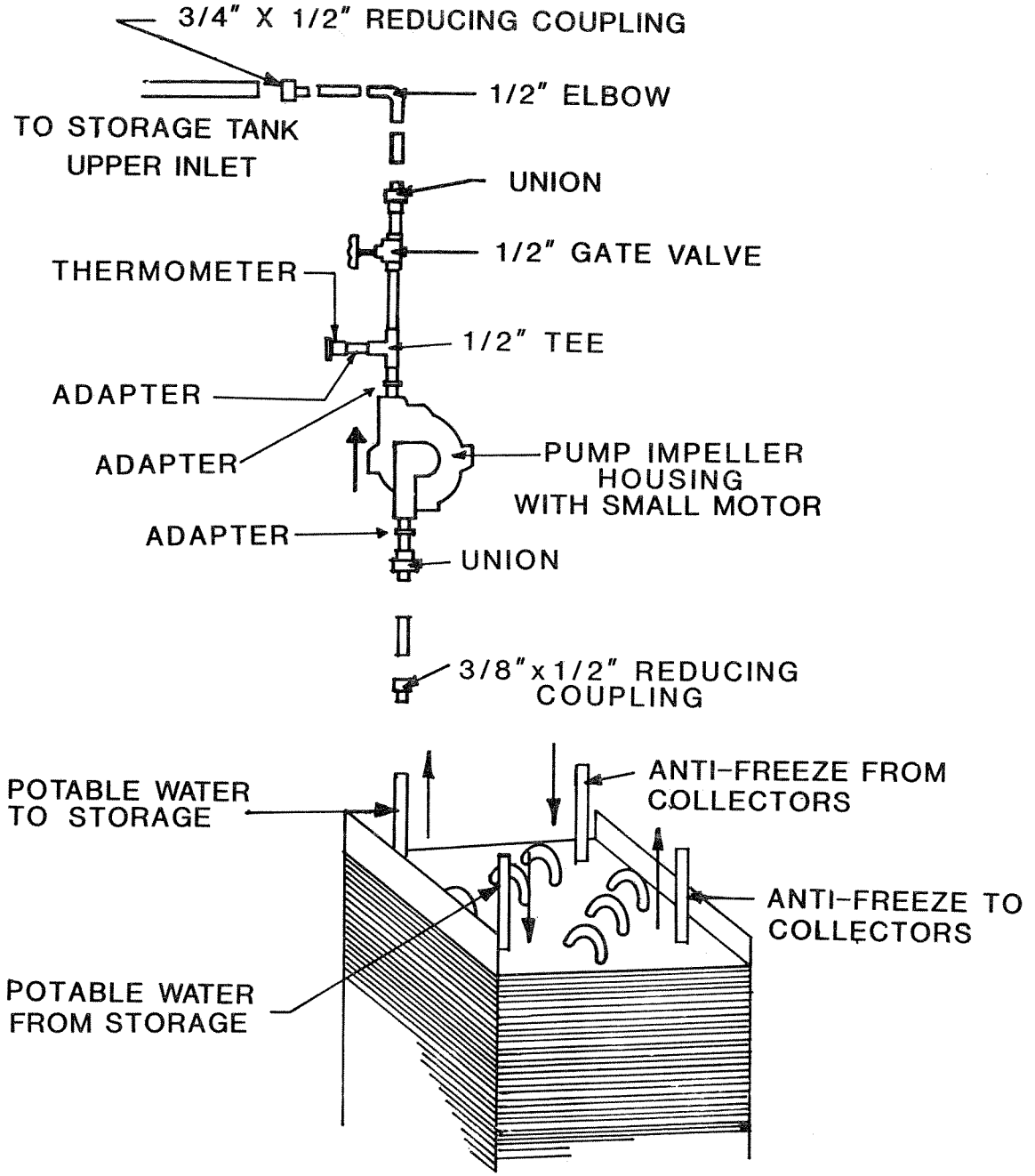


Figure 2.29

4. Solder unions to tubing and connect pre-assembled storage pump sub-assembly. NOTE: Arrow on pump housing points in the direction of the flow-upward, toward the storage tank. Mount pump motor with oil ports up.

   Connections between the 3/4" × 1/2" reducing coupling and the storage tank are supplied by homeowner. Be sure to purchase new dielectric unions of the old ones are corroded.

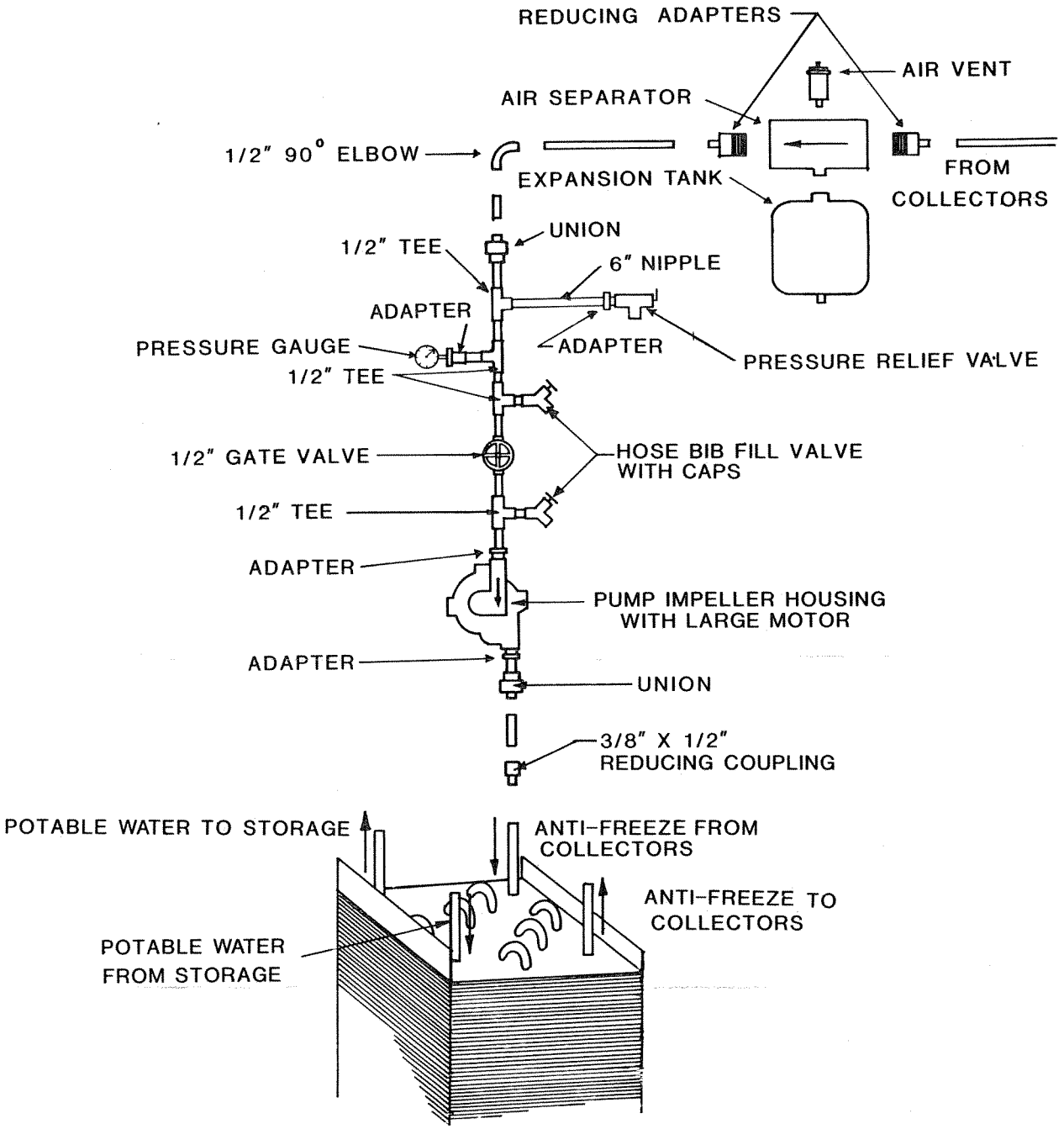


Figure 2.30

5. NOTE: Arrows on pump housing and air separator are to point in direction of flow — downward toward heat exchanger. Mount pump motor with oil ports up.

   Be sure pressure relief valve outlet is piped to a safe place per local codes.

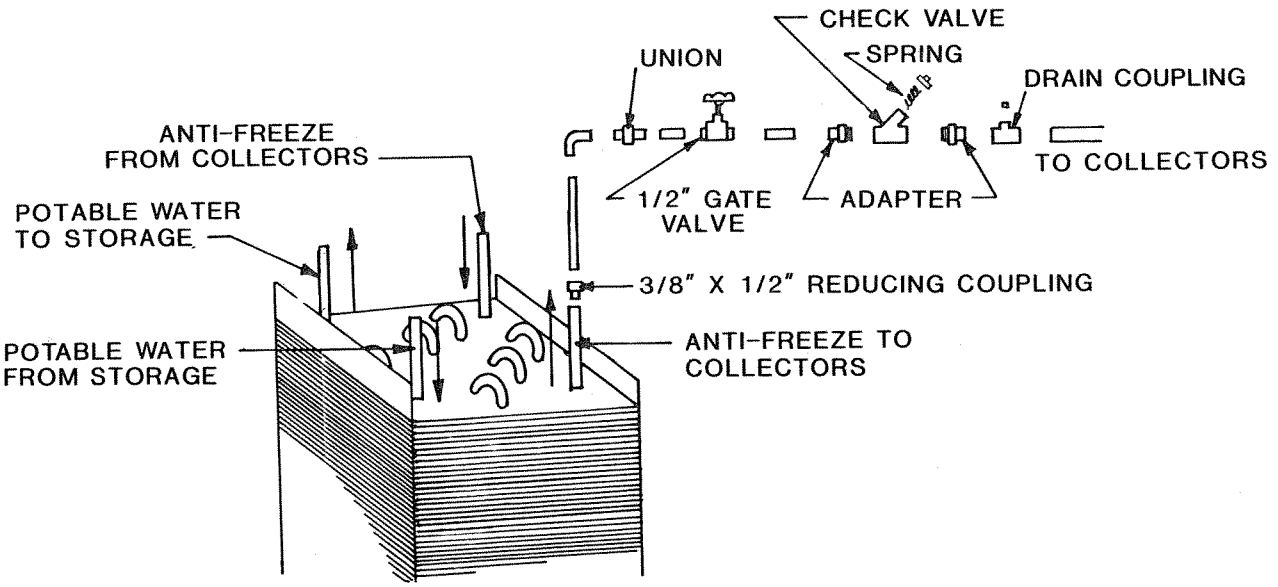


Figure 2.31

6. NOTE: Arrow on check valve must be pointed in direction of flow-upward toward collectors. Orient drain coupling to facilitate easy draining of supply lines. Insert the spring in the check valve as shown in the detail.

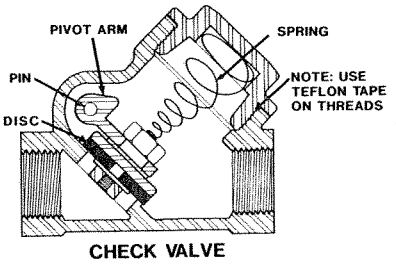


Figure 2.32

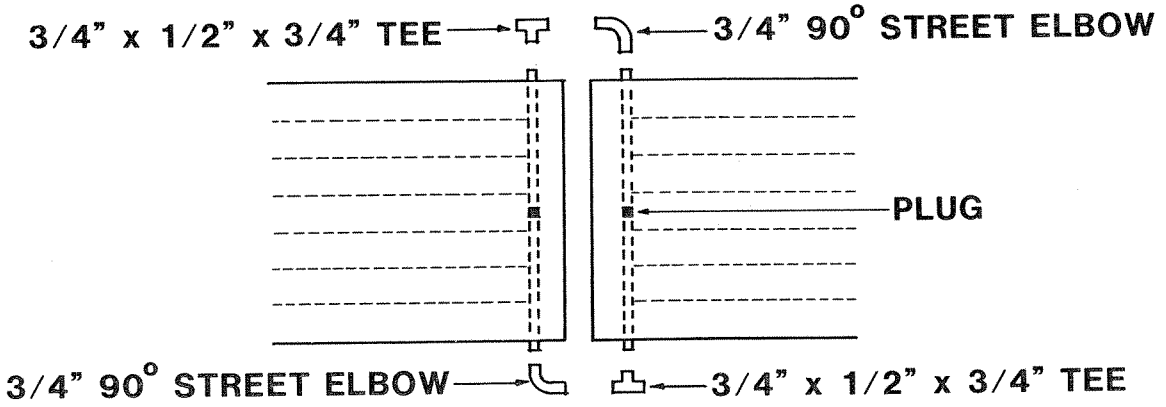


Figure 2.33

7. Collectors are placed tightly together and plumbed as shown in Figure 2.33.
8. Seal your roof jacks with roof cement where the tubing exits the jack if necessary to prevent water infiltration.

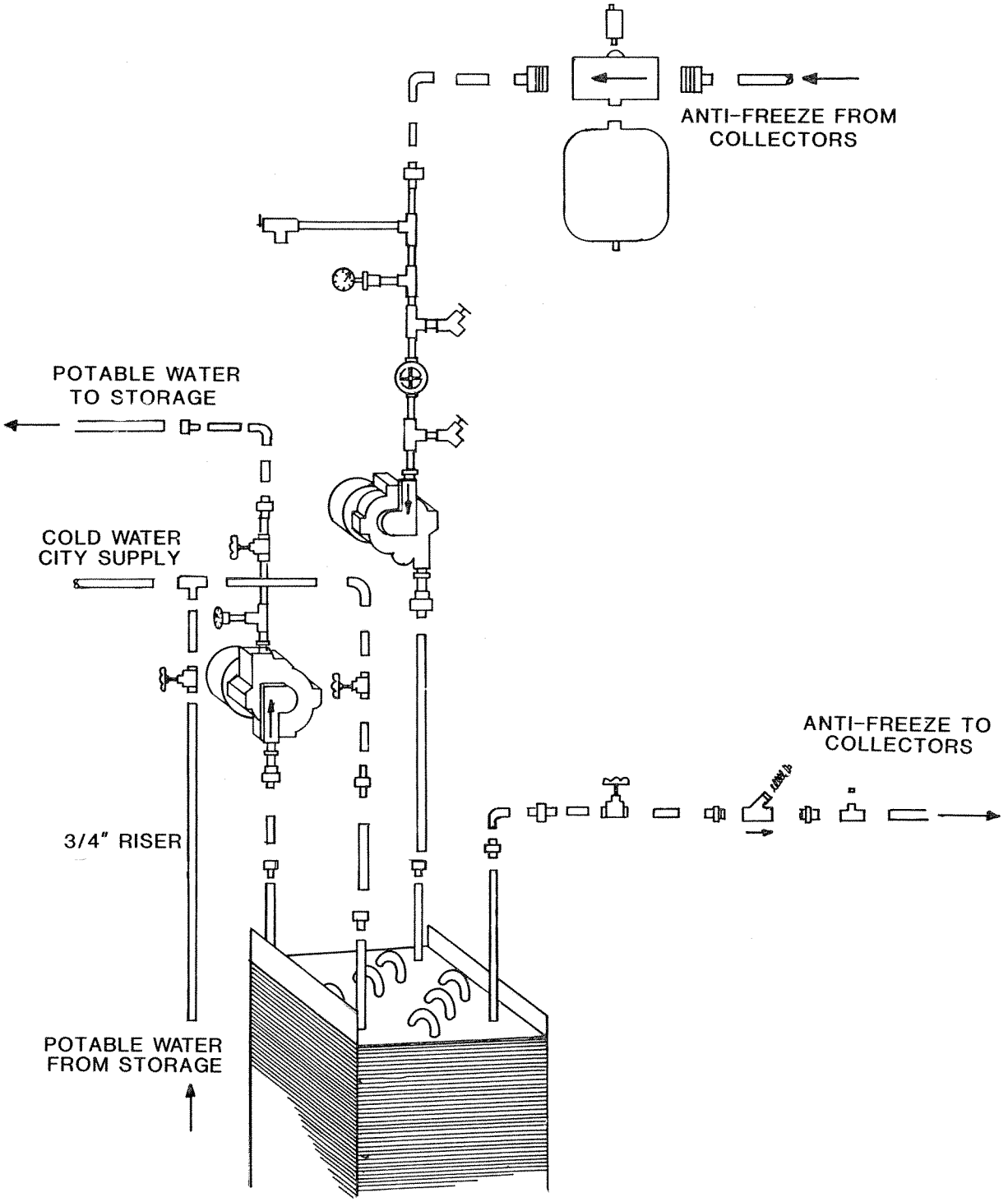


Figure 2.34

Heat Exchanger Plumbing Isometric

Additional Information:

Parallel Heat Exchanger Installation

- Two heat exchangers or one larger one is required if three or more collectors are used. Dual heat exchangers improve system efficiency and therefore are cost effective. The installation of parallel exchangers must be as shown on in Figure 2.35. Be certain anti-freeze fluid from the collectors flows in the opposite direction of the potable water from storage. Avoid cross contamination which would result in poisoning the potable water.

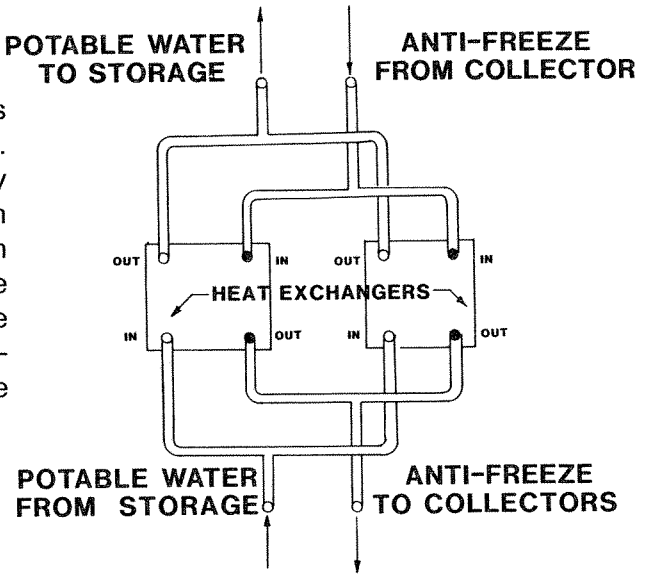


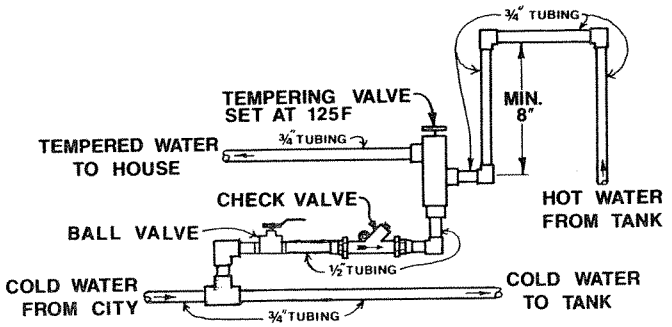
Figure 2.35

Optional Equipment:

- Check with local building department if you intend to include any of the following options.

  TEMPERING VALVE: Thermostatically adjustable valve which mixes storage water with cold water supply; recommended for safety reasons: to prevent possible scalding. The valve serves to increase the effective storage cpacity by restricting the flow of the solar heated water from the storage. This valve may be required by your local building code.

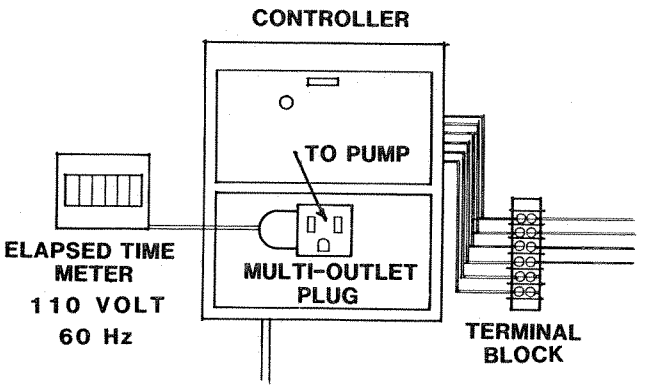
NOTE: Install the tempering valve as shown. The ball valve before the check valve is used to restrict the cold water flow through the tempering valve to facilitate its proper operation. Furthermore, **this ball valve must be closed during the system fill operation.**



TEMPERING VALVE INSTALLATION DETAIL

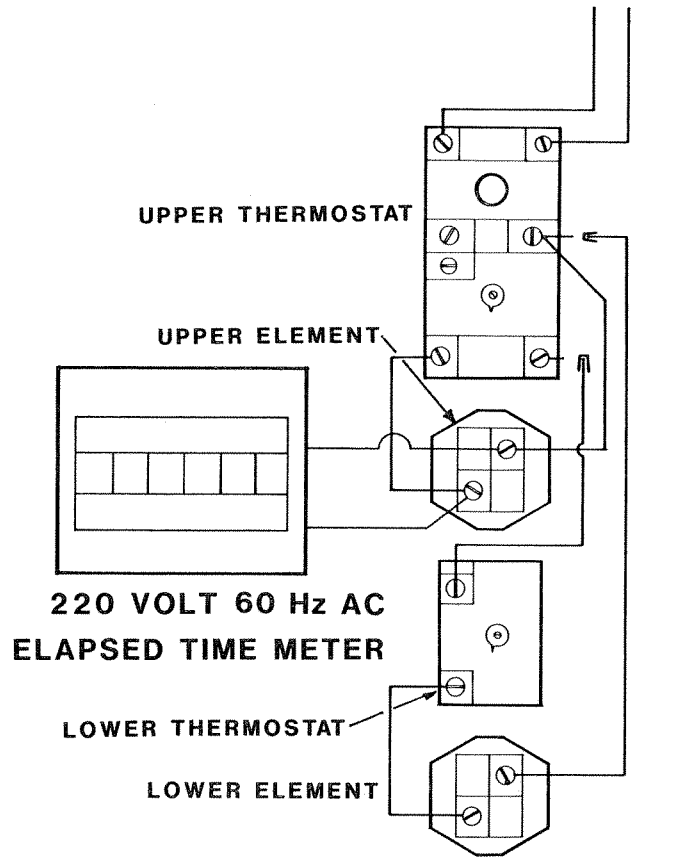
Figure 2.36

PUMP RUNNING TIME METER: can be used to determine the amount of time your pump is running; a recommended diagnostic instrument.



PUMP RUNNING TIME METER

Figure 2.37



AUXILLIARY ENERGY RUNNING TIME METER

Figure 2.38

AUXILIARY ENERGY RUNNING TIME METER: Recommended to determine the amount of auxiliary energy consumed by the domestic water heater element. Similar to a clock but displays the accumulated operating hours. The product of the elapsed time and the kW rating of the heating element is the kWh of auxiliary power used by the water heater during that time.

- Alternative tank arrangements, for standard electric retrofit see Figure 1.1.

Preheat to Gas, Electric or Boiler

In this situation, the hot supply to the house which comes off the top of the solar storage tank is directed into the cold water supply port of the existing gas tank or boiler heating coil. In this way, all water received is preheated by the solar system.

A bypass should be installed to isolate the gas tank or boiler and use 100% solar when possible. Also, a future option is to remove the gas tank or boiler from the circuit and install electricity to your solar tank should the cost of your present fuel increase.

NOTE: Capacity of solar storage should be related to collector and family size.

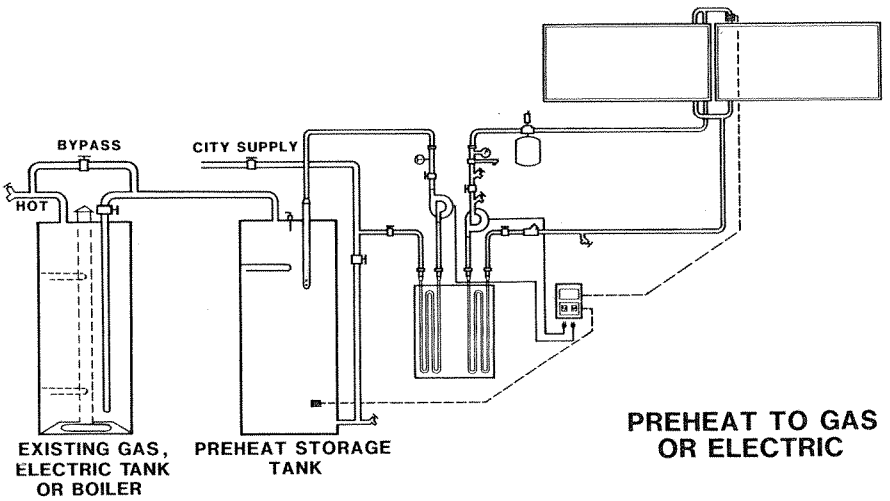


Figure 2.39

Solar Tank

There is one very important detail to note which you may find contrary to solar tank manufacturer's installation instructions; it is essential to the air purge/system-fill procedures. Put a brass or steel cap onto the port labelled "Solar Supply." Then install the system using the ports labelled "Cold Supply" and "Solar Return," as shown.

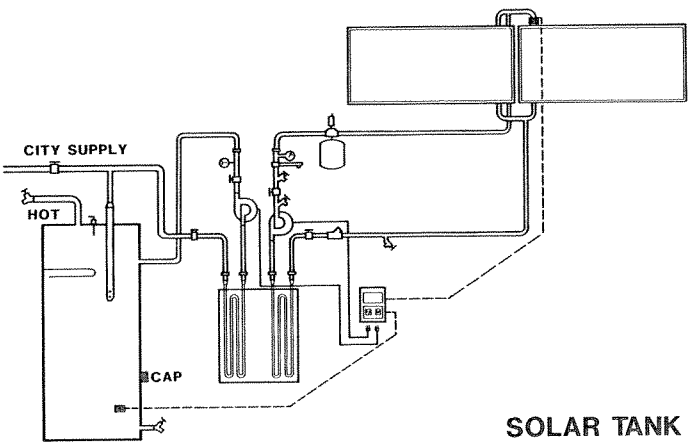


Figure 2.40

Dual Tank

If your present tank is in good condition and less than two years old, but only 30 - 40 gallons in capacity, there is a substantial improvement in annual system performance if the total storage capacity is increased. However, be careful not to increase the total storage capacity beyond 82 gallons for two collectors, 100 gallons for three collectors, or 120 gallons for four collectors.

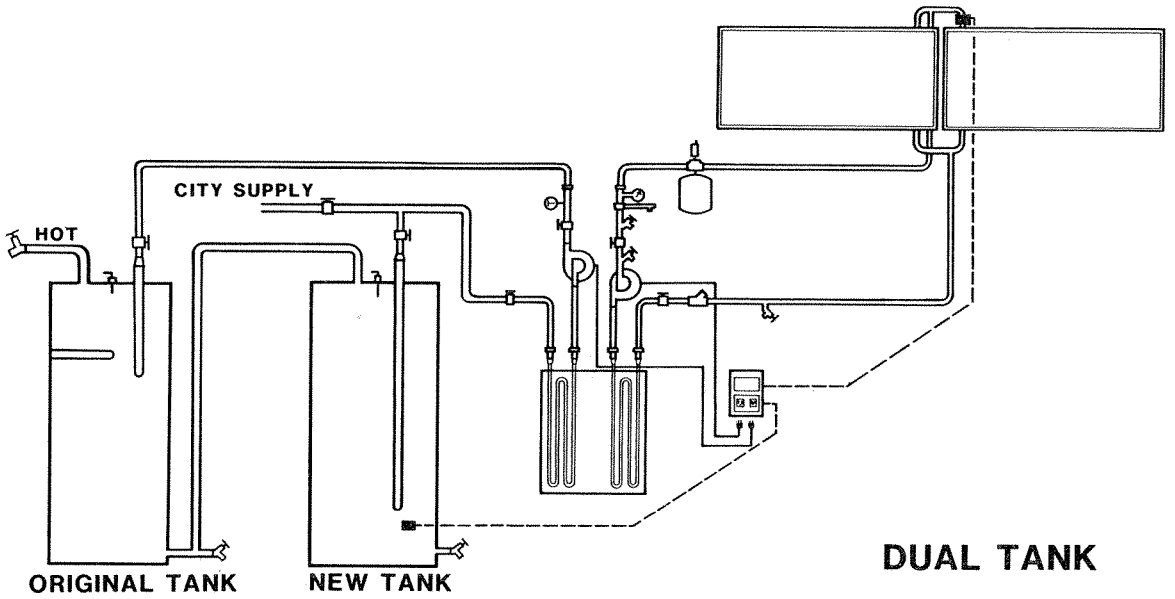


Figure 2.41

Installation of the dual tank system is relatively simple. The newly acquired storage tank is plumbed as shown. The cold water dip tube within the tank replaces the need for an external riser. Figuratively, one tank has been put on top of another. Follow the original tank's plumbing. Cold water is drawn from the bottom of the new tank through the internal dip tube. The water then passes through the exchanger and is returned to the top of the original storage tank via the modified dip tube. The coolest water from this tank is then drawn from the bottom and deposited into the top of the new tank to be eventually pumped through the exchanger thus completing the circuit. If the hot water faucet is opened in the house, the flow is reversed. This results in the hot water being drawn off the top of the original tank. This tank is filled from the bottom with water from the top of the new tank, which in turn receives its supply from the city, via the internal dip tube.

NOTE: This arrangement has greater thermal losses due to a larger surface area to volume ratio. Be sure to insulate extra well.

TABLE 2.5 SMALL FITTINGS USE

Gate valve, 1/2"C (Four furnished)	(1) Isolates exchanger from main line. *(2) Isolates storage circulator and exchanger from tank. (3) Isolates exchanger from line to collectors. *(4) Serves as fill check valve.
Gate valve, 3/4"C	Opens lines between tank bottom and exchanger. Closed during purging.
*Boiler drain (Two furnished)	Used with washing machine hose to fill system.
Elbow, 1/2" 90° C (Three furnished)	Three used in lines to heat exchanger.
Hose thread caps (Two furnished)	Two used to cap boiler drains.
Adapter, 1/2" C×F (Five furnished)	*(1) Connects to storage circulator inlet. *(2) Connects to storage circulator outlet. *(3) Used with pressure relief valve. *(4) Two used with collection circulator.
Tee, 3/4" C×F×C	Used at tank bottom with drain valve.
Tee, 3/4"×1/2"×3/4" C×C×C (Three furnished)	(1) Used at junction of incoming main line, line from bot- of tank, and 1/2" line to exchanger. (2) Two used with collector inlet/outlet.
Tee, 1/2"×C×C×C (Five furnished)	*(1) Used with temperature gauge. *(2) Used with pressure relief valve. *(3) Used with pressure gauge. *(4) Two used with boiler drain.
Elbow, 3/4" 90° Ell ftg.×C (Three furnished)	(1) Used at tank bottom. Fits into dielectric union. (2) Two used with collector inlet/outlet.
Union dielectric 3/4"	Used at tank bottom between galvanized nipple and copper elbow.
Reducing coupling, 3/4" × 1/2" × C×C	Located above tank in return line.
Drain coupling, 1/2" C×C	Assists in draining collectors and supply lines to collectors.
Adapter, 1/2"×1/4" C×F (Two furnished)	*(1) Used to install thermometer. *(2) Used with pressure gauge.
Adapter, 1/2" C×M (Three furnished)	*(1) Connect to pressure relief valve exit. (2) Two used with check valve.
Adapter, 1/2" × 1" C×M (Two furnished)	Two used with vent, air purger, expansion tank combination.
Reducing coupling, 1/2"×3/8" C×C (Four)	Four used with heat exchanger.
Unions, 1/2" C×C (Six furnished)	*(1) Used to disconnect exit side of storage circulator. *(2) Used at air purger. *(3) Four used to disconnect exchanger.
Nipple, 3/4" Gal × Close	Used at tank bottom outlet.

*Fittings used in laboratory to assemble plumbing "trees."

Step 8 Install the Controller/Sensors

Overview:

- Install the controller, sensors and wiring.

Materials:

- Liquid steel (or equivalent thermal conductive adhesive)
- Control wire (22 gauge stranded two conductor jacketed wire)
- Wire nuts
- Electrical tape
- Silicone sealant
- Roof cement
- Hose clamp

Notes:

- Do not plug controller into an outlet controlled by a switch.
- Do not use staples to fasten wires. The insulation can be broken and the wire may short or open.
- Be sure all wires are correctly secured for protection against breakage or damage.
- Use caution when pulling wires through roof jack(s) as wires may be easily stripped by sharp metal edges and could short or ground out.
- Protect buried wire from shovels, burrowing animals, etc.; use conduit.
- Attach sensors securely and insulate from ambient air temperatures to insure correct operation.
- Waterproofing is important because moisture from rain and humidity can corrode the wire connections and cause sensor failure. Seal wire nut connections with silicone and wrap with electrical tape.
- The controller compares the temperature-related resistance of the sensors at the collector and the storage tank. When the collectors are warmer than the storage tank, the pumps are energized.
- Sensor dynamics vary with controllers and must be matched; therefore, do not use any tank manufacturers' pre-mounted sensors.

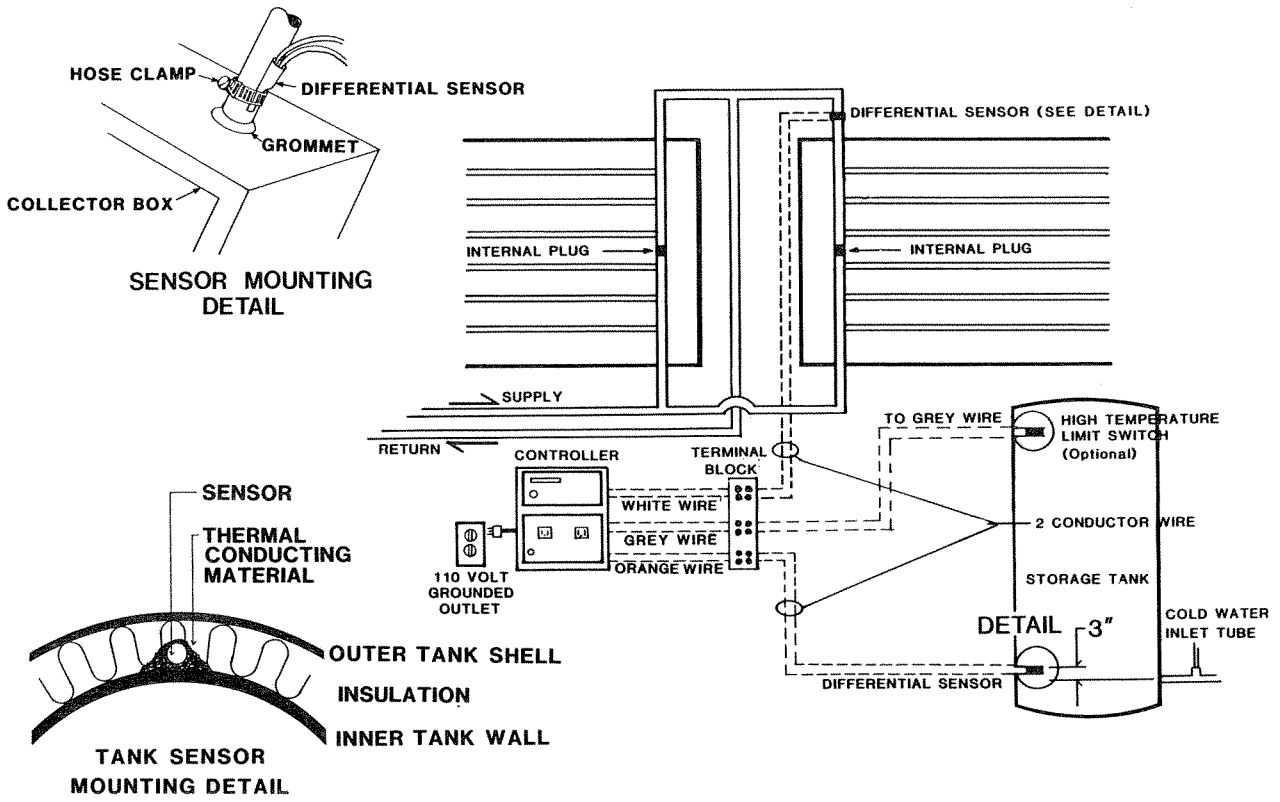


Figure 2.42

NOTE: Installation details may vary slightly depending on controller used. Follow the instructions included with controller, and save for future reference.

Procedure:

1. Install the controller indoors, near the pump sub-assemblies and near an unswitched 110-volt grounded receptacle. Do not plug controller into a receptacle at this time.
2. Mount the terminal block nearby and attach the wires from the controller as shown.
3. Attach control wires to terminal block and run to sensor locators.
4. Plug the pumps into the receptacles on the controller.
5. Mount one thermistor beneath the tank insulation directly to the steel storage tank 3" to 4" above the cold water supply port. Use a good quality thermal conductive adhesive, such as Liquid Steel or silicone. This exact procedure is important for satisfactory performance.
6. Securely attach the second thermistor to the return tube of one of the collectors as shown: use the hose clamp provided in your kit. Do not collapse the sensor body; apply clamp to sensor tab.
7. You may wish to add an optional high-temperature switch to limit storage water temperature for safety and to extend tank life (this may be a tank warranty requirement). Consult the instructions supplied with the controller for specifics, and refer to Figure 2.42.
8. With silicone-filled wire nuts, connect the sensors to the control wiring. For strain relief, tie an overhand knot in the leads after joining them together. When insulating (Step 10), insulate over the sensor and attach the control wires outside the insulation with suitable tape.

Step 9 Fill System and Start-up

Overview:

- Fill and fine tune your new solar system.

Materials and Equipment:

- Prestone II or Dowtherm SR I anti-freeze and distilled water
- Charging pump with two hoses
- Bucket — 5 gallon capacity minimum
- Filter — fine mesh paint filter or ladies' nylon stocking
- Tire pump
- Tire pressure gauge

Notes:

- CAUTION: Anti-freeze fluid is highly toxic; **handle it carefully**. Store out of children's reach and clean spills immediately.
- Open the valve stem cover on the air vent two full turns to automatically expel any air.
- After purging your system, be sure to clean any trapped particles from screens at your faucets.
- Under normal operation all gate valves in the system must be wide open.

Procedure:

FILL PROCEDURE: POTABLE SIDE OF HEAT EXCHANGER

1. Examine all solder joints for leakage potential.
2. Purge the system of air:
   Open — city supply to storage (A)
   Open — gate valve in pump sub-assembly (B)
   Open — hot water faucet in house (C)
   Open — gate valve in heat exchanger supply (D)
   Close — 3/4" gate valve in external riser (E)

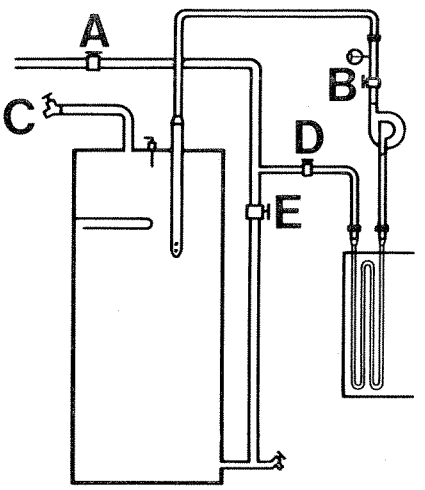


Figure 2.43

3. Allow the system to fill the storage tanks — approximately 15 to 20 minutes for 50 gallons of storage capacity. The system will be full when no air flow is heard at the hot water faucet in the house. Close the faucet.

4. Open the 3/4" gate valve (E) in the external riser and the system will function normally.
5. Re-examine all piping and all connections to be sure no leaks are in this portion of the solar system.

FILL PROCEDURE: COLLECTORS AND ANTI-FREEZE SIDE OF HEAT EXCHANGER.

NOTE: The charging pump used in the fill procedure can produce a pressure of about 18½ PSI. In order to keep the expansion tank from filling with an excessive amount of fluid, thus, preventing adequate expansion volume when the system heats up, you should increase the pressure in the lower portion of the expansion tank before the fill procedure. Use a tire pump and tire gauge — not the system pressure gauge — for this operation. If the fill valves are located in close proximity to the expansion tank, pressurize the expansion tank to 17 PSI.

As noted in Step 7, if your collectors are more than 35' above the pressure gauge, you should have located your fill valves at a higher point. In this case, see "High Fill Position" under Additional Information.

1. Calculate the volume of 50% anti-freeze and 50% distilled water necessary for your solar system. List this information below.

Number of collectors × .9 ("Terralite")	=	_____ gal.
or Number of collectors × .5 ("Thermafin")	=	_____ gal.
or Number of collectors × .72 (Phelps Dodge)	=	_____ gal.
Number of heat exchangers × .2	= +	_____ gal.
Number of feet of 1/2" fittings and tubing in coll. circuit × .013	= +	_____ gal.
Number of feet of 3/4" fittings and tubing in coll. circuit × .027	= +	_____ gal.
Sub Total		_____ gal.
Sub Total × .25 (Volume required for adequate fill)	= +	_____ gal.
TOTAL		_____ gal. of anti-freeze and water solution.

Record the total volume on the Preventative Maintenance Sheet (Section 5).

Example

a. 2 Collectors ("Terralite"), b. 1 Heat exchanger, c. 15 feet of 1/2" tubing and fittings, d. 50 feet of 3/4" tubing and fittings.

a.	2	× .9	= 1.8
b.	1	× .2	= 0.2
c.	15 ft.	× 0.013	= 0.2
d.	50 ft.	× 0.027	= 1.35
	Sub Total		= 3.55
	Add 25%		= .89
	TOTAL		= 4.44 Gal.

CONVERSION TABLE

Fraction of Gallons	Volume
.1	12.8 oz
.25	1 qt
.50	1/2 gal
.75	3 qt
1.00	1 gal

Table 2.6

Mix 2.22 gallons of anti-freeze with 2.22 gallons of distilled water.

This 50/50 mixture will prevent freezing to -34F; a mixture of 70/30 (anti-freeze/water) will provide protection down to -84° F solutions with greater than 70% anti-freeze will freeze at a higher temperature.

2. Examine all solder joints for leakage potential. This is extremely important to avoid time-consuming and difficult rework. See air pressure test (Additional Information).
3. Couple one hose to the discharge side of the charging pump and to the lower hose bibb fill valve (F).
4. Cut the second hose 18" to 20" long. Attach this short piece to the suction side of the charging pump and submerge the other end into the anti-freeze/water solution.

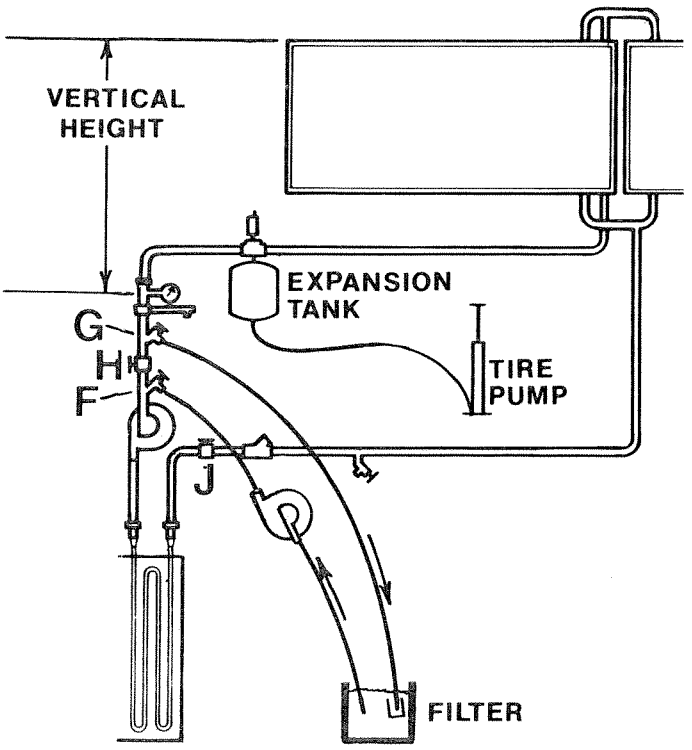


Figure 2.44

WARNING: Secure the pump so it cannot fall into the bucket.

5. Couple the remaining longer end of the second hose to the upper hose bibb fill valve (G). Secure a filter to the other end and submerge it into the bucket.
6. Close the 1/2" gate valve between the hose bibb fill valves (H).
7. Open the 1/2" gate valve in the supply line (J).
8. Plug the charging pump.
9. Plug in the circulation pump in the collector loop sub-assembly to boost flow rate.
10. Circulate the solution continuously through the system for 15 minutes. Be sure hoses are always under the surface of the fluid and bubbles are not drawn from one hose through another. Clean the filter as often as necessary.
11. Close the bibb valve (G). When no further increase is observed on the pressure gauge, close the hose bibb valve (F); then unplug the charging pump, and
12. Open the gate valve (H). Remove, clean and store the charging apparatus.
13. Re-examine all piping and all connections to be sure no leaks are in this portion of the solar system.
14. Remove the handles from the hose bibb fill valves after the system is charged and tightly secure threaded caps onto valve outlets. This eliminates accidental depressurization.
15. Pressure must be increased relative to your specific system characteristics. Use a tire pump and the valve stem located at the base of the expansion tank to adjust system pressure. Follow the formula below. Record the total pressure on the Preventative Maintenance Sheet (Section 5).

$$\frac{\text{Vertical Height of Collectors Above the Pressure Gauge}}{2.16} + 25 \text{ p.s.i.} = \text{Total Pressure to be applied to solar system. (As indicated on pressure gauge.)}$$

Start-up Procedure:

1. Orient the pump motors with oil ports **up** and apply four or five drops of non-detergent oil to each port.
2. **Controller start-up:**
   - Check all sensor wiring for short circuits.
   - Plug the controller into a 110 volt outlet (verify voltage). Plug the pumps into the controller.
   - Move the switch to manual "ON." In this position the indicator light comes on and the pumps should start.
   - Switch to the "AUTO" mode.
   - See the instructions with your controller for complete check-out procedures.
3. If your system utilizes balancing valve(s) adjust the valve(s) to equalize the flow to the collectors until the exit temperatures from all collectors are equal. Feel the inlet and outlet of each collector to determine the temperature rise. Make these adjustments at midday during clear days. Allow ten minutes for the temperature to stabilize. When correct, remove the handle(s) on the valve(s).

Additional Information:

Air Pressure Leak Test

Before filling the collector loop of your solar system, you may wish to perform this optional air pressure test to locate any leaks. Install the fittings shown in Figure 2.45 at any point in the collector loop. Be sure the drain coupling and the air vent are both capped tightly, and that both hose bibb fill valves are closed; using the tire pump, pressurize the collector loop with air to 50 PSI as shown on the pressure gauge. You may test for leaks with soapy water. Pressure should be held by the system for 24 hours; a reduction in pressure indicates a leak.

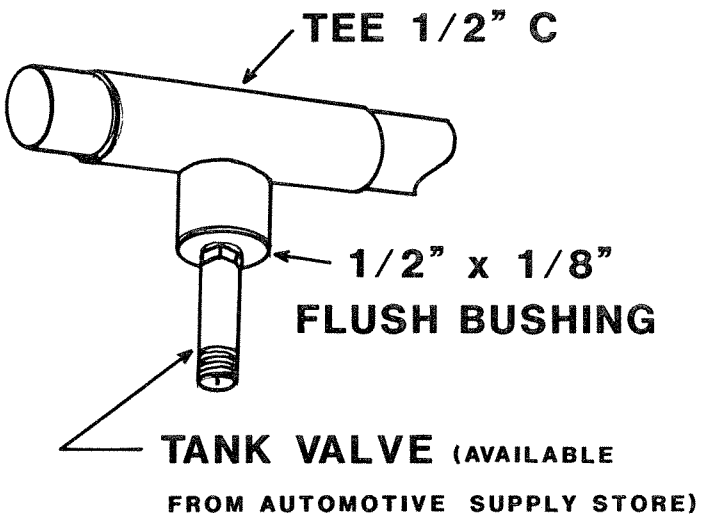


Figure 2.45

High Fill Position

Because the small charging pump can only raise fluid a maximum of 40 ft.; it is recommended in Step 7 that the fill valves be located near the collectors if the vertical height between the collectors of the height exceeds 35'. In this case, both the weight of the column of fluid and the charging pump pressure will be pressing down on the expansion tank diaphragm.

To compensate, you must increase the expansion tank pressure by an amount equal to that produced by the height of the collectors. Begin by calculating the PSI due to height of the collectors above the expansion tank:

$$\frac{\text{height}}{2.16}\text{(feet)} = \_\_\_\_\_ \text{ PSI}$$

Record this number above. Increase the expansion tank pressure by this amount so that the total is this number plus 17 PSI (pressure due to charging pump).

Then continue the fill procedure as described earlier. At the end of the fill procedure, be sure to add additional pressure as required in Procedure 15.

- HOUSEHOLD DEMAND MODE: As water is drawn at the faucet, the city pressure fills the tank through the external riser from the bottom up. This duplicates the function of the original dip tube. The result is that the warmest water is on top of the storage tank available for household use.
- SOLAR MODE: When the hot water faucets are not in use, the system is entirely full and no more water is able to enter from the city supply. The small circulating pump within the system then is able to draw water up the external riser through the heat exchanger and back into the upper volume of the storage tank available for household use the next time a hot water faucet is opened. The external riser is a two-way street: water flowing downward to fill the tank as necessary and otherwise flowing upward to circulate through the heat exchanger.
- SYSTEM SERVICING: When servicing system, make sure that either loop of the heat exchanger is not isolated. For example, if both gate valves on the storage side (labelled #15 on system diagram, Figure 1.1), or both valves on the collector side are closed, then a union at the heat exchanger on the opposite loop must be disconnected. This will assure that damaging pressure will not be produced within the heat exchanger.

System Refill Procedure:

See Preventative Maintenance to determine when necessary to refill.

1. Fill a bucket with the calculated volume and proportion of the anti-freeze and distilled water solution for your system capacity.
2. Orient the charging pump and hoses as described previously. Secure the pump to assure it does not fall into the bucket.
3. Position a second empty bucket of equal volume; then position the remaining hose as shown below.
4. Close gate valve (H).
5. Start charging pump and circulating pump in collector loop.
6. Open hose bibb fill valve (F).
7. Quickly open hose bibb fill valve (G).
8. Pump new fluid until only 20% remains in the bucket.
   NOTE: Be sure to keep the suction hose under the surface of the fluid to avoid drawing air into the system.
9. Quickly move the discharge hose into the new anti-freeze solution bucket and submerge it below the surface of the fluid. Continue circulating for 15 minutes. Be sure the hoses are always under the surface of the fluid and bubbles are not drawn from one hose through the other.
10. Close the hose bibb fill valve (G).
11. Continue pumping the solution until no further increase is observed on the pressure gauge; close hose bibb fill valve (F). Remove, clean and store charging apparatus.
12. Increase the pressure in your solar system using a tire pump according to the procedure 15 outlined in the fill procedure for the anti-freeze side.
13. Open gate valve (H).

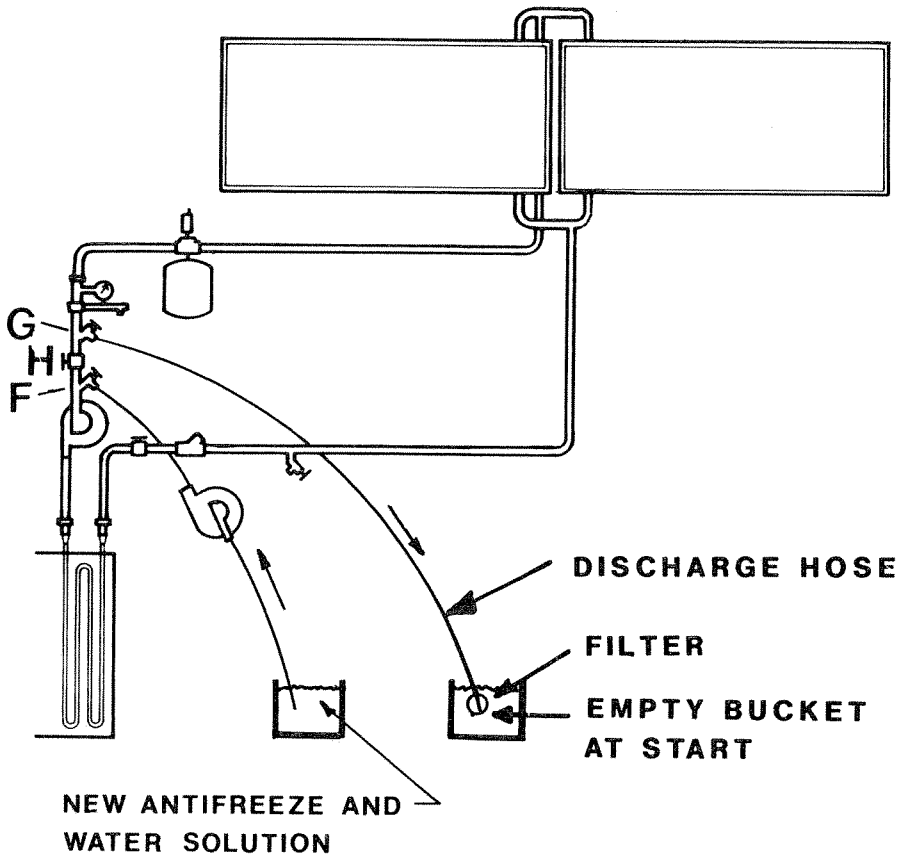

G
H
F
DISCHARGE HOSE
FILTER
EMPTY BUCKET
AT START
NEW ANTIFREEZE AND
WATER SOLUTION

Figure 2.46

Step 10 Insulate Tank and Piping

Overview:

- Insulate piping, valves and storage surfaces to reduce heat loss and increase the overall system efficiency.

Materials:

- Pipe insulation.
- Storage tank insulation jacket (3" thick R-11).
- Pipe cover material or ultraviolet-resistant duct tape or aluminum adhesive tape.
- Silicone sealant.

Notes:

- Pay special attention to details. Proper insulation and correct application techniques will greatly improve the total system performance.
- All piping, valves and storage surfaces must be methodically insulated.
- Gas tanks have special insulation requirements. Consult the instructions included with the tank insulation package.
- Make all intersections fit tightly.
- Do not rest insulation on roof surface. Allow at least 2" clearance..
- Do not use polyurethane foam insulation within 3 feet of the collectors.
- Do not insulate pump motors or pressure relief valve outlet port.
- Be sure to insulate over collector differential sensor to protect it from ambient air temperatures.

Procedure:

1. Carefully insulate all piping and valves.
2. Cover all exterior insulation with a protective jacket, orient and seal seams so water cannot enter.
3. Use silicone to seal any likely water infiltration points.
4. If using tape, carefully wrap all of the insulation exposed to outdoor elements from the bottom up. Apply at least 25% overlap with tape wrap.
5. Use an insulation jacket on the storage tank(s). Cover sides and top to decrease losses by 30 - 35%.
6. Be sure heat exchanger is properly insulated.

Additional Information:

Available Insulation for System Piping

3/4" thick closed-cell polyurethane or polyisocyanurate rigid foam R-6.5.

Advantages —
- Greatest effectiveness
- Easy to mold and fit
- Not susceptible to water infiltration

Disadvantages —
- Not appropriate at temperatures above 220F.

1" thick high-density fiberglass R-3.

Advantages —
- Effective at high internal temperatures.

Disadvantages —
- Drastic decrease in effectiveness when wet.

Elastometric flexible foam R-3.5.

Advantages —
- Easily applied before completing solder joints.

Disadvantages —
- Not suitable for outdoor use.

SECTION 3

MAXIMIZE SOLAR SYSTEM PERFORMANCE

- Leave auxiliary power off to determine system effectiveness related to family demands.
- Conservation —

  Use hot water only when necessary.

  Install faucet restrictors.

  Install shut-off valve at the shower head.

  Wash clothes in cold water.

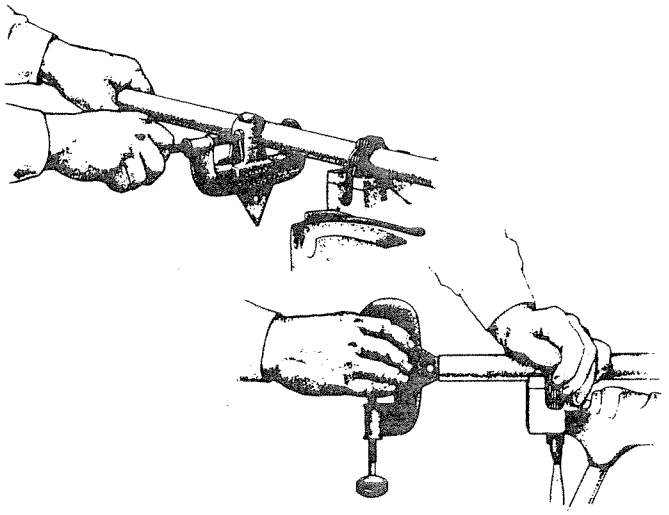
  Set auxiliary heating thermostat to 125 F.
- Load Management —

  Use hot water at midday to increase daily system effectiveness.

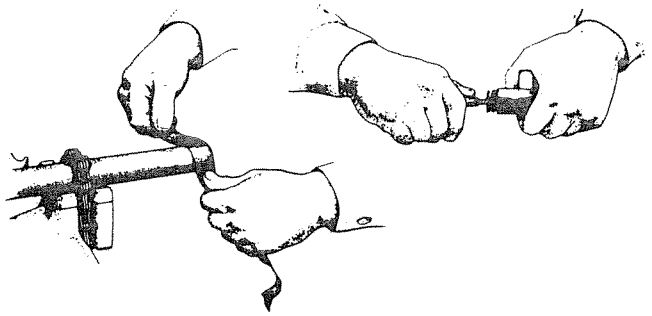
SECTION 4
THE FINE ART OF SOLDERING

When adjoining surfaces of copper and copper alloys meet under proper conditions of cleanliness and temperature, solder will make a perfect adhesion. The strength of joint is equal to or even greater than the strength of tube alone. This is due to the great affinity of tin and copper. . .tin of the solder and copper of the tube and fittings. Surface tension seals the joint. Capillary attraction draws solder into-around-through-and-all about the joint. It's easy to learn to make a perfect joint when you use NIBCO Fittings from Tubes.

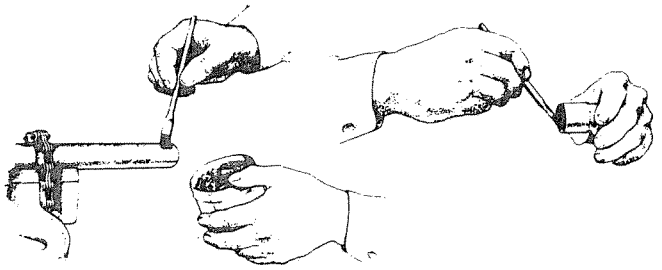
WITH 50-50 SOLDER



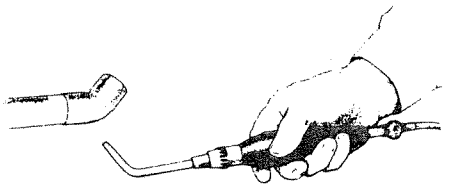
1. Cut tube end square; ream, burr and size.



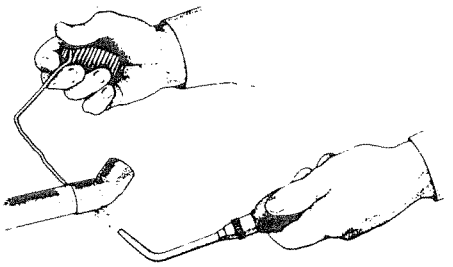
2. Use sand cloth, steel wire brush or steel wool to clean both tube and cup to a bright metal finish.



3. Apply solder flux to outside of tube and inside of cup of fitting carefully so that surfaces to be joined are completely covered. Use flux sparingly.

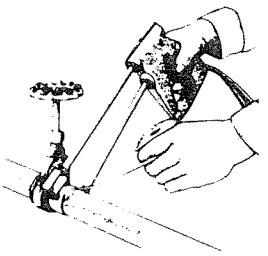


4. Apply flame to the fitting to heat tube and solder cup of fitting until solder melts when placed at joint of tube and fitting.

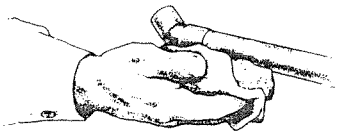


5. Remove flame and feed solder to the joint at one or two points until a ring of solder appears at the end of the fitting. THE CORRECT AMOUNT OF SOLDER IS APPROXIMATELY EQUAL TO THE DIAMETER OF THE FITTING. . .⅜" solder for ⅜" fitting, etc.

In 1974, NIBCO introduced an easier, flameless method of soldering called Lectro-Swet, using an electric soldering tool.



6. Hold solder gun on fitting cup with solder wire at lip until solder begins to melt. After cup has filled, remove grips. Fast, clean, safe. The new flameless way to solder.



7. Remove excess solder with a small brush or wiping cloth while plastic, leaving a fillet around end of fitting as it cools.

The above illustrations are taken from "The Theory and Technique of Soldering and Brazing of Piping Systems," a copyrighted book by H.A. Sosnin. For information on obtaining the text for use in classroom instruction, write to NIBCO, INC., Elkhart, Indiana.

SECTION 5

PREVENTATIVE MAINTENANCE
PHOTOCOPY & POST NEAR TANK

National Solar Water Heater Workshop
Do-It-Yourself Hot Water Heating System

1. **FLUSH THE TANK** — once a year to prevent material buildup in the storage tank which could cause the heat exchanger and associated system to become clogged. See Fill Procedure, Step 9.
2. **OIL THE PUMP** — once every six months through the ports on top of the motor with lightweight, non-detergent oil. Do not over oil, follow the manufacturer's recommendations.
3. **RECORD IDEAL PRESSURE OF THE SOLAR SYSTEM** — as calculated in Step 9, Procedure 15.

   Pressure at initial start-up _____ p.s.i.

   Check pressure gauge occasionally or after extended period of non-use. If the system pressure drops more than 15 p.s.i. from initial start-up, check for leaks and then recharge your solar system. (See Step 9)
4. **CHECK ANTI-FREEZE WITH pH TEST PAPER ONCE A YEAR** — (Paper is supplied in the kit.) If pH is below 7.5, refill the system with new anti-freeze. To check anti-freeze solution, release a small amount of the fluid into the fill valve cap.

   RECORD TOTAL VOLUME OF ANTI-FREEZE AND WATER as calculated in Step 9, Procedure 1.

   Total volume of water and anti-freeze solution at start _____ .

   Circle proportion of anti-freeze/water 50/50 70/30.

   To refill solar system see "System Refill Procedure", Step 9 in the student handbook.
5. **WASH COLLECTOR GLAZING** — as required. Dust accumulation on glazing does have a slight effect on the efficiency of the system.

Information

Date Installed _____

Hardware Source _____ Telephone # _____

Date of Workshop Class _____

School Attended _____

Instructor _____ Telephone # _____

SECTION 6

TROUBLESHOOTING GUIDE

1. PUMP WILL NOT RUN OR RUNS AT PARTIAL SPEED

   1.1 Verify full 110V power source to controller. Plug pump directly into this outlet. Check power cord to pump.
   1.2 Remove motor from impeller housing. If motor runs at full speed, check impeller for material causing clog.
   1.3 Oil motor according to maintenance schedule.
   1.4 Check for a short in the tank sensor control wires or poor connection or fray in the collector sensor wires.
   1.5 Check that the storage tank and collector sensor wires have not been interchanged.
   1.6 Refer to controller instructions for complete check-out procedure.

2. MOTOR RUNS LOUD

   2.1 A noticeable hum can be expected.
   2.2 A loud sqeak — check impeller alignment on housing shaft or impeller bushings.
   2.3 A gurgling or swishing — air is trapped in housing. To correct, purge system or air (see Step 9, Fill Procedure, potable side of heat exchanger).

3. MOTOR RUNS HOT

   3.1 Under normal operation the motor will be too hot to hold in your hand for more than a few seconds.
   3.2 Clear area near motor to assist heat dissipation.

4. PUMPS RUNS ALL DAY

   This may not be a problem!
   4.1 During clear days the pump will run continuously from approximately 9:00 a.m. to 3:00 p.m or longer, depending on storage tank temperature. It may run intermittently on cloudy days.

5. PUMP RUNS ALL THE TIME — DAY AND NIGHT

   This is a control problem. Check on a late afternoon, after energy collection period.
   5.1 Check collector sensor control wires for possible short circuit.
   5.2 Check tank sensor control wires for an open circuit.
   5.3 Consult controller instructions for complete check-out procedure.

6. INSUFFICIENT OR NO HOT WATER

   6.1 Climatic conditions or family demand may be exceeding solar system capability. Check auxiliary energy source — see Troubleshooting #14.
   6.2 A collector, may be air locked. To determine if an air lock exists in a collector feel the glass covers during a clear sunny day. The covers should be the same temperature. If not — the hot collector is air locked. To remove air locks follow Step 9 — System Fill Procedure.
   6.3 Check position of all valves (refer to Step 9 in handbook).
   6.4 Check circulation pumps. Verify full 110V power at controller receptacle.
   6.5 Wash collector covers.

7. WATER IS TOO HOT!

   7.1 Draw off hot water at midday.
   7.2 Add a tempering valve (see Optional Equipment, Step 7).
   7.3 Add high temperature limit switch (See notes, Step 8 in handbook).

8. NO HOT WATER IN MORNING

   8.1 Add extra insulation to storage tank jacket and piping.
   8.2 Check pressure/temperature relief valve for leakage.

9. FLUID LEAKS FROM PRESSURE RELIEF VALVE

   9.1 Check pressure gauge to verify that the pressure is less than 65 p.s.i. If it is, then go on to 9.2. If the presure is greater than 65 p.s.i., then the collectors are likely stagnating due to ineffective circulation. Refer to #1 of this section to assure that the pump is operating or refer to Step 9 to refill system.
   9.2 Turn screw under cap down (clockwise) slightly.
   9.3 Check for mineral buildup between spring plunger and valve body.

10. WATER LEAKS FROM PRESSURE/TEMPERATURE VALVE ON STORAGE TANK, OR OPENS EXCESSIVELY

   10.1 Check water temperature — and compare with temperature rating of P/T valve. See Troubleshooting #7.
   10.2 Check for mineral buildup between spring plunger and valve body, if possible.
   10.2 Replace P/T valve.

11. FLUID LEAKS FROM AIR VENT

   11.1 Remove small cap and depress stem to dislodge float.
   11.2 Replace air vent.

12. WATER LEAKS FROM DIELECTRIC UNION

   12.1 Tighten slightly.
   12.2 Remove threaded connection and replace washer.

13. CONDENSATION FORMS INSIDE COLLECTOR COVERS IN THE MORNING

   13.1 This is normal. However, if condensation does not dissipate by mid-morning, then loosen cover and wedge open slightly to facilitate drying.
   13.2 Reseal carefully; silicone entire back and corners.
   13.3 Check all areas of collector for water infiltration; seal as necessary.

14. ELECTRIC HEATING ELEMENTS WILL NOT OPERATE

   WARNING: Be absolutely certain power is off before attempting to troubleshoot or repair.
   14.1 Check circuit breaker or fuse.
   14.2 Push reset button on thermostat.
   14.3 Turn power off and tighten all terminal connections.
   14.4 To determine if heating element is functional, remove one lead from terminal screws on the element face. Use an ohmmeter to test resistance across these terminals. Infinite resistance indicates burnt-out heating element.

15. WHAT DO I DO WHEN I LEAVE FOR VACATION?

   15.1 Unplug controller. Have a nice time!

SECTION 7

BUILDING CODE REQUIREMENTS

Overview:

- Compile the required information to obtain a building permit and receive final inspection approval.

Materials:

- Plumbing Schematic
- Building address and legal description
- Schematic of optional equipment to be installed
- Money to cover the permit fee.

Notes:

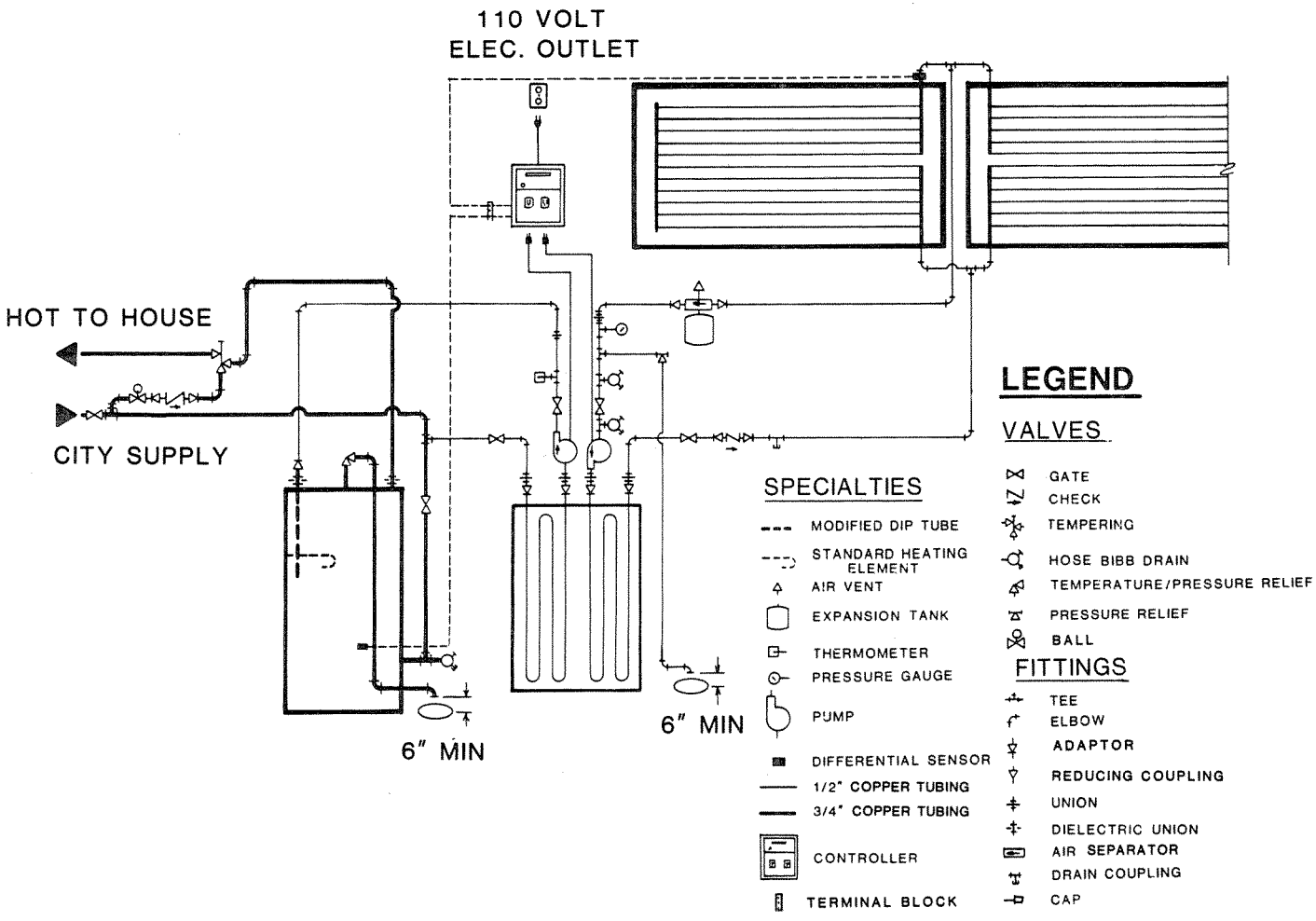
- It is very important to obtain a building permit from your local building safety department. Failure to do so could lead to a penalty.
- Insurance companies may not pay claims on damages resulting from systems that are installed without building permits.
- Building code requirements will vary from one jurisdiction to another; therefore, call the building code official in your area to determine specific requirements.

Procedure:

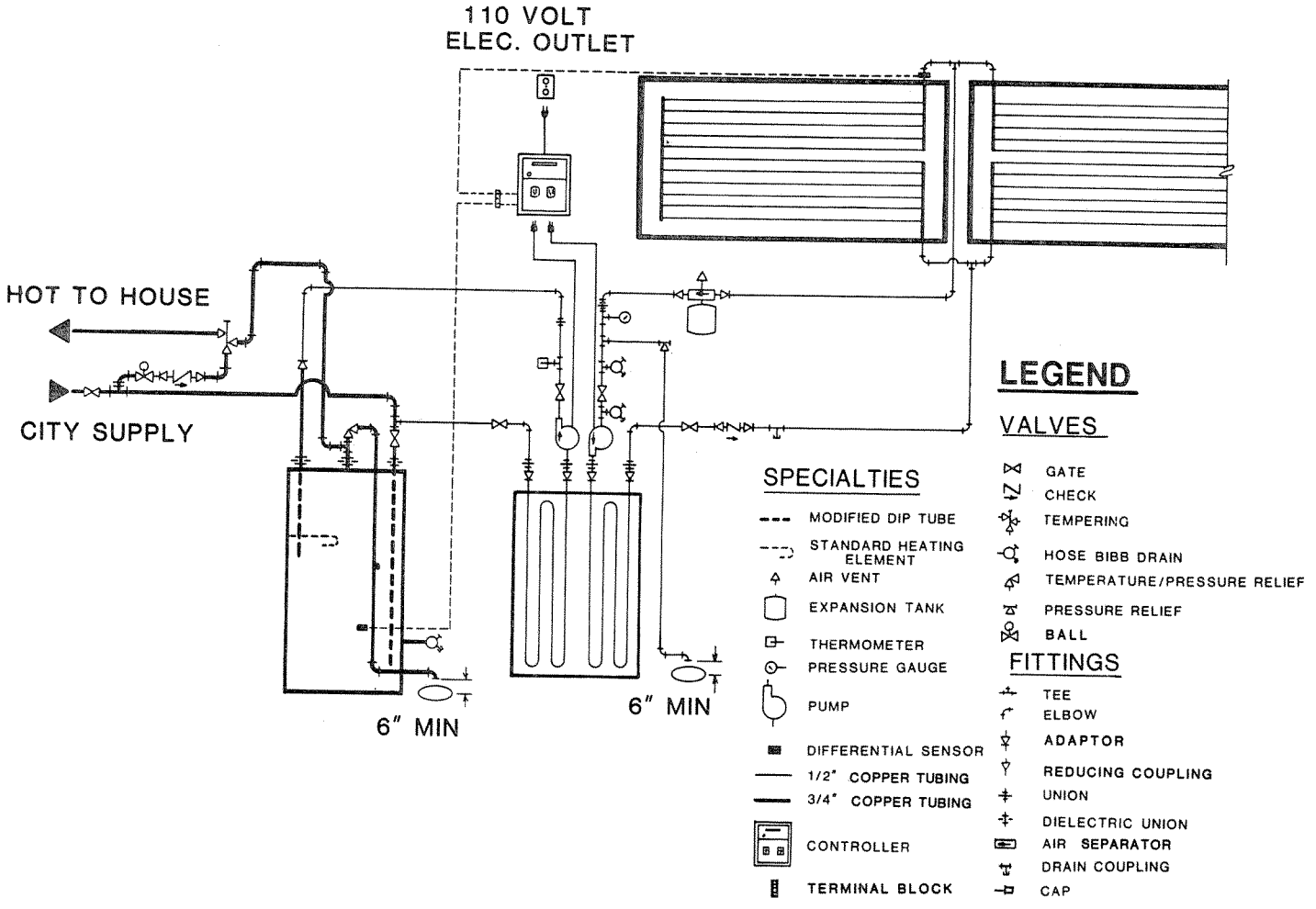
1. Sketch out building, roof configuration, proposed location of collector and storage unit, and their relationship to adjacent streets and properties.
2. From the Plumbing Schematics provided (A, B, C, D, E, F) select one which will fit your installation. Sketch any components to be included or deleted from your system. (i.e., delete the tempering valve from the drawing if none is to be installed.)
3. Call your building safety department to explain your intentions and request specific requirements.
4. Complete all requirements.
5. Visit the building safety department to complete all forms, pay permit fees, and obtain your building permit.
6. Follow their instructions regarding when to call for final inspection.

Additional Information:

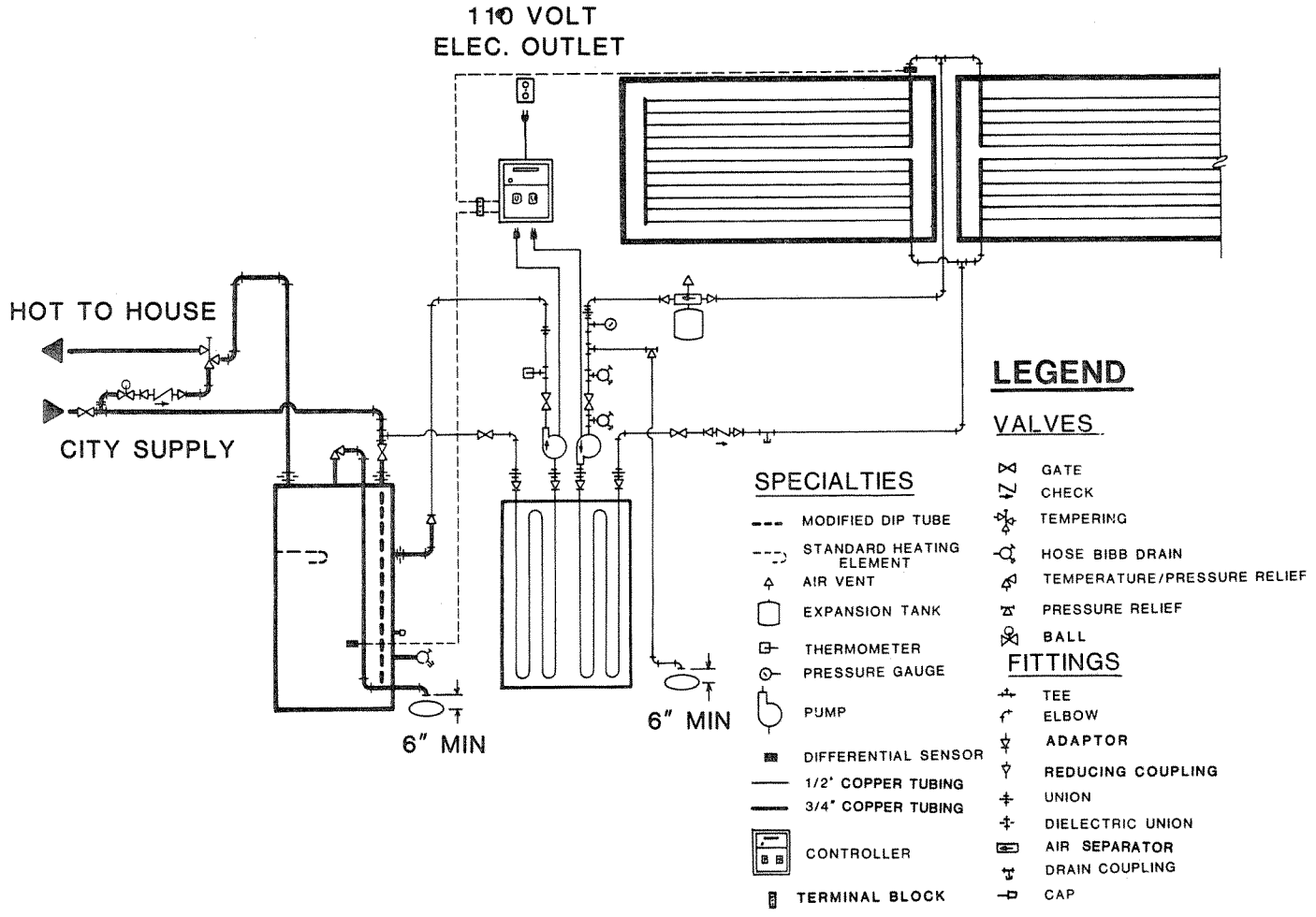
- If a homeowner's association exists in your community, check to find out if a design review process is in order.
- Check the title to your home to see if any deed restrictions exist.



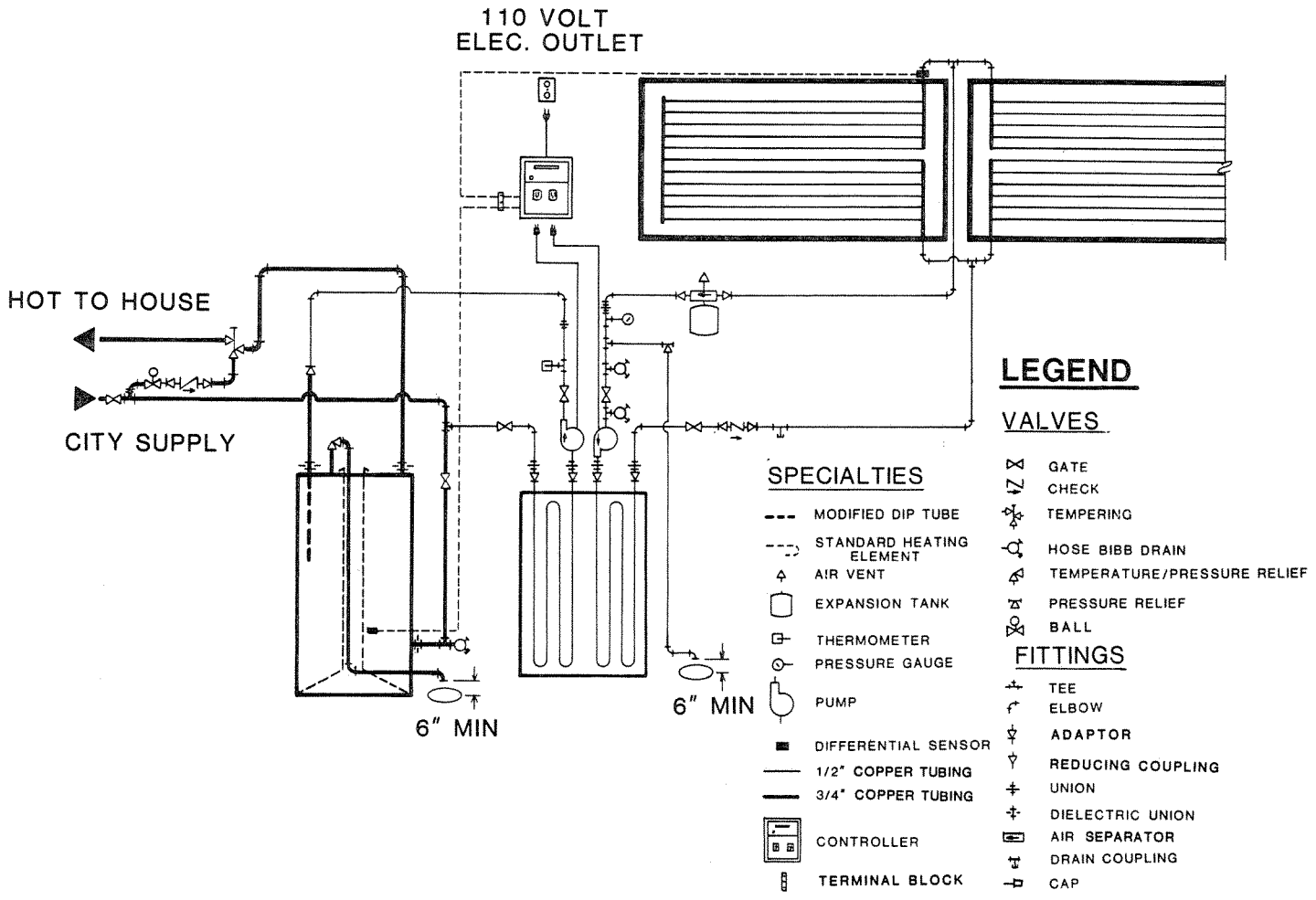
A ELECTRIC RETROFIT



B ELECTRIC RETROFIT


110 VOLT
ELEC. OUTLET
HOT TO HOUSE
CITY SUPPLY
6" MIN
6" MIN
LEGEND
VALVES
GATE
CHECK
TEMPERING
HOSE BIBB DRAIN
TEMPERATURE/PRESSURE RELIEF
PRESSURE RELIEF
BALL
FITTINGS
TEE
ELBOW
ADAPTOR
REDUCING COUPLING
UNION
DIELECTRIC UNION
AIR SEPARATOR
DRAIN COUPLING
CAP
SPECIALTIES
MODIFIED DIP TUBE
STANDARD HEATING ELEMENT
AIR VENT
EXPANSION TANK
THERMOMETER
PRESSURE GAUGE
PUMP
DIFFERENTIAL SENSOR
1/2" COPPER TUBING
3/4" COPPER TUBING
CONTROLLER
TERMINAL BLOCK

C SOLAR TANK


110 VOLT
ELEC. OUTLET
HOT TO HOUSE
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6" MIN
6" MIN
LEGEND
VALVES
GATE
CHECK
TEMPERING
HOSE BIBB DRAIN
TEMPERATURE/PRESSURE RELIEF
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TERMINAL BLOCK
FITTINGS
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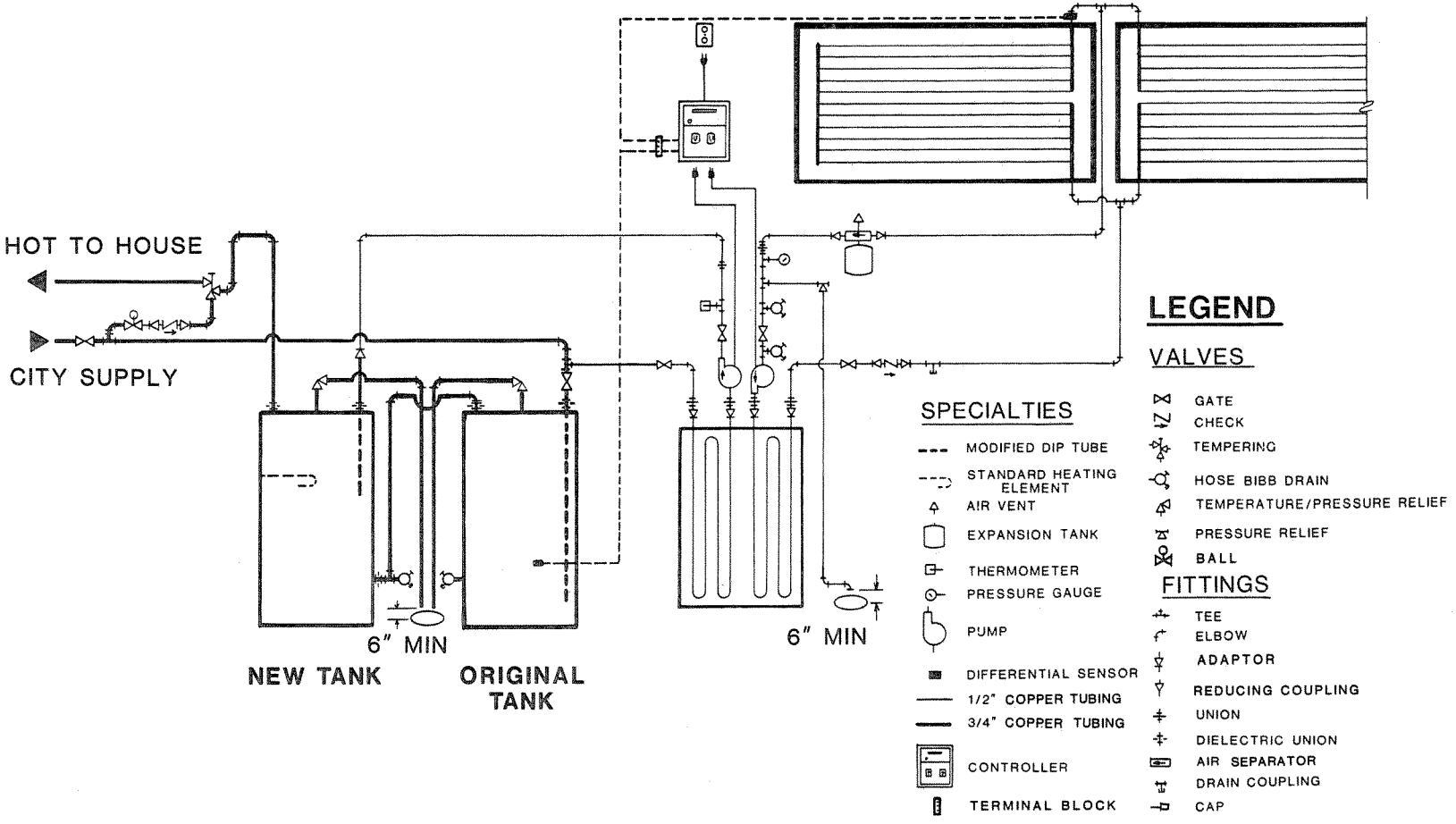
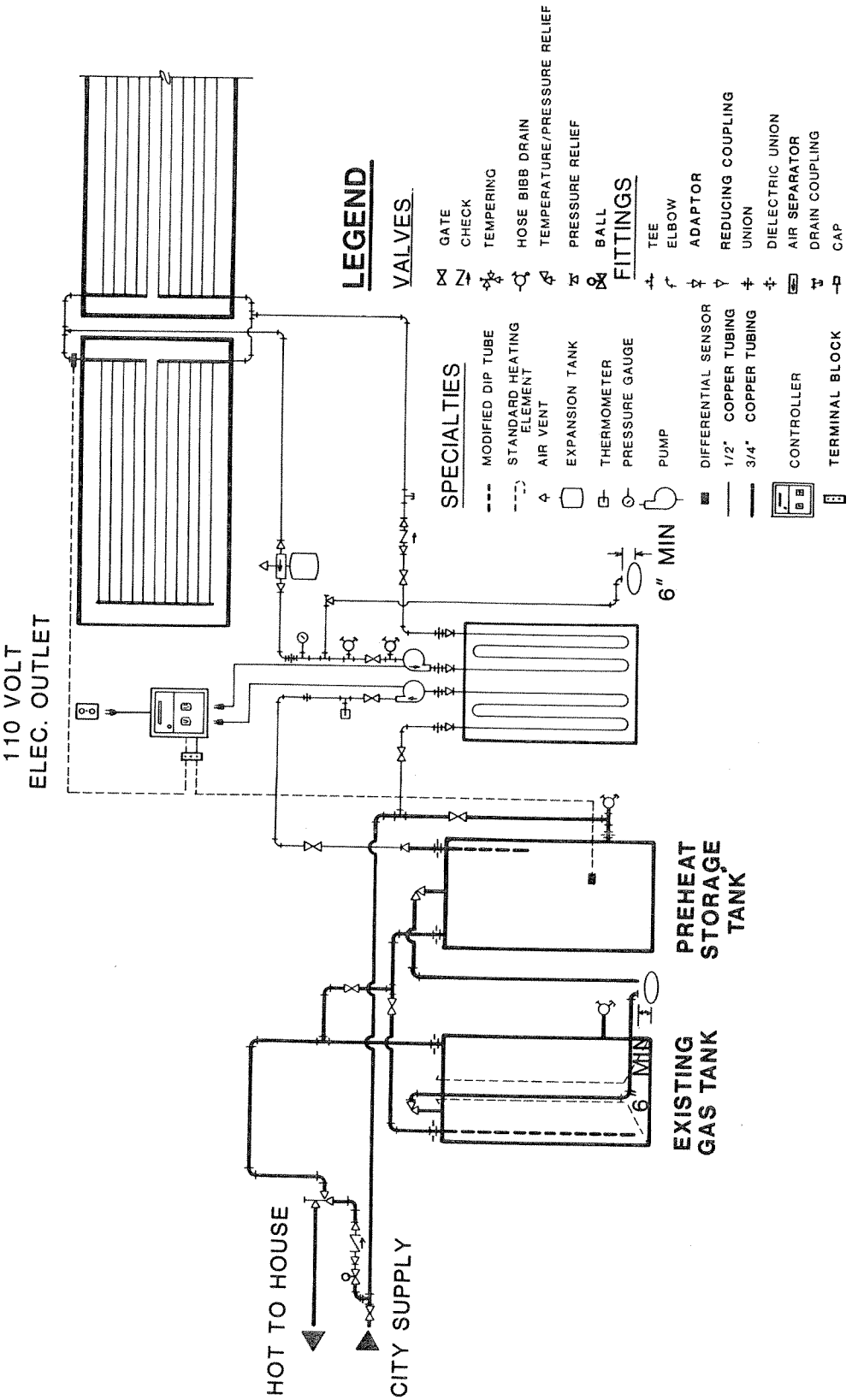
ELBOW
ADAPTOR
REDUCING COUPLING
UNION
DIELECTRIC UNION
AIR SEPARATOR
DRAIN COUPLING
CAP

D GAS TANK



E DUAL TANK SYSTEM



F PREHEAT TO GAS


Taken on 21st Birthday Fall 2005
• Installed Fall 1984
• 1st cost: $1,200
• Saved: 300 million Btu
• Reduced CO_2 emissions by 200,000 lbs
• >$6,000 saved
• ROI ~ 7.5%