sure rise, if the heating continues for any length of time, may result in rupturing of the tank.

If the tank water is not confined, continued heating would, of course, cause no increase in pressure beyond ordinary line pressure. However, the temperature would continue to increase. If this should happen at elevated temperatures, the flashing of the water into steam might cause a serious tank explosion.

In order to guard against the development of excessive pressure inside a hot water storage tank (owing to the thermal expansion of the water), it is customary to install a spring-loaded pressure-relief valve which is set to open at a pressure about 20 psi higher than the normal line pressure.

The amount of water discharged by any pressure-relief device is usually quite small, since it takes only a small quantity of water to relieve any pressure rise due to the thermal expansion of the water. The rate of discharge should be such as to limit the pressure rise for any given heat input to 10 percent of the pressure at which the valve is set to open. For any given installation, the discharging capacity should be in excess of the water to be discharged by the heater. The heater discharge Q_m in gallons per minute may be computed by Equation 5:

$$Q_m = 0.00005b \qquad (5)$$

where b is the heat input of heater in Btu per minute.

To prevent danger of overheating, temperature-relief devices should be used. One type of such a device has a fusible plug of metal which melts at about 212 F. The hot water then runs from the opening until the device is serviced. A better type of relief device is one which incorporates a bellows or bimetallic disc, which opens at a temperature of 210 F and closes when the temperature drops to approximately 160 F.

Another type of safety device is a fuel cut-off switch or valve in which a fusible plug is melted by excessive water temperature. The fuel supply is cut off until the fusible plug is replaced. Combination temperature and pressure relief valves also are available.

The capacity of temperature-relief devices may be calculated by Equation 6:

$$Q_m = 0.0008b \qquad (6)$$

where Q_m and b denote the same quantities as in Equation 5.

Pressure-relief valves should be installed in the cold water line near the tank, on the tank side of any shut-off device, and out of contact with the hot water in order to prevent excessive corrosion and lime deposit on the valve seat. *Temperature-relief* valves, in general, must be installed at the point of maximum water temperature, usually in the tank, but if installed in the pipe, must be on the tank side of any shut-off device.

SOLAR WATER HEATERS

Solar heaters utilize the energy of the sun for heating water. The successful operation of such heaters requires the availability of sunshine practically every day in the year, which has limited their use to Florida and the southern portions of California. When supplemented with some other means of gas, coal, or oil water heating, solar heaters may be used in climates where sunshine may be more or less intermittent. They have been used in summer homes as far north as Chicago. When properly installed and proportioned, solar water heaters render satisfactory service, especially in climates where the outdoor temperatures are high and extremely hot water is not necessarily desirable. Such installations consist essentially of a storage tank, heating coil, and hot box. The coil is installed in the hot box, and is arranged to circulate water to and from the storage tank. The advantage in the use of this type of heater is the fact that it requires no fuel. The same materials should be used for the coil, circulation lines, and tank. A copper coil is more efficient in absorbing heat in the box, but galvanized iron or steel may be substituted, depending on the local water conditions, cost, and other considerations.

The storage tank must be able to store sufficient heated water for the night period of about 16 hr when the coil is not functioning, or is operating under such poor sun conditions as to make its heating effect negligible. Due to the fact that the *no sun* period includes the night period when little or no hot water is used, an available storage of 50 percent of the average daily usage is considered adequate. Since about 25 percent of stored hot water cannot be drawn out of a storage tank before the incoming cold water reduces the temperature of all of the water in the tank to an unsatisfactory point for usage, the equation for calculating the storage capacity of the tank becomes:

$$S = \frac{Q_d \times 0.50}{0.75} = 0.666Q_d \qquad (7)$$

where

S = storage capacity of tank, gallons.
Q_d = average daily usage, gallons.

Thus, for a family of four persons using an average of 40 gal of hot water per (person) (day), the size of the tank would be 4 persons x 40 gal x 0.666 or 106 gal, and the nearest standard size of tank would be used. The tank should be well insulated to prevent undue loss of heat during the 16-hour period when the coil is inoperative, and it should be located as high as possible in the building (under the peak of the roof if such exists) so as to secure a maximum circulation head from the coil. The hot water supply line to the house, as shown in Fig. 15, is connected to the top of the tank and serves to vent the air from the tank through the hot water faucets as fast as it accumulates.

The coil should be of the return-bend type (square or slightly rectangular in form), and should have the pipes running east and west, with the coil on the south side of the building where it can receive the full sun effect all day long without shadows from the building itself, or from the adjacent obstructions such as trees or other structures. The coil should be placed as low as possible in relation to the storage

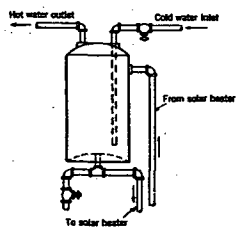

Fig. 15.... Solar Heater Tank Connections

Table 18.... Suggested Solar Heater Design Data[a]

Design Item	Based on Rate of 30 Gal per Day per Person								Based on Rate of 40 Gal per Day per Person							
No. of occupants in residence	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Hot water used at night, gal per person	15	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20
Hot water used at night, gal total	15	30	45	60	75	90	105	120	20	40	60	80	100	120	140	160
Retained in tank, 25 percent, gal	4	8	11	15	19	23	27	30	5	10	15	20	25	30	35	40
Tank capacity required, gal	20	40	59	75	94	113	130	150	25	50	75	100	125	150	175	200
Hot water used during day, gal	15	30	45	60	75	90	105	120	20	40	60	80	100	120	140	160
Total water to be heated:																
Gal per 8-hr period	35	70	104	135	169	203	235	270	45	90	135	180	225	270	315	360
Gal per hour	4.5	9	13	17	21	26	29	34	6	12	17	23	28	34	39	45
Copper coil required:																
Surface area, sq ft	25	50	75	100	121	145	168	192	32	64	96	128	160	192	224	256
Equivalent length 1-in. coil, ft	100	200	300	400	484	580	664	768	128	256	384	512	640	768	896	1024
Box size:																
Area, sq ft	25	50	75	100	121	145	168	192	32	64	96	128	160	192	224	256
Width, ft	4	6	7	8	9	10	10	11	4	6	8	9	10	11	12	12
Length, ft	6	8	11	12.5	13.5	14.5	16.5	17.5	8	10	12	14	16	18	19	21

[a] Sun Effect and the Design of Solar Heaters, by H. L. Alt (ASHVE Transactions, Vol. 41, 1935, p. 131).

tank level, such as on a porch roof, the roof of a one-story extension or, if necessary, even on the ground. Both the coil and the circulation lines should be designed to facilitate the circulation flow as much as possible, using long-radius copper fittings or recessed galvanized-iron fittings to match the materials of the coil, circulation lines, and tank. The coil should be inclined, as shown in Fig. 16, so that the north end is raised above the south end to secure an angle with the horizontal of about 53 deg. This will result in the inlet end of the coil being on the south side (or bottom), and the outlet end being on the north side (or top). This will satisfy conditions along the 30-deg N latitude, which includes the portions of Florida and Southern California where these heaters are most frequently used.

The hot box is usually constructed of wood on the four sides and bottom, and is insulated. Glass sash are placed over

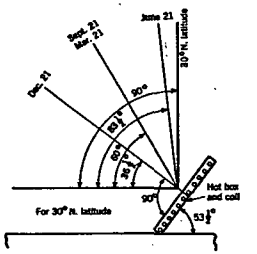

Fig. 16.... Solar Heating Coil Inclination

the top of the box which should be airtight. The interior surfaces should be painted white to reflect the heat, while the coil should be painted black to absorb the heat. The box need not be deeper than necessary to house the coil and to protect it from the weather.

The addition, on the bottom of the box, of a light gage copper plate to which the pipe of the coil is soldered for good metallic contact, will add to the amount of heat received by the coil, due to the fact that this plate will receive all of the sun's rays which fail to directly strike the coil. The heat from this source is transmitted to the coil through the plate rather than from the heated air surrounding the coil. Otherwise, only part of the heat enters the coil, the balance being transmitted through the glass.

Design data given in Table 17 may be used with judgment in selecting the size of solar heater coil and box for a particular application. These data are based on consumptions of 30 and 40 gal of hot water per (day) (person).

DOMESTIC HOT WATER BY HEAT PUMP

Hot water may suitably be obtained by using a heat-pump installation. The hot water heater may be either a heat exchanger installed just ahead of the compressor of a heat-

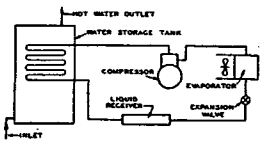

Fig. 17.... Heat Pump Arrangement for Hot Water Supply