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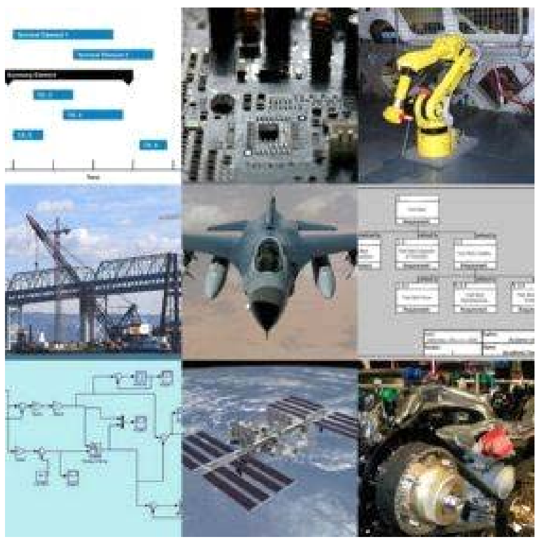

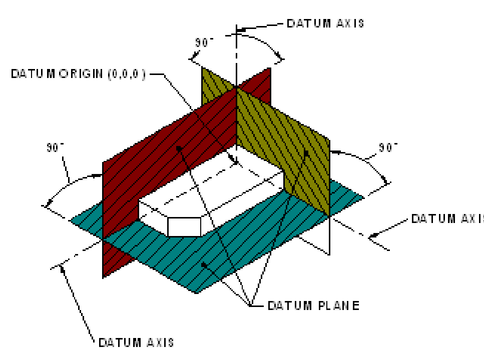

PDH Storm, by Engineers Edge, LLC

An Introduction to Solar Collectors for Heating and Cooling of Buildings and Domestic Hot Water Heating

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The Figures, Tables and Symbols in this document are in some cases a little difficult to read, but they are the best available. **DO NOT PURCHASE THIS COURSE IF THE FIGURES, TABLES AND SYMBOLS ARE NOT ACCEPTABLE TO YOU.**

1. INTRODUCTION

1.1 SCOPE. This course presents design criteria and cost analysis methods for the sizing and justification of solar heat collectors for potable water and space heaters. Information is presented to enable engineers to understand solar space conditioning and water heating systems or conduct feasibility studies based on solar collector performance, site location, and economics. Both retrofit and new installations are considered.

1.2 RELATED CRITERIA. Standards and performance criteria relating to solar heating systems have been evolved by government agencies and various associations and institutes. The most widely used are listed below. Because solar technology is a continuously evolving field, be aware that publications listed below may have been revised or superseded.

Subject	Document
Solar Collector Instantaneous Performance	ASHRAE Standard 93-77, "Methods of Testing to Determine the Thermal Performance of Solar Collectors"
Thermal Storage Devices	ASHRAE Standard 94-77, "Methods of Testing Thermal Storage Devices Based on Thermal Performance"
Complete Solar Collector Performance Evaluation	National Bureau of Standards, NBSIR 78-1305A, "Provisional Flat Plate Solar Collector Testing Procedures: First Revision"
Testing Solar Hot Water Heaters (includes Thermo-syphon, Batch, Breadbox, or Integral Storage Collectors)	ASHRAE Standard 95-81, "Methods of Testing to Determine the Thermal Performance of Solar Domestic Water Heating Systems"
Testing Swimming Pool Solar Collectors	ASHRAE Standard 98-80, "Methods of Testing to Determine the Thermal Performance of Unglazed Flat-Plate Liquid Solar Collectors"

Testing Tracking Concentrator Collectors	Solar Energy Industries Association, "Methodology for Determining the Thermal Performance Rating for Tracking Concentrator Solar Collectors"
Solar System Performance	National Bureau of Standards, NBSIR 76-1187, "Interim Performance Criteria for Solar Heating and Cooling Systems in Commercial Buildings"
Property Standards for Solar Systems	HUD Report 4930.2, "Intermediate Minimum Property Standards Supplement, Solar Heating and Domestic Hot Water Systems"
Property Standards Developed for HUD Domestic Hot Water Initiative	National Bureau of Standards, NBSIR 77-1272, "Intermediate Standards for Solar Domestic Hot Water Systems/HUD Initiative"
Solar Collector Certification and Labeling	ARI Standard 910, "The Air Conditioning and Refrigeration Institute (ARI) Certification Program for Solar Collectors"
Solar Collector Certification, Rating, and Labeling	Solar Energy Industries Association Standard, Directory of SRCC Certified Solar Collector Ratings
Building Code	Council of American Building Officials DOE/CS/34281-01, "Recommended Requirements to Code Officials for Solar Heating, Cooling, and Hot Water Systems"
Overall Standards Summary	National Bureau of Standards, NBSIR 78-1143A, "Plan for the Development and Implementation of Standards for Solar Heating and Cooling Applications"; or "ASTM Standards on Solar Energy", ASTM Committee E-44
Installation Guidelines	National Bureau of Standards, NBS Tech. Note 1134, "Guidelines for the Installation of Solar Components on Low Sloped Roofs"; and Dept. of Energy,

	"Installation Guidelines for Solar DHW Systems in One and Two-Family Dwellings"; and National Bureau of Standards, NBSIR 80-2116, "Dimensional Considerations in Solar Installations"; and Sheet Metal and Air Conditioning Contractor National Association, Inc., "Installation Standards for One and Two-Family Dwellings and Multifamily Housing Including Solar"
Solar Materials and Components	Dept. of Energy, DOE/TIC-11374 "Solar Heating Materials Handbook"; and National Bureau of Standards Technical Note 1132, "Solar Energy Systems - Standards for Cover Plates for Flat Plate Collectors"; and National Bureau of Standards, NBSIR 79-1913, "Solar Energy Systems - Standards for Rubber Hose"; and National Bureau of Standards, NBSIR 81-2232, "Solar Energy Systems - Standards for Absorber Materials"
Miscellaneous Tests	National Bureau of Standards, NBSIR 81-2344, "Fire Testing of Roof-Mounted Solar Collectors by ASTM E108"; and National Bureau of Standards, NBSIR 81-2199, "Wind, Earthquake, Snow, and Hail Loads on Solar Collectors"; and NBSIR 82-2487, "Hail Impact Testing Procedures for Solar Collector Covers"
Product Safety	National Bureau of Standards, NBSIR78-(See also HUD Report 4930.2) 1532, "Environmental and Safety Considerations for Solar Heating and Cooling Applications"
Certified Test Labs	National Bureau of Standards, NBSIR

78-1535, "Laboratories Technically Qualified to Test Solar Collectors in Accordance with ASHRAE Standard 93-77"

In addition to these standards, there are plumbing standards published by The International Association of Mechanical and Plumbing Officials (IAMPO), and various state building codes.

1.3 SOLAR ENERGY.

1.3.1 SOLAR RADIATION. Energy from the sun is received by the earth as electromagnetic radiation. Most of the energy is received in the visible and infrared portions and a small amount as ultraviolet radiation. North of the Tropic of Cancer (23 deg. N latitude), the sun makes a daily arc across the southern sky from east to west as shown in Figure 1-1. For a typical location at 32 deg. N latitude the sun would be 81.5 deg. above the southern horizon or nearly overhead at noon (solar time) on June 21 while on December 21 it would be only 34.6 deg. above the horizon. Solar insolation (I) is measured in Langleys (L) or Btu/ft^2. One Langley equals 3.688 Btu/ft^2. The amount of solar energy that exists outside the atmosphere, often called the solar constant, is 116.4 L/hr or 429.2 Btu/ ft^2-hr. At most 70% to 80% of this amount will strike the earth's surface, the remainder being absorbed or reflected in the atmosphere.
Monthly average and yearly average daily insolation data for numerous locations are given in Table 1-1. In general, the higher the latitude, the less insolation is received on a horizontal surface.

1.3.2 COLLECTING SOLAR ENERGY. Collection of solar energy is based on the very high absorption of radiant energy by dull, black surfaces and on the "greenhouse effect." The latter refers to the ability of glass to transmit visible radiation but prevent the loss of heat from the collector plate which radiates at longer wavelengths (infrared frequencies). Glass (or plastic) cover plates are generally used over flat absorber plates to reduce heat loss (see Figure 1-2). The heated absorber plate may have a fluid (water, air or other) pass over it or through tubes attached to the plate. The fluid thus heated may be used to heat potable water, heat spaces, or drive an absorption or Rankine power cycle air conditioner.

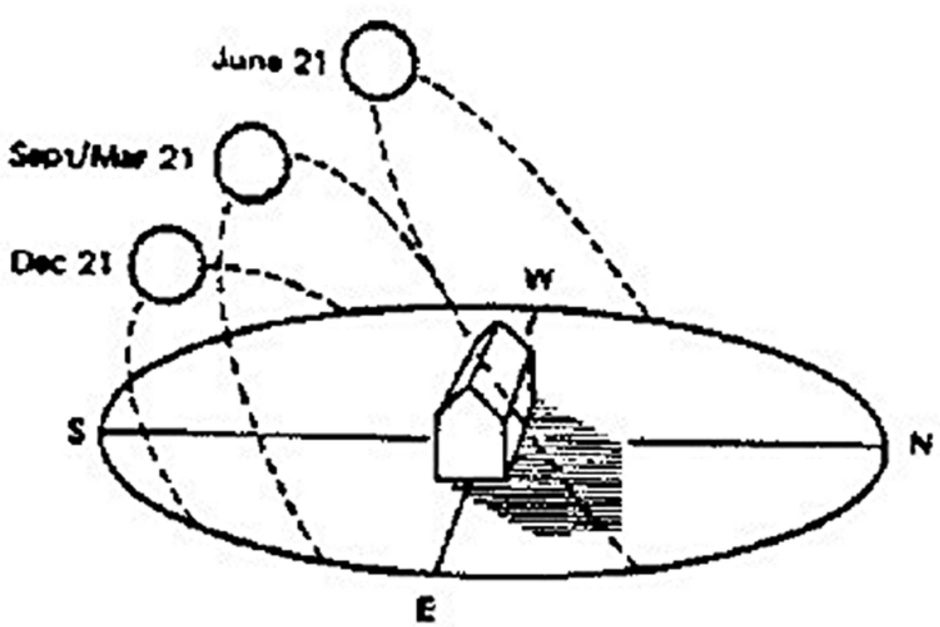

Figure 1-1

The sun's path across the sky at specific times of year

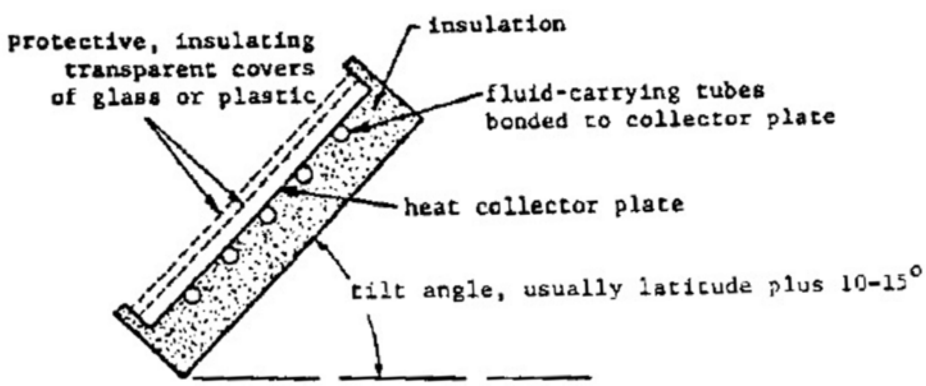

Figure 1-2

Schematic cross-section of typical solar collector with

heavy black insulation and two cover sheets

STATE AND STATION	LATITUDE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ALABAMA														
Birmingham	33°34'N	706.6	967.1	1296.3	1673.5	1856.9	1918.5	1809.8	1723.8	1454.6	1710.8	857.9	661.4	1346.7
Mobile	30°41'N	828.2	1099.6	1407.5	1721.7	1872.1	1868.5	1715.3	1641.5	1449.4	1298.7	955.1	759.2	1384.7
Montgomery	32°18'N	751.7	1013.0	1340.6	1728.9	1897.4	1972.3	1841.0	1745.7	1467.7	1266.6	935.4	719.4	1387.9
ALASKA														
Adak	51°53'N	231.2	432.6	716.4	1032.6	1179.6	1182.0	1120.4	948.6	759.3	528.7	308.0	187.7	718.8
Annette	55° 2'N	177.9	374.7	717.1	1149.5	1473.1	1465.6	1439.2	1162.3	812.2	422.2	218.6	122.5	794.6
Barrow	71°18'N	0.0	73.8	490.5	1050.2	1140.0	1527.5	1459.1	855.8	414.3	125.7	1.6	0.0	595.0
Fairbanks	64°49'N	30.1	221.4	674.2	1193.9	1603.6	1751.9	1542.5	1118.0	709.4	292.6	74.1	2.5	767.8
Kodiak	57°45'N	149.3	355.9	781.9	1207.8	1376.3	1529.9	1408.2	1164.2	794.0	489.2	206.5	97.1	796.7
ARIZONA														
Phoenix	33°26'N	1021.3	1374.1	1814.1	2354.8	2676.5	2739.2	2486.5	2292.6	2015.4	1576.5	1150.5	932.0	1869.4
Tucson	32° 7'N	1099.0	1432.0	1864.3	2363.0	2673.4	2729.6	2341.1	2187.9	1978.8	1601.9	1208.4	995.8	1872.3
Yuma	32°40'N	1096.1	1443.2	1919.2	2412.8	2728.3	2813.9	2453.4	2329.3	2051.0	1622.8	1214.7	1000.1	1923.7
ARKANSAS														
Fort Smith	35°20'N	743.7	998.9	1311.7	1615.9	1912.1	2089.4	2065.3	1877.4	1501.5	1200.7	851.4	681.4	1404.3
Little Rock	34°44'N	733.3	1002.8	1312.7	1610.7	1929.3	2106.5	2032.3	1869.5	1518.0	1228.3	847.2	673.7	1404.4
CALIFORNIA														
Bakersfield	35°25'N	766.4	1101.9	1594.8	2094.7	2509.1	2749.3	2683.5	2420.7	1991.8	1458.3	942.3	677.4	1749.2
China Lake	35°41'N	909.4	1229.5	1734.9	2233.5	2548.5	2746.8	2612.2	2615.9	1979.7	1472.6	1033.7	840.8	1829.8
Daggett	34°52'N	958.2	1280.7	1772.3	2274.1	2593.2	2766.3	2603.4	2382.6	2007.9	1515.6	1085.1	876.0	1842.8
El Toro	33°40'N	947.0	1236.0	1630.2	1928.5	2070.2	2194.1	2363.4	2155.0	1737.3	1356.9	1076.4	869.2	1624.5
Fresno	36°46'N	656.7	1012.3	1565.8	2092.6	2483.8	2732.8	2685.1	2421.3	1985.1	1439.2	888.5	574.2	1710.8
Long Beach	33°49'N	927.7	1215.0	1609.9	1937.7	2064.5	2139.9	2299.9	2099.8	1701.0	1326.4	1003.5	846.8	1597.7
Los Angeles	33°56'N	926.1	1214.0	1618.7	1950.9	2059.6	2139.1	2307.5	2079.5	1681.4	1317.0	1003.9	848.5	1593.8
Oakland	37°44'N	707.8	1071.5	1456.3	1922.1	2213.3	2350.0	2322.5	2052.6	1701.1	1212.0	822.1	647.0	1535.2
Point Mugu	34° 7'N	927.2	1219.9	1635.7	1951.0	2018.0	2054.6	2118.3	1934.9	1607.7	1296.1	1006.4	856.2	1552.2
Sacramento	38°31'N	596.9	939.4	1458.4	2003.6	2434.8	2683.8	2688.0	2368.3	1906.7	1317.9	781.9	538.4	1642.9
San Diego	32°44'N	975.7	1266.3	1631.6	1936.7	2002.8	2062.2	2186.5	2057.3	1717.4	1373.3	1062.7	903.8	1598.0
San Francisco	37°37'N	707.6	1009.3	1455.1	1920.0	2225.6	2375.9	2391.6	2136.5	1742.0	1226.1	821.4	642.4	1552.8
Santa Maria	34°54'N	853.8	1140.9	1581.9	1921.0	2140.6	2348.6	2341.1	2105.7	1730.3	1353.4	973.6	803.9	1607.9
Sunnyvale	37°25'N	737.6	1037.5	1485.3	1943.8	2276.8	2452.8	2441.3	2167.1	1759.5	1248.4	841.1	660.3	1587.8

Table 1-1
Total Horizontal Solar Radiation Intensity (Btu/ft^2-day)
from Solar Energy Research Institute

STATE AND STATION	LATITUDE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
COLORADO														
Colorado Springs	38°49'N	890.7	1178.2	1550.0	1931.2	2128.7	2368.9	2211.8	2025.4	1759.1	1358.6	944.2	781.9	1594.1
Denver	39°45'N	840.1	1127.0	1530.4	1879.3	2134.9	2350.7	2272.6	2044.1	1726.8	1300.5	883.5	731.8	1568.4
Grand Junction	39° 7'N	791.3	1119.0	1553.5	1986.4	2379.8	2598.5	2465.2	2182.0	1834.4	1345.0	918.1	731.3	1658.7
CONNECTICUT														
Hartford	41°56'N	477.5	714.7	978.5	1315.0	1568.5	1685.0	1649.0	1421.7	1154.5	852.9	497.3	385.1	1058.3
CUBA														
Guantanamo Bay	19°54'N	1403.0	1648.1	1926.3	2120.0	2037.6	1960.8	2082.4	2002.5	1824.0	1584.6	1431.8	1313.0	1777.9
DELAWARE														
Wilmington	39°40'N	571.4	827.0	1149.2	1480.1	1710.2	1882.6	1822.8	1614.6	1317.7	983.9	644.9	488.6	1207.7
DISTRICT OF COLUMBIA														
Washington/Sterling	38°57'N	572.0	815.3	1125.0	1458.9	1718.1	1900.9	1817.5	1617.4	1340.0	1003.8	650.9	481.1	1208.4
FLORIDA														
Apalachicola	29°44'N	852.9	1125.9	1474.0	1878.9	2090.6	1998.3	1813.6	1687.5	1535.4	1371.4	1040.1	817.6	1473.8
Jacksonville	30°30'N	899.9	1164.3	1521.7	1855.7	1956.3	1885.2	1802.0	1694.2	1442.3	1223.1	996.0	817.6	1438.2
Miami	25°48'N	1057.4	1314.0	1603.3	1859.0	1843.6	1707.9	1763.4	1629.8	1456.3	1302.7	1118.6	1019.1	1472.9
Tampa	27°58'N	1010.7	1259.4	1593.7	1908.5	1998.2	1847.4	1752.7	1653.1	1492.0	1346.4	1107.8	935.4	1492.1
GEORGIA														
Atlanta	33°39'N	717.6	968.9	1303.6	1686.2	1853.8	1913.8	1812.2	1708.5	1422.0	1199.9	882.9	674.2	1345.3
Augusta	33°22'N	751.0	1015.2	1338.3	1728.4	1865.1	1903.7	1803.5	1667.1	1409.6	1219.6	916.5	720.9	1361.6
Savannah	32° 8'N	794.7	1043.8	1398.5	1761.4	1852.3	1844.3	1783.5	1620.9	1363.7	1216.7	941.1	753.7	1364.5
HAWAII														
Barbers Point	21°19'N	1207.7	1441.0	1645.1	1833.5	1972.5	2024.5	2018.3	1971.1	1814.7	1554.8	1299.4	1165.7	1662.4
Hilo	19°43'N	1119.8	1246.2	1348.6	1434.8	1553.0	1658.5	1624.5	1592.4	1546.8	1372.1	1104.9	1019.3	1385.1
Honolulu	21°20'N	1179.8	1396.3	1621.7	1795.8	1949.3	2004.4	2002.2	1966.5	1810.1	1540.3	1266.1	1132.5	1638.7
Lihue	21°59'N	1103.0	1299.7	1475.6	1640.7	1824.0	1867.8	1862.5	1818.1	1742.4	1449.4	1154.2	1053.1	1524.2
IDAHO														
Boise	43°34'N	485.3	839.7	1304.1	1826.9	2276.7	2463.2	2612.7	2196.5	1737.2	1137.8	628.3	437.2	1495.5
Lewiston	46°23'N	339.7	609.0	1019.6	1435.0	1842.5	2014.8	2335.8	1931.3	1434.6	859.8	412.8	286.1	1210.1
ILLINOIS														
Chicago	41°47'N	507.0	759.5	1106.9	1459.0	1788.9	2007.0	1943.8	1719.4	1353.9	968.9	565.6	401.5	1215.1
Springfield	39°50'N	584.7	860.9	1143.0	1515.0	1865.5	2096.7	2058.2	1805.8	1453.9	1068.3	676.6	490.1	1301.5

Table 1-1 (continued)
Total Horizontal Solar Radiation Intensity (Btu/ft^2-day)
from Solar Energy Research Institute

STATE AND STATION	LATITUDE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
INDIANA														
Evansville	38° 3'N	574.1	823.2	1151.0	1500.8	1782.8	1982.7	1920.3	1735.1	1403.3	1087.0	682.5	498.7	1261.8
Indianapolis	39°44'N	495.6	746.9	1037.4	1398.4	1688.0	1868.1	1806.3	1643.5	1324.0	977.0	579.1	416.6	1165.0
South Bend	41°42'N	415.7	659.6	992.5	1387.4	1722.5	1921.9	1852.4	1666.3	1291.3	909.2	497.1	340.3	1138.0
IOWA														
Des Moines	41°42'N	580.7	860.7	1180.5	1556.6	1867.5	2124.8	2096.8	1827.9	1433.9	1067.8	658.3	486.9	1311.8
Mason City	43° 9'N	553.7	836.2	1168.0	1518.6	1895.3	2113.8	2084.2	1832.8	1405.4	1010.5	599.9	443.2	1288.5
KANSAS														
Dodge City	37°46'N	826.6	1122.0	1476.4	1885.8	2089.1	2358.2	2295.5	2055.3	1686.7	1300.7	893.7	731.9	1560.2
Topeka	39° 4'N	680.9	941.0	1256.9	1641.6	1915.4	2126.4	2127.9	1910.0	1516.4	1146.6	771.6	583.5	1384.8
KENTUCKY														
Lexington	38° 2'N	545.9	779.5	1099.5	1479.2	1747.0	1897.1	1850.4	1685.3	1362.1	1044.2	657.3	485.5	1219.4
Louisville	38°11'N	545.5	789.3	1102.0	1466.7	1719.8	1903.5	1837.5	1680.2	1361.2	1042.2	652.8	487.9	1215.7
LOUISIANA														
Lake Charles	30° 7'N	728.4	1009.8	1313.4	1570.4	1849.4	1970.3	1787.7	1657.4	1485.2	1381.1	916.6	705.6	1364.6
New Orleans	29°59'N	834.6	1111.9	1414.8	1780.3	1967.7	2003.8	1813.5	1716.6	1513.6	1335.0	972.6	779.4	1437.0
Shreveport	32°28'N	762.3	1038.4	1341.5	1612.8	1886.2	2064.8	2013.9	1877.3	1553.9	1303.5	928.6	730.6	1426.1
MAINE														
Caribou	46°52'N	419.3	724.0	1133.1	1414.2	1577.8	1757.4	1762.4	1500.7	1102.6	688.3	366.4	310.5	1063.1
Portland	43°39'N	450.3	681.9	969.6	1303.9	1567.4	1711.6	1659.1	1460.9	1157.8	822.4	459.3	362.9	1050.6
MARYLAND														
Baltimore	39°11'N	586.9	840.0	1162.2	1487.9	1713.9	1879.1	1873.2	1599.5	1330.3	997.6	660.3	499.3	1215.0
MASSACHUSETTS														
Boston	42°22'N	475.5	709.6	1016.4	1325.8	1620.5	1817.1	1749.2	1486.5	1259.9	889.6	502.9	403.0	1104.7
MICHIGAN														
Detroit	42°25'N	417.4	680.4	1000.2	1399.0	1715.9	1866.1	1835.4	1575.5	1253.2	876.1	477.8	343.5	1120.0
Grand Rapids	42°53'N	369.6	648.3	1014.4	1411.9	1755.2	1956.5	1914.4	1676.3	1262.1	857.8	455.7	310.7	1135.3
Sault Ste. Marie	46°28'N	324.8	603.3	1028.6	1383.3	1688.1	1810.8	1835.1	1522.7	1049.1	673.0	331.7	252.9	1041.9
MINNESOTA														
Duluth	46°50'N	388.6	672.8	1034.5	1372.8	1642.6	1767.2	1854.3	1546.9	1095.0	724.6	380.7	291.7	1064.3
Minneapolis/St. Paul	44°53'N	464.0	763.9	1103.5	1441.9	1737.3	1927.5	1970.0	1687.0	1254.7	859.6	480.4	353.3	1170.2
MISSISSIPPI														
Jackson	32°19'N	753.5	1026.4	1369.1	1708.4	1940.8	2024.2	1909.0	1780.5	1509.2	1271.4	901.6	708.8	1408.6

Table 1-1 (continued)
Total Horizontal Solar Radiation Intensity (Btu/ft^2-day)
from Solar Energy Research Institute

STATE AND STATION	LATITUDE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MISSOURI														
Columbia	38°49'N	611.5	874.8	1178.8	1525.9	1879.0	2089.5	2116.1	1877.9	1450.4	1100.8	702.7	522.5	1327.6
Kansas City	39°18'N	647.9	894.7	1202.9	1575.0	1872.6	2079.6	2202.1	1862.4	1452.4	1092.3	737.3	561.5	1340.0
St. Louis	38°45'N	627.4	885.6	1204.7	1564.2	1871.3	2092.5	2049.5	1816.5	1459.2	1099.8	718.3	530.6	1326.6
MONTANA														
Billings	45°48'N	468.0	763.2	1189.5	1526.3	1912.8	2173.7	2383.7	2022.4	1470.0	986.8	561.4	421.2	1324.7
Great Falls	47°29'N	420.5	720.2	1170.6	1488.7	1847.6	2101.4	2329.0	1933.0	1378.5	924.6	497.6	336.2	1262.3
Missoula	46°55'N	311.8	574.2	981.5	1382.2	1782.5	1935.0	2327.5	1880.9	1357.8	812.5	410.2	267.2	1168.5
NEBRASKA														
North Omaha	41°22'N	634.0	892.3	1222.5	1558.4	1872.6	2122.5	2106.5	1858.5	1373.2	1049.8	644.1	511.2	1320.5
Scottsbluff	41°52'N	675.7	950.5	1307.4	1668.0	1935.2	2236.6	2283.7	1949.5	1598.9	1145.0	723.2	575.1	1424.7
NEVADA														
Elko	40°50'N	688.4	1034.4	1463.0	1899.7	2303.3	2533.7	2622.9	2315.9	1892.6	1322.5	812.1	617.0	1625.5
Las Vegas	36° 5'N	978.0	1339.5	1823.5	2311.0	2646.3	2777.8	2588.4	2354.8	2037.3	1539.8	1085.5	880.5	1864.2
Reno	39°30'N	800.4	1149.9	1649.4	2159.3	2523.1	2701.4	2692.1	2405.7	1997.7	1431.0	912.3	705.5	1760.7
NEW HAMPSHIRE														
Concord	43°12'N	459.5	686.1	973.6	1371.1	1582.2	1704.6	1674.6	1455.3	1140.2	817.1	462.7	362.1	1053.0
NEW JERSEY														
Newark	40°42'N	551.7	793.0	1106.7	1448.6	1687.1	1795.3	1759.9	1564.8	1272.9	950.9	596.2	454.4	1165.3
NEW MEXICO														
Albuquerque	35° 3'N	1016.5	1342.0	1767.6	2228.4	2538.1	2678.9	2488.6	2290.1	1971.7	1546.7	1133.7	927.7	1827.5
Farmington	36°45'N	944.5	1280.9	1693.4	2132.9	2451.6	2665.5	2478.2	2252.1	1934.3	1478.7	1047.2	837.1	1766.3
Roswell	33°24'N	1046.5	1372.7	1807.4	2217.6	2459.2	2610.3	2440.6	2241.8	1913.0	1527.1	1131.4	951.0	1810.0
NEW YORK														
Albany	42°45'N	456.5	688.4	985.9	1335.2	1569.9	1729.9	1724.9	1498.9	1170.3	817.3	457.1	355.9	1065.8
Buffalo	42°56'N	348.9	546.4	888.5	1314.9	1596.5	1803.7	1776.4	1513.2	1151.8	784.4	403.4	283.3	1034.3
New York City (La Guardia)	40°46'N	576.6	794.5	1117.6	1456.6	1690.4	1801.9	1784.1	1583.2	1280.1	950.6	593.0	456.8	1171.4
NORTH CAROLINA														
Cape Hatteras	35°16'N	685.6	952.2	1326.4	1773.9	1961.8	2035.9	1920.6	1705.4	1470.4	1136.6	872.9	658.7	1375.0
Greensboro	36° 5'N	715.3	970.0	1313.2	1683.2	1860.0	1953.1	1863.6	1696.6	1417.6	1141.6	839.2	658.7	1383.3

Table 1-1 (continued)
Total Horizontal Solar Radiation Intensity (Btu/ft^2-day)
from Solar Energy Research Institute

STATE AND STATION	LATITUDE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
NORTH DAKOTA														
Bismarck	46°46'N	466.8	775.7	1168.1	1459.3	1848.1	2059.8	2183.6	1876.7	1354.5	907.8	507.3	372.9	1248.4
Minot														1178.3
OHIO														
Cincinnati (Covington,														1158.5
Cleveland														1090.6
OKLAHOMA														
Oklahoma City														1461.3
OREGON														
Medford														1352.9
Pendleton														1259.1
Portland														1066.8
PACIFIC ISLANDS														
Koror Island														1503.9
Kwajalein Is														1420.5
Wake Island														1720.1
PENNSYLVANIA														
Philadelphia														1168.7
Pittsburgh														1068.9
PUERTO RICO														
San Juan														1639.6
RHODE ISLAND														
Providence														1112.2
SOUTH CAROLINA														
Charleston														1345.1
Greenville/ Spartanburg														1346.6
SOUTH DAKOTA														
Rapid City														1341.3
Sioux Falls														1290.2

Table 1-1 (continued)
Total Horizontal Solar Radiation Intensity (Btu/ft^2-day)
from Solar Energy Research Institute