Ownership matrix	**USQ# 19-2269-D**

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF ATTACHMENTS

1.0 PURPOSE AND SCOPE

This standard identifies the environmental and climatological conditions of the Hanford Site to be addressed in the design of facilities, structures, systems, and components (SSCs) under the responsibility of the Tank Operations Contractor (TOC) and establishes requirements for winterization/summerization of SSCs to provide protection from expected seasonal changes.

This information applies to new facility SSCs and modifications to existing facility SSCs in the Hanford Site Areas, under the responsibility of the TOC.

This standard does not include climatological conditions for use in heating, ventilation and air conditioning (HVAC) system equipment sizing calculations and design. Use TFC-ENG-STD-07 for the design of new ventilation systems or significant modification of existing ventilation systems.

The meteorology data apply to the design of SSCs that are exposed to the outdoor environment unless temperature controls are implemented or other temperatures are specified in governing codes or standards (e.g., American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. [ASHRAE®[1]]). Safety-significant SSC temperatures are expected to be maintained above the minimum design temperatures (e.g., freeze protection). If the temperature drops below the minimum design temperature for the safety SSC, the required actions will be taken in accordance with HNF-SD-WM-TSR-006.

2.0 IMPLEMENTATION

This standard is effective on the date shown in the header. Responsible engineers should review on-going designs to ensure that they meet the requirements of this standard.

Design projects that are in progress with approved design inputs prior to the issue date of this standard revision shall continue to use of their code of record based on the functional and operational requirements at the time the systems were authorized for operation.

NOTE: Deviations to any requirements of this standard shall be requested from the standard document owner. Approved clarifications and deviations shall be documented for implementation in this standard after approval of this document.

[1] ASHRAE is a registered trademark of the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, Georgia.

3.0 STANDARD

3.1 Climate Conditions

Sections 3.1.1 through 3.1.8 provide key climatological data for the Hanford Site design of SSCs within TOC facilities based on their Natural Phenomenon Hazard (NPH) Design Categories. These data are to be used in conjunction with the design loads required by TFC-ENG-STD-06 to ensure that facilities and SSCs will be compatible with expected Hanford Site environmental conditions. The data presented in Sections 3.1.1 through 3.1.8 are obtained from PNNL-15160, "Hanford Site Climatological Summary 2004 with Historical Data," and HNF-SD-GN-ER-501, "Natural Phenomena Hazards, Hanford Site, Washington." The outside air temperatures are to be adjusted accordingly for the SSC's NPH Design Categories that are located within buildings and structures, or otherwise insulated. Data is provided for:

- "Temperature," Section 3.1.1
- "Precipitation," Section 3.1.2
- "Winds," Section 3.1.3
- "Psychrometric data," Section 3.1.4
- "Thunderstorms, dust, and glaze," Section 3.1.5
- "Solar radiation," Section 3.1.6
- "Atmospheric pressure," Section 3.1.7
- "Ashfall airborne concentration," Section 3.1.8.

TFC-ENG-STD-07 environmental/seasonal design conditions shall be used for HVAC system equipment sizing or load calculations and system design.

3.1.1 Temperature
(5.1.1)

The highest temperatures are experienced in the months of July and August, with the observed maximum temperature of 113°F. The lowest temperatures are experienced in the months of January and February, with the observed minimum temperature of -20°F. A further discussion on the temperature extremes experienced on the Hanford Site is presented in Attachment A of this standard.

Tank Farm SSCs shall be designed for the ambient environmental temperature conditions as they are specified in this standard. Extreme temperature shall be considered during the evaluation of the SSCs important to safety (e.g., Safety Class [SC], Safety Significant [SS], Defense-In-Depth [DID]), requiring operating in outdoor environments and above surfaces based on their performance categories (Table 1).

Table 1. Extreme Natural Phenomenon Hazard Air Temperatures.

Maximum (°F)	Minimum (°F)
115	-25

NOTE: The indicated minimum and maximum ambient air temperatures apply to the design of SSCs that are exposed to the outdoor environment unless temperature controls are implemented or other temperatures are specified in governing codes or standards (e.g., ASHRAE).

The outdoor design conditions described by the ASHRAE tables represent long –term average temperatures that will not be exceeded more than a few hours per season. They do not represent the worst weather conditions experienced in a given location. The ASHRAE tabulated temperature data is adequate for calculating peak heating and cooling loads and should not be increased as an additional safety factor.

The monthly average differences between daily maximum and minimum temperatures show that a much greater range of temperatures is experienced in the summer months than in the winter months. Tank Farm SSCs shall be designed to withstand a maximum daily temperature range of 50°F. Diurnal temperature variations may be used for the design.

Subsurface temperature for frost and freeze protection of buried SSCs shall be provided in accordance with appropriate current codes and consensus standards. For example, the 2015 International Building Code"®[2] (IBC 2015), contains requirements for frost protection of building foundations. The 2015, Uniform Plumbing Code®[3] (IAMPO/ANSI UPC 1-2015, addresses freeze protection for water supply piping. These code requirements refer to the local average frost depth or frost line, which is established in Benton County as 24 in. (Benton County, WA 2015, "Climatic and Geographic Design Criteria").

The monthly average maximum and minimum subsurface soil temperatures and the absolute hourly extreme temperatures are reported in PNNL-15160. For purposes other than frost heave and pipe freeze protection (above), SSCs in all performance categories shall be designed for operation with subsurface temperatures based on the hourly extreme subsurface soil temperatures recorded at depths of 15 and 36 in. as shown in Table 2. The values at 0.5 in. may be used for consideration of a reflective surface, but have no value for facility structures that may be placed on grade which requires some amount of stabilization (i.e., grading, backfill and/or compaction, prior to placement) or below grade, which requires some amount of excavation and stabilization prior to construction. When designing below grade structures for thermal performance, site specific moisture content shall be considered along with the natural diurnal temperature variation. Thermal modeling may be performed in accordance with National Renewable Energy Laboratory publication NREL/TP-550-33954 ("A Model for Ground-Coupled Heat and Moisture Transfer from Buildings") or other models that considers parameters such as moisture content, porosity/compaction, soil (or backfill composition), and diurnal temperature variations. For a survey of references on the Hanford Site's ground, temperatures, and thermal properties refer to Attachment B.

[2] IBC and *International Building Code* are registered trademarks of The International Code Council, Inc., Country Club Hills, Illinois.
[3] UPC and *Uniform Plumbing Code* are registered trademarks of International Association of Plumbing and Mechanical Officials, Ontario, California.

Table 2. Temperature Ranges for Subsurface System, Structure, and Component Operation.

Depth (in.)	Design Temperature Range*
0.5	160°F to -25°F (a)*
15	95°F to 10°F
36	87°F to 30°F (b)*

(a). The maximum temperature, without heat island effect as described in NREL/TP-550-33954 above, is based on data from a site with no vegetation or shade and there is no verification that the probe was covered with 0.5 in. of soil during the high hourly readings. The soil is sandy and mixed with large gravel. The minimum temperature is considerably lower than the minimum recorded at this depth to accommodate the extreme differences in exposure and isolation at the Hanford Site.

(b). For depths below 36 in. refer to Attachment B. RPP-RPT- 61499, "Hanford Site Seasonal Environmental Temperature Data."

3.1.2 Precipitation

(5.1.1)

The annual average precipitation at the Hanford Meteorology Station is 7.0 in. The wettest year on record was 1995, with 12.3 in.; the driest was 1976, with 3 in. Historically, the months of November through February provide 3.64 in. (52%) of the normal annual precipitation. July and August are the driest months, each normally receiving only 0.27 in.

The average snowfall is 15.3 in. per year at the Hanford Site. The maximum snowfall was recorded at 15.6 in. in December of 1985 and the maximum monthly snowfall was recorded at 25.3 in. for the month of February 2019. Tank Farm SSCs shall consider average for the snow loads given in TFC-ENG-STD-06.

3.1.3 Winds

The prevailing wind direction for every month of the year is either WNW or NW, and the peak gusts for every month are from SSW, SW, or WSW. The highest monthly average wind speeds occur in June, the lowest in December. The variability in monthly average wind speeds is much greater in the winter months than during the remainder of the year. The ambient wind speeds are recommended as defined in the ASHRAE Handbook - Fundamentals (ASHRAE 2017) for the Hanford Site HVAC design conditions. For SSCs, performance categories as defined in DOE-STD-1020-2016, "Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities, "are recommended to be based on wind speeds mph corresponding to 1% (25.2 mph), 2.5% (21.0 mph), and 5% (18.6 mph) annual cumulative frequency of occurrence. SSCs classified as safety significant (SS) correspond to 1% wind speed (25.2 mph) condition for the Hanford Site.

TFC-ENG-STD-07 shall be used for stack dispersion model, HVAC process conditions, and equipment qualification.

Tank Farm SSCs shall be designed for structural wind loads given in TFC-ENG-STD-06.

3.1.4 Psychrometric Data

(5.1.1)

Psychrometric data include observations of dry bulb, wet bulb, dew point temperatures, and relative humidity. The annual mean relative humidity recorded at the Hanford Meteorology Station is 55%, with the highest average monthly relative humidity (80%) occurring in December and the lowest average monthly relative humidity (33%) occurring in July. Daily relative humidity can change 20 to 30% between early morning and late afternoon. Changes in relative humidity are less pronounced during the winter months (PNL-4622, "Climatological Summary for the Hanford Area"). Higher relative humidity can be expected at locations near the Columbia River and at some locations on the Hanford Site periphery where there is increased airborne water vapor from the Columbia River and from irrigated land.

The minimum and maximum ambient air temperature and relative humidity apply to the design of SSCs that are exposed to the outdoor environment unless other temperatures and relative humiditys are specified in governing codes or standards (e.g., ASHRAE).

3.1.5 Thunderstorms, Dust, and Glaze

(5.1.1)

Tank Farm SSCs shall be designed for operation under the conditions specified below.

The thunderstorm season is essentially from April through September, but thunderstorms can occur during any month of the year. The average number of thunderstorm days per year is 10.

The criterion for both dust and blowing dust is that horizontal visibility be reduced to 6 miles or less. Dust is carried into the area from a distant source and may occur without strong winds. Blowing dust occurs when dust is picked up locally and occurs with stronger winds. The average number of days per year with dust or blowing dust is 5. The greatest number of such days in any year was 20 in 1980 subsequent to the Mount St. Helens eruption. The greatest number of days with dust or blowing dust in any month was 9 in May 1980. SSCs subjected to dust shall be designed for a concentration of 0.177 g/m^3, with wind speeds of 18 m/s at a height of 3 m. Under these conditions, the bulk of the particles are likely to be less than 150 µm in size.

Glaze is a coating of ice formed when rain or drizzle freezes on contact with any surface having a temperature that is below freezing. The average number of days with freezing rain or freezing drizzle is 6. The highest number of days with glaze in any winter season was 18 during the winter of 1969-1970; the least, 1 day during the winter of 1987-1988 and earlier winters. The greatest number of such days in any single month was 9 in January 1970.

3.1.6 Solar Radiation

(5.1.1)

The highest daily solar radiation values (reported in Langleys) occur with a clear sky and clean air; the lowest daily solar radiation values commonly occur on days overcast with low stratus clouds. Tank Farm SSCs shall be capable of operation in a solar radiation environment of 900 Langleys (3316 Btu/ft^2). For interpretation and clarification guidance for solar energy calculations, using industry practices and ASHRAE methodology (ASHRAE 2017, Chapter 14) refer to Attachment C.

3.1.7 Atmospheric Pressure

The Hanford Meteorology Station atmospheric pressure is measured at an elevation of 733 ft.; sea-level pressure is the station pressure adjusted to sea level. The highest sea-level pressure ever recorded at the Hanford Meteorology Station was 31.12 in. of mercury in January 1979; the lowest sea-level pressure was 28.91 in. of mercury in December 2002. The greatest sea-level pressure change during a 1-day period was 1.02 in. of mercury (December 8, 1971). Tank Farm SSCs shall be designed to operate within these extremes.

3.1.8 Ashfall Airborne Concentration

(5.1.1)

Airborne ash concentrations include the combined effects of the initial ashfall event and ash resuspension. Safety-significant SSCs that must operate in an ash environment (e.g., double shell tank primary ventilation system fans and support systems) shall be designed for a total peak ashfall concentration of 1,325 mg/m^3 or shall use Figures 10 and 11 in HNF-SD-GN-ER-501 for total airborne ash concentration over time. RPP-RPT-58380, Ashfall Effects on Ventilation System high efficiency particulate air (HEPA) Filters, shall be used for protecting systems and equipment from after effects of an eruption in the current tank farms ventilation system HEPA filters. (NOTE: Design ashfall structural loads are given in TFC-ENG-STD-06.)

3.2 Seasonal Environmental Requirements

The following facility and equipment-related requirements derive from DOE G 433.1-1A, "Nuclear Facility Maintenance Management Program Guide" for Use with DOE O 433.0B, Section III.N., "Seasonal Facility Preservation," and operational experience.

Designing a system using peak heating and cooling loads based on extreme weather conditions that occur for only a few hours per season, such as the hottest day on records, will result in an overly conservative system. RPP-RPT- 61499, "Hanford Site Seasonal Environmental Temperature Data."

3.2.1 Cold Weather Protection

Cold weather protection measures shall be incorporated into design of new SSCs and modification of existing SSCs, as applicable.

- Protect heating system power and temperature controls against inadvertent deactivation.
- Secure air intakes, windows, doors, and other access ways that could provide abnormal inflows of cold air. Functionally test automatically controlled systems of this type.
- Provide temperature alarms and/or automatic backup heat sources for systems that require or deserve special protection due to hazards or costs associated with freeze damage.
- Ensure the main water supply cutoffs for each facility are marked and readily accessible to emergency personnel responding to freeze/thaw incidents.

- Provide heat-traced systems with power indication lights or temperature indication. Functionally test heat trace in accordance with manufacturer's guidance.

- Locate portable heaters away from sensitive instruments, and route the heating circuits separate from instrumentation. The switching of inductive loads in instrumentation cabinets has proven to cause instrumentation errors. The use of direct current heaters or self-regulating heat trace is preferable to alternating current heaters to reduce noise and interference.

- Provide heat trace, heaters, and/or insulation to protect against condensation as well as freezing, especially sample lines running from cabinet to cabinet.

- Consider over-sizing the ampacity of supply circuits to self-regulating heat trace. Damp and humid conditions in Hanford site valve pits and the "campaign" approach to many Hanford site projects cause these circuits to be left un-energized for long periods of time in damp locations. The initial inrush of current to "dry" these circuits may be considerably in excess of regular steady state current draw needed to maintain equilibrium.

- Provide protection to shield sensitive equipment from the elements.

The following requirements shall apply to cold weather protection of SSCs.

NOTE 1: SSCs include waste transfer primary piping systems, isolation valves for double valve isolation, safety-significant facility process and safety-significant DST flow bypass lines and monitoring instrumentation.

NOTE 2: Freeze protection is not required for hose-in-hose transfer lines and flexible non-metallic hoses, including their hose barb and Chemjoint connectors (see RPP-RPT-42153, "Safety-Significant Hose-in-Hose Transfer Line (HIHTL) Systems Functions and Requirements Evaluation Document," and RPP-RPT-42297, "Safety-Significant Waste Transfer Primary Piping Systems–Functions and Requirements Evaluation Document," respectively).

NOTE 3: Freeze protection requirements for safety-significant waste transfer system SSCs when physically connected to a waste transfer pump not under administrative lock are established by the tank farms technical safety requirements (see HNF-SD-WM-TSR-006). Freeze protection of safety-significant waste transfer systems at all other times is provided by TOC winterization/freeze protection requirements (i.e., safety basis defense-in-depth feature).

NOTE 4: Other measures such as heat tracing, heating system, piping slope, etc., will require safety basis amendment.

- Ensure temperatures are maintained above the minimum design temperatures of safety-significant SSCs. If temperatures drop below the minimum design temperatures, for safety SSCs, required action will be taken in accordance with HNF-SD-WM-TSR-006.

- Protect safety-significant waste transfer system SSCs by providing safety-significant temperature monitoring, unless a documented analysis shows there is no potential for freeze damage. Provide freeze protection measures (from a documented analysis) when the minimum daily temperature is ≤ 32.0°F based on measurements at the Hanford

Meteorological Station. If freeze damage is suspected, evaluate or test the waste transfer SSCs for damage and document the evaluation/test. When design conditions or physical configuration of safety-significant waste transfer system SSCs are changed, evaluate the change and document the analysis.

3.2.2 Hot Weather Protection

Hot weather protection measures shall be incorporated into design of new SSCs and modification of existing SSCs, as applicable.

- Provide auxiliary cooling and/or plans for the safe shutdown of systems that require special protection from extremes of hot weather.
- Shield instrumentation displays and equipment labels that are susceptible to ultraviolet radiation from direct sunlight or place in a position protected from direct sunlight.
- Protect cooling system power and temperature controls against inadvertent deactivation.
- Place instrument cabinets on the north side of control trailers or in the shade.
- Provide sunshades over temperature sensitive cabinets to shield displays from direct sunlight, and to minimize the duty cycle of engineered cooling systems.
- Specify cabinets with an air gap between the back of the cabinet and instrument mounting plane. This provides insulation between exterior cabinet surfaces struck by solar radiation and the instruments.
- Specify separate instrument power supplies and repeaters to reduce instrument heat generation. Often devices such as Programmable Logic Controllers and Vector drives include direct current power supplies for instrument loops. Use of separate, hardier direct current power supplies, located away from these devices is preferable to minimize the internal heat produced by sensitive microprocessor equipment.
- Minimize the number of intermediate connectors on data buses (such as RS 232 or 485 protocols) connecting field instruments to remote operator control stations. These connections increase network resistance, and therefore heat. Provide network repeaters to minimize strain on sensitive instruments.
- Specify Programmable Logic Controller carriages with extra “slots” and larger power supplies than anticipated for initial service needs. This allows the power supply to be less “taxed,” provides for better heat dispersion, and allows future upgrade capability.

The following requirement shall apply to hot weather protection of safety-significant SSCs:

- Ensure service conditions do not exceed the design life temperatures of safety-significant SSCs.
- Where passive or active design features are required to protect the design life temperature, and over-temperature can cause acute failure of the safety-significant SSC, support SSCs required to protect against aging mechanism may also be required to be safety-significant.

- Operability evaluation may be required to document the effect on SSC performance capabilities, operability, and service life.

- Appropriate corrective actions shall be taken when SSC performance, operability, or qualified life is determined to be degraded.

3.2.3 Other Environmental Considerations

In addition to extreme temperature conditions, the service condition for equipment and items may include the nominal values and expected service durations. The SSCs design life should consider recognition of significant degradation caused by environmental aging mechanisms occurring over the duration of the SSCs service life. These conditions include ambient pressure, relative humidity, radiation, environment, seismic and nonseismic vibration, operating cyclical parameters, condensation, chemical spray, and submergence. Systems requiring continuous operation within mild environments must be evaluated for their applicable environments, proper design.

For hose-in-hose transfer line service life and fitness-for-service evaluation for piping systems refer to RPP-6711 and TFC-ENG-STD-42 respectively.

4.0 DEFINITIONS

Aging mechanism. An aging mechanism that, under normal and abnormal service conditions, causes degradation of equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its safety function(s) during the design basis event conditions.

Design life. The time period during which satisfactory performance can be expected for a specific set of service conditions.

Qualified life. The period of time, prior to the start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions.

Service conditions. Environmental, loading, power, and signal conditions expected as a result of normal operating requirements, expected extremes (abnormal) in operating requirements, and postulated conditions appropriate for the design basis events.

Service life. The time period from initial operation to removal from service.

5.0 SOURCES

5.1 Requirements

5.1.1 DOE-STD-1020, 2016, "Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities," U.S. Department of Energy, Washington, D.C.

5.1.2 HNF-SD-GN-ER-501, 2017, "Natural Phenomena Hazards, Hanford Site, Washington," Rev 3, Washington River Protection Solutions LLC, Richland, Washington.

5.1.3 HNF-SD-WM-TSR-006, "Tank Farms Technical Safety Requirements," Washington River Protection Solutions LLC, Richland, Washington.

5.2 References

5.2.1 ASHRAE, 2017, ASHRAE Handbook – Fundamentals, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, Georgia..

5.2.2 Benton County, WA 2015, "Climatic and Geographic Design Criteria," Prosser, Washington (www.co.benton.wa.us/pView.aspx?id=1606&catid=45).

5.2.3 DOE G 433.1-1A Chg 1 (Admin Chg), "Nuclear Facility Maintenance Management Program Guide for Use with DOE O 433.1B," Section III.N, "Seasonal Facility Preservation," U.S. Department of Energy, Washington, D.C.

5.2.4 HNF-SD-WM-TSR-006, "Tank Farms Technical Safety Requirements," Washington River Protection Solutions LLC, Richland, Washington.

5.2.5 IAPMO/ANSI UPC-1- 2015, "2015 Uniform Plumbing Code," International Association of Plumbing and Mechanical Officials, Ontario, California.

5.2.6 IBC 2015, "2015, International Building Code," International Code Council, Inc., Country Club Hills, Illinois.

5.2.7 Kusuda, T and P.R. Achenback (1965). "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States," National Bureau of Standards, Building Research Division, Washington, D.C.

5.2.8 NREL/TP-550-33954, "A Model for Ground-Coupled Heat and Moisture Transfer from Buildings," National Renewable Energy Laboratory, Washington, D.C.

5.2.9 PNNL-15160, 2005 "Hanford Site Climatology Summary 2004 with Historical Data," Pacific Northwest National Laboratory, Richland Washington.

5.2.10 RPP-6711, 2017, "Evaluation of Hose-in-Hose Transfer Line Service Life," Rev. 8, Washington River Protection Solutions LLC, Richland, Washington.

5.2.11 RPP-RPT-42153, 2019, "Safety-Significant Hose-in-Hose Transfer Line (HIHTL) Systems – Functions and Requirements Evaluation Document," Rev. 10, Washington River Protection Solutions LLC, Richland, Washington.

5.2.12 RPP-RPT-42297, 2019, "Safety-Significant Waste Transfer Primary Piping Systems – Functions and Requirements Evaluation Document," Rev. 21, Washington River Protection Solutions LLC, Richland, Washington.

5.2.13 RPP-RPT-58380, 2015, "Ashfall Effects on Ventilation System HEPA Filters," Rev. 0, Washington River Protection Solutions LLC, Richland, Washington.

5.2.14 RPP-RPT-61499, "Hanford Site Seasonal Environmental Temperature Data."

5.2.15 TFC-ENG-STD-06, "Design Loads for Tank Farm Facilities."

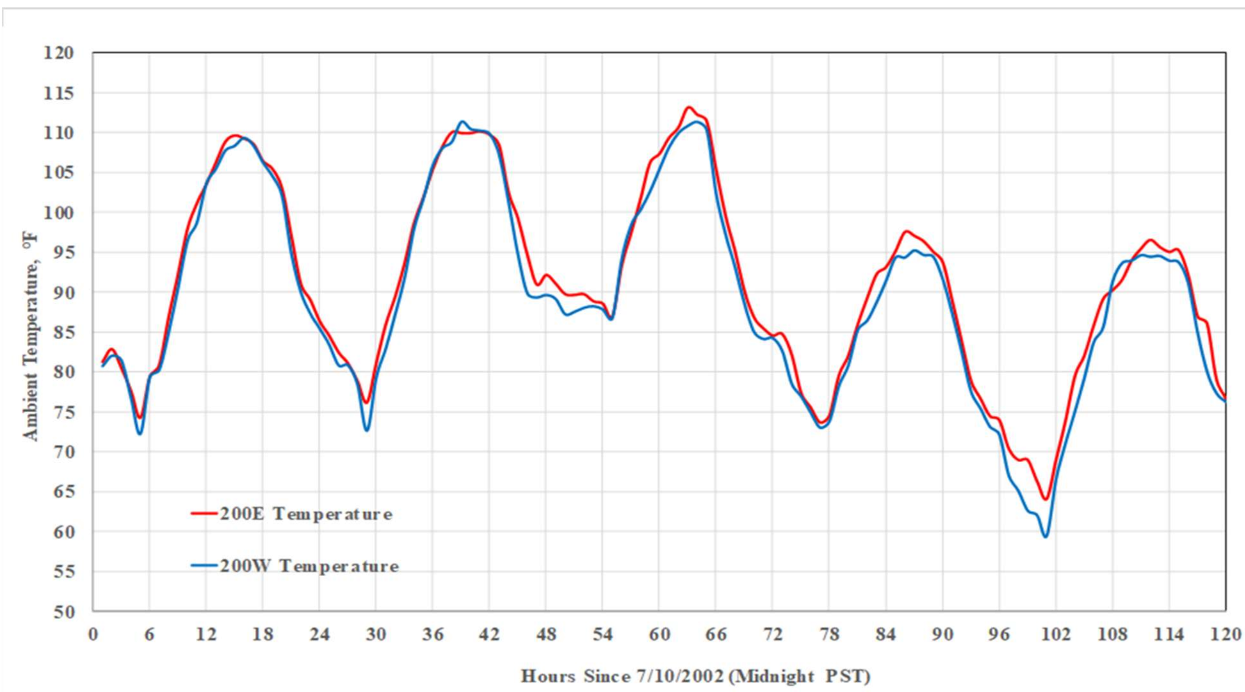
5.2.16 TFC-ENG-STD-07, “Ventilation System Design Standard.”

ATTACHMENT A - HOT AND COLD DAY ON THE HANFORD SITE DATA

PART 1 – HOT HANFORD DAY

The hottest day recorded at the Hanford Site occurred on July 13, 2002 according to Hanford Meteorological Station with a maximum temperature of 113 °F recorded at 3 p.m. Daylight Savings Time (DST). This temperature has been used in Section 3.1.1, "Temperature," with a design requirement on structures, systems, and components (SSCs) of 115 °F maximum ambient temperature. Figure A-1 is a plot of the ambient temperatures as recorded by the Hanford Meteorological Station in the 200 West Area and as recorded in the 200 East Area. These recorded temperatures are for a five-day range at the time of the record high temperatures. This figure illustrates that high temperatures can last for an appreciable period of time. The figure also illustrates that a peak temperature of greater than 100 °F can occur over a period of time of 10 a.m. to 8 p.m. Pacific Standard time (PST), with the absolute peak at around 3 p.m. PST. The approximate daily average temperature during this period was 92.5 °F.

Figure A-1. Record of Hanford Hot Day.

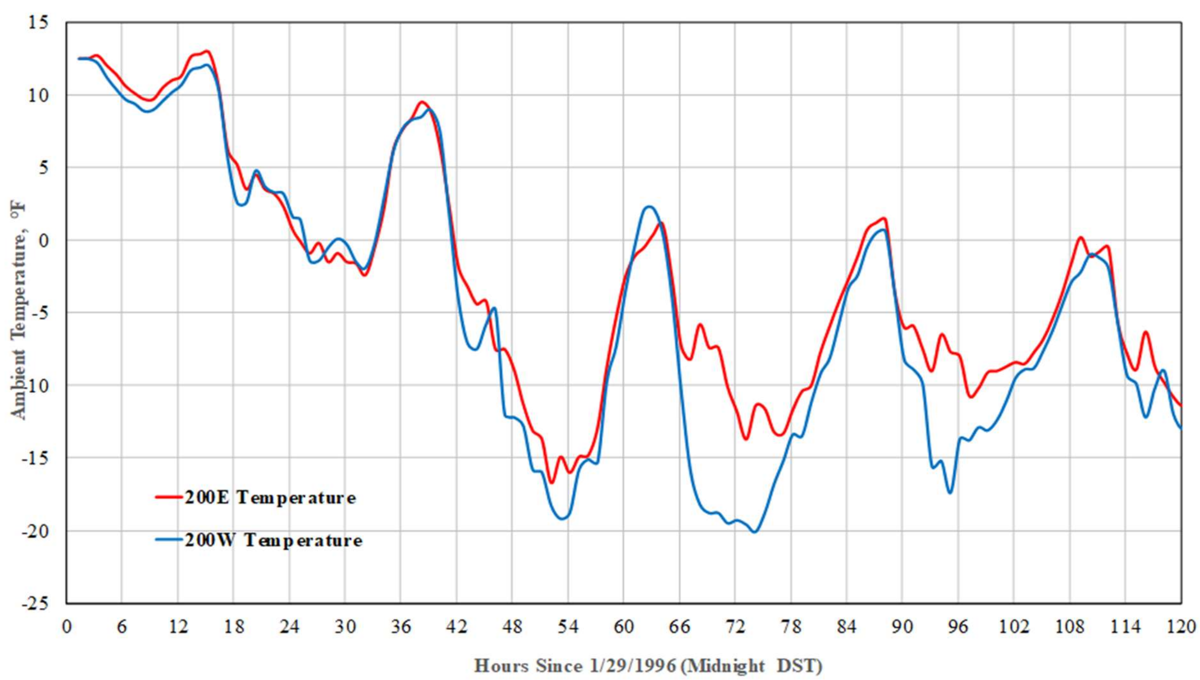


ATTACHMENT A - HOT AND COLD DAY ON THE HANFORD SITE DATA (cont.)

PART 2 – COLD HANFORD DAY

The coldest day recorded at the Hanford Site occurred on February 1, 1996 according to Hanford Meteorological Station with a minimum temperature of -20.1 °F recorded at 2 a.m. DST. This temperature has been utilized in Section 3.1.1, "Temperature," with a design requirement on SSCs of –25°F minimum ambient temperature. Figure A-2 is a plot of the ambient temperatures as recorded by the Hanford Meteorological Station in the 200 West Area and as recorded in the 200 East Area. These recorded temperatures are for a five-day range at the time of the record low temperatures. This figure illustrates that low temperatures can last for an appreciable period of time. The figure also illustrates that a minimum temperature approximately less than 0 °F can occur over a period of time of up to 3 days. The approximate daily average temperature during this period was 10 °F.

Figure A-2. Record of Hanford Cold Day.



Hours Since 1/29/1996 (Midnight DST)

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES

This attachment presents technical references for determining the subsurface temperature distribution on the Hanford Site. This presentation is for primarily the three different scenarios. The first scenario is that the depth being analyzed is less than 36-in. If this is the case, then Section 3.1.1, "Temperature" (Table 2) may be referenced for below ground temperature values. The second scenario is concerned with ground depths greater than 36-in., such as tanks, pump pits, etc. down to approximately 25 ft. The third scenario is concerned with ground depths greater than 25 ft. down to the water table.

The rationale for the use of Scenarios 2 and 3 is that the subsurface temperature effect due to the surface ambient temperature change is mitigated as the depth below the surface is increased. BNWL 1712, "A Study of Soil Matric Potential and Temperature in Hanford Soils," provided the following: "At depths from 7.5 meters to the surface, the temperature is influenced by the season and the climate." 7.5 m is approximately 25 ft. Conversely, if the subsurface depth is greater than 25 ft., then the temperature profile is constant throughout the time of year.

PART 1 – SUBSURFACE TEMPERATURE DISTRIBUTION AT DEPTHS LESS THAN 36 INCHES

From Section 3.1.1, (Table 2) the subsurface temperature distribution values are defined down to 36-in. below the surface. Design basis minimum (for winter) and maximum (for summer) temperatures are provided in Table 2

PART 2 – SUBSURFACE TEMPERATURE DISTRIBUTION FOR DEPTHS GREATER THAN 36 INCHES, BUT LESS THAN 25 FEET

A correlation from Kusuda and Achenbach (1965), "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States" provides the periodic ground temperature, T (z,t), as a function of depth (z) and time of year (t) is a cosine wave function. This correlation is presented in Equation B-1 as follows:

$$T\ (z,t) = T_{av} - \Delta T_o e^{-z\sqrt{\omega/2\alpha}} \cos\left[\omega(t - t_{min}) - z\sqrt{\omega/2\alpha}\right] \qquad \text{Equation B-1}$$

Where;

T (z,t) = ground temperature as a function of depth (z) and time of year (t);

z = depth below the surface, ft;

t = day of the year, day (1 to 365);

T_{av} = time averaged soil temperature at z = ∞, for this report, z = 25 ft;

ΔT_o = amplitude of surface temperature $(t_{max} - t_{min})/2$, °F;

α = thermal diffusivity of soil, ft^2/day;

t_{min} = day of the year when the minimum temperature occurs, day;, and

ω = cycle speed, rad/day (2π/365).

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

This methodology will determine periodic average values of the soil temperature down to about the constant temperature level. From Kusuda and Achenbach (1965), this level is at about 25 ft deep. A set of representative subsurface temperature values for the Hanford Site (assumes a water table temperature of 69 °F) is presented in Table B-1 and Figure B-1.

NOTE: The ambient temperatures and thermophysical properties of Hanford Site soil needed to perform the above calculation can be found in:

- PNNL-4015, "Thermal Properties of Soil Samples Buried Waste Test Facility."
- PNNL-15160, "Hanford Site Climatology Summary 2004 with Historical Data," Table 3.15.
- RPP-RPT-23308, "Hanford Double-Shell Tank Thermal and Seismic Project – Thermal and Operating Loads Analysis."

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

Table B-1. Seasonal Variation of Subsurface Soil Temperature – Hanford Site.

Month	Soil Depth (z), ft./Soil Temperature (°F)				
	0.0	**1.25**	**2.0**	**3.0**	**25.0**
January	33.8	39.0	42.0	45.8	64.6
February	37.9	40.2	41.8	44.2	64.6
March	47.9	47.0	47.0	47.5	64.5
April	63.1	58.8	57.0	55.3	64.1
May	78.0	71.7	68.6	65.2	63.6
June	89.5	82.7	79.2	75.0	63.2
July	93.8	88.4	85.4	81.5	62.9
August	90.0	87.6	85.8	83.4	62.9
September	78.9	80.1	80.2	79.8	63.1
October	64.1	68.5	70.3	72.0	63.4
November	48.8	55.2	58.4	61.8	63.9
December	37.9	44.7	48.2	52.4	64.3
t_{min}, °F	33.8	39.0	41.8	44.2	62.9
t_{max}, °F	93.8	88.4	85.8	83.4	64.6
ΔT, °F	30.0	24.7	22.0	19.6	0.9

Notes:

T_{av}	63.8	[Temperature at 25 ft, ARH-2983, Table V].[(a)]
ΔT_o, °F	30.0	[PNNL-15160, Table 3.15].[(b)]
k, Btu/h-ft-F	0.50	[Native soil, RPP-RPT-23308, Table 3.27].[(c)]
ρ, lb/ft^3	110	[Native soil, RPP-RPT-23308, Table 3.27].[(c)]
Cp, Btu/lb/ft^3	0.25	[Native soil, RPP-RPT-23308, Table 3.27].[(c)]

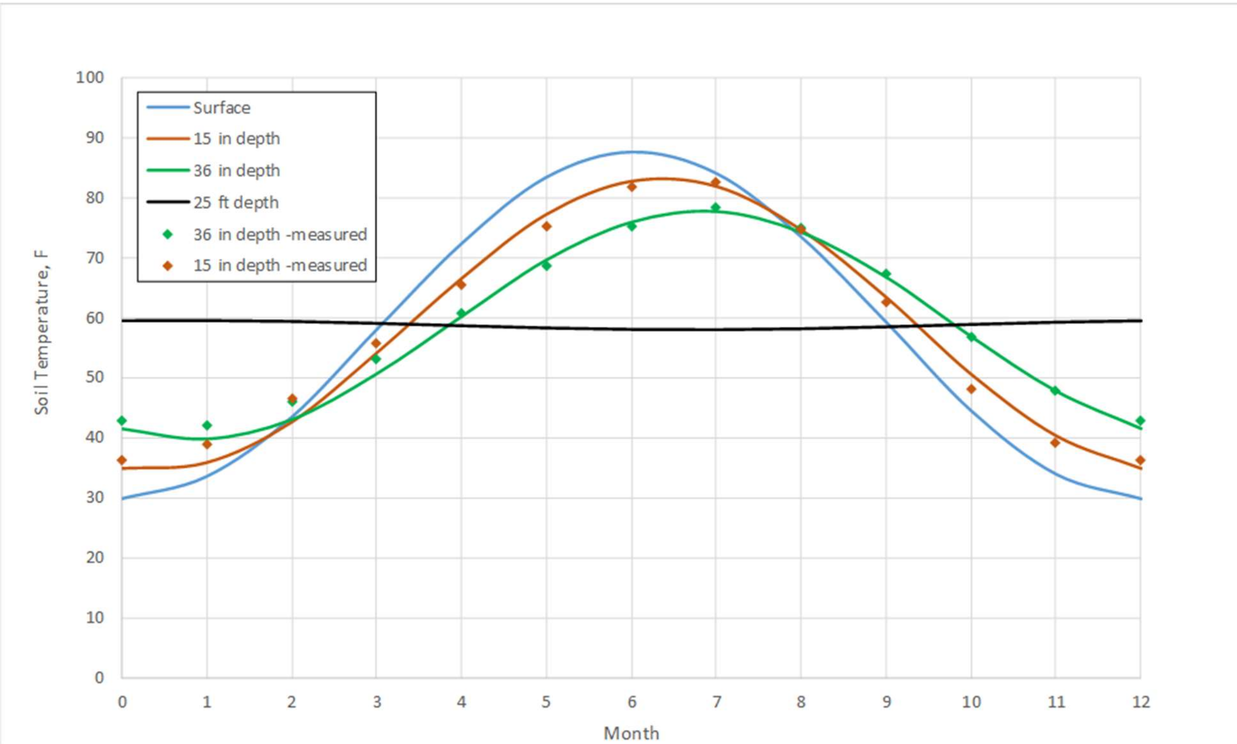
[(a)]ARH-2983, 1974, "Soil Moisture Transport in Arid Site Vadose Zones," Atlantic Richfield Hanford Company Richland, Washington.

[(b)]PNNL-15160, 2005, "Hanford Site Climatology Summary 2004 with Historical Data," Pacific Northwest National Laboratory, Richland, Washington.

[(c)]RPP-RPT-23308, 2005, "Hanford Double-Shell Tank Thermal and Seismic Project – Thermal and Operating Loads Analysis," Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

Figure B-1. Seasonal Variation of Subsurface Soil Temperature – Hanford Site.



PART 3 – SUBSURFACE TEMPERATURE DISTRIBUTION FOR DEPTHS GREATER THAN 25 FEET, BUT LESS THAN THE GROUND WATER TABLE DEPTH

ARH-2983, "Soil Moisture Transport in Arid Site Vadose Zones," provides for the average ground temperature distribution of the Hanford Site 200 Areas (undisturbed areas) from 6 m (~20 ft) down to the water table (at about 92 m or 302 ft) as follows (Equation B-2 and Equation B-3):

$$T_{gc} = 17.4 + 0.035 \times d_m \quad \text{Equation B-2}$$

$$T_{gf} = 63.32 + 0.019 \times d_f \quad \text{Equation B-3}$$

T_{gc} in °C and d_m in meters (T_{gf} in °F and d_f in ft), these equations were based upon field measurements using a linear least squares regression. ACH-2983 states, *"After installation of the transducers at the 32 49D site {Hanford 200E Area Southeast boundary}, temperature readings were recorded at various soil depths from a period of February 1971 to April 1972."*

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

ARH-ST-123, "Soil Moisture Transport in Arid Site Vadose Zones – Part II," provides for the average ground temperature of the Hanford Site 200 Areas (undisturbed areas) as follows:

"For the geothermal gradient given by Equation 2 for the depths between 7.5 and 93 meters. Equations are based upon a least square fit to data for temperature measurements at the 32-49D site."

See Equation B-4 and Equation B-5, below.

$$T_{gc} = 16.986+0.0572\times d_m \quad \text{Equation B 4}$$

$$T_{gf} = 62.575+0.0314\times d_f \quad \text{Equation B 5}$$

T_{gc} in °C and dm in meters (Tgf in °F and df in ft), these equations were based upon field measurements using a linear least squares regression.

Comparing this result to the ARH-2983 data; per ARH-2983 at d = 92 m (302 ft), T = 20.6 °C (69.0 °F) per ARH-ST-123 at d = 92 m (302 ft), T = 22.1 °C (71.9 °F) or dT of 1.6 °C (2.9 °F).

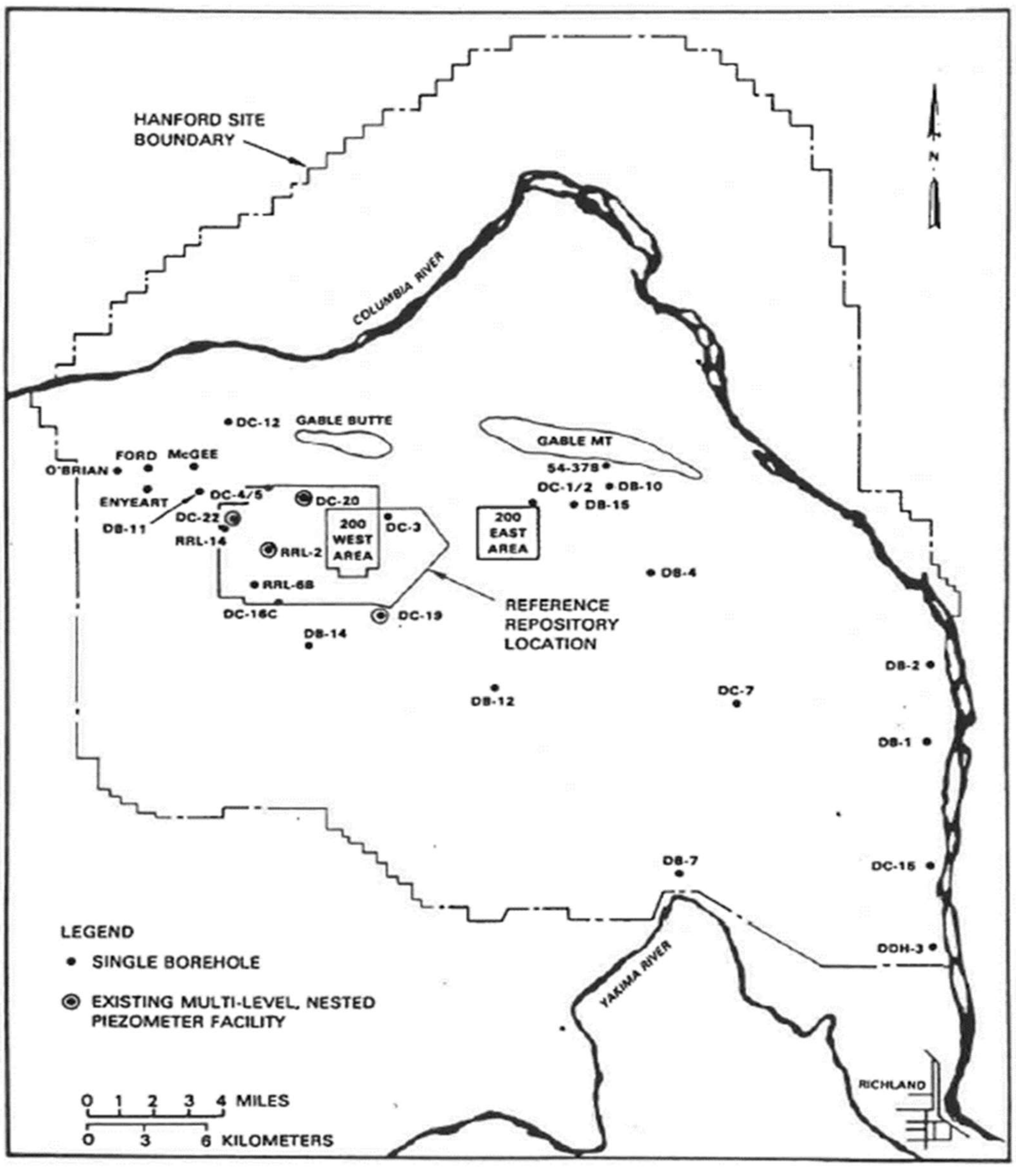
BNWL-1712, "A Study of Soil Matric Potential and Temperatures in Hanford Soils," provides instrumented readings for a borehole located near the 200 East Area (1 mile south), extending down to about 300 ft. The temperature varied from about 16 °C (61 °F) at 20 ft depth to 21 °C (70 °F) at 300 ft depth. The water table was listed as 310 ft at the borehole location.

A second well (well 699-19-47B) located 6 miles southeast of the 200 East Area produced temperature readings down to about 300 ft. The temperature varied from about 16 °C (61 °F) at 20 ft depth to 21 °C (70 °F) at 300 ft depth. Both borehole reported subsurface temperature of 21 °C (70 °F) at 300 ft depth.

The following data was compiled from SD-BWI-DP-065, "Fluid Temperature Data from Selected Boreholes on the Hanford Site." The data collected included several locations on the Hanford Site although the area of interest is around the 200 Areas. The location of all boreholes across the Hanford Site can be seen in Figure B-2. The selected data is repeated in Table B-2.

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

Figure B-2. Map of the Hanford Site Showing the Locations of the Boreholes.
(Source SD-BWI-DP-065)



ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

Table B-2. Temperature (°F) Versus Depth (Meters) for Selected Boreholes Across the Hanford Site. (a,b)

Borehole #	DB-4	DB-10	DB-11	DB-14	DB-15	DC-1(c)	DC-3	DC-4	DC-5	RRL-2(c)	RRL-14	Average
Depth (ft)	Temperature (°F)											
82.0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
164.0	67.1	64.0	63.7	32.0	61.3	63.1	64.0	NR	NR	NR	67.3	64.4
246.1	67.6	65.3	65.5	65.7	63.1	64.2	65.7	NR	NR	64.0	67.6	65.5
328.1	68.4	66.9	66.2	67.8	64.8	65.3	66.6	NR	67.3	65.1	68.7	66.7
410.1	70.0	68.7	67.5	68.9	66.4	66.7	67.6	70.2	68.4	66.2	69.8	68.2
492.1	71.6	70.5	69.6	70.5	68.5	68.7	68.9	71.1	69.8	67.8	72.1	70.0
574.1	72.7	72.7	71.4	72.1	70.5	69.8	70.3	72.5	71.1	69.1	71.1	71.2
656.2	74.1	74.5	72.7	74.1	72.7	71.6	72.1	73.8	73.4	70.5	72.9	72.9
738.2	75.7	76.8	74.8	75.2	74.8	73.8	73.8	75.2	74.7	72.3	74.5	74.7
820.2	77.5	79.0	76.6	77.0	77.0	74.8	75.2	76.5	75.9	73.6	74.8	76.1

(a)SD-BWI-DP-065, 1987, "Fluid Temperature Data from Selected Boreholes on the Hanford Site," Westinghouse Hanford Company, Richland, Washington.

(b)Results from SD-BWI-DP-065 have been converted from International System of Units to United States Customary Units.

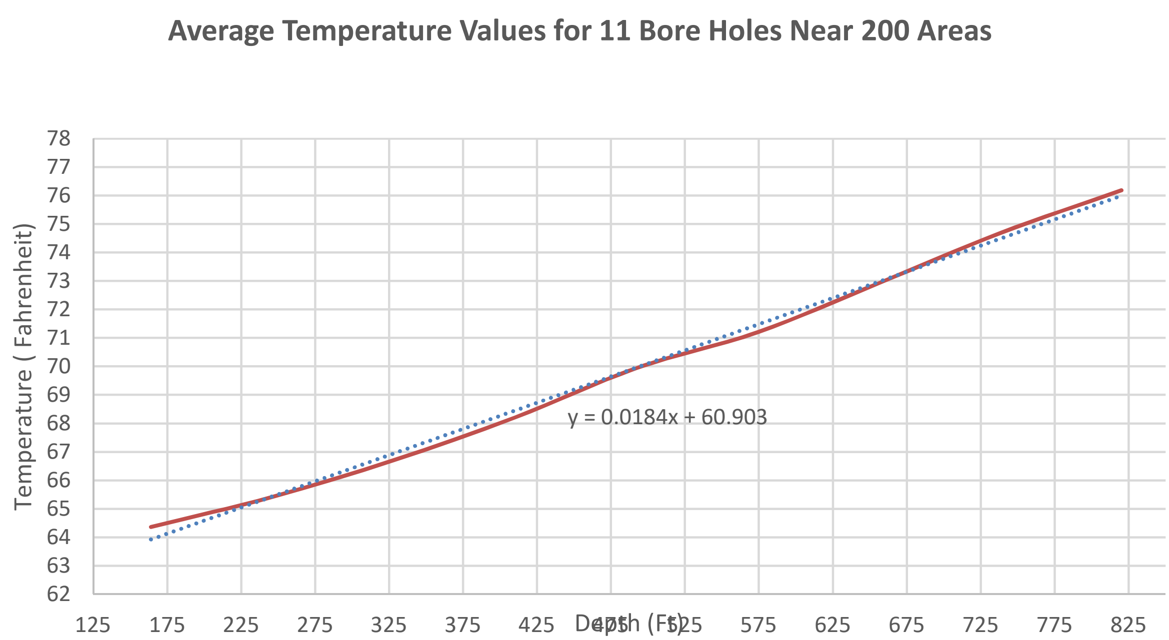
(c)Data from boreholes DC-1 and RRL-2 provide direct information related to the 200 Areas.

NR = No Record.

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

The temperature profiles for the selected boreholes in areas of interest were compiled into an Excel®[4] spreadsheet, allowing for an easy comparison of ground temperatures near the 200 Areas to be made. A plot of the average temperature versus depth for the 11 boreholes analyzed is show in Figure B-3. Also shown is the linear regression line of the data.

Figure B-3. Subsurface Temperature versus Depth for the Hanford Sites' 200 Areas.
(Source SD-BWI-DP-065)



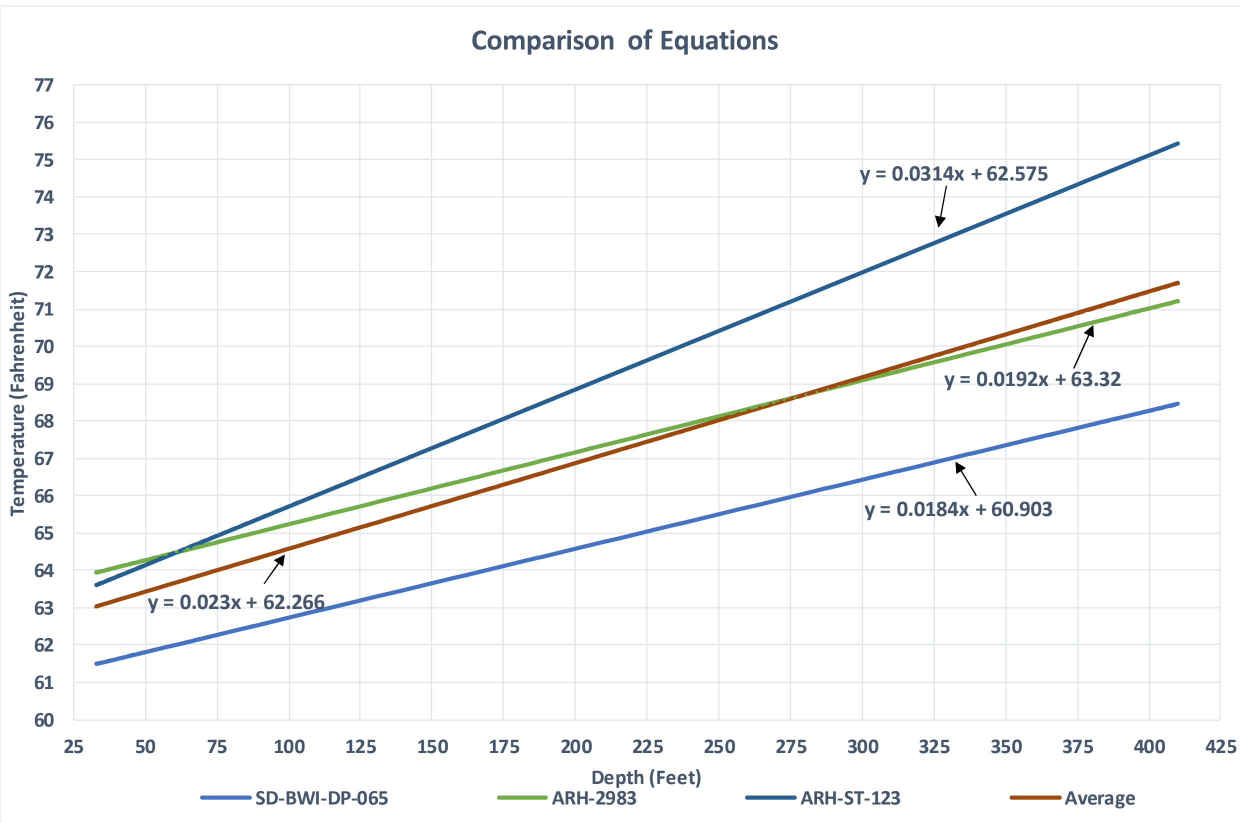
[4] Excel is a registered trademark of the Microsoft Corporation, Redmond, Washington.

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

Comparison of Reports

In an effort to determine which of the previously stated temperature data sets should be used, an analysis and comparison of the methodologies is required. Since the water table is located at varying depths throughout the Hanford Site, there will be slight dissimilarities in the temperature information collected at similar depths due to variation in thermal properties, experimental errors, or both. The data from three reports to compare were ARH-2983, ARH-ST-123, and the linear best-fit trend line from SD-BWI-DP-065. These reports are of interest as they all provide a linear temperature gradient used for analysis. This comparison shows that the trend line from SD-BWI-DP-065 provides a lower temperature for all depth values compared to the other reports analyzed. The comparison data plot is depicted in Figure B-4.

Figure B-4. Comparison of Select Data Reports on Subsurface Temperature versus Depth.



ARH-2983 has a thermal gradient of 0.019 °F/ft (0.035 °C/m), which is 0.16% different than the average gradient. This is the smallest difference in thermal gradient between all reports analyzed.

ARH-ST-123 has a more aggressive slope with a temperature gradient of 0.031 °F/ft (0.0572 °C/m) or a 0.36% difference from the average gradient.

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

SD-BWI-DP-065 provided a temperature gradient of 0.017 °F/ft (0.0312 °C/m) or a 0.25% difference from the average gradient. This information, plus the fact that the information collected is at a minimum 12 years newer, provides reasonable assurance that this gradient is more useable for thermal design of systems below ground than previous reports.

These reports are all relatively similar in regards to thermal gradients, although it can be seen that the true average of all three reports provides a more conservative value for design purposes. This average trend line with a gradient of 0.023 °F/ft (0.0419 °C/m) is comparable to Einfield, et. al. (1973), "Evaluation of Water Flux above a Deep Water Table Using Thermocouple Psychrometers," which declared a thermal gradient of 0.025 °F/ft (0.046°C/m) between depths of 49.2 to 262.5 ft (15 to 80 m). The difference in Einfield's values versus the average gradient is only 0.10%, which is the smallest difference in all reports analyzed.

PART 4 – HANFORD SITE GROUND WATER LEVELS AND TEMPERATURES

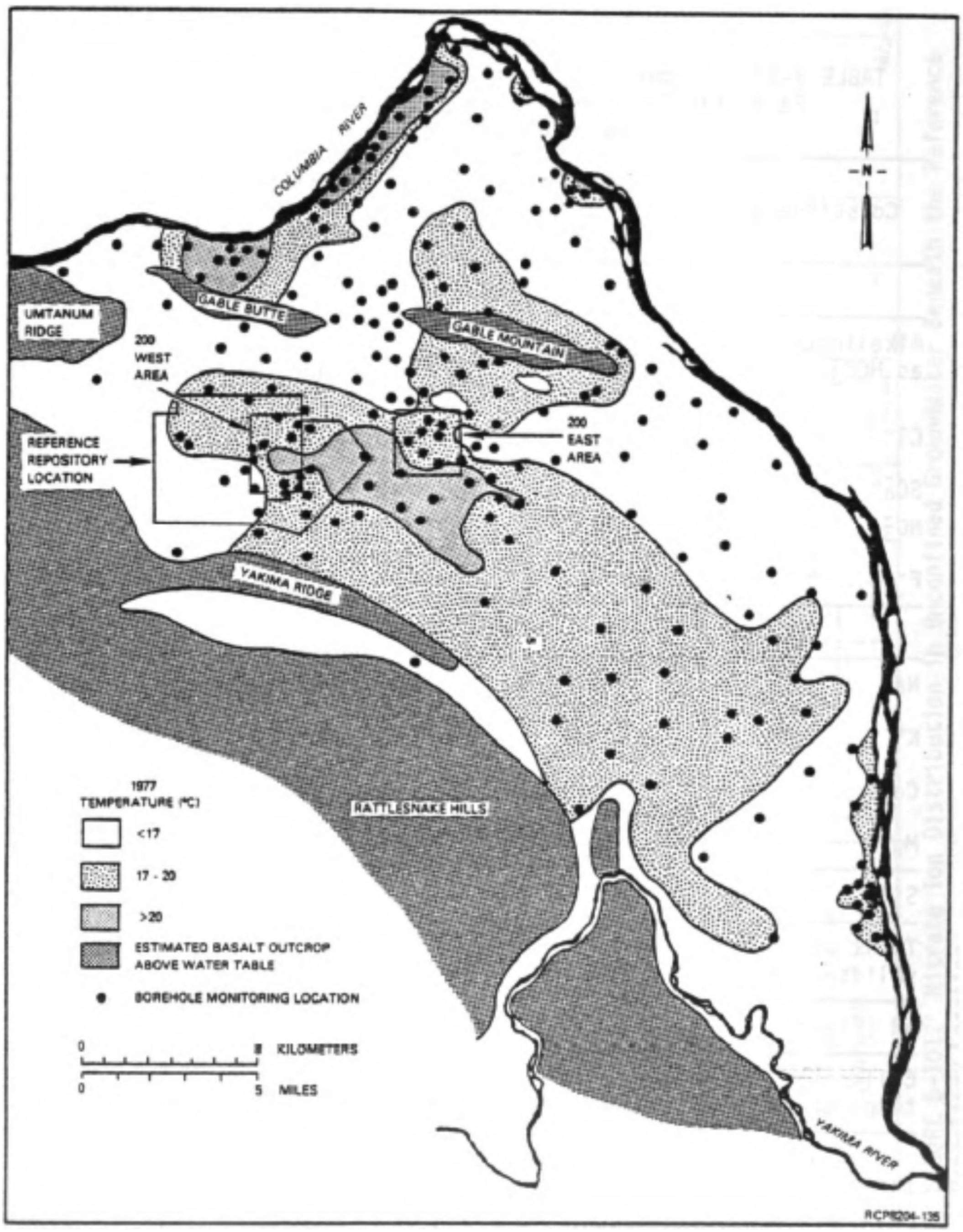
ARH-ST-155 (page 27), "The Hanford Environment as Related to Radioactive Waste Burial Grounds and Transuranium Waste Storage Facilities" provides for information on ground water levels across the Hanford Site as follows:

> *"The partly saturated sediments (Vadose Zone) beneath the 100 Areas is within the upper portion of the Hanford Format (Figure 16). Depths to groundwater in the reactor areas vary from zero at river level to 27 meters (89 ft)."*
>
> ARH-ST-155 (Page 30) states:
>
> *"The depth to groundwater beneath the 200 East Area varies from 55 meters (180 ft) in the northeastern portion of the area to 100 meters (328 ft) toward the southwest."*
>
> ARH-ST-155 (page 33) states:
>
> *"Under 200 West Area, the surface of the groundwater lies within the Ringold."*
>
> ARH-ST-155, Figure 17, depicts the groundwater level at approximately 55 m (180 ft) depth at the 200 West Area.
>
> ARH-ST-155 (Page 37) states:
>
> *"Minimum depths to groundwater beneath the 300 Area and 300-N and 300 Wye burial grounds are 9, 22, and 18 meters respectively (29.5, 72 and 59 ft respectively)."*

ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

DOE/RL-82-3, "Site Characterization Report for the Basalt Waste Isolation Project," presented the following Hanford Site ground water temperature distribution map (Figure B-5):

Figure B-5. Ground Water Temperature Distribution – Hanford Site.
(Source DOE/RL-82-3)



ATTACHMENT B - SURVEY OF REFERENCES ON THE HANFORD SITES' GROUND TEMPERATURE AND THERMAL PROPERTIES (cont.)

The importance of Figure B-5 is that it can be used to determine heat sink temperatures for underground facilities and equipment that will be located on undisturbed areas of the Hanford Site. At the 200 East and 200 West Areas, the ground water temperature is shown to be in the range of 17 to 20 °C (63 to 68 °F). This compares favorably with the other reports referenced in this attachment.

REFERENCES

1. ARH-2983, 1974, "Soil Moisture Transport in Arid Site Vadose Zones," Atlantic Richfield Hanford Company Richland, Washington.

2. ARH-ST-123, 1975, "Soil Moisture Transport in Arid Site Vadose Zones – Part II," Atlantic Richfield Hanford Company Richland, Washington.

3. ARH-ST-155, 1977, "The Hanford Environment as Related to Radioactive Waste Burial Grounds and Transuranium Waste Storage Facilities," Atlantic Richfield Hanford Company, Richland, Washington.

4. BNWL-1712, 1973, "A Study of Soil Matric Potential and Temperatures in Hanford Soils," Battelle Pacific Northwest Laboratories, Richland, Washington.

5. DOE/RL-82-3, "Site Characterization Report for the Basalt Waste Isolation Project," Volume 1, U.S. Department of Energy, Assistant Secretary for Nuclear Energy7, Office of Terminal Waste Disposal and Remedial Action, Washington, D.C.

6. Enfield, C. G., J. J. C. Hsieh, and A. W. Warrick, 1973, "Evaluation of Water Flux above a Deep Water Table Using Thermocouple Psychrometers," Vol. 37, No. 6, pg. 968-970, Soil Science Society of America, Madison, Wisconsin.

7. Kusuda T. and P.R. Achenbach, 1965, "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States," Report 8972, National Bureau of Standards, Washington, D.C. (also ASHRAE Transactions, Vol. 71, Part 1, 1965)

8. PNNL-4015, 1981, "Thermal Properties of Soil Samples Buried Waste Test Facility," Pacific Northwest National Laboratory, Richland, Washington.

9. PNNL-15160, 2005, "Hanford Site Climatology Summary 2004 with Historical Data," Pacific Northwest National Laboratory, Richland, Washington.

10. RPP-RPT-23308, 2005, "Hanford Double-Shell Tank Thermal and Seismic Project – Thermal and Operating Loads Analysis," Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

11. SD-BWI-DP-065, 1987, "Fluid Temperature Data from Selected Boreholes on the Hanford Site," Westinghouse Hanford Company, Richland, Washington.

ATTACHMENT C – INTERPRETATION AND CLARIFICATION GUIDANCE FOR SOLAR ENERGY CALCULATIONS USING INDUSTRY PRACTICES AND ASHRAE METHODOLOGY

SOLAR RADIATION PARAMETERS FOR DESIGN AT THE HANFORD SITE

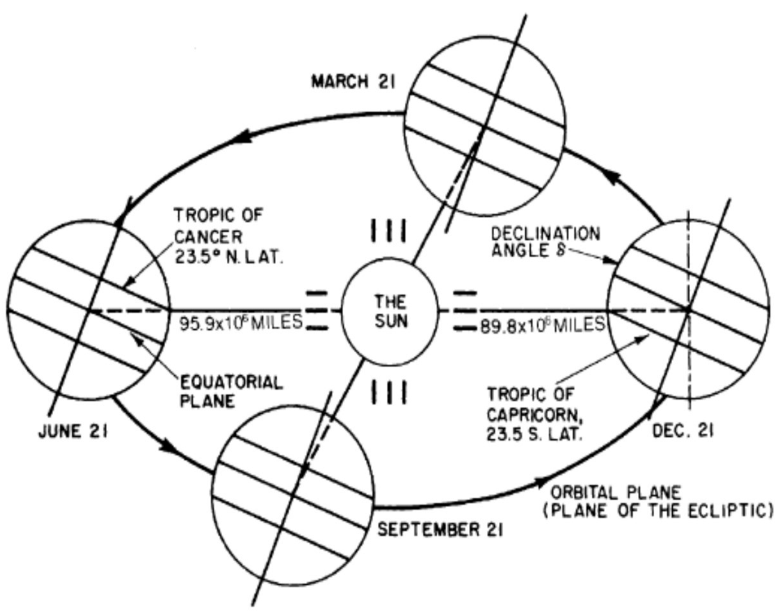
This attachment provides the effects of solar radiation on structures, systems, and components (SSC) applicable for use at the Hanford Site. The Hanford Site is located at approximately -119.6 degrees longitude and 46.57 degrees latitude and values for the calculations regarding solar radiation come directly from the ASHRAE Handbook – Fundamentals (ASHRAE 2017).

The locational values are important as they play a factor in Apparent Solar Time (AST) and Local Standard Time (LST) found at that specific location, as well as modifying the solar radiation from direct beam due to geographical location. These values vary due to the rotation of the earth around the sun, limiting the amount of sun absorbed and also affecting the path of the sun across the sky including the trajectory and angle of declination (angle between the equatorial line and sun/earth plane) as seen in Figure C-1. It is also important to consider that the days increase in length until the summer solstice (June 21), and then they decrease from there on until the winter solstice.

This makes noting the day of the year crucial as it provides a more accurate AST due to daylight savings and the elliptical orbit of the earth around the sun. All of these factors combine to help provide a proper representation of the suns duration, angle, and intensity of exposure, thus providing a more accurate solar radiation calculation.

NOTE: See ASHRAE (2017, Chapter 14, Section 2) for variation of solar declination δ (the angle between the earth/sun line and the equatorial plane).

Figure C-1. Motion of Earth Around the Sun.

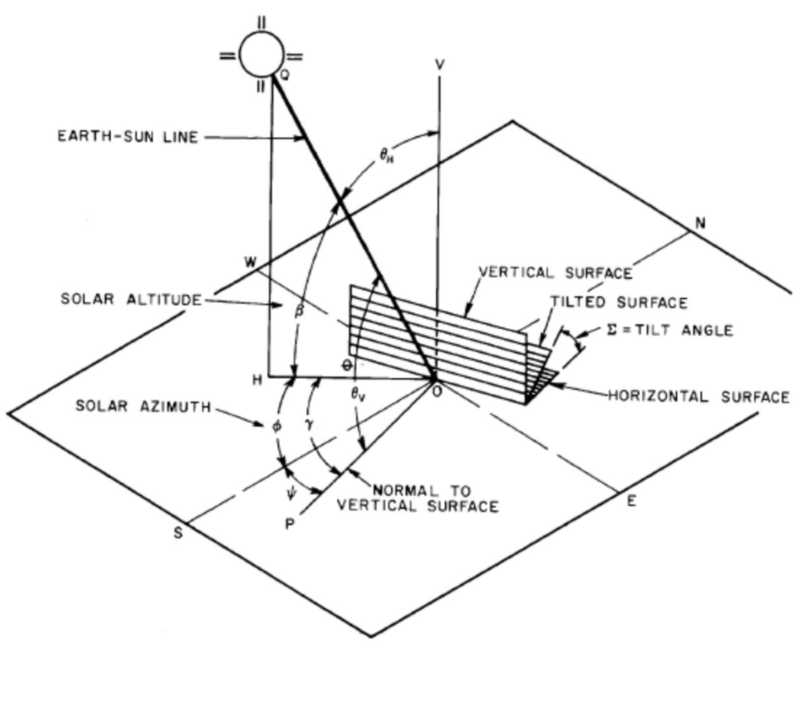


ATTACHMENT C – INTERPRETATION AND CLARIFICATION GUIDANCE FOR SOLAR ENERGY CALCULATIONS USING INDUSTRY PRACTICES AND ASHRAE METHODOLOGY (cont.)

The first part of analyzing solar radiation requires the day of the year and time of interest as well as the primary orientation (North, West, East, South, Horizontal or Vertical) of the primary surfaces as these orientations play a key factor in the total amount of energy absorbed due to exposure time on each surface (Figure C-2). Using a horizontal analysis (Sigma [Σ] = 0 degrees) generally yields the highest recorded solar radiation values due to a larger solar angle and, therefore, is predominantly used in order to achieve a conservative estimate for analysis. The day and time will provide the AST for use in the calculation of declination, solar altitude, and the solar azimuth angle. These values are used in calculation of air-mass ratio (the ratio of the mass of the atmosphere in the actual earth/sun path compared to mass that would exist if the sun were directly overhead the object being analyzed), beam direct solar radiation (solar radiation emanating from the solar disc directly towards the object) diffuse solar radiation (radiation emanating from the rest of the sky, not from the direct beam) and reflected radiation from adjacent surfaces. These factors contribute to the calculation of total solar radiation, allowing for a range of values to be achieved due to multiple variables at different locations (latitude, time of day, day of year, and surface orientation).

NOTE: See ASHRAE (2017, Chapter 14, Section 2) for definition of solar radiation parameters and analysis methods. Also, see the attached Figure C-3 for ASHRAE Climate Data for the Hanford Site for the Clear Sky Irradiance values and other climate data.

Figure C-2. Solar Angles for Vertical and Horizontal Surfaces.



ATTACHMENT C – INTERPRETATION AND CLARIFICATION GUIDANCE FOR SOLAR ENERGY CALCULATIONS USING INDUSTRY PRACTICES AND ASHRAE METHODOLOGY (cont.)

Figure C-3. ASHRAE Climate Data for the Hanford.

2017 ASHRAE Handbook - Fundamentals (IP)

HANFORD AP, WA, USA WMO#: **727840**

Lat: **46.567N** Long: **119.600W** Elev: **732** StdP: **14.31** Time Zone: **-8.00 (NAP)** Period: **86-95** WBAN: **94187**

Annual Heating and Humidification Design Conditions

	Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
		99.6%	99%	99.6%			99%			0.4%		1%				
				DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
(1)	12	7.7	15.2	-0.5	5.5	13.6	7.2	8.2	20.3	29.9	49.6	24.6	44.3	6.1	20	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

	Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
			0.4%		1%		2%		0.4%		1%		2%				
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(2)	8	28.2	100.7	67.3	97.4	65.5	93.8	64.2	68.3	97.6	66.5	93.9	65.2	91.3	7.4	30	(2)

	Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB	
	0.4%			1%			2%			0.4%		1%		2%			
	DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(3)	58.0	73.7	72.2	55.6	67.6	73.6	53.6	62.9	74.0	32.7	97.3	31.3	94.2	30.3	91.0	73.6	(3)

Extreme Annual Design Conditions

	Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature								
					Mean		Standard Deviation		n=5 years		n=10 years		n=20 years		n=50 years		
	1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
	(n)	(o)	(p)		(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	
(4)	25.2	20.9	18.5	DB	4.6	105.5	8.5	3.4	-1.5	107.9	-6.5	109.9	-11.2	111.9	-17.4	114.3	(4)
(5)				WB	4.2	69.4	8.0	4.5	-1.6	72.7	-6.2	75.3	-10.7	77.9	-16.5	81.1	(5)

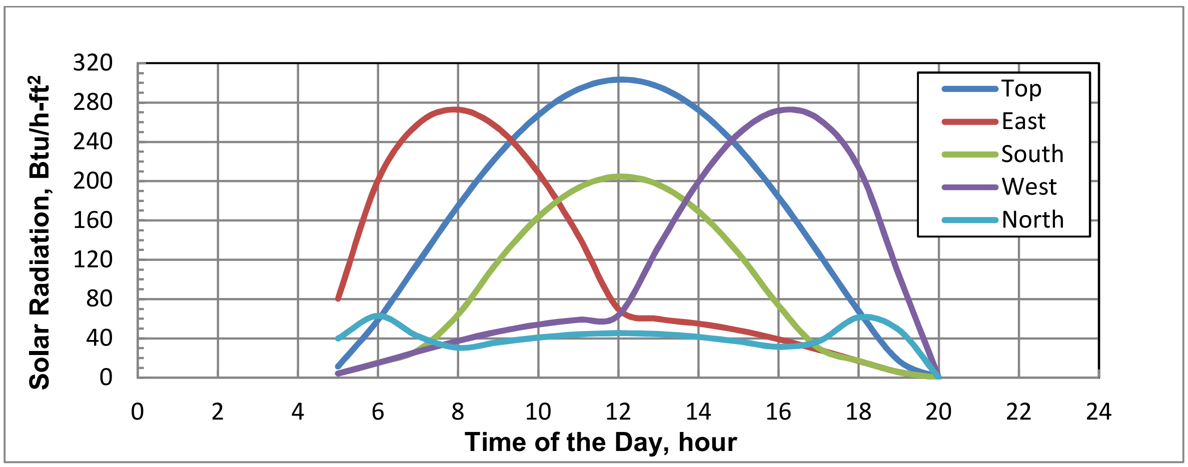
Monthly Climatic Design Conditions

				Annual (d)	Jan (e)	Feb (f)	Mar (g)	Apr (h)	May (i)	Jun (j)	Jul (k)	Aug (l)	Sep (m)	Oct (n)	Nov (o)	Dec (p)	
(6)	Temperatures, Degree-Days and Degree-Hours		DBAvg	55.1	33.8	38.4	46.9	55.3	63.5	71.1	76.1	76.5	67.9	55.2	42.2	32.6	(6)
(7)			DBStd	17.29	8.79	9.66	6.29	6.34	7.94	7.80	7.19	6.59	6.95	7.52	7.98	9.05	(7)
(8)			HDD50	1810	502	332	130	19	1	0	0	0	0	30	255	541	(8)
(9)			HDD65	4784	966	744	560	298	128	26	3	3	51	315	685	1005	(9)
(10)			CDD50	3653	1	8	35	178	419	632	810	821	538	191	19	1	(10)
(11)			CDD65	1154	0	0	0	7	82	208	348	359	139	11	0	0	(11)
(12)			CDH74	15244	0	0	4	140	1145	2713	4611	4632	1830	169	0	0	(12)
(13)			CDH80	7759	0	0	0	27	513	1356	2541	2491	800	31	0	0	(13)
(14)	Wind		WSAvg	7.8	6.7	7.2	7.8	8.8	9.2	9.3	9.3	8.3	7.4	6.7	7.3	6.0	(14)
(15)	Precipitation		PrecAvg	7.20	0.90	0.60	0.60	0.50	0.60	0.60	0.20	0.20	0.30	0.60	1.00	1.10	(15)
(16)			PrecMax	12.50	2.40	1.70	1.70	1.70	1.40	2.00	1.60	1.00	1.20	1.30	2.60	3.60	(16)
(17)			PrecMin	4.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	(17)
(18)			PrecStd	2.00	0.60	0.40	0.40	0.40	0.40	0.40	0.30	0.20	0.30	0.40	0.60	0.80	(18)
(19)	Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB	59.0	65.0	73.1	83.7	97.9	103.3	106.0	103.4	96.7	83.8	65.3	56.9		(19)
(20)			MCWB	49.6	53.7	53.3	60.5	66.6	68.8	69.7	68.4	64.8	60.2	54.0	47.7		(20)
(21)		2%	DB	54.3	60.4	67.5	77.9	91.6	96.7	101.0	100.0	92.7	78.9	61.3	52.5		(21)
(22)			MCWB	45.9	49.8	51.3	57.3	63.2	65.6	66.8	67.1	63.0	58.7	51.3	44.9		(22)
(23)		5%	DB	50.0	56.0	62.9	73.6	85.9	92.4	97.2	96.8	88.6	74.3	57.8	48.7		(23)
(24)			MCWB	43.0	46.2	49.3	54.3	60.7	63.8	65.1	65.6	61.8	56.4	49.2	42.2		(24)
(25)		10%	DB	45.6	51.8	59.5	69.4	80.1	88.0	93.3	92.5	84.6	69.5	54.0	44.5		(25)
(26)			MCWB	40.2	43.6	47.2	52.5	58.1	61.9	64.1	63.9	60.2	53.6	46.0	39.8		(26)
(27)	Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB	50.0	55.2	55.0	61.8	69.4	69.3	70.0	70.1	65.8	62.0	55.0	49.0		(27)
(28)			MCDB	58.1	63.3	68.9	80.7	94.7	101.9	103.1	101.2	94.4	81.4	62.7	55.2		(28)
(29)		2%	WB	46.4	50.1	52.8	58.9	63.8	66.5	67.9	68.1	64.0	59.4	52.6	45.8		(29)
(30)			MCDB	53.3	59.3	63.6	74.0	87.8	94.7	97.4	96.7	89.9	77.0	59.9	51.5		(30)
(31)		5%	WB	43.7	46.7	50.7	56.1	61.3	64.5	66.3	66.5	62.4	57.2	49.9	42.9		(31)
(32)			MCDB	49.5	54.3	61.3	70.8	82.9	89.8	93.9	93.2	86.7	71.4	56.9	47.7		(32)
(33)		10%	WB	40.8	44.4	48.4	53.5	59.1	62.6	64.8	65.0	60.9	54.9	46.9	40.1		(33)
(34)			MCDB	44.6	50.6	58.0	67.1	78.5	85.5	90.6	90.2	83.3	67.2	53.0	44.0		(34)
(35)	Mean Daily Temperature Range		MDBR	12.8	17.1	21.9	24.0	25.5	26.1	27.3	28.2	28.8	24.2	15.6	11.1		(35)
(36)		5% DB	MCDBR	18.5	23.5	27.2	30.0	32.7	31.0	31.4	31.6	34.5	29.0	17.9	17.6		(36)
(37)			MCWBR	11.5	14.2	15.1	14.6	13.0	12.5	11.5	11.8	14.1	13.7	10.7	11.8		(37)
(38)		5% WB	MCDBR	18.1	20.6	24.8	27.2	30.7	29.3	30.3	29.5	32.1	27.8	16.7	16.5		(38)
(39)			MCWBR	11.5	13.0	14.4	13.4	12.8	12.2	11.5	11.5	13.2	13.2	10.7	11.4		(39)
(40)	Clear-Sky Solar Irradiance		taub		0.286	0.290	0.299	0.331	0.346	0.346	0.347	0.344	0.331	0.309	0.293	0.282	(40)
(41)			taud		2.548	2.566	2.563	2.439	2.415	2.440	2.442	2.443	2.476	2.538	2.544	2.539	(41)
(42)			Ebn,noon		263	285	298	294	292	291	289	286	281	273	257	251	(42)
(43)			Edh,noon		20	23	27	34	36	35	35	33	29	23	19	18	(43)
(44)	All-Sky Solar Radiation		RadAvg		381	726	1136	1640	1989	2213	2384	1997	1472	917	473	313	(44)
(45)			RadStd		40	87	59	70	129	80	88	100	67	66	41	29	(45)

ATTACHMENT C– INTERPRETATION AND CLARIFICATION GUIDANCE FOR SOLAR ENERGY CALCULATIONS USING INDUSTRY PRACTICES AND ASHRAE METHODOLOGY (cont.)

The orientation of an object plays a key role in the total solar radiation absorbed as previously stated. A graphical representation of the variation of solar radiation with respect to surface orientation can been seen in Figure C-4, where five different surface orientations were analyzed for the maximum values for each orientation occurs at various times during the day.

Figure C-4. Surface Orientation Analysis at the Hanford Site's Latitude.

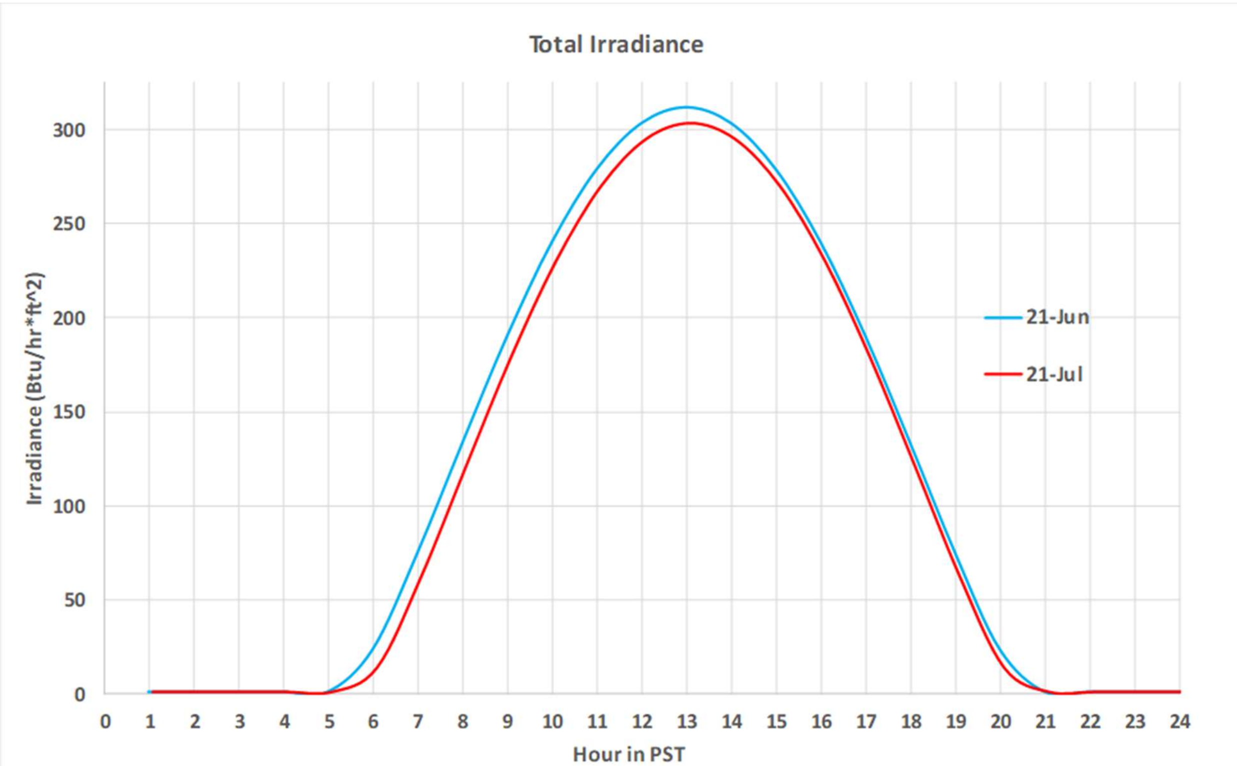


It is important to note that at the Hanford Site, we are predominantly interested in the maximum values of total solar radiation as specified in Section 3.1.6 "Solar Radiation," at 900 Langleys (3316 Btu/ft2 or 10460 Watt*hr/m2) maximum. SSCs are required to be designed to comply with this value. This 900 Langley value is slightly higher than 838 Langley maximum-recorded value (PNNL-15160, "Hanford Site Climatological Summary 2004 with Historical Data") in the past at the Hanford Site with an average annual value of 352 Langleys. The maximum value of solar radiation occurs on June 21 as it is the longest day (Summer Solstice), and maximum temperatures for the year typically occur from June to July. A comparison of June and July with their respective solar radiation can be seen in Figure C-5.

Recorded June value of 312 Btu/hr*ft2 is slightly higher total radiation than July at 303 Btu/hr*ft2 due to the increased length of the day as previously noted.

ATTACHMENT C – INTERPRETATION AND CLARIFICATION GUIDANCE FOR SOLAR ENERGY CALCULATIONS USING INDUSTRY PRACTICES AND ASHRAE METHODOLOGY (cont.)

Figure C-5. Solar Radiation Comparison Values for June and July.



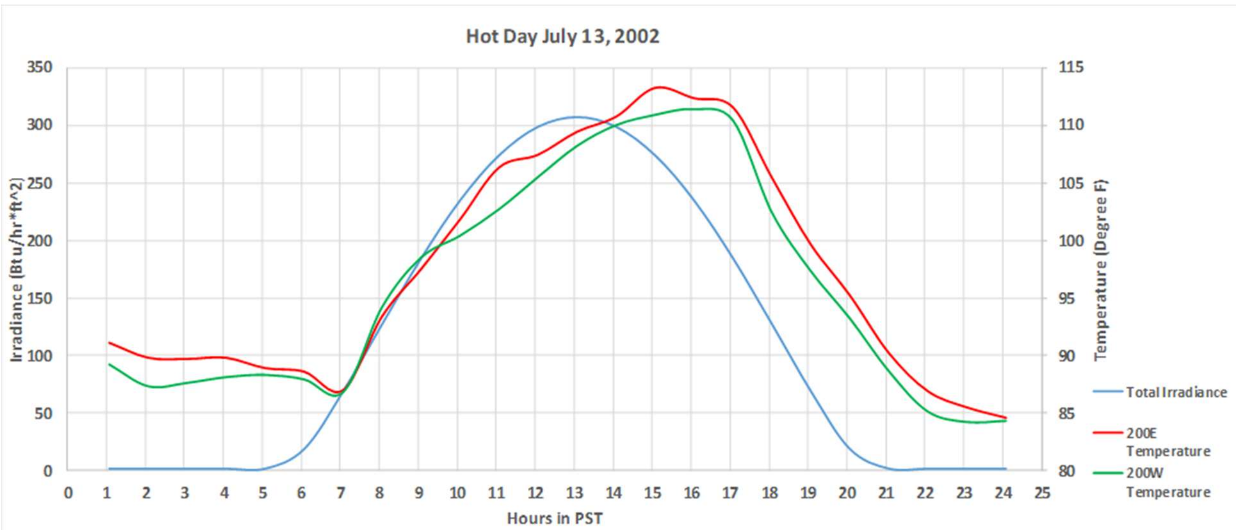
The next relationship is a comparison of transient solar radiation with ambient temperature. The hottest day recorded at the Hanford Site occurred on July 13, 2002 according to Hanford Meteorological Station with a maximum temperature of 113 °F recorded at 3 p.m. DST. This temperature has been used by Section 3.1.1, "Temperature" (Table 1), with a 115 °F maximum ambient temperature. The comparison of the Hanford Site hottest day temperature profile for both the 200 East Area and the Hanford Meteorology Station along with the total solar radiation (horizontal surface) can be seen in Figure C-6. The temperature peak for the day slightly lags behind the peak in solar radiation by approximately 3 hours with a temperature delta of approximately 4 degrees. If multiple days are analyzed, the same cyclical pattern can be observed of the maximum ambient temperatures occurring around 2 to 3 hours after the maximum solar radiation value.

NOTE: PST is Pacific Standard Time (1 hour differential with the AST).

The combination of peak solar radiation with peak ambient temperature can be used in a conservative thermal evaluation of SSCs with low thermal mass (e.g., electrical enclosures). Time averaging of solar radiation and ambient temperatures should be used for SSCs having large thermal masses (e.g., pump pits).

ATTACHMENT C – INTERPRETATION AND CLARIFICATION GUIDANCE FOR SOLAR ENERGY CALCULATIONS USING INDUSTRY PRACTICES AND ASHRAE METHODOLOGY (cont.)

Figure C-6. Solar Radiation and Ambient Temperature Values for June and July.



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1. ASHRAE, 2017, *ASHRAE Handbook – Fundamentals*, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, Georgia.

2. PNNL-15160, 2005, "Hanford Site Climatology Summary 2004 with Historical Data," Pacific Northwest National Laboratory, Richland, Washington.