6.1.4 THERMAL ENVIRONMENT

6.1.4.1 Cargo Bay Wall Temperature

Typical temperature ranges at the cargo bay walls are defined in Table 6.1.4.1-1. Actual temperatures are dependent upon flight parameters and upon cargo element configuration. The maximum temperature for the radiator panels when the doors are closed shall not exceed 210°F.

6.1.4.2 (DELETED)

6.1.4.2.1 Payload Bay Vent Door Failure Contingency

The payload bay vent doors are normally closed at the start of entry and do not begin to open until after peak aerodynamic heating has occurred. However, the payload is required to make a thermal assessment of the payload and all payload supplied hardware considering a vent failure, wherein any vent fails in the open position and remains in that position throughout entry. The payload shall verify that this condition will not cause the payload to present a hazard to the Orbiter.

6.1.4.2.2 Vent Failure Heating Environment/Analysis Methodology

Failure of a vent in the open position will allow heated air to flow into the payload bay and convectively heat payload components in the path of the plume. The envelope of the ingested air plume increases in diameter with the distance from the vent filter. The heat transfer rate to payload components varies with time, location within the plume, shape, size and component surface temperature. A preliminary safety assessment shall be submitted to STS and shall be made assuming a conservative, worst case condition, wherein the location of the payload is directly in front of the ingested air plume with respect to the Xo direction. If a detailed analysis is required, the STS will determine the exact Xo location to be used based on final flight manifesting. Figure 6.1.4.2.2-1 describes the heating regions of the plume and the dimensions of the filter. The stagnation heating rate varies according to the following:

$$q_s = q_r \times F_c \times F_p \, [0.736 \, T_w^{\,.05} \, (T_A - T_w)/(T_A - 460)]$$

Where:

- q_s = stagnation heating rate, BTU/ft^2-sec
- q_r = reference heating rate, BTU/ft^2-sec
- F_c = factor to account for component configuration and size
- F_p = factor to account for component location in air plume
- T_A = air temperature, ^oR
- T_w = wall (payload component surface) temperature, ^oR

The reference heating rate (q_r) and air temperature (T_A) histories are given in Table 6.1.4.2.2-1. In addition, Table 6.1.4.2.2-1 also lists payload compartment pressure and filter temperature, for analyses requiring this data.

Within Region 1 of Figure 6.1.4.2.2-1, the stagnation heating is independent of component location. Components outside the plume (Region 3) do not experience convective heating from the ingested air. The component location factor (F_p) accounts for plume heating decay effects outside the plume core. F_p, as a function of the location dimensions for the heating regions, is further defined in Figure 6.1.4.2.2-2. For components with surfaces that span more than one region of the plume, the intersection of the Yo and R coordinates shall be used as a conservative approach in establishing the heating distributions.

The configuration factor (F_C) for cylinders, spheres and flat plates are calculated as:

Cylinders: $F_C = D^{-0.5}$
Spheres: $F_C = 1.36D^{-0.5}$
Flat Plates: $F_C = 0.5D^{-0.4} (1 + q_r) (.47 + .53 \sin A)$

Where:

D = component diameter, inches
A = flat plate angle-of-attack to flow direction, degrees, where A = 90^o is for flow normal to the surface.

For configurations of less than one inch in diameter or larger than 48 inches, heating should be calculated using one inch and 48 inches, repectively. For configurations where the heating cannot be synthesized from the generic configuration data or where critical component temperatures would be exceeded, the payload should contact the STS.

6.1.4.3 Reflected Solar Energy

Cargo Elements and Orbiter components which extend above the cargo bay door hinge line (Zo 400.00 ref.), or are deployed transversely over the radiators, may be subjected to locally concentrated solar radiation due to the focusing by the Orbiter reflective radiators. The radiator thermo-optical properties are given in Table 6.1.2.2.1-1 and the radiator configuration and contour equations are provided in JSC-19540. The magnitude of the local solar fluxes will be a function of cargo element or component design, its location in the payload bay and Orbiter orientation relative to the sun.

Payloads which could be subject to this environment shall make an assessment of its effect on the payload. If attitude constraints are indicated by this evaluation, the payload shall notify JSC.

6.1.4.4 Prelaunch and Post-landing Environments

Worst case hot and cold prelaunch and post-landing environments, as well as nominal environments, are defined, and shall be used in verifying Orbiter/cargo elements thermal compatibility. Constant values for environmental extremes are provided, which may be used for calculating conservative thermal predictions. Diurnal data is also provided which may be used for performing more rigorous predictions.

6.1.4.4.1 Solar Flux

The solar constant, which is defined as the heating flux to a surface normal to the incident solar radiation, has a mean value of 429 BTU/hr-ft^2 outside the earth’s atmosphere. Because of attenuation due to atmospheric interference, the solar constant at the earth’s surface varies as a function of time of day.

6.1.4.4.1.1 Solar Flux Diurnal Variation

Figure 6.1.4.4.1.1-1 shows the diurnal variation of the solar constant to be used for normal hot and cold environment cases of prelaunch and post-landing analyses. For prelaunch conditions, it shall be assumed that the Orbiter is in the vertical position on the launch pad with its tail facing south at the Eastern Test Range (ETR). For landings at the ETR the Orbiter is assumed to be generally oriented with the X-axis in a north-south direction.

For hot case analysis, the flux represents the direct flux for a surface normal to the flux. The direct fluxes for the various surfaces of the Orbiter must be corrected for the Angle of Incidence which varies for each surface and with time of day. For cold case analysis, the flux is assumed to represent the diffuse flux for a cloudy day and does not need to be corrected for the Angle of Incidence.

6.1.4.4.1.2 Solar Flux at Contingency Landing Sites

Figure 6.1.4.4.1.2-1 shows the curve to be used for the maximum solar flux at contingency landing sites. The curve was generated assuming a March "noontime" equatorial flux of 396 BTU/hr-ft^2 and the timewise distribution equation shown on Figure 6.1.4.4.1.2-1. Minimum flux at a contingency landing site is assumed to be equal to zero.

6.1.4.4.1.3 Solar Flux Constant Values

For cases where it is desirable to use constant (conservative) values for the solar flux, the following values may be used:

Hot Environment*

Prelaunch and normal post-landing	363 BTU/hr-ft2
Contingency landing	396 BTU/hr-ft2

Cold Environment**

Prelaunch and normal post-landing	70 BTU/hr-ft2
Contingency landing	0 BTU/hr-ft2

* For prelaunch hot conditions with the Orbiter in a vertical position on the pad, assume the sun is in the Orbiter X-Z plane at an angle 38 degrees up from the local horizontal at the ETR. For hot analyses for normal post-landing and contingency landings, assume the sun is directly overhead, Figure 6.1.4.4.1.1-1.

** For cold conditions, assume the flux is diffuse, Figure 6.1.4.4.1.1-1.

6.1.4.4.2 Ambient Air Temperature

The ambient air temperature varies with time of day, season and local weather conditions.

6.1.4.4.2.1 Eastern Test Range (ETR)

Figure 6.1.4.4.2.1-1 shows diurnal air temperatures for the ETR location for cold, hot and nominal days for representative months. The temperatures for hot and cold days represent the maximum and minimum values, respectively, for 95 percent of all measurements while the temperature for a "nominal" day represents the median (50 percentile) of all measurements.

6.1.4.4.2.2 (Reserved)

6.1.4.4.2.3 Air Temperature at Contingency Landing Sites

The diurnal air temperatures for contingency landing sites for missions with inclination of greater than 30° are shown in Figure 6.1.4.4.2.3-1. Diurnal air temperatures for contingency landing sites for missions with inclination of 30° or less are shown in Figure 6.1.4.4.2.3-2. The curves for a hot day were synthesized assuming a maximum temperature of 110°F at noon and a minimum temperature at the ETR in July for a 95 percent hot day. The curve for a cold day for inclination > 30° was synthesized assuming a minimum temperature of 0°F with a 50°F temperature rise and fall in the morning and afternoon, respectively. For inclination ≤ 30°, the curve for a cold day was based on historical data for Moron, Spain.

6.1.4.4.2.4 Ambient Temperature Constant Values

Where it is desired to use constant (conservative) values of ambient temperature, the following values are recommended:

Hot Environment

Prelaunch and normal post-landing	99°F
Contingency landing	110°F

Cold Environment

Prelaunch and normal post-landing	25°F
Contingency landing	0°F

6.1.4.4.3 Ground Surface Temperature

The ground surface temperature is influenced by incident daytime solar radiation, sky/ground radiation interchange, air temperature and velocity, and surface properties. Generally, it is assumed that the ground surface temperature is the same as the air temperature. If desired, the ground temperature may be assumed to be equal to the diurnal air temperature. When constant (conservative) values are appropriate, the following values may be used:

Hot Environment

Prelaunch	99°F (60°F*)
Normal post-landing	99°F
Contingency landing	110°F

Cold Environment

Prelaunch	25°F
Normal post-landing	25°F
Contingency landing	0°F

* When in a vertical position on the launch pad, the bottom of the Orbiter views the external tank which has a temperature of approximately 60°F.

6.1.4.4.4 Sky Temperature

The sky temperature is influenced by climatic conditions such as ambient temperature and cloud cover and time of day. While on the runway the upperbody surfaces of the Orbiter radiate heat primarily to the sky. While on the launch pad in a vertical position, these surfaces radiate approximately one-half to the ground and one-half to the sky. The following constant values are recommended for design purposes:

Hot Environment

Prelaunch	50°F*
Normal post-landing	50°F
Contingency landing	50°F

Cold Environment

Prelaunch	5°F
Normal post-landing	-22°F
Contingency landing	-22°F

* Average radiation temperature viewed by Orbiter top surfaces is 76°F assuming sky temperature of 50°F and ground temperature of 99°F.

6.1.5 (DELETED)

6.1.6 (Reserved)

TABLE 6.1.4.1-1 CARGO BAY WALL TEMPERATURE

CONDITION	TEMPERATURE	
	Minimum	Maximum
1. Prelaunch (1)	+40°F	+120°F
2. Launch (1)	+40°F	+150°F
3. On-Orbit (doors open) (2) (4)	-250°F	+200°F
4. Entry and Post-landing (3) (4)	-50°F	+220°F

NOTES:

(1) Conditions 1 and 2 are for an assumed adiabatic cargo element.

(2) Condition 3 is for an assumed empty cargo bay. The effect on wall temperature which results with a cargo element installed is dependent upon cargo element configuration, cargo element location in the bay, and on-orbit attitude. Under hot case conditions, the effects generated by the cargo element can cause local cargo bay wall insulation temperatures to substanially exceed 200°F.

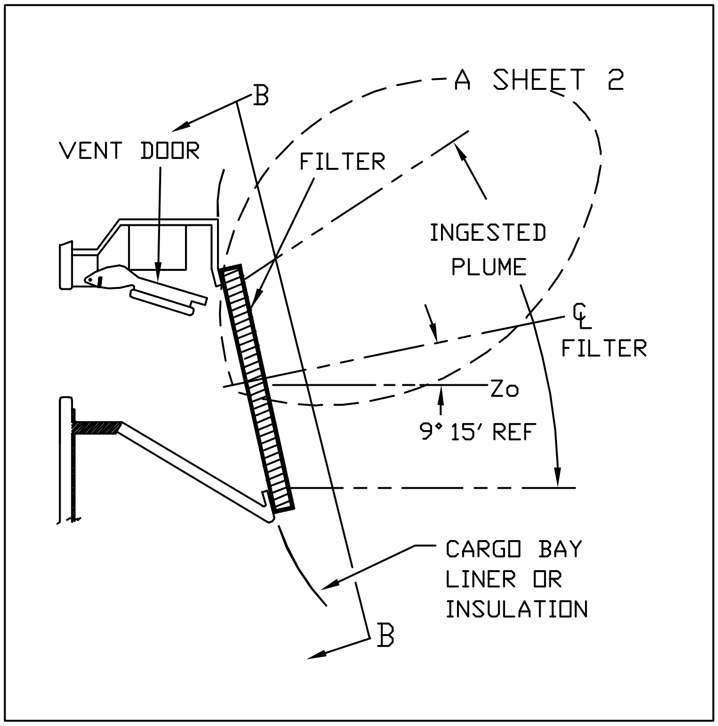
(3) Condition 4, minimum, is for an assumed adiabatic cargo element with an initial -250°F cargo bay wall temperature. Condition 4, maximum, is for an assumed empty cargo bay.

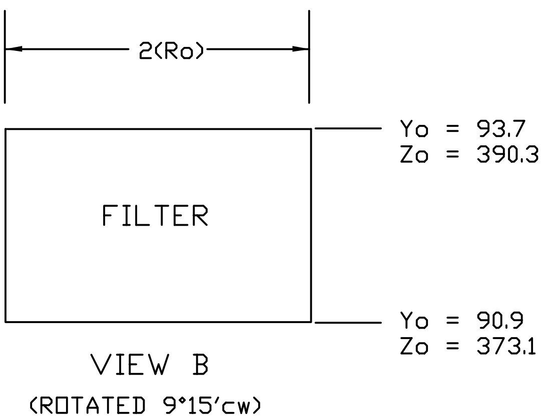
(4) Conditions 3 and 4 should be analyzed using detailed integrated Orbiter/cargo element math models to define cargo element and Orbiter cargo bay temperatures for specific cargo element configurations.

TABLE 6.1.4.2.2-1 REFERENCE HEATING RATE, TEMPERATURES AND PRESSURE

t (sec)	q_r (BTU/ft^2 sec)	T_A (^oR)	T_F (^oR)	P_o (psf)
0	.0000	500	460	4.46E-5
100	.0000	650	470	6.56E-5
200	.0004	850	480	4.44E-4
300	.0050	1040	520	4.44E-3
400	.0156	1350	640	1.30E-2
500	.0277	1470	780	2.33E-2
600	.0416	1530	920	3.54E-2
700	.0600	1660	1000	5.43E-2
800	.0866	1750	1080	8.66E-2
900	.1215	1760	1150	1.60E-1
1000	.2165	2140	1180	3.52E-1
1100	.1367	1830	1160	5.76E-1
1200	.2778	2140	1110	1.138
1300	.3177	1770	1080	2.716
1400	.4644	1380	1050	9.366
1450	.3642	1060	1020	1.680E+1
1475	.3248	660	940	2.287E+1
1500	.2089	560	760	1.738E+1
1550	.1564	520	580	6.244E+1
1650	.0000	500	460	3.362E+1
1700	.0000	500	450	5.865E+1
1750	.0244	500	470	9.547E+2
1800	.0615	530	530	1.459E+3
1850	.0926	530	530	2.029E+3

t = Time from entry interface at 400K ft.
q_r = Reference heating rate (for a 1" D cyl, T_W = 460^oR).
T_A = Reference air temperature (at Yo = 0, ^oR = 0).
T_F = Filter temperature.
P_o = Payload compartment air pressure.





NOTE:

1. FOR CALCULATION PURPOSES, PLUME IS CONSIDERED TO BE CONICAL IN SHAPE

WHERE:

2(Ro)= LARGEST SIDE DIMENSION OF FILTER SCREEN(23.7 FOR CALCULATION PURPOSES)

R = RADIAL DISTANCE FROM CENTERLINE OF PLUME TO OBJECT

Rp = RADIAL DISTANCE FROM CENTERLINE OF PLUME TO OUTERMOST EDGE OF PLUME

FIGURE 6.1.4.2.2-1 AIR PLUME ENVELOPE AND HEATING REGIONS
(SHEET 1 OF 2)

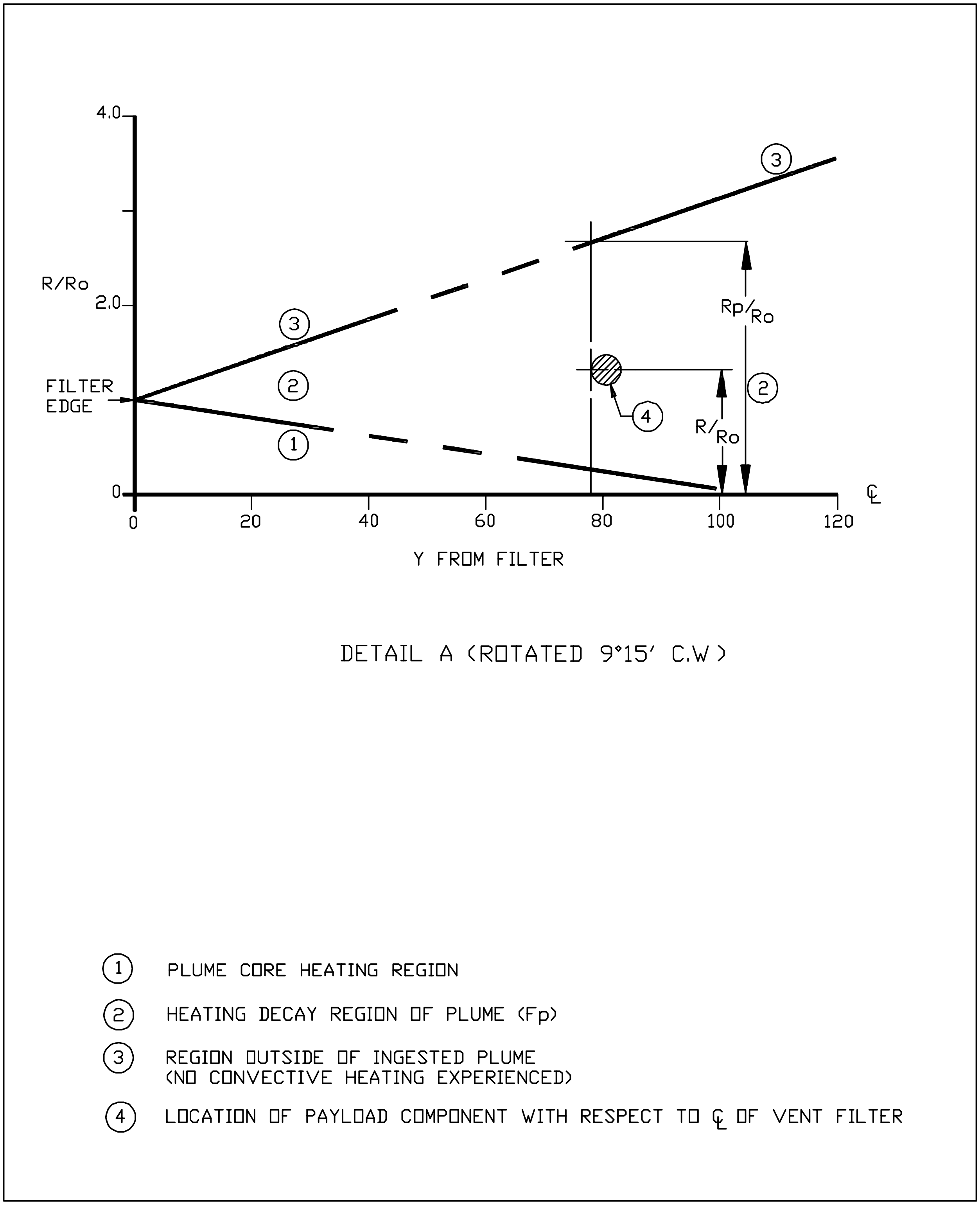
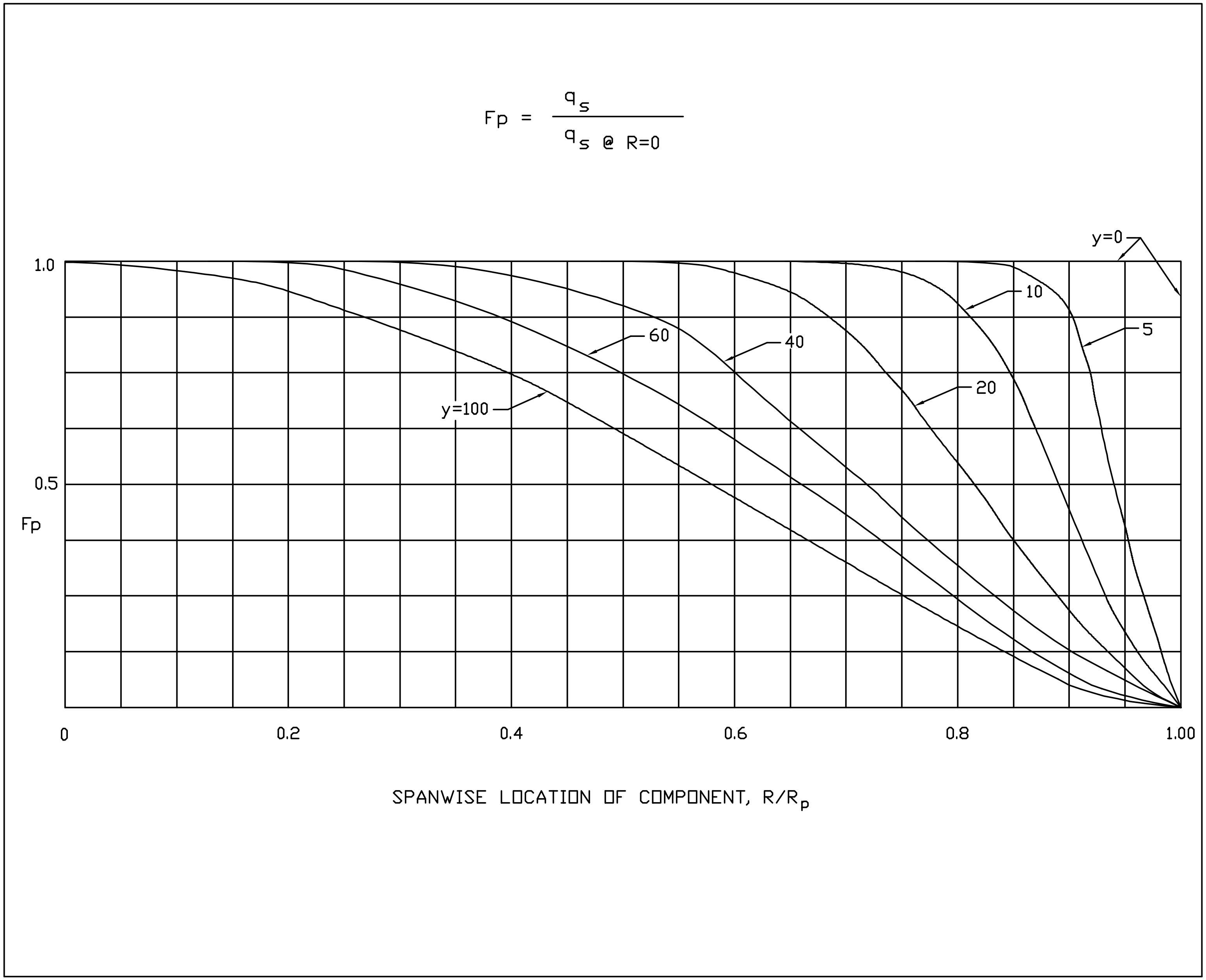


FIGURE 6.1.4.2.2-1 AIR PLUME ENVELOPE AND HEATING REGIONS
(SHEET 2 OF 2)

FIGURE 6.1.4.2.2-2 SPANWISE HEATING DISTRIBUTION WITHIN THE PLUME



TIME OF DAY	DESIGN HIGH SOLAR RADIATION		DESIGN LOW SOLAR RADIATION	
HOUR	BTU/FT^2/HR	GM-CAL/CM^2/MIN	BTU/FT^2/HR	GM-CAL/CM^2/MIN
0500	0	0.00	0	0.00
1100	363	1.64	70	0.32
1300			80	0.36
1400	363	1.64		
2000	0	0.00	0	0.00

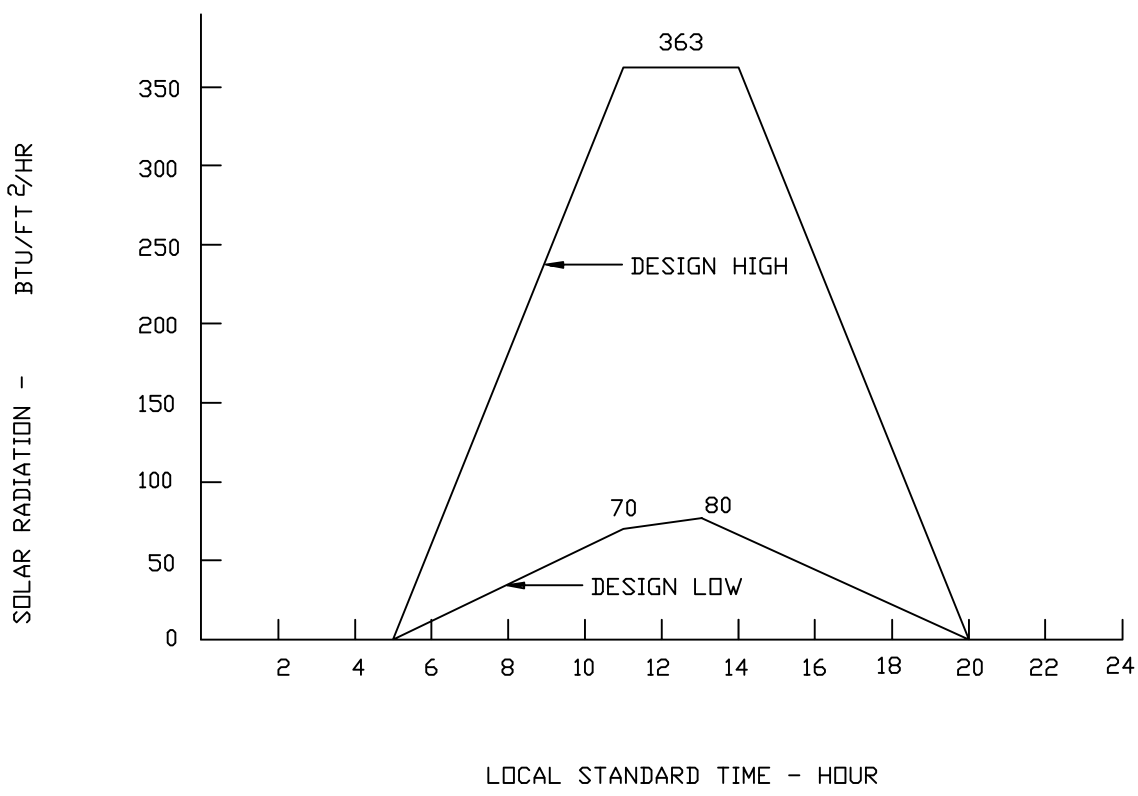


FIGURE 6.1.4.4.1.1-1 DIURNAL VARIATION FOR SOLAR CONSTANT

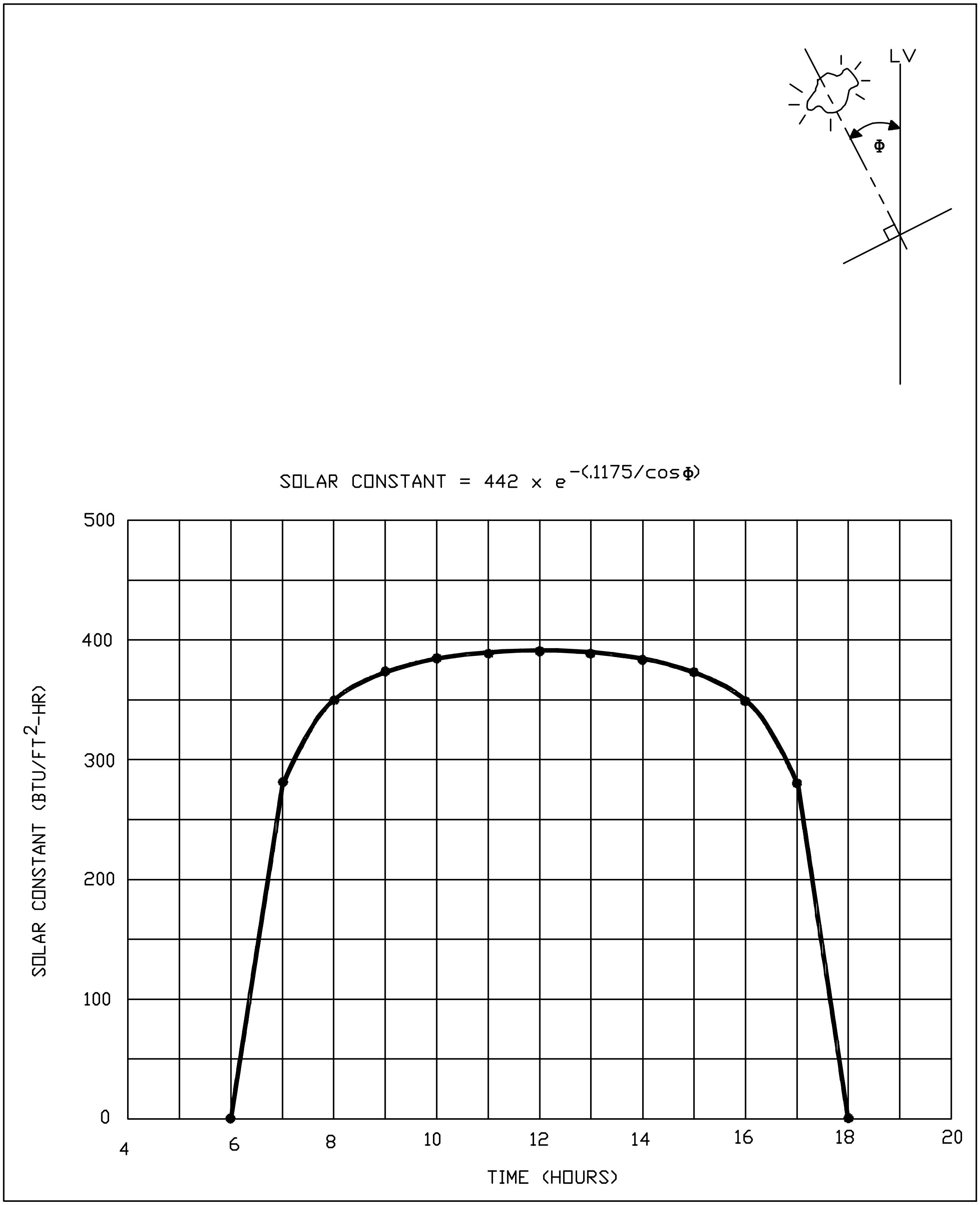


FIGURE 6.1.4.4.1.2-1 EQUATORIAL SOLAR CONSTANT VARIATION AT CONTINGENCY LANDING SITES

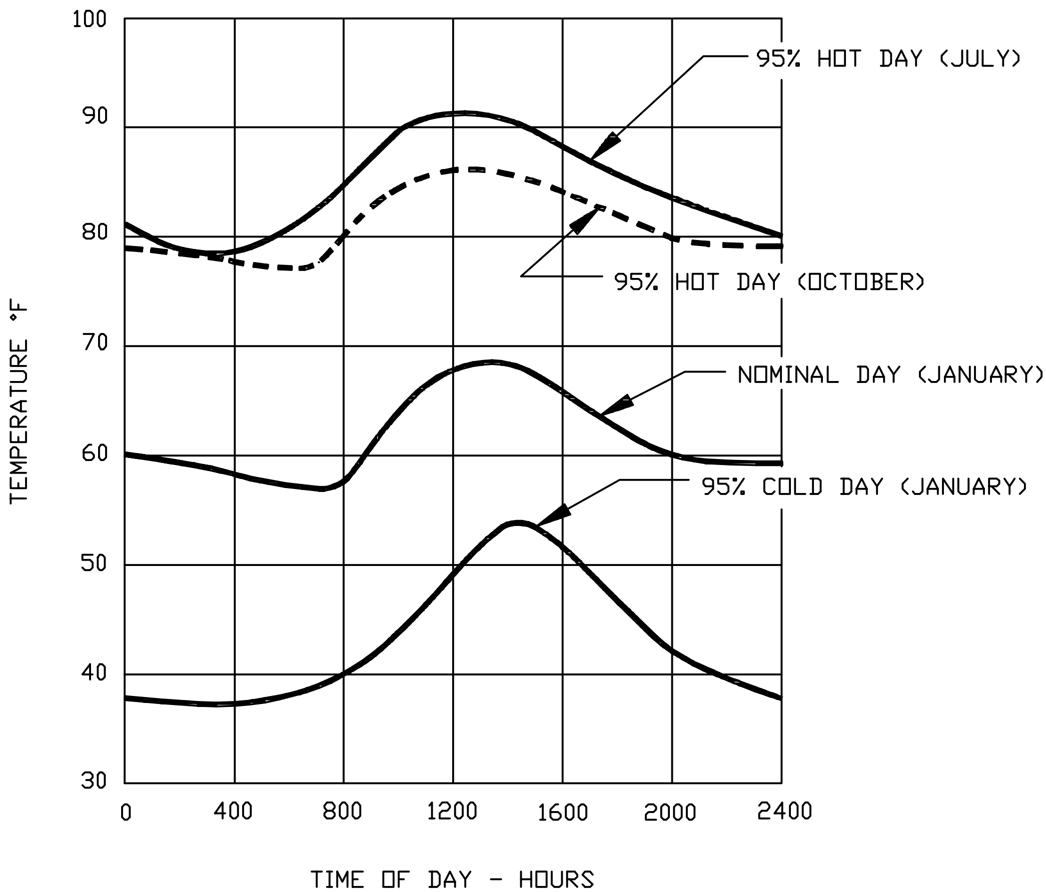


FIGURE 6.1.4.4.2.1-1 EASTERN TEST RANGE (ETR) DIURNAL AIR TEMPERATURE EXPERIENCE

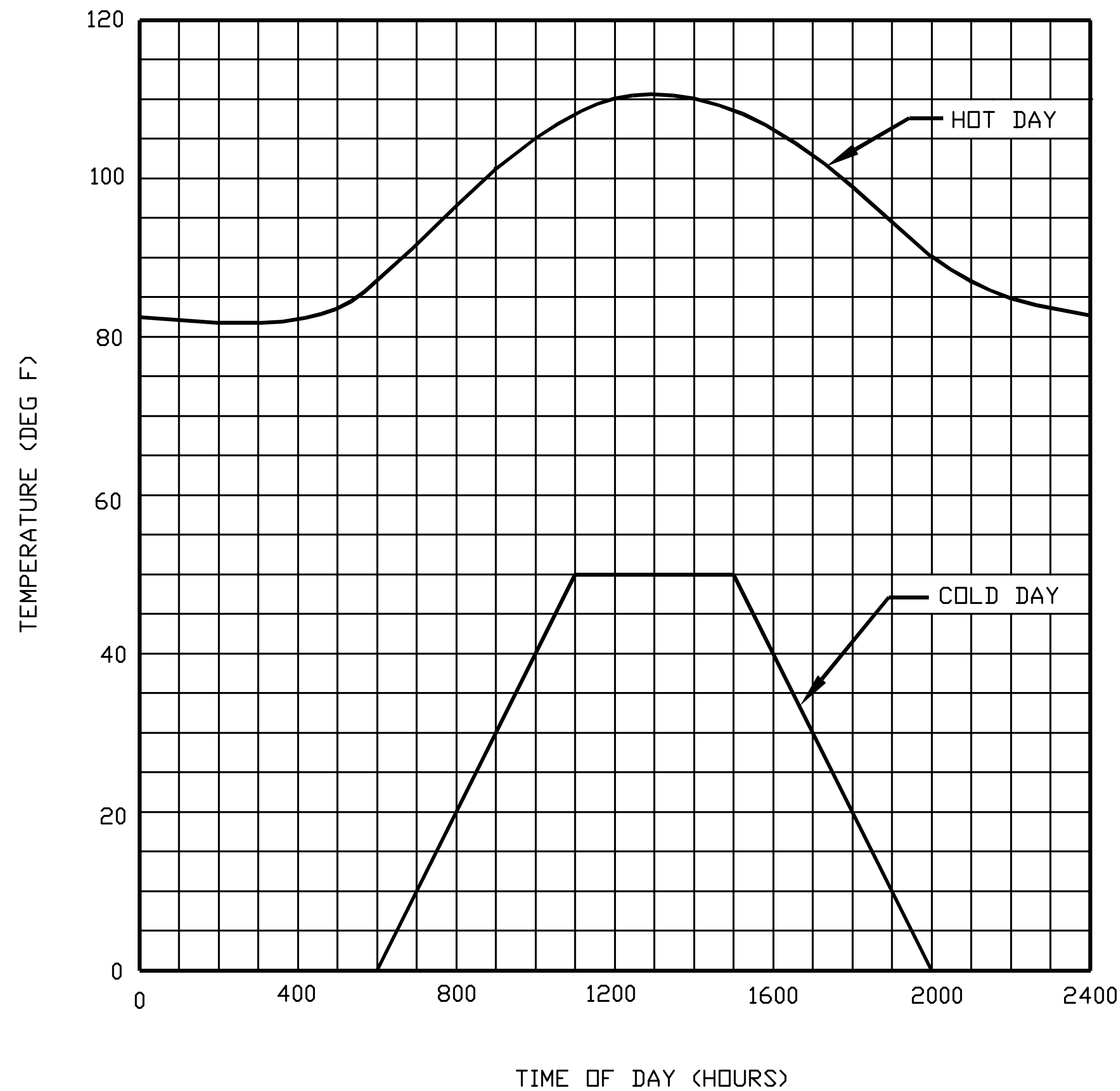


FIGURE 6.1.4.4.2.3-1 WORST CASE DIURNAL AIR TEMPERATURE AT CONTINGENCY LANDING SITES FOR MISSIONS WITH INCLINATION GREATER THAN 30 DEGREES

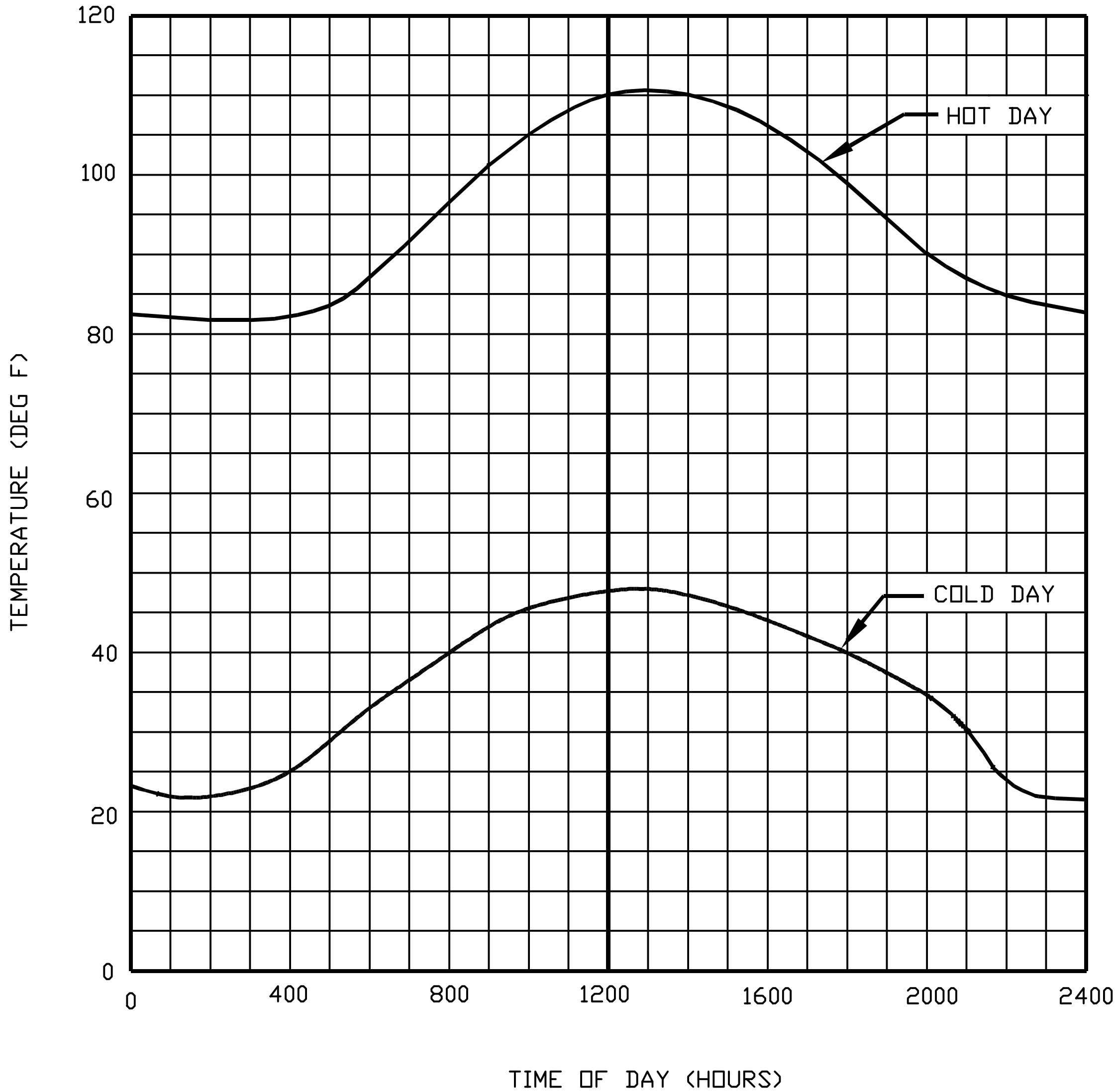


FIGURE 6.1.4.4.2.3-2 WORST CASE DIURNAL AIR TEMPERATURE AT CONTINGENCY LANDING SITES FOR MISSIONS WITH INCLINATION 30 DEGREES OR LESS

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