6.1 PASSIVE THERMAL CONTROL

6.1.1 Thermal Design Mission

6.1.1.1 (Reserved)

6.1.1.2 Orbiter Vehicle Attitude Constraints

During on-orbit operations, the Orbiter attitude-hold time limits depend on a combination of the following factors:

a. Sun angle to orbital plane (Beta angle)

b. Orbiter altitude

c. Orbiter attitude and attitude history

d. Water management for heat rejection

e. On-orbit thermal conditioning requirements

f. Pre-entry thermal conditioning requirements

Because these factors depend on Orbiter operations in response to payload mission requirements, the Orbiter's attitude-hold capability shall be established in the mission-specific Payload Integration Plans (PIPs) for each payload which requires attitude-hold periods greater than the minimum durations defined in Paragraph 6.1.1.2.1, including the deorbit and entry requirements defined in Paragraph 6.1.1.2.3. The attitude-hold periods presented in this paragraph are composite values based on consideration of a number of Orbiter thermal issues. The durations are referenced from specific initial conditions (passive thermal control (PTC) steady-state conditions at the particular beta angle). The attitude-hold periods are intended only as an initial simplified presentation of Orbiter capabilities for STS users.

Payloads manifested with Extended Duration Orbiter (EDO) pallets shall refer to Appendix E for attitude hold constraints.

6.1.1.2.1 Orbiter Constraints as a Function of Attitude and Sun Angle-to-Orbital Plane (Beta Angle)

Depending on the combination of factors noted in Paragraph 6.1.1.2, the maximum attitude-hold capability for the Orbiter will be limited to the durations and ranges given in Table 6.1.1.2.1-1 for $0^\circ \leq$ beta angle $< 20^\circ$, $20^\circ \leq$ beta angle $< 60^\circ$, and $60^\circ \leq$ beta angle $\leq 90^\circ$. Attitude-hold periods longer than the minimum specified durations may impose constraints on mission variables such as vehicle orientation, orbital parameters, etc. Such extended attitude holds, and the corresponding mission constraints, shall be specified in the applicable mission-specific PIPs as a basis for mission planning. Before the attitude-hold durations can be repeated, the Orbiter must be placed in a preferred attitude for a specific duration to allow the accumulation of fuel cell generated water used for active thermal control and/or passive thermal conditioning, also to be defined in applicable PIPs.

6.1.1.2.2 (Reserved)

6.1.1.2.3 Orbiter Constraints for De-orbit and Entry Preparation

Orbiter pre-entry thermal conditioning attitudes and duration requirements are dependent upon the thermal state of the orbiter and nature (normal or contingency) of the impending entry. The Orbiter pre-entry thermal conditioning time will be established during the mission using real-time temperature measurements. These data will be used to determine the actual required pre-entry thermal conditioning duration within the range defined in the following table.

Beta Angle Range, Degrees	Long Term Orbiter Orientation Prior To Pre-Entry Thermal Conditioning	Thermal Conditioning Time Range, Hours
0° To 90°	Any	0 To 12

The operational objective will be to accomplish pre-entry conditioning required for normal entry by attitude holds compatible with both the Orbiter and payload operational or refurbishment requirements. If mutually compatible requirements cannot be established, pre-entry conditioning will be accomplished by passive thermal conditioning (PTC) by rotating the Orbiter at 2 to 5 revolutions per hour about the X-axis with the orientation of the X-axis within ±20 degrees of the perpendicular to the sun vector.

For an aborted entry resulting from an Orbiter problem, the pre-entry thermal conditioning will be constrained only by the payload flight safety constraints defined in the PIP Annex. However, for an aborted entry, effort will be made to satisfy the pre-entry thermal requirements without violating the payload operational or refurbishment attitude-hold constraints also defined in the cargo element PIP.

6.1.1.2.4 (Reserved)

6.1.1.3 Space Environment

The numerical values of the parameters defining the space environment shall be as follows:

a. Solar Radiation (hot case) — 444 Btu/hr. - ft^2

b. Earth albedo — 30 percent of solar radiation

c. Earth Radiation — 77 Btu/hr. - ft^2

d. Space Sink Temperature — 0°R

6.1.1.4 (DELETED)

6.1.2 Thermal Design Configurations/Models

6.1.2.1 Orbiter Interface Models

Orbiter thermal models for integrated analysis shall be as defined in ES3-76-1, ES3-77-3, JSC-19540 and JSC-19692.

6.1.2.2 Coating Surface Properties

6.1.2.2.1 Orbiter Surfaces

For thermal design purposes, the infrared emittance and solar absorptance of the Orbiter surfaces shall be as defined in Figure 6.1.2.2.1-1 and Table 6.1.2.2.1-1.

6.1.2.2.2 (DELETED)

6.1.3 (Reserved)

TABLE 6.1.1.2.1-1 ORBITER ATTITUDE-HOLD DURATION LIMITS

Cargo Bay Orientation*	Orbiter Attitude-Hold Duration Limits From PTC Initial Conditions (Hours)+		
	$0^\circ \leq \beta < 20^\circ$	$20^\circ \leq \beta < 60^\circ$	$60^\circ \leq \beta \leq 90^\circ$
Three-Axis Inertial			
Solar Viewing (Bay to Sun)	160 (Approx)	160 (Approx)	52 to 160
Other Inertial Attitudes			
- Tail Sun	12	6	5
- Nose Sun	37	35	33
- Side Sun	110	110	98
- Bottom Sun	160	160	14
Local Vertical (LV)**			
Earth Viewing (Bay to Earth)			
- With Nose Toward Sun at Beta Near 90° (Wing on VV)	---	---	7
- With Tail Toward Sun (Wing on VV)	61 to 160	71 to 160	5
- With Either Side Toward Sun (Nose or Tail on VV)	160	37 to 160	16 to 160
Other LV Attitudes			
- Port Side LV with Tail Toward Sun	160	6	5
- Bottom LV with Tail Toward Sun	160	6	5
- Starboard Side LV with Tail Toward Sun	160	7	5
- Bottom LV with Either Side Toward Sun	160	7	7
- Tail LV with Bottom Toward Sun	160	12	7
- Tail LV with Either Side Toward Sun	160	12	7
- Tail LV with Top Toward Sun	160	120	90 to 160
- Nose LV with Top Toward Sun	160	120	71 to 160
- Nose LV with Bottom Toward Sun	160	160	160
- Bottom LV with Nose Toward Sun at Beta 75°	---	---	16

TABLE 6.1.1.2.1-1 ORBITER ATTITUDE-HOLD DURATION LIMITS (CONTINUED)

(Continued) Cargo Bay Orientation*	Orbiter Attitude-Hold Duration Limits From PTC Initial Conditions (Hours)+		
	$0° \leq \beta < 20°$	$20° \leq \beta < 60°$	$60° \leq \beta \leq 90°$
- Either Side LV with Nose Toward Sun at Beta > 75°	---	---	23
- Either Side LV with Top Toward Sun at Beta > 75°	---	---	48 to 160
Orbrate (Single-Axis Inertial) ***			
Solar Viewing (Bay to Sun)	160 (Approx)	160(Approx)	63 to 160
Space Viewing (Bay Heating Near Zero)			
- Tail Sun with Top to Space	7	6	5
- Nose Sun with Top to Space	23	7	7
- Nose Sun (But Pitched up -10° with Top to Space)	160	7	
Other Orbrate Attitudes			
- Tail Sun with Star-board Side to Space	7	6	5
- Tail Sun with Port Side to Space	7	7	5
- Tail Sun with Bottom to Space	12	7	5
- Nose Sun with Bottom to Space	25	7	7
- Nose Sun with Either Side to Space	23	23	23
- Side Sun with Top to Space	110	7	7
- Side Sun with Nose to Space	110	7	7
- Side Sun with Bottom to Space	160	43 to 160	18 to 160
- Bottom Sun with Nose to Space	160	7	7
- Bottom Sun with Side to Space	160	7	7
- Bottom Sun with Tail to Space	160	160	160

TABLE 6.1.1.2.1-1 ORBITER ATTITUDE-HOLD DURATION LIMITS (CONCLUDED)

* The orientations shown are generalized attitudes with no intent to include a tolerance. For significant deviations from the general attitude, unique assessment may be required.

** Local vertical attitudes are those with an Orbiter axis (usually a major axis) pointed continually toward the Earth (e.g., top or bay local vertical).

*** Orbrate attitudes are those with a single Orbiter axis (usually a major axis) inertial but with a rotation period about that axis equal to one orbit period. Orbrate orientations can produce the most severe thermal conditions for the Orbiter or payload.

+ The Orbiter attitude-hold periods shown are based on consideration of both passive and Active Thermal Control System (ATCS) limits. The passive limits included were obtained from "Space Shuttle Program Thermodynamic Design Data Book - Thermal Control System - Constraints" (Rockwell International Document SD73-SH-0226, Volume 1E, Book V, September 1985). The passive thermal limits are referenced from specific initial conditions (PTC steady-state condition at each beta angle). ATCS attitude duration limits are strong functions of the internal heat load added to the Orbiter Freon loops and these heat loads are highly dependent on the specific mission, the payload configuration, and other operational factors. Attitude duration limits for specific payload configurations and missions must be determined by analysis, and these shall be addressed in the mission-specific PIPs. The ATCS duration limits presented here reflect a nominal on-orbit supply water quantity (478 pounds) at the beginning of each attitude hold, a 245 pound minimum on-orbit supply water quantity redline, Orbiter fuel cell power of 22 kilowatts, a constant water production rate of 18 pounds per hour, a 110°F radiator Freon inlet temperature, a seven member crew, a deployed forward radiator panel configuration, and eight radiator panels. The attitude-hold periods shown are intended only as an initial simplified presentation of Orbiter capabilities for STS users.

TABLE 6.1.2.2.1-1 THERMO-OPTICAL PROPERTIES OF ORBITER SURFACES

Surface Description	Design Criterion	Surface Material	α New	α Degr.	ε New	ε Degr.	ρ Diffuse Percent	ρ Specular Percent
Cargo Bay Liner	$\alpha_S/\varepsilon \le .4$ and $\varepsilon \ge .8$	Teflon Coated Glass Cloth	.22	.36	.9	.9	99	none
Fwd Bulkhead	$\alpha_S/\varepsilon \le .4$ and $\varepsilon \ge .8$	Teflon Coated Glass Cloth	.22	.36	.9	.9	99	none
Aft Bulkhead	$\alpha_S/\varepsilon \le .4$ and $\varepsilon \ge .8$	Teflon Coated Glass Cloth	.22	.36	.9	.9	99	none
Radiator Concave Surface	N/A	Silver-Coated Teflon	.08	.11	.8 min	.8	50	50
Radiator Convex Surface	N/A	Silver-Coated Teflon	.08	.11	.8 min	.8	50	50
Cargo Bay Doors Con-cave Surface	Fwd 2 Pnls	Silver-Coated Teflon	.08	.11	.8 min	.8	50	50
	Fourth Pnl (w/o radi-ator) $\alpha_S/\varepsilon \le .4$ and $\varepsilon \ge .8$	Teflon-Coated Glass Cloth	.22	.36	.9	.9	99	none
Cargo Bay Doors Convex Surface	$\alpha_S/\varepsilon = .2$ to .4 and $\varepsilon \ge .8$	FRSI (1)	.16	.32	≥.8	≥.8	N.A.	N.A.
		LRSI (2)	.16	.32	≥.8	≥.8	N.A.	N.A.
Fuselage Mid-Section Sides	$\alpha_S/\varepsilon = .2$ to .4 and $\varepsilon \ge .8$	FRSI (1)	.16	.32	≥.8	≥.8	N.A.	N.A.
		LRSI (2)	.16	.32	≥.8	≥.8		
Wing Upper Surface Surface	$\alpha_S/\varepsilon = .2$ to .4 and $\varepsilon \ge .8$	FRSI (1)	.16	.32	≥.8	≥.8	N.A.	N.A.
		LRSI (2)	.16	.32	≥.8	≥.8		

TABLE 6.1.2.2.1-1 THERMO-OPTICAL PROPERTIES OF ORBITER SURFACES (CONTINUED)

Surface Description	Design Criterion	Surface Material	α New	α Degr.	ε New	ε Degr.	ρ Diffuse Percent	ρ Specular Percent
Wing Lower Surface	α_S/ε = .7 to 1.1 $\varepsilon \geq$ .85	LI 900 HRSI(3)(4)	.92	≥.6	.85	.85	N.A.	N.A.
Bottom of Orbiter	α_S/ε = .7 to 1.1 $\varepsilon \geq$ .85	LI 900 HRSI(3)(4)	.92	≥.6	.85	.85	N.A.	N.A.
Fuselage Fwd Section (Top and Portion of Sides, See Figure 6.1.2.2.1-1)	α_S/ε = .2 to .4 $\varepsilon \geq$ .8	FRSI (1)	.16	.32	≥.8	≥.8	N.A.	N.A.
		LRSI (2)	.16	.32	≥.8	≥.8	N.A.	N.A.
Fuselage Fwd Section (Nose and Portion of Sides, See Figure 6.1.2.2.1-1)	α_S/ε = .7 to 1.1 $\varepsilon \geq$ .85	LI 900 HRSI(3)(4)	.92	≥.6	.85	.85	N.A.	N.A.
Fuselage Aft Section Sides	α_S/ε = .2 to .4 $\varepsilon \geq$ .8	FRSI (1)	.16	.32	≥.8	≥.8	N.A.	N.A.
Vertical Fin	α_S/ε = .2 to .4 $\varepsilon \geq$ .8	FRSI (1)	.16	.32	≥.8	≥.8	N.A.	N.A.
Base Heat Shield	α_S/ε = .7 to 1.1 $\varepsilon \geq$ .85	LI 900 HRSI(3)(4)	.92	≥.6	.85	.85	N.A.	N.A.
OMS Pods	α_S/ε = .2 to .4 $\varepsilon \geq$ .8	FRSI (1)	.16	.32	≥.8	≥.8	N.A.	N.A.
		LRSI (2)	.16	.32	≥.8	≥.8	N.A.	N.A.

TABLE 6.1.2.2.1-1 THERMO-OPTICAL PROPERTIES OF ORBITER SURFACES (CONCLUDED)

Surface Description	Design Criterion	Surface Material	α New	α Degr.	ε New	ε Degr.	ρ Diffuse Percent	ρ Specular Percent
Body Flap (Upper and Lower Surfaces)	α_S/ε = .7 to 1.1 $\varepsilon \geq$ .85	LI 900 HRSI(3)(4)	.92	$\geq$.6	.85	.85	N.A.	N.A.
SSME Nozzles External Surfaces	α_S/ε = 1.0	Inconel 718	.8	.85	.8	.85	N.A.	N.A.
SSME Nozzles Internal Surfaces	α_S/ε = 1.8	A286 Stainless Steel	.55	.55	.3	.3	N.A.	N.A.

NOTES:

(1) Felt reusable surface insulation.

(2) Low-temperature reusable surface insulation.

(3) High-temperature reusable surface insulation.

(4) HRSI coating absorptance is highest when new and decreases with degradation.

(5) Small Orbiter surfaces (e.g. wing and vertical fin leading edges, nose cone, T-0 umbilical, etc.) and minor Orbiter vehicle differences are not shown.

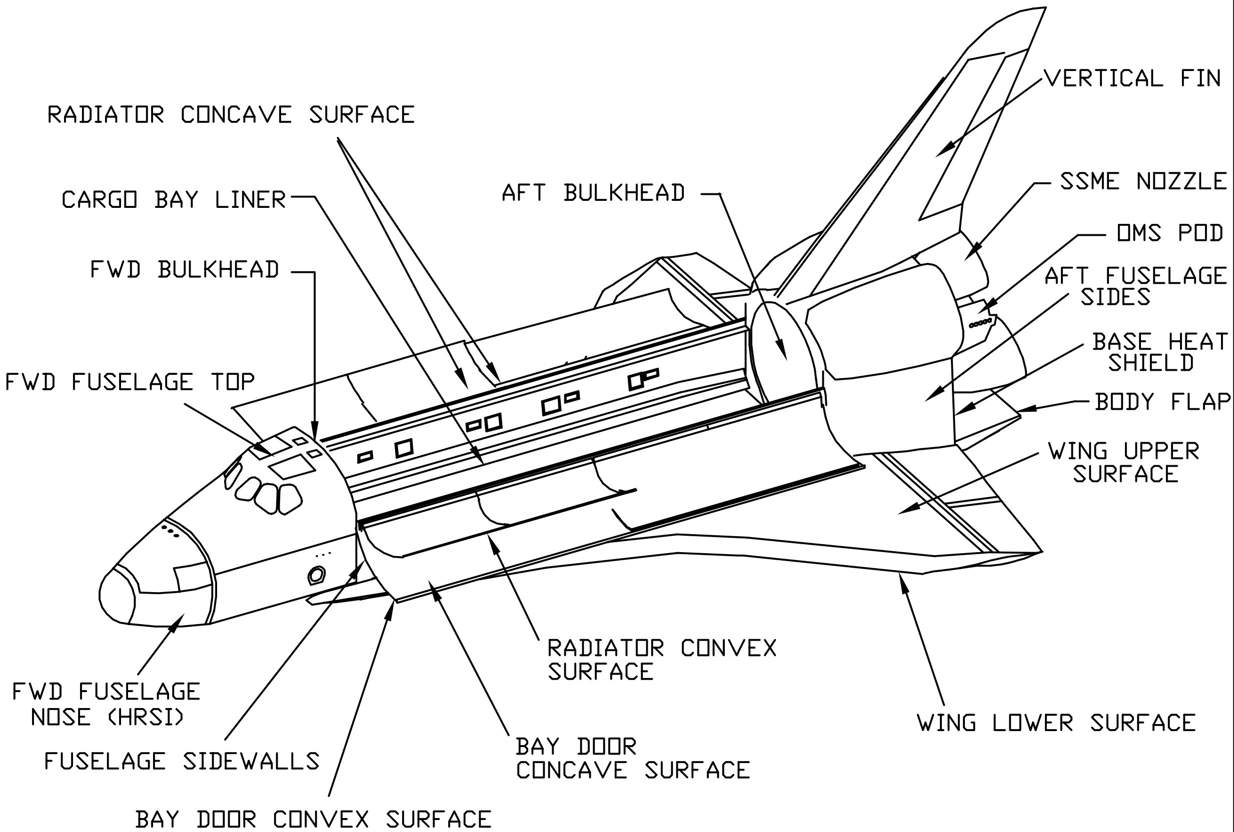

FIGURE 6.1.2.2.1-1 ORBITER SURFACES AFFECTING CARGO ELEMENT THERMAL BALANCE

THIS PAGE INTENTIONALLY LEFT BLANK