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2) KSC-STD-Z-0012B, (June 20, 1990), Flame Deflector Design Standard For	*Yes*	*No*	*SBU Reviewer's Signature*	*Date*
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KSC-STD-Z-0012B
June 20, 1990
Supersedes
KSC-STD-Z-0012A
March 3, 1980

FLAME DEFLECTOR DESIGN,

STANDARD FOR

ENGINEERING DEVELOPMENT DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

KSC FORM 16-12 (REV. 8/76)

KSC-STD-Z-0012B
June 20, 1990
Supersedes
KSC-STD-Z-0012A
March 3, 1980

FLAME DEFLECTOR DESIGN,

STANDARD FOR

Approved:

for James D. Phillips
Director of Engineering Development

JOHN F. KENNEDY SPACE CENTER, NASA

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FLAME DEFLECTOR DESIGN, STANDARD FOR

1. SCOPE

This standard establishes the minimum design requirements for new flame deflectors intended for installation and use at the John F. Kennedy Space Center (KSC). It is applicable to the conventional flame deflector design used in KSC launch facilities.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitation, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents shall be specified in an attachment to the Solicitation/Statement of Work/Contract.

Governmental

NASA Management Directives

NHB 5300.4(1C)	Inspection System Provision for Aeronautical and Space System Materials, Parts, Components and Services

Specifications

John F. Kennedy Space Center, NASA

KSC-SPEC-P-0012	Specification for Refractory Concrete

Standards.

John F. Kennedy Space Center, NASA

KSC-STD-Z-0004	Structural Steel Buildings and Other Steel Structures, the Design of, Standard for

Military

MIL-STD-129	Marking for Shipment and Storage

Publications

John F. Kennedy Space Center, NASA

KSC-DE-512-SM	Guide for Design Engineering of Ground Support Equipment and Facilities for use at Kennedy Space Center

(Copies of specifications, standards, and publications required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

3. REQUIREMENTS

3.1 General. - The flame deflector design shall be compatible with the launch vehicle and launch complex design. The flame deflector shall be designed to minimize the exhaust impingement effects on the launch facility and to minimize the induced environmental effects on the vehicle. Design shall be in accordance with KSC-DE-512-SM.

3.2 Structure. - The flame deflector structural steel framework shall be designed as a nonconventional structure in accordance with KSC-STD-Z-0004.

3.3 Impingement Angle. - The nominal impingement angle shall minimize the induced pressure and temperature on the vehicle. For the velocities encountered in present rocket engines, the nominal impingement angle shall be a maximum of 30 degrees. Where impingement angles greater than 30 degrees are required, scale model tests of the vehicle and deflector configuration shall be performed prior to incorporation into the design (see figure 1).

3.4 Impingement Point. - The impingement point shall fall at least 0.5 nozzle exit diameters upstream of the tangent point between curved and flat surfaces (see figure 1). The impingement point should not fall on the apex of the flame deflector.

3.5 Separation Distance. - The separation distance shall be a minimum of three nozzle exit diameters (see figure 1).

3.6 Exit Radius. - The flame deflector exit radius shall be a minimum of 1.7 nozzle exit diameters for a vehicle thrust-to-weight ratio greater than 1.3 to 1.

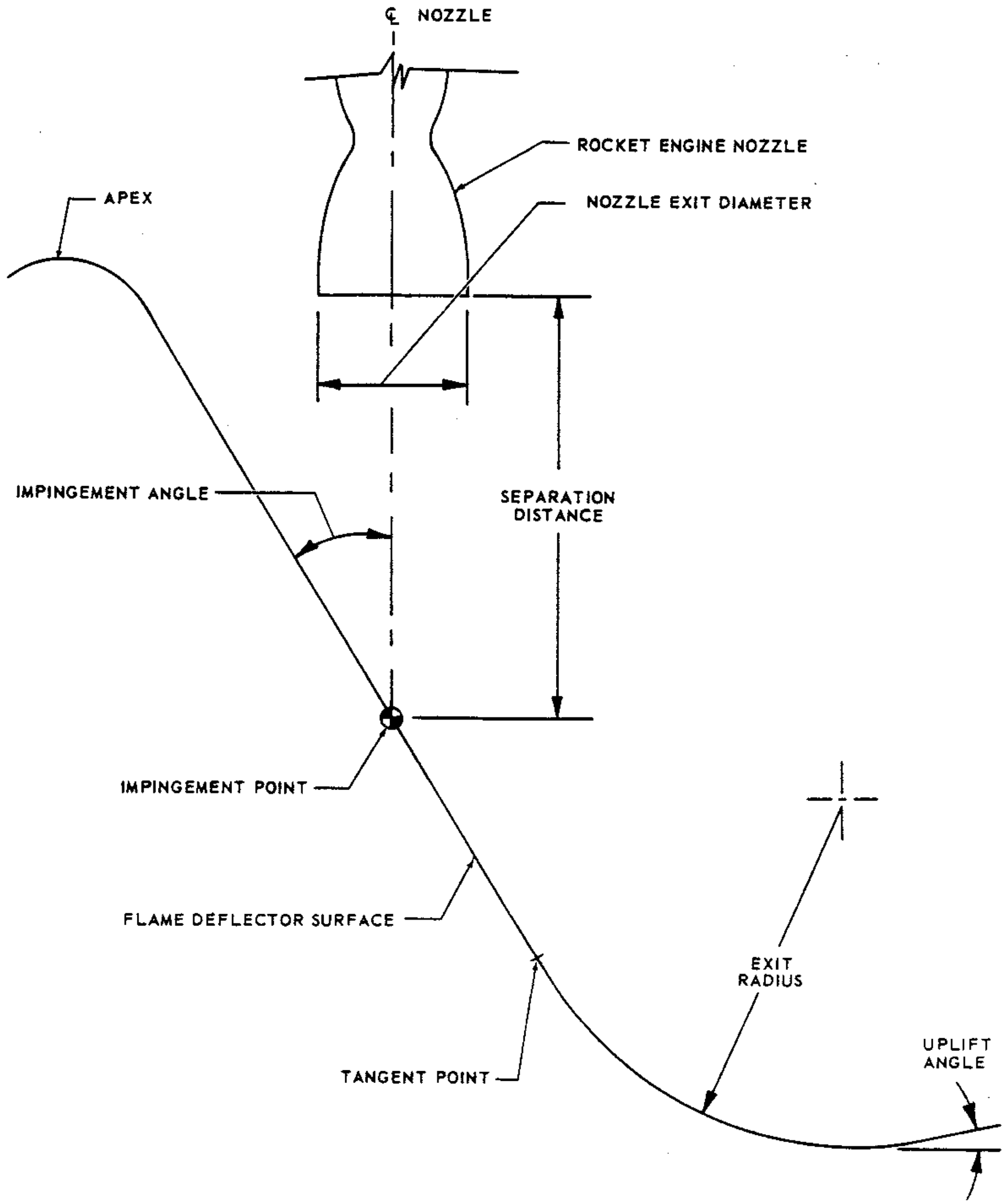

Figure 1. Typical Deflector/Rocket Engine Profile

For a vehicle thrust-to-weight ratio of less than 1.3 to 1, the exit radius shall be a minimum of two nozzle exit diameters.

3.7 Exhaust Environment. - The sea level rocket engine exhaust environment will be defined by the Government. The environment shall be based on the vehicle configuration and rocket engine parameters supplied by the manufacturer.

3.8 Quench Requirements. - The flame deflector shall require a surface quench in those applications where additional heat dissipation is necessary after flame impingement. Water shall be used as the quenching fluid.

3.9 Uplift Angle. - The flame deflector shall require an uplift angle in those applications where the exhaust plume may damage surrounding facilities as it exits the deflector. In these cases, the uplift angle shall be 5 to 10 degrees.

3.10 Live Load Criteria. - The live load criteria for the design of a flame deflector is defined in the following paragraphs.

The external forces acting on the flame deflector are determined by the impulse-momentum equation $F = \dot{m}V$. The exhaust plume of each rocket engine shall be considered a separate load. The sequence of engine ignition or shutdown and the combination of any normal or abnormal loading shall be considered. Engine gimbaling and the changing geometric patterns of liftoff shall be considered. Backflow up the surface of the deflector shall be zero. The component forces acting normal (N) and parallel to the surface of the deflector on flat plate 1 (see figure 2) are:

$$F_T = T \cos \delta$$

$$F_N = T \sin \delta$$

where T = sea level thrust of rocket engine (pounds)

δ = impingement angle (degrees)

The flow along the plate is assumed to be frictionless; therefore, assume $F_T = 0$, then the horizontal (H) and vertical (V) forces are:

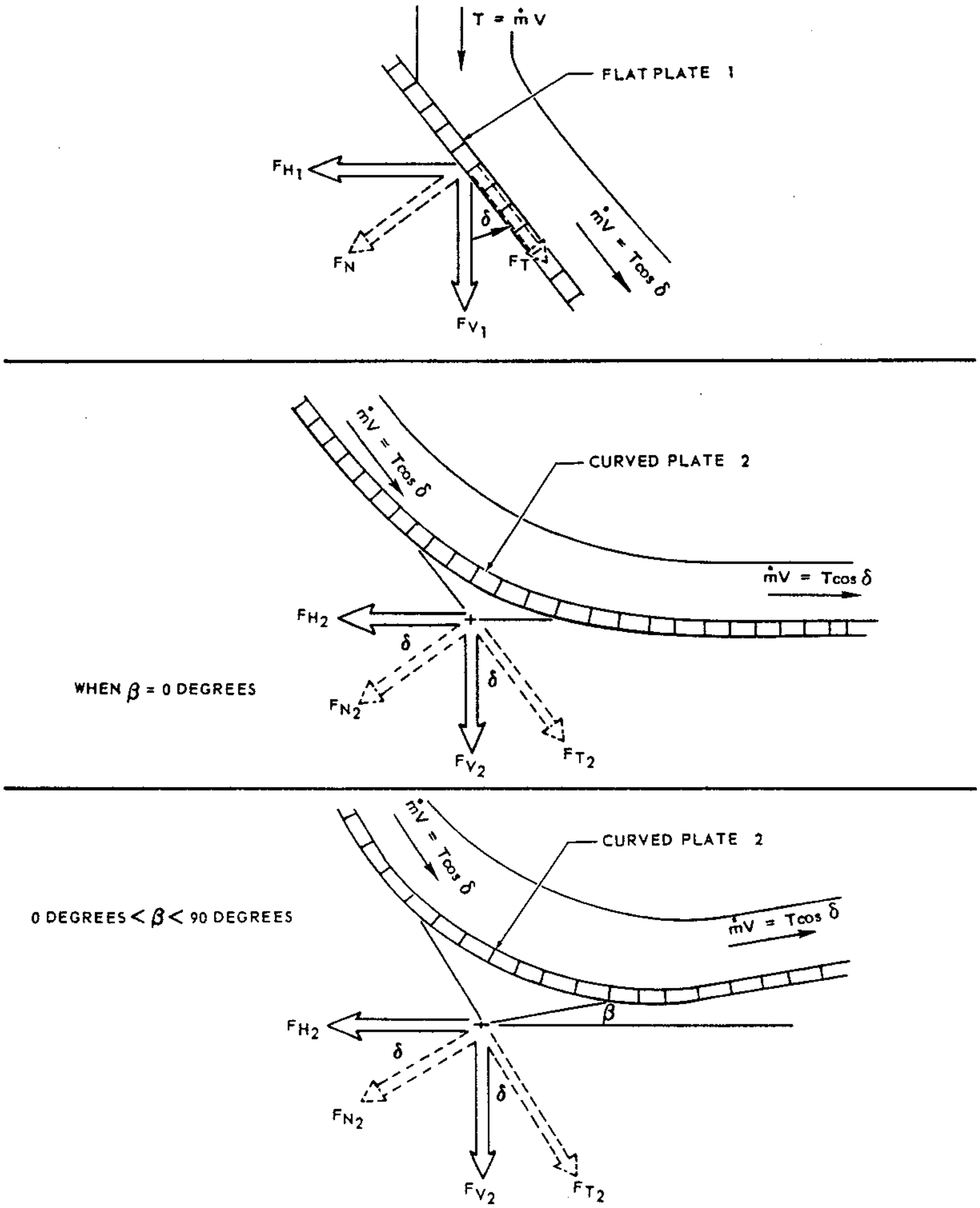

Figure 2. Forces Acting on a Flame Deflector

$$F_{H_1} = F_N \cos\delta = (T \sin\delta)\cos\delta = \frac{T}{2}\sin 2\delta;$$

$$F_{V_1} = F_N \sin\delta = (T \sin\delta)\sin\delta = T \sin^2\delta.$$

When the uplift angle β is 0 degrees, the forces acting on curved plate 2 (see figure 2) are:

$$F_{V_2} = F_{N_2}\sin\delta + F_{T_2}\cos\delta = T\cos^2\delta;$$

$$F_{H_2} = F_{N_2}\cos\delta - F_{T_2}\sin\delta = T\cos\delta\,(1 - \sin\delta).$$

When the uplift angle 0 degrees < β < 90 degrees, the forces acting on curved plate 2 (see figure 2) are:

$$F_{H_2} = F_{N_2}\cos\delta - F_{T_2}\sin\delta = T\cos\delta\,(\cos\beta - \sin\delta);$$

$$F_{V_2} = F_{N_2}\sin\delta + F_{T_2}\cos\delta = T\cos\delta\,(\sin\beta + \cos\delta).$$

The flame deflector surface shall be designed for the average pressure (P_{ave}) in the primary impingement area. The average pressure shall be calculated from the following (see figure 3):

$$P_{ave} = \frac{F_N}{A} = \frac{T\sin\delta}{A}$$

where T = sea level thrust of rocket engine (pounds)

A = primary impingement area (ft^2)

F_N = normal component of force (pounds)

δ = impingement angle (degrees)

The structural members supporting the deflecting surface shall be designed by assuming that one-half of the load is evenly distributed over the primary impingement area and one-half concentrated at the impingement point. Exit radius loads shall be distributed over the length of the arc.

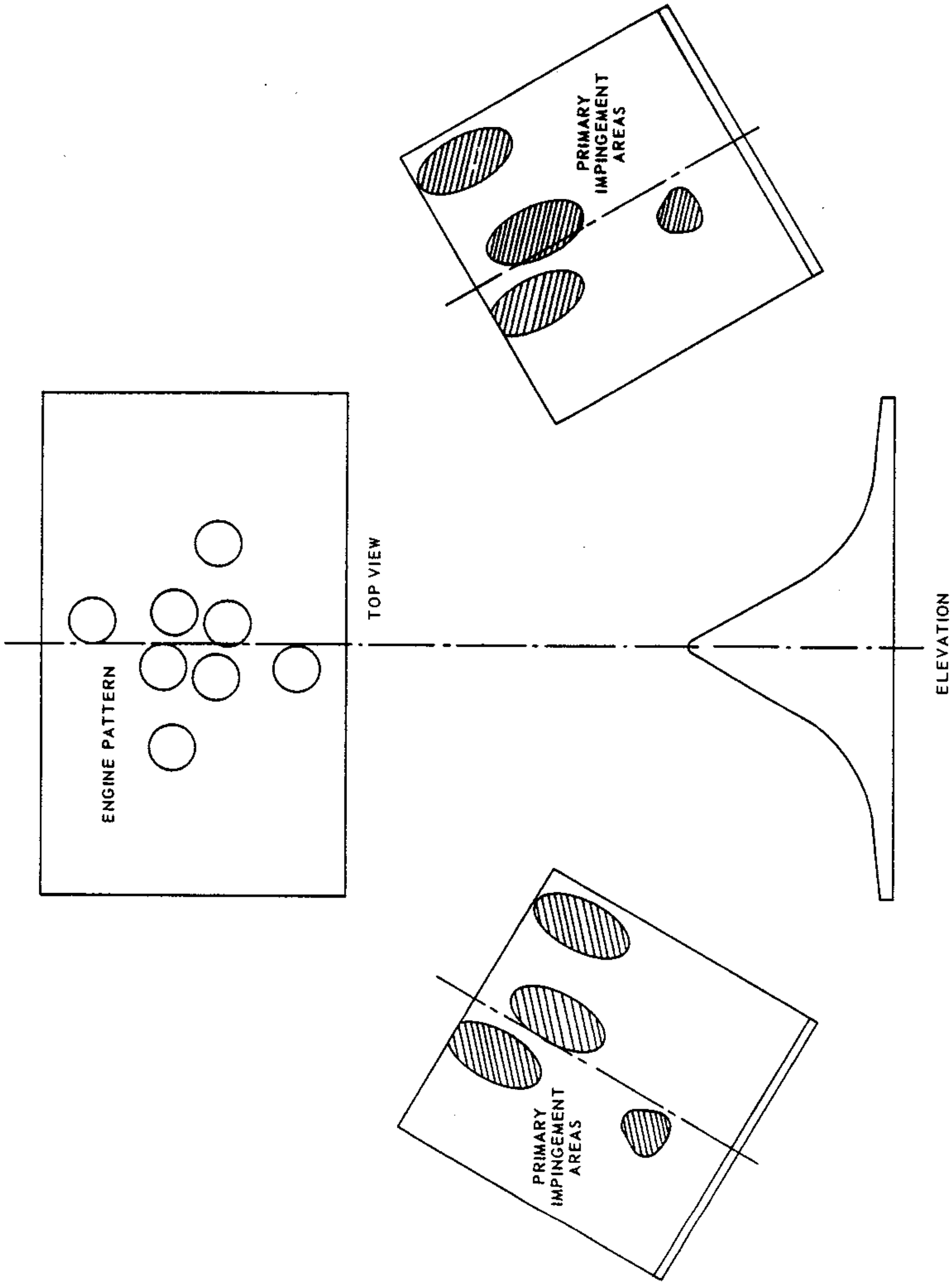

Figure 3. Typical Flame Deflector Exhaust Pattern

3.11 Thermal Loads. - The surface of the flame deflector shall maintain its structural integrity after being subjected to the exhaust plume thermal load. The thermal load shall be considered for the time duration of the worst case launch.

In general, the total thermal load at a point can be expressed as:

$$\dot{q} = \dot{q}_r + \dot{q}_c + \dot{q}_p$$

where

$\dot{q}$ = total heat transfer rate (Btu/ft^2 - sec)

$\dot{q}_r$ = radiant heat transfer rate (Btu/ft^2 - sec)

$\dot{q}_c$ = convective heat transfer rate (Btu/ft^2 - sec)

$\dot{q}_p$ = particle heat transfer rate (Btu/ft^2 - sec)

The convective heat transfer rate of the exhaust plume shall be calculated from the following:

$$\dot{q}_c \doteq \frac{\dot{q}_{stag}}{S_c\sqrt{R_{eff}}} f(\delta)$$

where:

$\dot{q}_{stag}$ = stagnation point heat transfer rate based on a 1-foot radius sphere (Btu/ft^2 - sec)

S_c = shape coefficient

R_{eff} = effective radius of curvature (ft)

$f(\delta)$ = local heating rate/stagnation point heating rate ratio based on the local impingement angle at the point of interest on the deflector

and:

S_c = 1.414 for the flat plate area of the deflector

S_c = 1.414 for the apex of the deflector

The radiant heat transfer rate shall be determined using the following empirical formula:

$$\dot{q}_r = 0.2\dot{q}$$

The particle heat transfer rate shall be calculated from the following:

$$\dot{q}_p = a_c \sin \delta \, (TE - h_w)$$

where:

a_c = accommodation coefficient

δ = Local impingement angle (degrees)

TE = total particle energy flux at a point (Btu/ft^2 - sec)

h_w = particle energy at the surface temperature (Btu/ft^2 - sec)

and:

a_c = 0.3

The surface temperature of a point on the deflector shall be calculated from the following:

$$T_s = \frac{2\dot{q}\sqrt{t}}{\sqrt{\pi \rho C p K}} + 540$$

where:

T_s = surface temperature at a point (degrees R)

$\dot{q}$ = total heat transfer rate (Btu/ft^2 - sec)

t = time (sec)

ρ = density (lb/ft^3)

C_p = specific heat of the surface material (Btu/lb degrees R)

K = thermal conductivity of the surface material (Btu/ft - sec - degrees R)

3.12 Refractory Concrete. - A refractory concrete shall be used on the flame impingement areas of the deflector. The refractory concrete shall conform to KSC-SPEC-P-0012.

3.13 Deflector Width. - The width of the flame deflector has been empirically established as a minimum of 1.6 times the sum of all the vehicle engine nozzle diameters impinging on a common surface. As an example, the minimum deflector width equals engine nozzle diameter x 4 x 1.6 in figure 3.

4. QUALITY ASSURANCE PROVISIONS

4.1 Design and Development Controls. - The designer shall ensure that the following are included in the technical documents so that conformance to the design requirements can be verified:

a. Inspection and test criteria (including specific nondestruct test methods, test equipment, environmental conditions, and sample size).

b. Identification of critical hardware characteristics necessary for procurement and fabrication.

c. Applicable process specifications, standards, and procedures.

d. Acceptance and rejection criteria.

4.2 Test Requirements. - A scale-model test of any new flame deflector design should be performed to determine the effects of the flame deflector on the launch vehicle and the launch facility. The model test shall simulate the size and configuration of the vehicle, rocket engines, and launch facility. Tests shall be conducted at various points along the flight trajectory to determine the exhaust impingement effects during ascent from the launch facility.

4.3 Contractual Requirements. - When this standard is a contract requirement, the statement of work shall invoke the applicable provision of NHB-5300.4(1C).

5. PREPARATION FOR DELIVERY

5.1 Packaging, Handling, and Transportation. - The packaging, handling, and transportation of flame deflector elements shall be in accordance with KSC-DE-512-SM. Packaging, handling, and transportation requirements specific to certain ground support equipment shall become part of the detailed specification for the individual element.

5.2 Marking for Shipment. - All containers shall be marked in accordance with MIL-STD-129.

6. NOTES

6.1 Intended Use. - This standard is intended to establish uniform engineering practices and methods for flame deflector design and does not constitute a specification for the procurement, fabrication, or installation of the system.

6.2 Definitions.

6.2.1 Conventional Flame Deflector. - The conventional flame deflector is an uncooled, heat-resistant deflector. The conventional deflector uses a refractory coating on the surfaces subjected to direct flame impingement.

6.2.2 Exit Radius. - The radius of curvature of the deflector at the point where the exhaust plume leaves the deflector.

6.2.3 Impingement Angle. - The angle between the rocket engine exhaust plume centerline and the flame deflector surface at the impingement point.

6.2.4 Impingement Point. - The point at which the rocket engine exhaust plume centerline strikes the surface of the flame deflector.

6.2.5 Primary Impingement Area. - The area defined by projecting the shape of the exhaust plume onto the surface of the flame deflector.

6.2.6 Separation Distance. - The straight line distance along the rocket engine exhaust plume centerline from the rocket engine nozzle exit plane to the impingement point.

6.2.7 Uplift Angle. - The angle between the horizontal and the exiting exhaust plume.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any right or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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Mechanical Engineering Division
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