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7) KSC-STD-Z-0004F (November 6, 2002), KSC-STD-Z-0004F, structural Design, Standard For,	*YesN*	*o*	*SBU Reviewer's Signature*	*Date*
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NASA
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7

METRIC/INCH-POUND

KSC-STD-Z-0004F
November 6, 2002

Supersedes
KSC-STD-Z-0004E
November 7, 1995

STRUCTURAL DESIGN, STANDARD FOR

National Aeronautics and
Space Administration

John F. Kennedy Space Center

METRIC/INCH-POUND

KSC-STD-Z-0004F
November 6, 2002
Supersedes
KSC-STD-Z-0004E
November 7, 1995

STRUCTURAL DESIGN, STANDARD FOR

National Aeronautics and
Space Administration

John F. Kennedy Space Center

TRANSMITTAL SHEET

To:

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Date

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Change Notice 1

KSC-STD-Z-0004F, Structural Design, Standard for

Michael J. Benik
Director, Center Operatioins

FILING INSTRUCTIONS

Remove pages 21 and 22 and replace with the attached.

KSC-STD-Z-0004F
November 6, 2002
Supersedes
KSC-STD-Z-0004E
November 7, 1995

STRUCTURAL DESIGN, STANDARD FOR

Approved:

James R. Heald
Director of Spaceport Engineering and Technology

JOHN F. KENNEDY SPACE CENTER, NASA

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ABBREVIATIONS AND ACRONYMS

AA	Aluminum Association
ACI	American Concrete Institute
A&E	architect and engineer
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AN	Army – Navy
ANSI	American National Standards Institute
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASCII	American Standard Code for Information Interchange
ASD	allowable stress design
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BSI	Building Systems Institute
CAD	computer-aided design
CFR	Code of Federal Regulation
CPD	correlated pressure distribution
D	diameter
DC	District of Columbia
DFT	dry film thickness
DM	design manual
DOF	degree of freedom
DXF	drawing interchange file
EIA	Electronic Industries Alliance
EMF	electromotive force
FEM	finite element model
FL	Florida
FPIH	Facility Project Implementation Handbook
ft	foot
ft^2	square foot
FR	fully restrained
GP	general publication
GSE	ground support equipment
h	hour
HDBK	handbook
HVAC	heating, ventilating, and air conditioning
Hz	hertz
IGES	Initial Graphics Exchange Specification
IL	Illinois
km	kilometer
kN	kilonewton
kPa	kilopascal
km/h	kilometer per hour

ABBREVIATIONS AND ACRONYMS (cont)

KSC	John F. Kennedy Space Center
ksi	kip per square inch
lb	pound
lb/ft^2	pound per square foot
L/D	length to diameter
LRFD	load and resistance factor design
LSE	launch support equipment
M	metric
m	meter
m^2	square meter
mi	mile
MI	Michigan
MIL	military
mm	millimeter
MPa	megapascal
mph	mile per hour
MRI	mean recurrence interval
MS	military specification
MSFC	George C. Marshall Space Flight Center
MSS	Mobile Service Structure
N	newton (kilogram-meter per square second)
NACE	National Association of Corrosion Engineers
NAS	National Aerospace Standard
NASA	National Aeronautics and Space Administration
NASTRAN	NASA Structural Analysis
NAVFAC	Naval Facilities Engineering Command
NDT	nondestructive test
NPG	NASA Procedures and Guidelines
OSHA	Occupational Safety and Health Administration
Pa	pascal (newton per square meter)
PA	Pennsylvania
PH	precipitation hardened
PR	partially restrained
PSD	power spectral density
psi	pound per square inch
rad/s	radian per second
rms	root mean square
SPEC	specification
SPECSINTACT	Specifications Kept Intact
STD	standard
TM	technical manual
TVM	time-varying mean
VA	Virginia
°C	degree Celsius

STRUCTURAL DESIGN, STANDARD FOR

1. SCOPE

This standard establishes applicable definitions and general design requirements for structural design at the John F. Kennedy Space Center (KSC). This standard is applicable to the framing of both conventional and nonconventional structures, ground support equipment (GSE), and temporary structures and enclosures.

1.1 Intent. - With few exceptions, the nonconventional structures and equipment at KSC are subject to recurring modification due to the development of new requirements or improved launch processes and procedures. On a broader scale, the change from one launch vehicle system to another requires that outmoded structures be adapted where practical for use in the new system. This standard is intended to direct structural design effort into practices that will facilitate future, rapid, accurate response in providing for the needs of KSC. It is also intended to set forth other structural design methods that have proven to be particularly suitable at KSC and that are compatible with other design guidelines specified in KSC-DE-512-SM. Conventional structures shall be designed to current accepted industry practices.

1.2 Application. - The current revision of this document shall be applicable to the design of all new structures and GSE. The revision of this document that was current at the time direction was issued to design, construct, manufacture, or procure the structure or GSE shall be applicable for the useful life of the hardware. Modifications of existing hardware may be done so the modified hardware complies with the revision that is current at the time directions are issued to modify the hardware except as noted otherwise. Detailed work orders, solicitations, statements of work, etc., prepared for architect and engineer (A&E) or other design services, shall cite this standard.

1.3 Measurement Units. - This document contains values in both metric and inch-pound units. In many cases, the two values shown for the same criterion are not exact conversions of each other. The metric conversions are rounded, rational values that provide reasonable guidelines when working in metric units in the same manner as the inch-pound units provide guidelines for working in nonmetric units. Therefore, when performing design and analysis functions for metric projects, the metric values shown shall be used exclusively. Likewise, when performing design and analysis functions for nonmetric projects, the inch-pound values shown shall be used exclusively. The inch-pound values shall not be soft converted to metric for use on metric projects and vice versa.

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 solicitations, 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.

2.1 Governmental.

2.1.1 Specifications.

National Aeronautics and Space Administration (NASA)

NASA-SPEC-5004	Welding of Aerospace Ground Support Equipment and Related Nonconventional Facilities

George C. Marshall Space Flight Center (MSFC), NASA

MSFC-SPEC-250	Protective Finishes for Space Vehicle Structures and Associated Flight Equipment, General Specification for

Federal

A-A-59298	Tape, Pressure Sensitive Adhesive
TT-P-1757	Primer Coating, Alkyd Base, One Component

Military

MIL-F-14072	Finishes for Ground Based Electronic Equipment

U.S. Department of Commerce, National Bureau of Standards

	Initial Graphics Exchange Specification (IGES) Version 4.0 or subsequent versions

2.1.2 Standards.

National Aeronautics and Space Administration, NASA

NASA-STD-8719.9	Standard for Lifting Devices and Equipment
NASA-STD-5008	Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities and Ground Support Equipment

John F. Kennedy Space Center (KSC), NASA

KSC-STD-E-0012	Facility Grounding and Lightning Protection, Standard for
KSC-STD-P-0006	Quick Release Pin and Pin Tethers, Standard for
KSC-STD-Z-0012	Flame Deflector Design, Standard for

George C. Marshall Space Flight Center (MSFC)

MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments

Federal

29 CFR	Code of Federal Regulations, Occupational Safety and Health Administration, Labor, Parts 1910 and 1926

2.1.3 Other Documents.

National Aeronautics and Space Administration (NASA)

NASA-HDBK-1001	Terrestrial Environment (Climatic) Criteria Handbook for Use in Aerospace Vehicle Development

John F. Kennedy Space Center (KSC), NASA

GP-435	Engineering Drawing Practices
KSC-DE-512-SM	Facility, System, and Equipment General Design Requirements
TM-584	Corrosion Control and Treatment Manual

Department of Defense

MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures

Department of the Navy

NAVFAC DM 7.01	Soil Mechanics
NAVFAC DM 7.02	Foundations and Earth Structures
NAVFAC DM 7.03	Soil Dynamics, Deep Stabilization and Special Geotechnical Construction

(Copies of specifications, standards, drawings, 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.)

2.2 Non-Governmental.

The Aluminum Association, Inc.

AA30	Aluminum Design Manual Rationale

(Application for copies should be addressed to The Aluminum Association, Inc., 900 19th Street, N.W., Washington, DC 20006.)

American Concrete Institute (ACI)

ACI 318	Building Code Requirements for Structural Concrete and Commentary
ACI 336.2	Suggested Analysis and Design Procedures for Combined Footings and Mats

(Application for copies should be addressed to the American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, MI 48219.)

American Institute of Steel Construction (AISC)

AISC 310-97	Hollow Structural Sections Connections Manual
AISC 316-89	ASD Manual of Steel Construction, 9th Edition
AISC 317-92	ASD Manual of Steel Construction, Volume II
AISC 325-01	LFRD Manual of Steel Construction – Third Edition
AISC 303-00	Code of Standard Practice for Steel Buildings and Bridges
AISC 336-89	Specification for Allowable Stress Design of Single-Angle Members
AISC S338	Load and Resistance Factor Design of Simple Shear Connections
AISC 346-00	Load and Resistance Factor Design Specification for Steel Hollow Structural Sections
AISC 348-00	Specification for Structural Joints Using ASTM A325 or A490 Bolts

AISC 351-00	Specification for Load and Resistance Factor Design of Single-Angle Members

(Application for copies should be addressed to the American Institute of Steel Construction, Inc., One East Wacker Drive, Suite 3100, Chicago, IL 60601-2001.)

American Iron and Steel Institute (AISI)

AISI SG 673, Part I	Cold-Formed Steel Design Manual, Specification for the Design of Cold-Formed Steel Structural Members

(Application for copies should be addressed to the American Iron and Steel Institute, 1101 17th Street, N.W., Suite 1300, Washington, DC 20036.)

American National Standards Institute/American Welding Society (ANSI/AWS)

ANSI/AWS A2.4	Standard Symbols for Welding, Brazing and Nondestructive Examination
ANSI/AWS D1.1	Steel-Structural Welding Code, Standard for
ANSI/AWS D1.2	Structural Welding Code Aluminum
ANSI/AWS D1.6	Structural Welding Code – Stainless Steel

(Application for copies should be addressed to the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 33126, Miami, FL 33126.)

American National Standards Institute/Electronic Industries Alliance (ANSI/EIA)

ANSI/EIA-222	Structural Standards for Steel Antenna Towers and Antenna Supporting Structures

(Application for copies should be addressed to the Electronic Industries Alliance, 2500 Wilson Blvd., Arlington, VA 22201.)

American Petroleum Institute (API)

API SPEC 5L	Specification for Line Pipe

(Application for copies should be addressed to the American Petroleum Institute, 1200 L St., N.W. Washington, DC 20005-4070.)

American Society of Civil Engineers (ASCE)

ASCE 7	Minimum Design Loads for Buildings and Other Structures

(Application for copies should be addressed to the American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.)

American Society for Testing and Materials (ASTM)

ASTM A53/A53M	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A123/A123M	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153	Standard Specification for Zinc Coated (Hot-Dip) on Iron and Steel Hardware
ASTM A242/A242M	Standard Specification for High-Strength Low-Alloy Structural Steel
ASTM A307	Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
ASTM A325	Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A325M	Standard Specification for High-Strength Bolts for Structural Steel Joints [Metric]
ASTM A435/A435M	Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates
ASTM A490	Standard Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength
ASTM A490M	Standard Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3 for Structural Steel Joints [Metric]
ASTM A500	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A501	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

ASTM A514/A514M	Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
ASTM A588/A588M	Standard Specification for High-Strength Low-Alloy Structural Steel With 50 ksi (345 MPa) Minimum Yield Point to 4 in. (100 mm) Thick
ASTM A992/A992M	Standard Specification for Steel for Structural Shapes for Use in Building Framing
ASTM C920	Standard Specification for Elastomeric Joint Sealants
ASTM D1143	Standard Test Method for Piles Under Static Axial Compressive Load
ASTM D3689	Standard Test Method for Individual Piles Under Static Axial Tensile Load
ASTM E985	Standard Specification for Permanent Metal Railing Systems and Rails for Buildings

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshokocken, PA 19428-2959.)

Building Systems Institute (BSI)

Metal Building Systems Manual; Design Practices, Code of Standard Practice, Guide Specifications, Nomenclature

(Application for copies should be addressed to the Building Systems Institute, 1211 Sunset Hills Road, Suite 140, Reston, VA 28190-3231.)

3. REQUIREMENTS

3.1 General. - The frequent studies and/or modifications to the structures associated with KSC structures and equipment establish the need for complete, detailed design drawings and specifications supported by clear, well-organized calculations. Modifications made during the operational life of the structure shall incorporate current safety factor requirements unless it is not feasible to do so. Deviation from established safety factor requirements shall be subject to the applicable program/project deviation/waiver process, as required. The resulting structural design shall be accomplished in accordance with the requirements, practices, and methods specified herein. Structures are classified into the following types:

a. Conventional (Institutional or Support). Conventional structures are office buildings, laboratory buildings, auditoriums, libraries, warehouses, cafeterias, shops, walkways, utility systems, and other facilities whose structures are characterized by well-established design precedents and loading conditions.

b. Nonconventional. Nonconventional structures are structures that are space program oriented or experimental in nature and include test stands, launch complexes, operational or research facilities, towers, and similar special-purpose facilities whose structures are characterized by unusual or inadequately defined loading conditions, a lack of established design precedent, or frequent modifications to support changes in the operational requirements.

3.1.1 Conventional Structures and Equipment. - Conventional structures shall be designed in accordance with this standard. For conventional steel structures and equipment designed using nonmetric units, the allowable stress design (ASD) method in accordance with the AISC manuals of Allowable Stress Design (ASD) AISC 316-89 and AISC 317-92 or the load and resistance factor design (LRFD) methods in accordance with the AISC 325-01 (or metric equivalent version) and the requirements of this standard shall be used. However, ASD and LRFD shall not be utilized concurrently on the same structural project. For conventional structures and equipment designed using metric units, the LRFD methods in accordance with AISC 325-01 (or metric equivalent version) and the requirements of this standard shall be the preferred method used.

Structural tubes and pipes shall be designed in accordance with AISC 310-97 using ASD (AISC 316-89) or LRFD (AISC 346-00) methods. Design of single angle members shall be in accordance with Specification for Design of Single-Angle Members (AISC 336-89) using the ASD AISC 316-89 or LRFD AISC 351-00 methods.

Low-rise nonresidential metal structure design shall conform to the requirements of the Building Systems Institute (BSI) Metal Building Systems Manual and the design wind load requirements of this standard.

3.1.2 Nonconventional Structures and Equipment. - The steel structures associated with nonconventional structures and equipment shall be designed utilizing either the ASD method or the LRFD method. The ASD method shall be used in accordance with AISC 316-89, AISC 317-92, or the design safety factor criteria specified in this standard. The LRFD method shall be used in accordance with AISC 325-01 (or metric equivalent version) and the requirements of this standard. However, ASD and LRFD shall not be utilized concurrently on the same structural project.

Structural tubes and pipes shall be designed in accordance with AISC 310-97 using ASD (AISC 316-89) or LRFD (AISC 346-00) methods. Design of single angle members shall be in accordance with AISC 336-89 using the ASD AISC 316-89 or LRFD AISC 351-00 methods.

Aluminum structure shall be designed in accordance with AA30.

3.1.3 Temporary Structures and Enclosures. - Temporary structures and enclosures are usually predesigned and procured from suppliers and manufacturers. The supplier or manufacturer shall provide design calculations covering stability of temporary building duly signed and sealed by a Florida Registered Professional Engineer. These calculations must meet the wind load requirements under ASCE 7. Such structures shall be selected so that the manufacturer's design specifications (e.g., load limits, design life, environmental limitations, etc.) of the temporary structure or enclosure best meets the requirements for its intended use. The design life for these structures should not exceed 4 years.

3.2 Design Process.

3.2.1 Design Criteria Document. - Before the design begins, the responsible design organization shall establish design criteria that clearly state the user requirements and identify the essential features and functions required in the hardware. For conventional structures and equipment, the criteria may be minimal and may consist primarily of a structural design criteria sheet or structural criteria notes on a sheet of the design drawings. Nonconventional structures and equipment may require a more explicit criteria document including historical background, philosophy of operation, and desired performance characteristics so the designer can develop the detailed requirements necessary for a complete design. The design criteria document shall be revised periodically to reflect the current status of the definite requirements as they are developed. Upon completion of the design, the design criteria document shall be released into the appropriate documentation center in order to serve as a historical record of the design's development. Any other design considerations shall be as specified in 3.7.

3.2.2 Design Calculations. - The design of all steel structures and other structures shall be based on documented, detailed design calculations. Design calculations must contain typical connection calculations, even if typical AISC standard connections were used in the design of structures. Use of AISC software on connections shall be acceptable. Use of Finite Element Models to justify connection design shall not be accepted unless validated by actual tests. The calculations shall be organized and indexed for easy reference. The safety factor and load factors used shall be clearly shown in the introduction to the document. The design calculations shall reflect the physical conditions of the completed hardware or structures and shall include provision for any intermediate condition during construction that produces greater stresses on any permanent member. Calculations shall be released into the appropriate documentation center.

3.2.3 Computerized Calculations. - When computer output data are used as design calculations or in conjunction with design calculations, the input and output shall be included as part of the design calculations. However, when the output is too voluminous, the pertinent part only shall be submitted. The entire output shall be available upon request in ASCII format on disk or tape. Complete instructions for deciphering the printout shall be included. Only proven programs shall be utilized in the analysis. The analysts shall be thoroughly knowledgeable and experienced in the program's use. Finite element methods using shell, plate, and solid elements often indicate local or discontinuity stresses. These stress concentrations or stress singularities are not consistent with the design intent of the structural steel and aluminum association codes. Highly localized peak stresses are not to be compared with code allowable stresses. The analyst's judgment is required to properly interpret finite element model results. Computer programs used for analysis of structural design (e.g., NASTRAN, STAAD-III, etc.) shall be subject to approval by the responsible Government design organization. The minimum information required on computer programs submitted for approval shall be:

a. The description of the program and the problem it solves

b. The method of solution including the supporting theory

c. The limits within which the program may be used

d. The designer's previous experience with the program in similar design problems

3.2.4 Design Drawings and Specifications. - The responsible design organization shall provide design drawings and specifications, responsive to the design requirements, in sufficient detail so a complete physical definition of the equipment or structure results. The design organization shall provide in document form the detailed, substantiating calculations for the design and any special erection requirements. The design organization shall be responsible for any field work necessary to ensure that the design is compatible with existing conditions. Notes and specifications for a design package shall clearly indicate whether the structure or equipment is conventional or nonconventional.

The design drawings shall be prepared in accordance with GP-435. For major structure or equipment projects, specifications shall use NASA SPECSINTACT. Specifications may be incorporated into the design drawings on those structure or equipment projects that are primarily structural and involve other design disciplines or construction crafts only to a minor degree. The design drawings and specifications shall define the physical interfaces between the newly designed hardware and existing hardware. All electronic information (computer-aided design [CAD] drawings, calculations, supporting information) shall be provided in an Initial Graphics Exchange Specification (IGES) or drawing interchange file (DXF) convertible software format. The suggested CAD packages are AutoCAD, MicroStation, Solidedge, and ProE. Drawings and specifications shall be released into the appropriate documentation center.

3.2.5 Checking. - The design shall not be considered complete until all the documentation related thereto has been thoroughly checked. Checking shall be performed by experienced personnel especially knowledgeable in the subject matter being checked.

3.2.6 Shop Drawing Review. - The responsible design organization shall be responsible for review and approval of the shop drawings, manufacturer's drawings, and catalog cuts for all components, members, or equipment supplied by the construction contractor. The design organization shall be responsible for ensuring that the manufacturer's or vendor's submissions comply with the design drawings, specifications, and design intent. Shop drawings should be released into the appropriate documentation center after construction is complete.

3.2.7 Design Discrepancies. - Discrepancies between the design documentation and the intent of the design that are identified after the construction has been awarded shall be reported to the construction contract technical representative for disposition.

3.2.8 Work in Progress. - The responsible design organization shall avail itself of all possible means to determine if the hardware is being manufactured and assembled in accordance with the drawings and specifications, as approved. Periodic inspections of the work in progress shall be performed by design personnel in accordance with the design statement of work.

3.2.9 Unauthorized Changes. - Changes in design drawings, specifications, structures, and/or structural members shall not be made without proper authorization. Proper authorization shall include, but not be limited to, the approval of the responsible structural design organization.

3.2.10 Supporting Documents. - Updated design drawings, specifications, calculations, design criteria, and shop drawings shall be the minimum documentation support for all structural projects.

3.3 Load Criteria. - The load criteria for structures shall be chosen based upon the use, function, and environment to which the structure will be subjected throughout its life cycle.

3.3.1 Nonexistent Load Conditions. - Snow and earthquakes are conditions that are nonexistent at KSC for structural steel applications and shall not be considered for design. Designs for projects not used at KSC shall use the load conditions peculiar to the area of usage in accordance with ASCE 7.

3.3.2 Soil and Hydrostatic Pressures. - Below-grade structures shall be designed to withstand soil and/or hydrostatic pressures in accordance with NAVFAC DM 7.01, DM 7.02, and DM 7.03.

3.3.3 Dead Loads. - Structures shall be designed for dead loads. These permanent loads comprise the weight of all permanent construction including walls, floors, roofs, ceilings, stairways, and fixed service equipment. Actual weights of materials and construction shall be used where possible. Dead loads on roofs of temporary structures and enclosures should not be less than 0.6 kilopascal (kPa) (12 pounds per square foot [lb/ft^2]) for conventional structures. Refer to ASCE 7, for typical construction material loads. In the absence of definite information, values that are satisfactory to the design agency having approval authority shall be used. The responsible design agency shall also consider factors that can result in differences between actual and calculated dead loads.

3.3.4 Equipment Loads. - The weight of equipment or fixed service equipment shall be estimated for purposes of design. These permanent loads shall include, but not be limited to plumbing; electrical feeders; heating, ventilating, and air conditioning (HVAC) system; control panels; racks; and other GSE whenever such equipment is supported by structural members.

3.3.5 Live Loads. - Structures shall be designed for those live loads produced by the use, occupancy, or function of the structure. This type of variable load includes personnel, furniture, tools, and materials with allowances for impact, but does not include environmental loads such as wind load.

3.3.5.1 Minimum Uniformly Distributed Live Loads. - Unless actual conditions of utilization and/or occupancy cause greater live loads, the minimum uniformly distributed live load shall be in accordance with ASCE 7, except as listed below or in the following text.

Structure Type	Live Load kPa (lb/ft^2)
Catwalks	2.9 (60)
Footwalks	2.4 (50)
Platforms and floors not otherwise noted	4.8 (100)
Mechanical, telephone, radio, or automatic data processing rooms; small equipment laboratories or shops	7.2 (150)
Loading platforms	9.6 (200)
Heavy equipment laboratories or shops	12.0 (250)

3.3.5.2 Minimum Concentrated Live Loads. - Floors shall be designed to safely support the uniformly distributed live loads in accordance with this standard or the concentrated live loads given herein, whichever loading condition causes the maximum stress in the member being considered. Unless actual conditions of utilization and occupancy cause greater concentrated loads, the minimum concentrated live load shall be in accordance with ASCE 7, except as listed below or in the following text.

Location	Load
All catwalks and floors	1.5 times the maximum wheel load
Small equipment laboratories or shops	9.0 kilonewton (kN) on a 750-millimeter square area (0.6 m^2) (2,000 lb on a 2.5-foot square area [6.25 ft^2])
Heavy equipment laboratories or shops	22.3 kN on a 750-millimeter square area (0.6 m^2) (5,000 lb on a 2.5-foot square area [6.25 ft^2])

3.3.5.3 Minimum Roof Live Loads. - Roofs shall be designed for minimum roof live loads in accordance with ASCE 7.

3.3.5.4 Impact Loads. - For structures carrying live loads that induce impact, the impact load shall be in accordance with ASCE 7 or as otherwise specified by the design organization.

3.3.5.5 Crane Runway Horizontal Forces. - The horizontal forces used for the design of crane runways shall be in accordance with ASCE 7 or as otherwise specified by the design organization.

3.3.5.6 Loads From Personal Fall Arrest Systems and Positioning Device Systems. - Loads from personal fall arrest and positioning device systems shall be determined in accordance with 29 CFR 1926.502. Structural members that support fall arrest anchorages for fall arrest or positioning device systems shall be designed to resist the combined effects of anchorages loads and other concurrently acting structural loads as deemed necessary by the engineer. Load-testing requirements shall be as determined by the responsible design organization and documented on the design drawings.

3.3.5.7 Loads From Personal Fall Restraint Systems. - Loads from personal fall restraint systems shall be determined in accordance with 29 CFR 1926.502 Interpretation No. 13, dated 11/02/1995. Structural members that support fall restraint anchorages shall be designed to resist the combined effects of anchorage loads and other concurrently acting structural loads as deemed necessary by the engineer. Load-testing requirements shall be as determined by the responsible design organization and documented on the design drawings.

3.3.6 Rain Loads. - Rain loads for structures shall be in accordance with ASCE 7, Section 8.

3.3.7 Load Combinations. - Combinations of loads shall be in accordance with ASCE 7 for conventional structures. For nonconventional structures combinations of loads shall be in accordance with ASCE 7 and the following:

a. $1.2\,D + 0.3\,L + 0.2\,W_S + 1.0\,A + 1.0\,T_L$
b. $1.2\,D + 0.3\,L + 0.2\,W_S + 1.0\,B_L + 1.0\,T_L$
c. $1.2\,D + 0.3\,L + 0.2\,W_S + 1.0\,A + 1.0\,B_L + 1.0\,T_L$
d. $1.2\,D + 0.2\,W_S + 2.0\,E_Q$

where:

A - Acoustic Load
B_L - Rocket Engine Blast Load
D - Dead Load
E_Q - Lifting Load
L - Live Load
T_L - Temperature Load
W_S - Service Wind

3.3.8 Load Reduction. - There shall be no reduction in live loads except for conventional structures, where the reduction may be taken in accordance with ASCE 7.

3.3.9 Launch Environment Loads. - Structures that are subjected to launch environment loads shall be designed as a nonconventional structure. These variable loads shall include rocket engine exhaust impingement or blast pressures, and acoustics or vibration. The launch environment shall be defined by the Government and will be based on the vehicle configuration and the rocket engine parameters supplied by the manufacturer. Launch environment acoustic and vibration loads shall be considered as dynamic loads in accordance with this standard.

Structures subject to direct rocket engine exhaust impingement (blast) shall be designed in accordance with the methods defined in KSC-STD-Z-0012. Structures adjacent to a rocket engine exhaust hole, which may be subject to direct exhaust impingement, shall be designed to a maximum static blast load at the edge of the hole. The blast load shall be reduced as the distance from the edge of the hole increases. At a specific distance from the edge of the hole, the blast load shall remain uniform for the area beyond this point. Empirical static blast loads of gage pressures of 14 kPa (2 pounds per square inch [psi]) in any direction shall be used for those structures exposed to secondary exhaust impingement. Worst-case liftoff drift shall be considered in establishing blast load criteria.

3.3.10 Dynamic Loads. - Structures subject to dynamic loads shall be designed as nonconventional structures or equipment. Dynamic loads for the design of cranes or other critical lifting structures and dynamic loads associated with high-velocity turbulent fluid flows in flexible ducts and in pipes containing orifices or other flow constrictions shall not be considered a part of this standard. The following types of dynamic loads shall be considered on permanent or fixed structures located on or near the launch pad.

a. Launch Vibration and Acoustic Loads. This type of dynamic load can be defined from direct measurements that define the dynamic environment at locations of the measuring sensors only. When measurements are not available, an analysis and extrapolation of available data shall be used in the development of these loads.

b. Launch Support Equipment Loads. Dynamic loads in launch support equipment and mechanisms shall be unique to launch operations, such as retracting umbilicals, tail service masts, service and access arms, etc. This type of dynamic load is defined by analysis considering requirements for equipment performance and, where applicable, by component testing.

c. Wind Dynamic Loads. These loads are caused by either a steady or gusting wind that induces vibration in structures and/or members. Structures and members with circular cross sections shall require the design of spoilers that reduce wind-induced vibration.

Dynamic loads shall not be defined as external loads acting on a structure in a manner similar to that of static loads. Dynamic loads shall be calculated as a structural response to a defined type of cyclic input (e.g., acoustics, wind, etc.) Dynamic loads shall be considered to cause fluctuating internal stresses as a result of external loads. Dynamic analysis shall employ analytical and experimental procedures and methods that define design values of internal structural stresses in a structure where vibration may be caused by any of the previously defined input. Two kinds of response analysis shall be used: (1) the frequency domain and (2) the time domain.

3.3.10.1 Modal Analysis. - A modal analysis shall be performed prior to the response analysis in order to establish the following modal parameters of a structure: (1) natural (resonance) frequencies, (2) natural modes (shapes of a vibrating structure), (3) modal mass, and (4) modal damping.

Theoretical modal analysis shall be performed by developing a finite element model (FEM) of the structure and by using an approved FEM computer program, in accordance with 3.2.3. Modal analysis shall be performed assuming an undamped structure. In application to response analysis, modal damping shall be estimated based on judgment and past experience and conservatively considering the criticality of the structure. For relatively simple structures, existing explicit analytical solutions may be used instead of an FEM.

Whenever a development prototype of a structure and/or mechanism is available, an effort shall be made to verify the theoretical model by means of an experimental modal analysis. Dynamic verification tests should begin with simple tests designed to verify resonance frequencies and may extend into a complete modal parameter identification that includes a definition of damping. The analysis of normal modes shall identify those modes that are most likely to be excited by external input. Generally, structurally significant response involves only a few modes with the lowest resonances. The analysis shall provide a matrix of internal stresses, reactions, etc., due to each normal mode selected for response analysis. This matrix is essential for later computations of actual response to specific input.

Most launch pad structures and their components (structural members, girts supporting siding, etc.) have fundamental resonances below 10 hertz (Hz), many below 5 Hz. The total frequency range of modal analysis is seldom required to extend above 20 Hz. The exception is stiff panels and plates where the fundamental mode resonances are usually higher than 20 Hz but below 100 Hz. When the fundamental modes or other modes identified as likely candidates to become excited have wide-spaced resonances, then individual structural models, each simulating a group of selected modes (separate substructures), are more efficient tools for structural design than a single model. Thus, an efficient modal analysis shall be the result of an interactive process, branching from a preliminary model.

3.3.10.2 Launch Vibration and Acoustic Loads. - The response analysis for these loads shall be performed in the frequency domain. The external excitation load shall be specified in the form of either a pressure power spectral density (PSD) or preferably a response spectra computed for a few values of damping from total measured pressure time histories. The prevailing type of acoustic field shall be specified by pressure correlation lengths. A complete input specification shall contain a specification of pressure correlation lengths for the frequency range of input excitation.

Structural response shall be computed separately for each mode and shall be in terms of modal participation factors, alternately known as response modal coordinates. The total response (an internal stress or a reaction) shall be computed by the root-square-sum rule from the contributions of peak responses of all participating modes with wide-spaced resonances. Contributions from modes with close resonances shall be summed before squaring. Generally, when a frequency response function contains a merged resonance peak, responses from corresponding modes shall be summed directly.

Because of inherent launch-to-launch variations, pressure correlation lengths shall be specified in the form of an upper and lower limit containing expected variations. The design value of a pressure correlation length shall be that which results in the maximum value of a generalized modal load. For modes where modal displacements of the surface loaded by acoustic pressures contain different signs (+ and - relative to the outboard surface), the simplified assumption of infinite pressure correlation lengths is not necessarily safe and conservative. For modes with different displacement signs, the positioning of the correlated pressure distribution (CPD) relative to the mode is critical, and the position of the CPD center shall result in the maximum value of a generalized load.

For many commonly encountered types of structures, the definition of generalized modal loads and computations of responses may be simplified by the use of joint acceptance coefficients. Diagrams of these coefficients as functions of pressure correlation lengths and the position of the CPD center over the mode can be found in KSC publications and other technical literature. For input containing the impinging plume pressures, the input specification contains two components:

a. Specification of acoustic (dynamic) input component in terms of response spectra (or PSD's) and pressure correlation lengths.

b. Specification of a slow-varying, pseudo-static pressure component, often referred to as a time-varying-mean (TVM) pressure, and a corresponding impingement area. In response analysis, this component is treated as a static load distributed either uniformly or by a specific distribution (usually assumed to be paraboloid) over the impingement area.

The response shall be computed separately for each component.

3.3.10.2.1 Response to a PSD Input. - Computation of response (modal coordinates) shall assume that both input and response are steady-state type. Since only the root-mean-square (rms) response can be computed, the instantaneous peak design values are computed from the rms (sigma) values multiplying them by a factor that ensures a high probability that design values are not exceeded "most of the time." The choice of multipliers (factors) shall be specified for each design and shall be based on cumulative probabilities computed from measured amplitude distributions of both input pressures and strain responses. These distributions are not Gaussian. The range of factors, which ensure that instantaneous response amplitudes remain below design values for at least 99 percent of the time, is between 2.2 and 2.5. In the absence of applicable measurements, a factor of 2.5 shall be used.

The application of acoustic input PSD's to the computation of modal responses often leads to an overestimate for modes with low resonance frequencies. The extent of the overestimate depends on modal damping and the actual duration of low-frequency pressure components in a transient input. The peak response mode may be approximately corrected by the factor $1\text{-Exp}(-2\pi NZ)$;

where N is the estimated number of input cycles at the frequency of mode resonance occurring during the peak of this pressure component and Z is the damping coefficient (fraction of critical damping). This correction factor should be applied judiciously because the estimate of both N and Z contains uncertainties. Application of the low-frequency correction factor shall be applied to a frequency range of 0 to 20 hertz. The input PSD's are multiplied by the low-frequency correction factors squared.

3.3.10.2.2 Response Computed From Response Spectra. - Response spectra shall be derived by solving an uncoupled equation of motion for a mode in terms of modal coordinate q. A design value of a spectral ordinate Y shall be interpolated from specification spectra by using damping values estimated for each mode.

The peak (design) value of the modal coordinate q shall be computed from the response spectrum Y=Y(f) by $q=Y(AJ/M/\omega^2)$ where:

Y is the spectral ordinate at mode resonance frequency f.

AJ is the generalized modal load per unit instantaneous pressure, computed from the correlated pressure distribution. Parameter AJ defines vibroacoustic coupling between the structure and acoustic field. Note that if PSD's were used, then $(AJ)^2$ is required to compute the mean square response of the modal coordinate.

M is the generalized modal mass obtained from modal analysis.

ω equals $2\pi f$ and is the circular resonance frequency of the mode (rad/s).

3.3.10.2.3 Preliminary Design Loads. - For a preliminary sizing of structural members subject to acoustic-type loads, static analysis using a concept of an equivalent static load may be substituted for a dynamic analysis for fundamental modes of a planar structure where modal displacements have the same sign throughout the structure, such as fundamental modes of single span beams and plates with various boundary conditions. This application also assumes an ideally correlated acoustic field with infinitely long pressure correlation lengths.

The value of an equivalent static load, in units of pascals (or psi in nonmetric situations), is equal to the ordinate of response spectra (value of Y in 3.3.10.2.2) taken at the resonance frequency of the fundamental mode. If response spectra are not available, the equivalent loads cannot be defined.

If an increasing loss of analysis accuracy is considered acceptable, then the equivalency concept may be extended to fundamental modes of other types of structures by applying the equivalent load to selected areas of the structure in a manner similar to the live load. The equivalent load concept is not applicable to modes above the fundamental mode.

3.3.10.3 Launch Support Equipment. - The dynamic analysis of launch support equipment (LSE) structures that contain moving parts and that perform their function during a vehicle launch is performed in the time domain. A suitable structural dynamic model/mechanism simulation shall be developed. Each moving part of a significant mass shall be assigned a number of degrees of freedom (DOF's) completely describing its rigid body of motion. Additional DOF's shall be assigned to flexible structure parts and links of the mechanism by selecting flexible modes of each part and link that are most likely to become excited during operation of the mechanism. Nonlinear elements, such as cables, shock absorbers, dampers, and pneumatically or hydraulically operated devices, require a separate modeling which may assign additional DOF's to them. Parameters of nonlinear elements shall be obtained either from existing test records or experimentally by separate component testing during mechanism development. Whenever possible, model formulation shall lead to a set of uncoupled equations of motion, one for each DOF.

The modeling process and the solution of equations of motion generally require a specialized computer program. The presence of nonlinear elements and large motions, mainly rotations, may exclude the application of off-the-shelf computer programs. The numerical integration procedure and integration steps shall reflect various phases of mechanism operation and shall be selected and adjusted to reflect the fastest varying DOF in the model, specifically at times of impacts and engagement of cables, dampers, and propulsion or explosive devices. The required computational stability of solution generally results in the range of integration steps from a fraction of a millisecond to a fraction of a second, an often-encountered range of 100 to 1; in such cases, a brute-force approach of constant integration steps employed by some available codes is unacceptable. Schemes employing variable, self-adjusting integration steps and independent output steps (some Runge-Kutta formulations) are suitable for such analysis although they may not be entirely free from a weak instability. Modeling procedures and solutions shall be approved in accordance with 3.2.3.

An initially developed model shall be continuously updated during the development test program. Reliable models cannot and are not expected to be developed on a rationale-only basis, without the support from developmental tests.

3.3.10.4 Wind Dynamic Loads. - Structural members must be exposed to a nonturbulent and unobstructed wind flow component around the member in the direction perpendicular to its lengths in order to be affected by dynamic wind loads. Under these conditions, self-exciting oscillations of members may occur even at low {25 kilometers per hour (km/h) [15 miles per hour (mph)]} to moderate [65 km/h (40 mph)] wind velocities. Generally, cylindrical members that are long and slender [length-to-diameter (L/D) ratios >10.0] with low resonance frequencies will be subject to wind-induced vibrations. Beams carrying bending loads or a combination of different types of loads are more susceptible to these oscillations at lower L/D. Reduction of this vibration shall be achieved by installation of spoilers that disrupt the correlation of vortex shedding or by decreasing the L/D of the beam.

The analysis of self-exciting wind vibration loads distinguishes two regions, subcritical and supercritical, defined by the Reynolds number R=1550VD, where V is the wind velocity in kilometers per hour and D is the diameter of the circular cross section in millimeters (R=780VD, when V is in miles per hour and D is in inches).

In the subcritical region ($R \leq 10^6$), the vibration is caused by the formation of Karman vortices. The shedding occurs at a nearly constant value of the Strouhal number (the nondimensional frequency) $S=fD/V=0.22$ (where V and D shall be in compatible units). When the shedding frequency f is near the natural frequency of the cylindrical member, resonance and high oscillations occur. The spoiler design, which has proved to be effective, consists of three helical strakes, 120 degrees apart in cross section, wound around the cylindrical member in accordance with these guidelines:

a. Round spoilers are effective with diameters of 0.1D. Rectangular, sharp-edged strakes with a height of 0.1D and at a 60-degree helix angle from the cylinder axis are widely used.

b. The pitch of each helical spoiler shall not exceed 12D (360-degree turn within less than 12 diameters of the cylindrical member) but is most effective between 3.6D and 5D.

c. The length of the straked section shall be greater than 0.4L, centered at L/2, where L is the length between supports of the cylindrical member.

At high Reynolds numbers ($R>10^6$) in the supercritical region, the flow around a cylinder becomes turbulent, vortex shedding is irregular and random, and the associated vibration is also random with the excitation input acting over a broad range of frequencies. Excitation shall be defined in terms of a PSD of lift force acting in the plane perpendicular to wind flow and perpendicular to the cylinder axis. The PSD shall be normalized to describe the lift force per unit stagnation pressure. The horizontal axis of normalized PSD is usually the nondimensional Strouhal number rather than the frequency f. Methods of response analysis shall be similar to those for acoustic loads, except that the peak value of the modal coordinate shall equal three times the rms value, corresponding to a normal distribution of vibration amplitudes. Nearly all cylindrical members with a large diameter are in the supercritical region even at low to moderate wind velocities.

The spoiler design, consisting of four helical strakes 90 degrees apart, shall be in accordance with the following guidelines:

a. Spoilers shall have a rectangular cross section, preferably with sharp edges. The depth of a spoiler shall be greater than D/30. The width of a spoiler is governed by structural consideration and it should not be less than 6 millimeters (mm) (1/4 inch).

b. The pitch of each helical spoiler shall equal 8D (360-degree turn within 8 diameters of the cylindrical member).

c. If the structure is a cantilever, the length of the straked section shall extend from the free end of the cantilever to at least 0.7L, where L is the total cantilever length.

3.3.11 Occupational Safety and Health Standards. - 29 CFR 1910 establishes certain minimum design loads. For design clarification, these minimum design loads are combined with the corresponding KSC requirements and are restated herein as minimum live loads for design.

3.3.11.1 Fixed Stairs. - Fixed stairs shall be designed to support a minimum uniformly distributed live load of 4.8 kPa or a moving live load of 4.45 kN concentrated over an area 750 mm square (0.6 m^2), whichever produces the greater stresses [100 pounds per square foot or 1000 pounds concentrated over an area 2.5 feet square (6.25 ft^2)], provided that each stair tread shall be capable of supporting a 1.33-kN live load on a 2500-mm^2 area (300-pound live load on a 4-in^2 area) concentrated at its center. All stairs shall have railings at open stringers and landings. The stairs shall not have a pitch greater than 50 degrees nor less than 30 degrees measured from the horizontal (reference 29 CFR 1910.24).

3.3.11.2 Floor Opening Covers. - Covers, hinged or otherwise, that are required for floor openings shall be of the same construction as the floor and shall be designed to the same live load as the floor (reference 29 CFR 1910.22 and 1910.23).

3.3.11.3 Wall Openings. - Wall openings and open-sided floors from which there is a drop of more than 1200 mm (4 ft) and a vertical opening 150 mm (6 in) or more wide shall be guarded by a standard railing or approved equivalent, except where there is an entrance to a ramp, stairway, or fixed ladder (reference 29 CFR 1910.22 and 1910.23).

3.3.11.4 Guardrails and Barriers. - The requirements specified in this section, by OSHA 29 CFR 1910.22 and 1910.23, and by other industrial standards are minimum requirements. Guardrail designs shall consider unique conditions, safety, strength, and intended use. For example, guardrails subject to blast, thermal, and/or acoustical loads that are more severe than loads specified in this section shall be designed for the more severe loads. Permanent guardrails subjected to rocket engine blast loads shall be designed for 10 psi for direct impingement and 5 psi for indirect impingement cases.

Guardrails are categorized as either rigid or nonrigid. Rigid guardrails may be either permanent or removable. Nonrigid guardrails shall be used only when rigid guardrails are not feasible. Guardrails shall be designed using either the ASD or LRFD design concept in accordance with 3.1.1 for steel designs and using AA 30 for aluminum designs in accordance with 3.7.4.

3.3.11.4.1 Rigid Guardrails. - The guardrail system shall consist of a smooth-surfaced top rail, one or more intermediate rails (or equivalent protection), and, if necessary, a toeboard (reference 29 CFR 1910.23). The top surface of the top rail shall be at a minimum height of 1070 mm (42 in) from the floor and the intermediate rails shall be positioned so the gap between rails, or between the rail and toeboard, is no more than 480 mm (19 in). The posts and railings should be pipe sections. Unless otherwise required by special design conditions, top handrail actual diameter or side dimensions shall not be less than 40 mm (1.5 in) nor larger than 50 mm (2 in). Posts shall not be spaced more than 2400 mm (8 ft) on center. For removable guardrails, posts should not be spaced more than 1800 mm (6 ft). The maximum clearance (gap) between adjacent guardrail systems and other structures shall be 150 mm (6 in). Removable guardrails shall be lightweight so that they may be easily removed and installed by hand.

Rigid guardrails shall be designed in accordance with the requirements of OSHA Regulation (Standard – 29 CFR), 1910.23(e)(3)(iv), which states: "The anchoring of posts and framing of members for railings of all types shall be of such construction that the completed structure shall be capable of withstanding a load of at least 200 pounds applied in any direction at any point on the top rail." Rigid guardrail gates shall be used unless it is not feasible due to the geometry or configuration of the opening. Only verifiable, positive means of fastening nonrigid barriers shall be used. "S-hooks" shall not be used since adequate closure of the hook cannot be visually verified or the "S-hook" may roll out under pressure.

3.3.11.4.2 Nonrigid Barrier. - Chain or cable types of nonrigid barrier systems shall be avoided whenever possible. Rigid guardrail gates shall be used unless it is not feasible due to the geometry or configuration of the opening. Only verifiable, positive means of fastening nonrigid barriers shall be used. "S-hooks" shall not be used since adequate closure of the hook cannot be visually verified or the "S-hook" may roll out under pressure. When these and other types of nonrigid barrier systems (e.g., chain and pipe combination) must be used, the barriers shall be designed such that prior to load, the maximum vertical deflection or sag of the barrier shall be 75 mm (3 in). In new systems, the lowest point of the barrier shall not fall below 990 mm (39 in.) Size and spacing of posts and openings shall be in accordance with the requirements specified in 3.3.11.4.1. Nonrigid barriers shall be designed to resist a 900-newton (N) (200-1b) load applied in any direction at any point on the post. Multiple-stanchion systems shall be designed to meet the requirements of this section when individual components of the system are removed or are under load. Off-the-shelf connecting hardware used should be selected with strength that is two times the load transferred at the connection.

3.3.11.4.3 Visual Barrier. - Chain or cable types of visual barrier systems shall be avoided whenever possible. When these and other types of visual barrier systems (e.g., chain and pipe combination) must be used, the barriers shall be designed such that prior to load, the maximum vertical deflection or sag of the barrier shall be 75 mm (3 in). In new systems, the lowest point of the barrier shall not fall below 990 mm (39 in.) In existing railing systems, the lowest point of the rail shall not fall below 915 mm (36 in.) Size and spacing of posts and openings shall be in accordance with the requirements specified in 3.3.11.4.1.

Visual barriers shall be designed to resist a 900-N (200-lb) load applied in any direction at any point on the post. Multiple-stanchion systems shall be designed to meet the requirements of this section when individual components of the system are removed or are under load. Off-the-shelf connecting hardware used should be selected with strength that is two times the load transferred at the connection.

3.3.11.5 Fixed Ladders. - Fixed ladders shall be designed to support, as a minimum, a 900-N (200-lb) live load applied at any point on any rung. The ladder's length and anticipated usage shall determine if additional 900-N (200-lb) live loads are to be considered in the design. The 900-N (200-lb) live loads shall be concentrated at points that cause the maximum stress in the member being considered. Fixed ladders shall not have a pitch greater than 90 degrees or less than 75 degrees measured from the horizontal. For other requirements, see 29 CFR 1910.27.

3.3.11.6 Ship Ladders. - Ship ladders shall be designed to support a minimum uniformly distributed live load of 4.8 kPa (100 lb/ft^2), provided that each stair tread shall be designed to support a 1.15-kN (250-lb) live load concentrated at any point on the tread. No moving concentrated live load is required. Ship ladders shall not have a pitch greater than 75 degrees or less than 50 degrees measured from the horizontal. Ship ladders are not acceptable for emergency egress purposes.

3.3.11.7 Footwalks. - Footwalks, as used herein, are walkways that are part of or adjacent to items of equipment and are used only by qualified personnel to gain access to portions of that equipment.

Walkways or catwalks that are readily accessible to the general work force shall not be designed as footwalks.

3.3.11.8 Ramps. - Ramps shall have as small an angle from the horizontal as reasonably possible but in no case shall the angle exceed 14 degrees. Ramps, whose angle from the horizontal exceeds 5 degrees, require nonslip surfaces and handrails. For other requirements see 29 CFR 1910.37. Ramps shall be designed to support a minimum uniformly distributed live load of 4.8 kPa or a moving live load of 4.45 kN concentrated over an area 750 mm square (0.6 m^2), whichever produces the greater stress [100 pounds per square foot or a moving live load of 1000 pounds concentrated over an area 2.5 feet square (6.25 ft^2)]. The ramp shall be designed to support live loads no less than those live loads that are supported by the floors at each end of the ramp.

3.3.12 Wind Speeds for Design. - Basic wind speeds are given below for a 3-second averaging time (i.e., 3-second gust) at a height of 10 m (33 ft) above natural grade. Unless specifically required, tornadic winds will not be considered for structural design.

3.3.12.1 Permanent Structures. - These wind speeds are associated with an ultimate load hurricane event. Permanent conventional and nonconventional structures shall be designed with a basic wind speed of 209 kph (130 mph).

3.3.12.2 Temporary Structures. - Ultimate wind loads can be adjusted to a lower mean recurrence interval (MRI) to create an extreme-wind service-load event for temporary structures, if required. Using a 5-year MRI for a 4-year design life, temporary structures should be designed with a basic wind speed of 138 kph (86 mph).

3.3.12.3 Wind Speeds for Moveable Parts of Permanent Structures. - Design requirements for operational or moving parts of permanent structures are frequently related to extreme winds of much less magnitude than those of a hurricane while the part is extended, deployed, or in use. While in a secure position and not in use, the operational or moving part must be able to withstand design wind speeds for permanent structures.

Unless project requirements dictate otherwise, operational or moving parts of permanent structures shall be designed for a minimum basic wind speed of 119 kph (74 mph). Exterior large panel doors shall be designed to be fully opened and closed with the sealing systems in full normal operation (i.e., the seals will inflate and retract normally) when subjected to pressures generated from the basic wind speed of this paragraph.

3.3.13 Wind Load Calculation. - Structures subjected to winds shall be designed for wind loads and pressures established in accordance with ASCE 7 and the basic wind speed indicated above using one of the following procedures.

3.3.13.1 Analytical Procedure.

3.3.13.1.1 Conventional Structures. - The category classification and importance factor are as required for the structure. The exposure category shall be C or D, as applicable.

3.3.13.1.2 Nonconventional Structures. – The importance factor is based on the structural classification of Category III. The exposure category shall be C or D, as applicable.

The responsible design organization is cautioned that judgment is required for nonconventional structures having unusual geometric shapes, response characteristics, or site locations. Shielding, channeling effects, vortex shedding, or buffeting in the wake of upwind obstructions may warrant special consideration. For such situations, recognized literature pertaining to wind load effects shall be consulted. Use of the wind tunnel procedure may also be appropriate.

3.3.13.1.3 Temporary Structures. - An importance factor of one should be used in determining velocity pressures. The exposure category shall be C or D, as applicable.

3.3.13.1.4 Moveable Structures. - An importance factor of one should be used in determining velocity pressures. The exposure category shall be C or D, as applicable.

3.3.13.2 Wind Tunnel Procedure. - Wind tunnel tests may be used for the determination of design wind loads in lieu of requirements specified in this standard. Such testing shall be in accordance with ASCE 7. Wind tunnel testing shall only be used for those structures where the analytical procedure is not practical or feasible.

3.4 Nonconventional Structures and Equipment. Nonconventional structural steel and other structures for nonconventional structures shall use the ASD method. Allowable design stresses shall be in accordance with AISC 316-89 or the design safety factor criteria specified in this standard, unless otherwise specified. The LRFD method shall be used in accordance with AISC 325-01 (or metric equivalent version) and the requirements of this standard. In either situation, the design shall incorporate requirements for critical deflection when it affects the function, safety, or usefulness of the structure. Structural design stresses for nonmetric, nonconventional equipment or GSE shall be limited by a factor of safety.

3.4.1 ASD Safety Factor. - Nonconventional GSE design projects, which may not be governed by the requirements specified in AISC 325-01 or AISC 316-89, shall use a safety factor as a measure of structural integrity. The safety factor shall be based on the material's yield and ultimate strength under given loads. The safety factor used must be based on the particular stress condition (e.g., bearing, tension, shear, etc.). For example, allowable stress in bearing must be based on bearing ultimate and bearing yield stresses, not ultimate tensile and tensile yield stresses or ultimate shear and shear yield stresses, and vice versa. A minimum safety factor shall be selected in accordance with the following guidelines:

a. Overhead suspension structures used to lift, handle, or support critical GSE/flight hardware or personnel (such as spreader beams, lifting cradles, and equipment lugs) shall have a minimum safety factor of 3 against yield and 5 against ultimate strength. These structures shall be load tested in accordance with this standard.

b. Other types of GSE structures, except guardrails, shall have a minimum safety factor of 2 against the yield strength.

c. The safety factor used for bearing stress shall be based on the bearing yield and bearing ultimate strength of the material and shall not be based on the tensile yield and tensile ultimate strengths. The material bearing properties used shall be in accordance with MIL-HDBK-5. If the bearing properties of the material are not listed in MIL-HDBK-5, the allowable stress shall be determined as follows:

  (1) For a pin or bolt in a circular hole with the edge distance less than twice the pin diameter, the bearing allowable shall be 1.40 multiplied by the tensile allowable stress.

  (2) For a pin or bolt in a circular hole with the edge distance greater than or equal to twice the pin diameter, the bearing allowable shall be 1.75 multiplied by the tensile allowable stress.

  (3) For contacting surfaces that are not a pin or bolt in a circular hole, the smallest dimension of the contact area shall be taken to be a pin diameter considering the requirements of (1) and (2) above. For example, if the contact area is 25 by 50 mm (1 by 2 in), the allowable bearing stress would be based upon a pin diameter of 25 mm, the smaller of the two dimensions.

Whereas tension, compression, or bending stress may be the usual basis for the expressed safety factor, the responsible design organization shall verify that no other stress condition or combination of stress conditions gives a safety factor less than the selected minimum safety factor. Other stress conditions or combinations of stress conditions, including shear, torsion, bearing, buckling, fatigue, creep, corrosion, and wear, shall be considered. For one-dimensional beam/truss elements, AISC combined stress equations shall be used for hand calculations or computer analysis. For computer analysis of multidimensional beam/truss elements, the combination of stress shall follow established theories of failure analysis, such as Maximum Principle Stress, Maximum Shear, and von Mises.

3.4.2 <u>LRFD Load Factor</u>. - Design of nonconventional structures shall be based on the actual strength of a member or component and equated to serviceability, durability, and stability requirements using ultimate strength and load factor concepts. For computer analysis of multidimensional beams, plates, and solid elements, combinations of stress conditions (including shear, torsion, bearing, buckling, fatigue, creep, corrosion, and wear) shall be considered and shall follow established theories of failure analysis such as Maximum Principle Stress, Maximum Shear, and von Mises.

Load factors for nonconventional structures shall be in accordance with ASCE 7. Load factors not mentioned in ASCE 7 shall be specified as shown below:

		Load Type	Load Factor
A	-	Acoustic Load	1.0
B_L	-	Rocket Engine Blast Load	1.0
T_L	-	Temperature Load	1.0
W_S	-	Service Wind	1.0
E_Q	-	Lifting Load	2.0

3.4.3 Connections and Fittings. - Special care shall be taken to ensure that connections or fittings are designed to represent the calculated end conditions of the members. Detailed design analysis shall be performed to reflect the stress concentrations that are generally inherent in connections and fittings.

3.4.4 Temporary Overloads. - Structural design practice shall not plan for overload conditions; however, if it becomes expedient to overload components or parts so that a special operation or test can be performed, a thorough analysis of the newly created situation must be performed to determine the margin of safety of the affected parts in all temporary configurations caused by the event. In no case shall the stresses be allowed to exceed the elastic range of the material as determined through rigorous analysis. Removal or loosening of a part shall be strictly prohibited while the part is carrying a load. Such a practice redistributes the load into unknown paths and prevents subsequent meaningful analysis. Temporary encroachment on established allowable stress, safety factors, or load and resistance factors shall be permissible only with the concurrence of and under the restrictions set by the responsible Government design organization.

3.5 Design Practices. - Steel design practices shall be in accordance with AISC 325-01 (or metric equivalent version) or AISC 316-89 and AISC 317-92 and with the requirements of this standard. The design of structural tube and pipe (Hollow Structural Sections) shall be in accordance with AISC 310-97 (ASD) and HSS AISC 346-00 (LFRD). For design of Single Angle, AISC 316-89 (ASD) and AISC 351-00 (LRFD) shall be used. For floor vibration, AISC publication Guide 1 shall be used. For opening in beams, AISC publication Guide 2 shall be used. For standard AISC connections, AISC software (for example, CONXPRT and WEBOPEN) may be used.

3.5.1 Types of Construction.

a. ASD Method. When using the ASD method, structural steel shall be designed in accordance with the elastic theory (elastic design) and shall be categorized as either type 1, type 2, or a combination of both, as described below, in accordance with AISC 316-89. Plastic design shall be used only when specified by the design contract statement of work.

(1) Type 1: commonly designated as "rigid frame" (continuous frame); assumes that beam-to-column connections have sufficient rigidity to hold virtually unchanged the original angles between intersecting members

(2) Type 2: commonly designated as "simple framing" (unrestrained, free-ended); assumes that, insofar as gravity loading is concerned, ends of beams and girders are connected for shear only and are free to rotate under gravity load

b. LRFD Method. When using the LRFD method, structural steel shall be categorized into two basic types of construction, either type FR (fully restrained) or type PR (partially restrained). Both types must comply with the stability requirements of AISC 325-01 (or metric equivalent version).

(1) Type FR: commonly designated as "rigid frame" (continuous frame); assumes that beam-to-column connections have sufficient rigidity to hold the original angles between intersecting members virtually unchanged

(2) Type PR: assumes that the connections of beams and girders possess an insufficient rigidity to hold the original angles between intersecting members virtually unchanged. This type of construction may necessitate some inelastic, but self-limiting, deformation of a structural steel part.

3.5.1.1 Connections. - Connections between structural members shall be designed to use welded or bolted joints in accordance with AISC 316-89 or AISC 325-01 and AISC S338. Structural joints shall use high-strength bolts in accordance with AISC 348-00; however, ASTM A307 bolts may be used in applications as allowed by AISC 316-89 or AISC 325-01. Joints utilizing ASTM A307 bolts, or Type I ASTM A325, or ASTM A325M bolts in exterior applications shall be galvanized in accordance with ASTM A153. Joints utilizing ASTM A490 or ASTM A490M heat-treated high-strength bolts shall use plain fasteners that are precoated with inorganic zinc paint to a dry film thickness (DFT) of 0.05 mm (2 mils) minimum, 0.037 mm (1.5 mils) minimum on bolt threads, and 0.0125 mm (0.5 mil) minimum on nut threads, in accordance with this standard. Following assembly, ASTM A490 and ASTM A490M bolts shall be coated for corrosion control in accordance with this standard. ASTM A325, ASTM A325M, ASTM A490, and ASTM A490M fasteners shall not be reused. Bolted structural joints that are not permanent (that is, joints that require periodic or occasional unbolting or disassembly) shall use MS, AN, or NAS fasteners equivalent to ASTM A307, ASTM A325, ASTM A325M, ASTM A490, or ASTM A490M. Welded connections shall use prequalified welded joints in accordance with AISC 325-01 (or metric equivalent version) or AISC 316-89, AISC S338 or AISC 348-00, and AWS D1.1.

3.5.1.2 Welded Splices. - When field-welded splices are necessary, the splice shall be designed and located to permit the proper prequalified joint to be made. All complex welds in structural members, particularly where copes or miters are required, shall be performed in the shop. Short stubs of the spliced members when properly aligned may be combined in a complex joint to remove the field splices from the immediate vicinity of the complexity.

3.5.2 Materials. - Materials conforming to one of the following specifications are approved for use under this standard: ASTM A36 or ASTM A992 for plates and shapes; ASTM A53 and API-SPEC-5L, grade X42, for pipe; and ASTM A500 or ASTM A501 for structural tubing. ASTM A992, ASTM A242, or ASTM A588 for plates and shapes may be used when there are distinct advantages to the design, providing the project's schedule will not be jeopardized by long procurement lead time. Only readily available steel shapes shall be used in structural design. Plates used to transmit tensile stress in the through thickness direction shall be tested for laminations and inclusions at the mill in accordance with ASTM A435. Unless otherwise specified by the design organization, rejectable defects shall be in accordance with ASTM A435. Extra-high-strength steel alloys such as T1, as specified in ASTM A514, may be utilized when there are distinct advantages to the project but shall be avoided for most applications. Materials subject to stress corrosion shall be avoided in accordance with this standard.

3.5.3 Welding. - All structural welds shall be shown or specified on the design drawings. Standard welding symbols in accordance with ANSI/AWS A2.4 shall be used on the design drawings. Structural steel and other structures shall be welded in accordance with ANSI/AWS D1.1, ANSI/AWS D1.2, ANSI/AWS D1.6, and NASA-SPEC-5004. Weld inspections shall be in accordance with section 4 of this standard. Critical welds shall be avoided wherever possible. If a critical weld is unavoidable, the weld shall be conspicuously noted on the tail of the weld symbol in the design drawings where it occurs and shall be inspected by the appropriate nondestructive test (NDT) method. Welding of extra-high-strength steel alloys, such as T1, shall be avoided wherever possible. When this is not possible, strict and careful adherence to NASA-SPEC-5004 shall be required to produce acceptable welds.

3.5.4 Members Under Load. - A member or part shall not be modified in its sectional properties, or removed or loosened while carrying a load. Where such a practice cannot reasonably be avoided, all provisions for the operation shall be planned and documented as part of the design for the approval of the Contracting Officer in accordance with the following text.

3.5.4.1 Member Removal. - Before removal or loosening of a load-carrying member, the member or members designed to carry the transferred load shall be firmly affixed in place. If the load in the removed or loosened member is intended to be redistributed through the existing structure without new members being added, all affected members and joints shall be investigated to ensure that the stress and deflection changes are not detrimental to the structure's integrity or functional purpose. The designer shall furnish details and procedures to perform the operation based on documented computations.

3.5.4.2 Member Reinforcement. - No member that is stressed to its allowable limit shall be reinforced in place. The slenderness ratio of columns can be improved by the addition of properly designed bracing if stressed to its allowable limit. Knee braces are prohibited for this purpose. Member reinforcement shall consist of adding unstressed steel sections to the stressed basic steel section to provide capability for greater loads without overstress to any part. Before reinforcement, the member shall be unloaded as prescribed by the design organization. The reliability of the method for determining and obtaining the lowered stress level in the basic section shall be considered when determining the amount of unloading required. Stress in all parts of the reinforced member, including the connections, shall be within the allowable stress limits when under the greater load. The responsible design organization shall furnish details and procedures to perform the operation, based on documented computations.

3.5.4.3 Newly Added Member. - No member or members shall be added to an existing framework or structure in such a manner as to redistribute the stress flow through the existing members without a carefully documented analysis of the new condition. Where possible, the end connections shall be designed to eliminate or minimize the redistribution of the existing stress flow.

3.5.5 Bonding and Grounding. - Structural steel and other structures shall be bonded together electrically in accordance with KSC-STD-E-0012. Each member's connections must satisfy electrical bond requirements as well as the structural requirements. KSC-STD-E-0012 specifies types of approved bonding methods; however, only two methods fully satisfy both electrical and structural requirements. When structural integrity is most important, the following two methods shall be used in preference to any others.

3.5.5.1 Welded Connections. - Any welds completed in accordance with this standard shall be an acceptable electrical bond as required by KSC-STD-E-0012.

3.5.5.2 Bolted Connections. - Bolted joints requiring electrical bonding shall have all faying surfaces abrasive-blasted to near-white metal and sealed from moisture in accordance with this standard.

3.5.6 Lightning Protection. - Structural steel and other structures exposed to atmospheric lightning shall be protected in accordance with KSC-STD-E-0012.

3.5.7 Critical Deflections. - All critical deflections that affect the function, safety, and usefulness of the structure shall be investigated by the responsible design organization. Deflections that induce loads into flight hardware, reduce hardware clearances, or cause hardware interferences are examples of critical deflections. In such critical deflection cases, the structure shall be designed for stiffness in order to reduce or eliminate problem deflections and meet the design, interface, or program requirements.

3.5.8 Special Strong Points. - In shops and other work areas where machinery, equipment, and other reasonably cumbersome objects are handled, overhead main members and trusses shall be designed as special strong points for contingency usage where only one strong point will be loaded at any given time. These strong points shall be designed for a vertical live load of 17.8 kN (4,000 lbs) and a horizontal live load in any direction of 6.7 kN (1,500-lb). These loads are to act simultaneously at any point on the member and at any panel point on the lower chord of the truss, in addition to all other required loads. Planned usage of specific strong points, such as man-rated anchor points, may require loads more severe than the general criteria above.

3.5.9 Special Design Restrictions.

3.5.9.1 Frangible Construction. - Frangible construction is prohibited for platforms, decks, and any other components that support personnel.

3.5.9.2 Nonstructural Members and Material. - In any steel structure or frame, all computed stress shall be carried through the various steel members. Properly designed reinforced concrete walls, columns, footings, or other major members of reinforced concrete can be used as anchors, supports, etc., for steel members or frames. Other material may be used with the expressed approval of the responsible design organization. Furthermore, walls, partitions, floors, or other components that mainly perform functions other than serving as primary members of the structural frame shall not be considered in the design as adding to the lateral bracing, rigidity, or load-carrying capacity of the structure, except that a properly designed, poured, reinforced concrete slab is acceptable lateral bracing.

3.5.9.3 Lateral Bracing of Compression Flanges. - Whenever the compression flanges of beams require bracing, the braces shall be structural members, a properly designed steel grating or metal deck welded to the beams, or poured reinforced concrete slab.

3.5.9.4 Knee Braces. - Use of knee braces shall be avoided where possible.

3.5.9.5 Flip Platforms. - All manually raised and hoist-raised flip platforms and supporting structures shall be designed to have a minimum safety factor of 1.4 against ultimate strength of the material for the "Free Falling" dynamic load case resulting from a secondary failure. Any existing platform with hinges and/or supporting structure that does not meet this criteria shall have a means of arresting the platform (e.g., cables, chains, straps, load arrestors, etc.) before it contacts other structures, which cannot withstand the impact of the falling platform or the flight hardware

3.6 Access Tower Design Practices.

3.6.1 General. - Towers intended to service or access a space vehicle on a launch complex shall be designed as an nonconventional open steel framework. This type of service tower is usually constructed initially as an open framework; however, the tower may be partially enclosed by (or open areas of the framework may be blocked by) subsequent ground support system modifications. This type of tower shall be freestanding and more slender than most tower applications. Operational requirements specify unusual slenderness in launch facility towers. Guyed towers hamper launch operations to the point that they shall not be used as launch structures. Guyed towers shall only be designed for instrumentation or communication purposes. Such towers shall be designed in accordance with ANSI/EIA-222.

3.6.2 Shielding. - No allowance shall be made for the shielding effect of other structures unless the shielded structure is surrounded by another structure that has been designed for the express purpose of shielding the inner structure. The shielded structure, however, shall be designed to withstand a nominal wind load, the magnitude of which shall be specified in the design statement of work or design criteria.

3.6.3 Overturning and Sliding. - The overturning moment due to wind load shall not exceed two-thirds of the dead-load stabilizing moment of the structure unless the structure is anchored to resist the excess moment. When the total friction force is insufficient to prevent sliding, anchorage shall be provided to resist the excess sliding force.

3.6.4 Wind Loads During Erection. - Provision shall be made for wind loads during erection of a structure. Special attention is directed to the hurricane season and the frequent line of squalls experienced in the KSC area at that time. Adequate temporary bracing shall be provided to resist wind loading on structural assemblies during erection and construction phases.

3.6.5 Natural Frequency. - Generally, the less slender the tower, the less complicated the design becomes; and the dynamic considerations proliferate rapidly as the height-to-base ratio increases. In the past, successful free-standing tower designs at KSC exhibited slenderness ratios (height to the least side of the base) between slightly over 6 to 1 and 9 to 1. The fundamental bending mode natural frequencies of the towers varied between 0.6 and 0.8 Hz; and hammerhead cranes at the tower tops have invariably lowered the natural frequency of the tower to some degree. Also, the distribution pattern of the tower's mass has not varied greatly from tower to tower.

3.6.6 Steady-State Wind Loads. - Steady-state hurricane wind loads shall be calculated in accordance with this standard. A tower shall be designed to withstand being enclosed, even though the current requirements specify open truss-work design. In this case, the solidity ratio is 1 and the design wind pressures of this standard directly apply to the projected area of the tower in any direction. No increase in allowable stresses due to wind load shall be permitted.

3.6.7 Dynamic Wind Loads. - Steady-state and gusting winds shall be used together to determine the magnitude of the maximum wind pressure delivered on the windward projected area of a tower (or other structure) at certain time intervals. The magnitude of the gust is the summation of each element of peak pressure less its corresponding steady-state pressure acting on the windward projection. The periods between adjacent gusts vary somewhat but, over a minute or two, the average time between gusts can be assumed to be constant with little effect on the final design; however, an array of gust periods should be studied for their effect on the tower as defined by this standard.

3.6.8 Configuration of Towers. - Launch facility umbilical towers, service or access towers, or structures shall be square or rectangular in plan because this shape is more operationally advantageous for personnel and equipment utilization. The K-type wind diagonals shall be used because the shapes of the openings between the platforms and diagonals are more operationally desirable. Future modifications to a tower would be greatly complicated by any other cross-sectional shape.

3.6.9 Battered Sides. - Umbilical, service, or access structures shall be designed without battered sides. Generally, structures with battered sides are more difficult to utilize in operations, more expensive to construct, and more difficult to modify. The main disadvantage of battered sides is the difficulty in making all but the simplest modifications.

3.6.10 Vertical Sides. - Umbilical, service, or access structures shall be designed with vertical sides. The vertical-sided tower is slightly heavier construction and may have more sail area as compared to the original tower construction and subsequent modifications which are much simpler. The vertical-sided tower shall be used because of its greater operational convenience.

3.6.11 Special Details. - Tower columns shall be full penetration butt welded at each splice over the full column length. Floor beams or horizontal struts, if appropriate, shall be equally spaced for the full height of the tower in a manner suitable to meet operational requirements and to fit the geometry of the wind diagonals advantageously. Each level, where the wind diagonals connect to the columns, shall be framed in the horizontal plane to furnish diaphragm action sufficient to maintain the horizontal cross section of the tower. Wind bracing shall be in the plane of each side of the tower. Wind bracing shall extend from a column/floor beam connection up to the center of the span in the beam above and then downward to an adjacent column/floor beam connection, forming a K-shape rotated 90 degrees in the vertical plane.

3.6.12 Tower Design Method. - At KSC as well as other similar installations, the structural frames for special structures and equipment are required long before the systems and the equipment to support the space vehicle have been fully developed or identified as requirements. The following design sequence has been found to be efficient in proceeding with the structural design under these circumstances.

3.6.12.1 Preliminary Design. - The general tower configuration shall be defined first. Loads shall then be calculated in accordance with this standard. The static wind load shall be calculated for the enclosed tower in accordance with this standard. The dead load, except the girt framing or siding, shall be used as part of the tower's weight in establishing the wind load-to-weight ratio for stability or tower natural frequency purposes. A reasonable estimate of weight and location for equipment known to be required may be included in the tower's weight. The tower members shall then be sized to withstand the static loads in accordance with this standard.

3.6.12.2 Final Tower Design. - When the static design has been essentially completed, the final dynamic design can be completed. When corrections improving the dynamic condition of the tower have been incorporated into the design in accordance with this standard, a final check shall be made on the dynamic condition. The final check should include:

a. Spring constants at tower leg reactions, if applicable

b. Strengthening of diagonals, where necessary, to transfer the shear of the accelerated mass above the diagonals as the tower oscillates

c. A study of the characteristics and prevailing directions of various high winds for the KSC area

3.7 Other Design Considerations.

3.7.1 Members Subjected to Dynamic Loads. - Members subjected to dynamic loads shall be free of structural discontinuities, such as notches, abrupt changes in the section, cracks, holes, etc.

3.7.2 Members Subjected to Reversal of Stress or Fatigue. - Members subjected to reversal of stress or fatigue, such as many types of wind bracing, tower legs, etc., shall be proportioned in accordance with AISC 316-89 or AISC 325-01 (or equivalent metric version), Appendix K.

3.7.3 Concrete Design. - Retaining walls, foundations, and other concrete designs associated with structural steel structures and other structures shall be in accordance with ACI 318.

3.7.4 Aluminum Structures. - Design for aluminum structures associated with structural steel structures, other structures, or GSE shall be in accordance with AA 30. Safety factors shall be determined in accordance with guidelines in 3.4.1.a, b, and c.

3.7.5 Cold-Formed Steel Design Structures. - Design for cold-formed steel structure members associated with structural steel and other structures shall be in accordance with AISI SG 673.

3.7.6 Stainless Steel Structures. - Design for stainless steel structures and associated structural steel structures, other structures, or GSE shall be in accordance with standard industry/commercial practices. Safety factors shall be determined in accordance with guidelines in 3.4.1.a,b, and c.

3.7.7 Quick Release Pins. - All quick release pins and tethers used in design of structures referenced within this standard shall be tethered in accordance with KSC-STD-P-0006. This standard identifies types of pins, materials approved for use, and installation methods to provide designers, engineers, and technicians with standard practices to ensure proper use of pins.

3.7.8 Foundations.

3.7.8.1 Soil Investigation. - A soil investigation of the project site shall be performed to establish the soil profile and the foundation design parameters. The use of existing soil data in the immediate neighborhood of the project site may be adequate, depending on the importance and characteristics of the project and if approved by the responsible design organization or specified in the statement of work/work order.

A soil investigation for minor projects, such as small equipment and light-weight secondary structures, shall not be required unless settlement of the structure is critical.

3.7.8.2 Spread Footings. - The design of spread footings shall be in accordance with ACI 318. The allowable bearing capacity of the soil under dead and live loads shall be obtained by applying a safety factor of 3 to the ultimate bearing capacity. A safety factor of 1.5 shall be applied to overturning and 1.2 for sliding. The total and differential settlements of the foundation shall be compatible with the type of superstructure construction.

3.7.8.3 Combined Footings and Mat Foundations. - Combined footings and mat foundations shall be designed based on the recommendations given in ACI 336.2. Variations of the soil properties within the foundation footprint shall be taken into consideration.

The allowable bearing capacity of the soil under dead and live loads shall be obtained by applying a safety factor of 3 to the ultimate bearing capacity. A minimum safety factor of 1.5 against overturning shall be used. The expected settlement of the foundation shall be considered.

3.7.8.4 Pile Foundations. - The size, type, and capacity of the piles shall be selected to provide an economical and safe design. The estimated tip elevation of the piles shall be calculated based on the soil profile and parameters. Consideration shall be given to the reduction of the allowable pile load capacity when piles are placed in groups.

For large or critical projects, pile load tests shall be performed to verify the pile design capacity. Test piles shall have the same characteristics as the production piles. Safety factors of 2 for compression and 1.5 for uplift shall be used. Load tests shall conform to ASTM D1143 and ASTM D3689, as applicable. The resulting allowable load on the piles shall be determined after consideration of the settlement characteristics of the soil based on the soil investigation.

The "wave equation analysis" or other pile load evaluation equations (i.e., static equations such as Janbu's equation) that take into consideration the soil properties, elastic properties of the piles, and pile-driving equipment data shall be specified to be used to obtain the minimum blow per meter (foot) required for acceptance of the driven piles. Soil properties used shall be based on soil investigations conducted at the particular site. Pile-driving equipment properties shall include the rated capacity, efficiency of the pile-driving equipment, and cushion between the pile and pile hammer.

3.8 Design for Corrosion Control. - Structural steel structures and other structures shall be designed to minimize corrosion problems. Standard corrosion control practices used for structural design shall be in accordance with TM-584 and the requirements of this standard. Design drawings and specifications shall clearly reflect corrosion control practices to ensure complete compliance during construction. The most frequently encountered corrosion problems have been minimized by adherence to the following requirements.

3.8.1 Protective Coating of Carbon Steel. - Abrasive blasting and coating applications, which may lead to air, soil, and water contamination, shall be performed prior to delivery to KSC when feasible. These operations shall be performed in compliance with local, state, and Federal laws and, when performed at KSC, shall be done in accordance with KSC policy and directives. When blasting and coatings are performed in the field, the blast debris and overspray shall be contained, collected, kept dry, and properly disposed of. Exemptions to the containment requirement shall be coordinated with the KSC Environmental Management Office.

An inorganic zinc-rich coating applied over abrasively blasted steel in accordance with NASA-STD-5008 shall be the basic coating used for carbon steel at KSC. Top coats, other than zinc-rich coatings, are not required or recommended for use unless required for safety, identification, immersion, reflectivity, or other special purposes such as the launch environment. Generally, an inorganic zinc-rich coating shall be applied to all steel in the shop before delivery and touched up in the field. A touchup includes the coating of damaged areas of the inorganic zinc-rich coat or galvanized surfaces and bare metal such as field bolts, field splices, field welds, etc. Procurement and application of the zinc-rich coatings, compatible topcoats, and requirements for

National Association of Corrosion Engineers (NACE) certified coating inspection shall be in accordance with NASA-STD-5008. When a component can be galvanized more economically, galvanizing in accordance with the pertinent ASTM specification is an acceptable alternative for the inorganic zinc-rich coating. Individual coating specifications shall be prepared for each job in accordance with NASA-STD-5008. Specifications shall reference the type of surface to be coated, exact surface preparation, surface profile, type of coating, coating dry film thickness, zone of exposure, and color of applicable finish coat. This information shall be assembled in a coating schedule as part of the specification.

3.8.2 Detailed Requirements. - Connections and discontinuities are particularly vulnerable to corrosion. Where possible, such localities shall be visible and accessible for inspection and maintenance. The design shall avoid the collection of dirt and moisture as follows:

a. Provide adequate drainage of moisture entrapment areas by use of obstruction-free drain holes with a diameter large enough to allow for coating access.

b. Seal-weld all hollow and tubular members at the ends and wherever they are pierced to exclude the moisture.

c. Ensure that all inaccessible surfaces are cleaned and coated with the inorganic zinc-rich coating before installation. The perimeter of all faying surfaces and skip-welded joints shall be completely sealed in accordance with ASTM C920 (Type S, Grade NS, Class 25, Use NT and O) or seal welded.

d. Use tee or tubular sections in preference to back-to-back angles and channels. Where back-to-back sections are used, keep the space between the zinc-rich coated backs less than 13 mm (0.5 in) and seal the edges of the built-up member with sealing compound in accordance with ASTM C920 (Type S, Grade NS, Class 25, Use NT and O) or seal weld. The exterior use of unistrut shall be avoided, and alternate angle, channel, or tee shapes shall be used.

e. Connections and other details shall be zinc-rich coated as their assembly is completed. Special attention shall be given to bolts, welds, seams, corners, edges, and crevices to ensure thorough coverage. Crevices, seams, pockets, etc., that were not sealed after the coating was correctly applied, shall be filled and sealed with sealing compound in accordance with ASTM C920 (Type S, Grade NS, Class 25, Use NT and O).

f. Lock or toothed washers shall not be used in exterior applications.

g. Acid-resistant topcoats in accordance with NASA-STD-5008 shall be used in the launch environment and other acidic or chemical atmospheres.

h. Consider fluidized bed coatings for metallic hardware.

i. Consider the use of plastic construction materials to replace the metal in corrosive environments.

j. Consider galvanizing of steel surfaces in accordance with NASA-STD-5008, ASTM A123/A123M, and ASTM A153/A153M.

k. Consider system compatibility, environment, and location in relation to hypergolic or cryogenic systems and their vapors.

l. Use galvanized or other corrosion-resistant bolts and avoid the use of cadmium-plated bolts for exterior applications. When cadmium-plated bolts cannot be avoided, the fasteners shall be painted withpolysiloxane PSX 700. Avoid lap welds or skip welds. Use butt welds or seal welds.

3.8.3 Dissimilar Metals. - Where dissimilar metals must be used, provide for their separation by use of barrier tape, protective coatings, or other methods of isolation. Compatibility properties of particular metals are specified in MSFC-SPEC-250 and MIL-F-14072. Bolts that pass through dissimilar metals shall be coated before installation with wet zinc chromate primer in accordance with TT-P-1757. Aluminum surfaces that are to be placed in contact with steel shall be given either of the following treatments:

a. Apply sealant in accordance with ASTM C920 to faying surfaces prior to assembly.

b. Apply tape in accordance with MIL-T-23142 to faying surfaces prior to assembly. Seal the edges of faying surfaces with sealant after assembly in accordance with ASTM C920 (Type S, Grade NS, Class 25, Use NT, O, and A).

3.8.4 Stress Corrosion. - Structural steel structures and other structures shall avoid the use of materials that are subject to stress corrosion cracking. The general criteria specified in MSFC-STD-3029 shall be used to control the use of materials susceptible to stress corrosion cracking. Alloys with high resistance to stress corrosion cracking shall be used in those applications that require high-strength materials. The appropriate Government or contractor materials engineer shall be consulted when any doubt exists as to the compatibility of a particular alloy with its intended service environment. When use of a material not listed in MSFC-STD-3029 is required, then a Material Usage Agreement approved by the Center Materials Representative shall be obtained.

3.8.5 Protection of Finished and Machined Surfaces. - Apply finishes in accordance with NASA-STD-5008, where protection of finished and machined surfaces must be considered.

4. VERIFICATION

4.1 Design and Development Controls. - The responsible design organization shall ensure that the design specifications include verification requirements needed to fulfill the design intent during all stages of the manufacture, fabrication, or construction of the hardware in accordance with the following requirements.

4.1.1 Inspection and Test Criteria. - The design specifications shall require the construction contractor to provide his own inspection and testing during all phases of the work. Verification inspection or testing by other qualified personnel on behalf of the Government shall be clearly identified in the contract documents for those items that are critical to the work. The design specifications shall include specific NDT requirements including methods, test equipment, environmental conditions, and material to be tested.

4.1.1.1 Inspection. - The degree of inspection required shall be designated in the design specifications. Characteristics necessary for procurement and fabrication, including performance and/or tolerance limits, of critical hardware shall be specifically identified.

4.1.1.2 Test Criteria. - Components and/or assemblies to be subjected to NDT's shall be specifically identified in the specifications along with the applicable process specifications, standards, and procedures. The acceptance/rejection criteria shall be clearly stated for each test.

4.1.1.3 Inspection of Welds. - All welds shall be inspected in accordance with NASA-SPEC-5004. NDT's for structural welds for conventional structures shall be required for a minimum of 10 percent of all shop welds and 100 percent of all field welds. Increased NDT inspection may be required by the design organization on those projects of a more critical nature. NDT's for structural welds for nonconventional structures shall be required for 100 percent of all shop welds and all field welds. All full-penetration tension welds and all partial-penetration groove welds shall be inspected by NDT methods. Class B inspection in accordance with NASA-SPEC-5004 shall be the standard NDT method used on structural welds. Welds that require radiographic testing shall be conspicuously noted on the design drawings where they occur.

4.1.1.4 Inspection of Protective Coatings. - All surface preparation and protective coating application shall be inspected in accordance with NASA-STD-5008 by a NACE-certificated coating inspector. The inspector shall be responsible for all field work and for coordination of deviation/waivers with the responsible design organization. Inspection logs shall be maintained by the inspector and submitted to the appropriate agency at the conclusion of the project.

4.1.1.5 Load Tests. - The responsible design organization shall require a load test of any construction whenever there is reason to question its safety for the intended occupancy or use. The design drawings and specifications shall indicate the maximum test load, the test configuration details, and the safe working load as it pertains to the individual project in accordance with the following guidelines.

a. The minimum test load shall be 125 percent of the design or working load.

b. Lifting and hoisting structures shall be initially proof-load tested to 200 percent of the design or working load as specified in NASA-STD-8719.9.

c. Lifting lugs and other lifting interfaces such as eyebolts, hoist rings, etc., on GSE other than lifting and hoisting structures shall be tested in accordance with b. above when it is feasible to do so. In those cases where there is no feasible method to physically proofload test the lifting lugs due to possible overloading of structural members or joints not required for lifting, the lugs can be certified through the design analysis as meeting the required safety factors and proofload tested in accordance with a. above. A note shall be added to the design drawings stating "The lifting lugs have been certified by design analysis and meet the required safety factors of 3 against yield and 5 against ultimate."

d. Guardrails may be proofload tested to 100 percent of the design or working load as specified in 3.3.11. The criteria for testing rigid guardrails is stated in ASTM E985. Nonrigid guardrails require only a vertical load applied at midspan.

e. Ground support equipment and other structures do not require periodic recertification load tests unless extensively modified or at the request of the end user. Those items requiring recertification shall be tested at 125 percent of the design or working load.

4.1.2 Other Controls. - The specifications shall include handling, storage, preservation, marking, labeling, packaging, packing, and shipping requirements, with special emphasis placed on critical items of hardware.

4.2 Waivers and Deviations. - Requests for waivers or deviations from the design drawings or specifications shall be acted upon by the responsible design organization. Approval shall only be granted where the design intent is not compromised.

5. PREPARATION FOR DELIVERY

Preparation for delivery shall be in accordance with the provisions of the design contract.

6. NOTES

6.1 Intended Use. - This standard is intended to establish uniform engineering practices and methods for the design of structural steel and other structures used at KSC for the receiving, handling, assembly, test, checkout, and launch of space vehicles and associated support structures.

6.2 Definitions. - For the purpose of this standard the following definitions shall apply.

a. Allowable Stress Design. A method of proportioning structural members so the stress does not exceed a specified limiting stress value.

b. Allowance for Corrosion or Wear. That portion of a member's thickness that is in excess of that required for the calculated strength of the member. The excess thickness is considered nonstressed and its purpose is to prolong the useful life of a member particularly subject to corrosion or wear.

c. Buildings. Structures that enclose a space.

d. Concentrated Load. A uniform load that is limited in its area of application. The indicated load concentration shall be assumed to occupy a square area 750 mm per side (0.6 m^2) when using metric units and 2.5 feet per side (6.25 ft^2) when using inch-pound units.

e. Critical Weld. A weld whose single failure during any operating condition could result in injury to personnel or damage to property or flight hardware.

f. Dead Load. The permanent weight of all materials and construction, including walls, floors, roofs, ceilings, stairways, and fixed service equipment, plus the net effect of prestressing.

g. Design Analysis. The detailed analysis performed during design to determine the proper size of the various members and components.

h. Design Drawings (Plans). The drawings, supplied by the owner or design agency to the construction contractor, that show the complete design with sizes, sections, the relative locations of the various members, and the type of connections required for the proper preparation of the shop drawings.

i. Design for Stiffness. Design based on critical deflection limits. Such a design is always within the elastic design range and generally results in safety factors higher than the design to an allowable stress.

j. Design Load. The maximum load resulting from a condition or combination of conditions that has a reasonable possibility of occurring.

k. Design Wind Pressure. The velocity pressure of the wind multiplied by factors of empirical origin that closely approximate the pressure per unit area on the given shape.

l. Deviation. A specific authorization granted before the fact to depart from a particular requirement of the specifications or design drawings.

m. Dissimilar Metals. Two metals or alloys that have different electromotive force (EMF) characteristics and which, when in contact with or in the presence of an electrolyte, will result in the accelerated corrosion of the more active dissimilar metal or alloy.

n. Elastic Design. Design based on allowable stresses or load and resistance factors that do not exceed the yield stress at any point of the component or structure.

When properly proportioned, a component so designed will return to its original shape upon removal of the load, thus behaving elastically.

o. Equipment Load. The permanent weight of material and/or service equipment supported in a fixed position by the structure, such as plumbing, electrical feeders, HVAC, control panels, racks, and other GSE.

p. Frangible Construction. Construction that is designed to collapse after a predetermined load has been reached to prevent an overload of critical structural members. A typical example is a wind shield for personnel that folds up under a very high wind load, thus reducing the sail area of the structure.

q. Ground Support Equipment (GSE). All equipment necessary to support the operations of receiving, handling, assembly, test, checkout, servicing, and launch of space vehicles and payload.

r. Ground Winds. Natural environmental surface winds to a height of approximately 450 m (1500 ft) above the natural grade.

s. Launch Support Equipment. Ground support equipment directly involved in the launch of space vehicles; more specifically, that equipment that is required to function during the launch of a space vehicle (for example, a tail service mast, service arm, or holddown post).

t. Live Load. Variable or temporary loads produced by the use, occupancy, or function of the building or structure, which does not include environmental loads such as wind load, rain load, earthquake, or dead load.

u. Load and Resistance Factor Design. A method of proportioning structural members using load factors and resistance factors so that no applicable limit state is exceeded (also called strength design).

v. Load Factor. A factor that accounts for unavoidable deviations of the actual load from the nominal value and for uncertainties in the analysis that transforms the load into a load effect.

w. Loads. Forces or other actions that arise on structural systems from the weight of all permanent construction, occupants and their possessions, environmental effects, differential settlement, and restrained dimensional changes. Permanent loads are those loads in which variations with time are rare or of small magnitude. All other loads are variable loads.

x. Other Structures. Structures constructed of materials other than structural steel.

y. Plastic Design. Design of components or structures using ductile materials where some of the stressed portions are allowed to exceed the yield stress in order to cause a natural redistribution of the loads.

z. Plastic Design Load Factor. In plastic design, the factor (greater than 1) by which the design load is multiplied in order that the component or structure can be analyzed within the plastic range of the material.

aa. Ratings. The completely documented evaluation of a component or structure in the as-built or existing condition. The rating is based on factors of safety calculated for the existing material and configuration under the existing loading parameters. A thorough rating includes a detailed field survey, an identification of all loads, and a rigorous stress analysis of the structure.

ab. Resistance Factor. A factor that accounts for unavoidable deviations of the actual strength from the nominal value.

ac. Safety Factor. The ratio of capability to requirements as applied to ground support equipment and structures. In strength of materials, the safety factor is the ratio of the yield stress to the maximum calculated stress based on design loads as applied to the strength of components in structures. The need for a safety factor in ASD results from the degree of uncertainty regarding loading, analysis, design, materials, construction, and the consequences of failure.

ad. Shape Factor. The coefficient derived experimentally by dividing the actual force on a given geometric shape by the product of the velocity pressure and the projected area that is normal to the direction of the wind.

ae. Shop Drawings. Drawings prepared in advance of the actual fabrication or purchase by the fabricator, erector, or supplier giving complete information necessary for the fabrication or installation of the component parts of the structure, including the location, type, and size of all rivets, bolts, and welds. The shop drawings clearly distinguish between shop and field rivets, bolts, and welds.

af. Statement of Work. That portion of the design contract documentation that defines the technical requirements of the project.

ag. Stress Analysis. A detailed analysis performed after various members have been proportioned to determine their stress levels under various loading conditions with particular attention to critical areas such as connections, discontinuities, etc.

ah. Stress Corrosion Cracking. Delayed failure of components subjected to a corrosive environment under residual or applied tensile stress. Failure is brittle in nature and is characterized by highly branched cracks with little evidence of surface corrosion.

ai. Structural Integrity. The structural soundness of equipment or structures under certain specified conditions.

aj. Structural Steel. The steel elements of the structural steel frame essential to support the design loads. Unless otherwise specified in the contract documents, these elements consist of material as shown on the structural steel plans and described as:

- Anchor bolts for structural steel
- Base or bearing plates
- Beams, girders, purlins, and girts
- Bearings of steel for girders, trusses, or bridges
- Bracing
- Columns and posts
- Connecting materials for framing structural steel to structural steel
- Crane rails, splices, stops, bolts, and clamps
- Door frames constituting part of the steel frame
- Expansion joints connected to the steel frame
- Fasteners for connecting structural steel items
- Floor plates
- Grillage beams and girders
- Hangers essential to the structural steel frame
- Leveling plates, wedges, shims, and leveling screws
- Lintels, if attached to the structural steel frame
- Marquee or canopy framing
- Machinery foundations of rolled steel sections and/or plate attached to the structural frame

- Monorail elements of standard structural shapes when attached to the structural frame
- Roof frames of standard structural shapes
- Shear connectors, if specified shop attached
- Struts, tie rods, and sag rods forming part of the structural frame
- Trusses

Structural steel does not include steel, iron, or other metal items not described above even when such items are shown on the structural steel plans or are attached to the structural frame. These items include but are not limited to:

- Chutes and hoppers
- Cold-formed steel products
- Door and corner guards
- Embedded steel parts in precast or poured concrete
- Flagpole support steel
- Floor plates (checkered or plain) not attached to the steel frame
- Grating and metal deck
- Items required for the assembly or erection of materials supplied by trades other than structural steel fabricators or erectors
- Ladders and safety cages
- Lintels over wall recess
- Miscellaneous metal
- Nonsteel bearings
- Open-web, long-span joists and joist girders
- Shear connectors, field installed
- Stacks, tanks, and pressure vessels

- Stairs, catwalks, handrails, and toeplates
- Trench or pit covers
- Wire rope for permanent bracing or suspension systems

ak. Temporary Structures and Enclosures. Structures not intended to be permanent and usually designed to be assembled and disassembled or to be easily relocated by moving or towing (e.g., clamshelters, trailers, storage sheds, etc.).

al. Ultimate Strength. The maximum stress or strength within a material at which rupture or failure occurs.

am. Velocity Pressure. The computed pressure on a unit area of surface perpendicular to the wind, representing the kinetic energy per unit volume of the moving air.

an. Waiver. A written authorization, granted after the fact, for use or acceptance of an article that does not meet the specified requirements.

ao. Yield Strength. The stress at which yielding begins in a ductile material.

6.3 Construction Contractor Hardware Documentation. - The construction contractor shall supply hardware documentation in accordance with the technical provisions of the construction contract. Hardware documentation shall consist of shop drawings and other documentation. The technical provisions of the construction contract shall call for the submission of hardware documentation in addition to shop drawings. The following requirements shall apply.

Where equipment specified by designations of the manufacturer requires modification to fully meet contract requirements, such modification shall be made by the contractor without additional cost to the Government subject to the Contracting Officer's approval.

When two or more types of equipment or materials are specified without indication of preference, the choice of the type of material or equipment shall be the option of the contractor, but the same type of equipment or material shall be used throughout.

When equipment or materials are specified by the manufacturer's part number, or equal, the contractor shall be responsible during the contract for any necessary redesign, relocation, and rework of associated construction if the contractor selects other than brandname products.

Prior to delivery of each major item of equipment, the contractor shall, unless otherwise directed in the contract provisions, submit six copies of an instruction manual for each item, containing the following minimum information:

a. Description, including ratings, construction details, bearing and lubrication details, dimensions, weights, location of any internal pressure or temperature devices, etc.

b. Erection and disassembly instructions

c. Operating instructions, including temperature limitations, lubrication recommendations, and operating procedures

d. Instructions for maintenance, inspection, cleaning, and adjustment

e. List of repair parts, including description and catalog numbers of each piece

f. Test reports and characteristic data

Custodian:

NASA - John F. Kennedy Space Center
Kennedy Space Center, Florida 32899

Preparing Activity:

John F. Kennedy Space Center
Spaceport Engineering and Technology Directorate

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document or to amend contractual requirements.

I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER KSC-STD-Z-0004F	2. DOCUMENT DATE November 6, 2002

3. DOCUMENT TITLE
Structural Design, Standard for

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)*	7. DATE SUBMITTED

8. PREPARING ACTIVITY

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