

Planning, Designing, and Constructing Fixed Offshore Platforms—Working Stress Design

API RECOMMENDED PRACTICE 2A-WSD
TWENTY-SECOND EDITION, NOVEMBER 2014

REAFFIRMED, SEPTEMBER 2020



Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001.

Copyright © 2014 American Petroleum Institute

Foreword

This document contains engineering design principles and good practices that have evolved during the development of offshore oil resources. Good practice is based on good engineering; therefore, this recommended practice consists essentially of good engineering recommendations. In no case is any specific recommendation included that could not be accomplished by presently available techniques and equipment. Consideration is given in all cases to the safety of personnel, compliance with existing regulations, and antipollution of water bodies. U.S. customary (USC) conversions of primary metric (SI) units are provided throughout the text of this publication in parentheses, for example, 150 mm (6 in.). Most of the converted values have been rounded for most practical usefulness; however, precise conversions have been used where safety and technical considerations dictate. In case of dispute, the SI units should govern.

Offshore technology continues to evolve. In those areas where the committee felt that adequate data were available, specific and detailed recommendations are given. In other areas, general statements are used to indicate that consideration should be given to those particular points. Designers are encouraged to utilize all research advances available to them. As offshore knowledge continues to grow, this recommended practice will be revised. It is hoped that the general statements contained herein will gradually be replaced by detailed recommendations.

Reference in this document is made to the 1989 edition of the AISC *Specification for Structural Steel Buildings—Allowable Stress Design and Plastic Design*. The use of later editions of AISC specifications is specifically not recommended for design of offshore platforms. The load and resistance factors in these specifications are based on calibration with building design practices and may not be applicable to offshore platforms. Research work is now in progress to incorporate the strength provisions of the new AISC code into offshore design practices.

In this document, reference is made to AWS D1.1/D1.1M:2010, *Structural Welding Code—Steel*. While use of this edition is endorsed, the primary intent is that the AWS code be followed for the welding and fabrication of fixed offshore platforms. However, where specific guidance is given in this API document, this guidance should take precedence.

This edition supersedes the 21st Edition dated December 2000, as well as Errata and Supplement 1 dated December 2002, Errata and Supplement 2 dated September 2005, and Errata and Supplement 3 dated October 2007. Revision bars are not used for this edition for clarity because of the extensive document reorganization outlined in the Introduction.

The verbal forms used to express the provisions in this recommended practice are as follows:

- the term “shall” denotes a minimum requirement in order to conform to the recommended practice,
- the term “should” denotes a recommendation or that which is advised but not required in order to conform to the recommended practice,
- the term “may” is used to express permission or a provision that is optional,
- the term “can” is used to express possibility or capability.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

Page

1	Scope	1
2	Normative References	1
3	Terms, Definitions, Acronyms, and Abbreviations	2
3.1	Terms and Definitions	2
3.2	Acronyms and Abbreviations	4
4	Planning	5
4.1	General	5
4.2	Operational Considerations	5
4.3	Environmental Considerations	7
4.4	Site Investigation-Foundations	13
4.5	Selecting the Design Environmental Conditions	14
4.6	Platform Types	16
4.7	Exposure Categories	18
4.8	Platform Reuse	20
4.9	Platform Assessment	20
4.10	Safety Considerations	20
4.11	Regulations	21
5	Design Criteria and Procedures	22
5.1	General	22
5.2	Loading Conditions	23
5.3	Design Loads	24
5.4	Fabrication and Installation Forces	51
6	Structural Steel Design	56
6.1	General	56
6.2	Allowable Stresses for Cylindrical Members	57
6.3	Combined Stresses for Cylindrical Members	63
6.4	Conical Transitions	68
7	Strength of Tubular Joints	73
7.1	Application	73
7.2	Design Considerations	73
7.3	Simple Joints	79
7.4	Overlapping Joints	83
7.5	Grouted Joints	84
7.6	Internally Ring-stiffened Joints	85
7.7	Cast Joints	85
7.8	Other Circular Joint Types	85
7.9	Damaged Joints	86
7.10	Noncircular Joints	86
8	Fatigue	86
8.1	Fatigue Design	86
8.2	Fatigue Analysis	86
8.3	Stress Concentration Factors (SCFs)	88
8.4	S-N Curves for All Members and Connections, Except Tubular Connections	89
8.5	S-N Curves for Tubular Connections	90
8.6	Fracture Mechanics	93

Contents

	Page
9	Foundation Design 93
9.1	General 93
9.2	Pile Foundations 93
9.3	Pile Design 95
9.4	Pile Capacity for Axial Compression Loads 96
9.5	Pile Capacity for Axial Pullout Loads 97
9.6	Axial Pile Performance 97
9.7	Soil Reaction for Axially Loaded Piles 98
9.8	Soil Reaction for Laterally Loaded Piles 98
9.9	Pile Group Action 99
9.10	Pile Wall Thickness 100
9.11	Length of Pile Sections 103
9.12	Shallow Foundations 103
10	Other Structural Components and Systems 104
10.1	Superstructure Design 104
10.2	Plate Girder Design 105
10.3	Crane Supporting Structure 105
10.4	Grouted Pile-to-structure Connections 106
10.5	Guyline System Design 110
11	Material 112
11.1	Structural Steel 112
11.2	Structural Steel Pipe 113
11.3	Steel for Tubular Joints 114
11.4	Cement Grout and Concrete 118
11.5	Corrosion Protection 118
12	Drawings and Specifications 118
12.1	General 118
12.2	Conceptual Drawings 119
12.3	Bid Drawings and Specifications 119
12.4	Design Drawings and Specifications 119
12.5	Fabrication Drawings and Specifications 120
12.6	Shop Drawings 121
12.7	Installation Drawings and Specifications 121
12.8	As-built Drawings and Specifications 121
13	Welding 122
13.1	General 122
13.2	Qualification 123
13.3	Welding Details 124
13.4	Records and Documentation 125
14	Fabrication 125
14.1	Assembly 125
14.2	Corrosion Protection 131
14.3	Structural Material 131
14.4	Loadout 131
14.5	Records and Documentation 132

Contents

	Page
15 Installation	132
15.1 General	132
15.2 Transportation	133
15.3 Removal of Jacket from Transport Barge	135
15.4 Erection	136
15.5 Pile Installation	139
15.6 Superstructure Installation	145
15.7 Grounding of Installation Welding Equipment	145
16 Inspection	146
16.1 General	146
16.2 Scope	147
16.3 Inspection Personnel	147
16.4 Fabrication Inspection	147
16.5 Loadout, Seafastening, and Transportation Inspection	152
16.6 Installation Inspection	153
16.7 Inspection Documentation	154
17 Accidental Loading	155
17.1 General	155
17.2 Assessment Process	156
17.3 Platform Exposure Category	158
17.4 Probability of Occurrence	158
17.5 Risk Assessment	159
17.6 Fire	160
17.7 Blast	160
17.8 Fire and Blast Interaction	160
17.9 Accidental Loading	160
18 Reuse	161
18.1 General	161
18.2 Reuse Considerations	161
19 Minimum and Special Structures	166
19.1 General	166
19.2 Design Loads and Analysis	167
19.3 Connections	168
19.4 Material and Welding	169
Annex A (informative) API 2A-WSD, 21st Edition vs 22nd Edition Cross-reference	170
Annex B (informative) Commentary	184
Bibliography	292
Figures	
5.1 Procedure for Calculation of Wave Plus Current Forces for Static Analysis	25
5.2 Doppler Shift Due to Steady Current	26
5.3 Regions of Applicability of Stream Function, Stokes V, and Linear Wave Theory (from Atkins, 1990; Modified by API Task Group on Wave Force Commentary)	28
5.4 Shielding Factor for Wave Loads on Conductor Arrays as a Function of Conductor Spacing	30
6.1 Example Conical Transition	69

Contents

	Page
7.2	In-plane Joint Detailing 77
7.3	Out-of-plane Joint Detailing 78
7.4	Terminology and Geometric Parameters, Simple Tubular Joints. 79
7.5	Examples of Chord Length, L_c 83
8.1	Example Tubular Joint S-N Curve for $T = 16$ mm ($5/8$ in.) 91
10.1	Grouted Pile-to-structure Connection with Shear Keys 108
10.2	Recommended Shear Key Details 109
10.1	Connection Design Limitations 109
14.1	Welded Tubular Connections—Shielded Metal Arc Welding 127
17.1	Assessment Process 157
B.5.1	Measured Current Field at 60 ft Depth Around and Through the Bullwinkle Platform in a Loop Current Event in 1991 189
B.5.2	Comparison of Linear and Nonlinear Stretching of Current Profiles. 190
B.5.3	Definition of Surface Roughness Height and Thickness 191
B.5.4	Dependence of Steady Flow Drag Coefficient on Relative Surface Roughness 193
B.5.5	Wake Amplification Factor for Drag Coefficient as a Function of K/C_{ds} 195
B.5.6	Wake Amplification Factor for Drag Coefficient as a Function of K 195
B.5.7	Inertia Coefficient as a Function of K 196
B.5.8	Inertia Coefficient as a Function of K/C_{ds} 196
B.5.9	Shielding Factor for Wave Loads on Conductor Arrays as a Function of Conductor Spacing 198
B.5.10	Example Structure 207
B.5.11	Seismic Load Deformation Curve 209
B.6.1	Elastic Coefficients for Local Buckling of Steel Cylinders Under Axial Compression 213
B.6.2	Comparison of Test Data with Design Equation for Fabricated Steel Cylinders Under Axial Compression. 213
B.6.3	Design Equation for Fabricated Steel Cylinders Under Bending. 215
B.6.4	Comparison of Test Data with Elastic Design Equations for Local Buckling of Cylinders Under Hydrostatic Pressure ($M > 0.825D/t$) 217
B.6.5	Comparison of Test Data with Elastic Design Equations for Local Buckling of Cylinders Under Hydrostatic Pressure ($M < 0.825D/t$) 217
B.6.6	Comparison of Test Data with Design Equations for Ring Buckling and Inelastic Local Buckling of Cylinders Under Hydrostatic Pressure 218
B.6.7	Comparison of Test Data with Interaction Equation for Cylinders Under Combined Axial Tension and Hydrostatic Pressure (F_{hc} Determined from Tests) 219
B.6.8	Comparison of Interaction Equations for Various Stress Conditions for Cylinders Under Combined Axial Compressive Load and Hydrostatic Pressure 220
B.6.9	Comparison of Test Data with Elastic Interaction Curve for Cylinders Under Combined Axial Compressive Load and Hydrostatic Pressure 221
B.6.10	Comparison of Test Data on Fabricated Cylinders with Elastic Interaction Curve for Cylinders Under Combined Axial Load and Hydrostatic Pressure 221
B.6.11	Comparison of Test Data with Interaction Equations for Cylinders Under Combined Axial Compressive Load and Hydrostatic Pressure (Combination Elastic and Yield-type Failures) 222
B.7.1	Adverse Load Patterns with α up to 3.8. 226
B.7.2	Computed α 226
B.7.3	Safety Index Betas, API 2A-WSD, 21st Edition, Supplement 1 231
B.7.4	Safety Index Betas, API 2A-WSD, 21st Edition, Supplement 2 231
B.7.5	Comparison of Strength Factors Q_u for Axial Loading 234
B.7.6	Comparison of Strength Factors Q_u for IPB and OPB. 235
B.7.7	Comparison of Chord Load Factors Q_f 237

Contents

Page

B.7.8	Effect of Chord Axial Load on DT Brace Compression Capacity Comparison of University of Texas Test Data with Chord Load Factor.	238
B.7.9	K-joints Under Balanced Axial Loading—Test and FE vs New and Old API.	241
B.7.10	T-joints Under Axial Loading—Test and FE vs New and Old API.	242
B.7.11	DT-joints Under Axial Compression—Test and FE vs New and Old API.	242
B.7.12	All Joints Under BIPB—Test and FE vs New and Old API.	243
B.7.13	All Joints Under BOPB—Test and FE vs New and Old API.	243
B.8.1	Selection of Frequencies for Detailed Analyses.	251
B.8.2	Geometry Definitions for Efthymiou SCFs	257
B.8.3	Basic Air S-N Curve as Applicable to Profiled Welds, Including Size and Toe Correction to the Data	273
B.8.4	S-N Curve and Data for Seawater with CP	273
B.10.1	Measured Bond Strength vs Cube Compressive Strength	279
B.10.2	Histogram of the Safety Factors—Tests with and Without Shear Key Connections	279
B.10.3	Cumulative Histogram of the Safety Factors—Tests with and Without Shear Key Connections	280
B.10.4	Measured Bond Strength vs. Cube Compressive Strength Multiplied by the Height-to-spacing Ratio.	280
B.17.1	<i>D/T</i> Ratio vs Reduction in Ultimate Capacity, 1220 mm, 1370 mm, and 1525 mm (48 in., 54 in., and 60 in.) Legs—Straight with $L = 18.3$ m (60 ft), $K = 1.0$, and $F_y = 240$ MPa (35 ksi)	288
B.17.2	<i>D/T</i> Ratio vs Reduction in Ultimate Capacity, 1220 mm, 1370 mm, and 1525 mm (48 in., 54 in., and 60 in.) Legs—Straight with $L = 18.3$ m (60 ft), $K = 1.0$, and $F_y = 345$ MPa (50 ksi)	288
B.17.3	<i>D/T</i> Ratio vs Reduction in Ultimate Capacity, 1220 mm, 1370 mm, and 1525 mm (48 in., 54 in., and 60 in.) Legs—Bent with $L = 18.3$ m (60 ft), $K = 1.0$, and $F_y = 240$ MPa (35 ksi).	289
B.17.4	<i>D/T</i> Ratio vs Reduction in Ultimate Capacity, 1220 mm, 1370 mm, and 1525 mm (48 in., 54 in., and 60 in.) Legs—Bent with $L = 18.3$ m (60 ft), $K = 1.0$, and $F_y = 345$ MPa (50 ksi).	289

Tables

4.1	Exposure Category Matrix	18
5.1	Design Loading Conditions	23
5.2	Approximate Current Blockage Factors for Typical Gulf of Mexico Jacket-type Structures	27
5.3	Values Coherence Spectrum Coefficients α , p , q , r , and Δ	38
5.4	Wind Shape Coefficients.	39
5.5	Design Level Criteria and Robustness Analysis	41
5.6	C_r Factors for Steel Jacket of Fixed Offshore Platforms	47
5.7	Offshore Design Reference Wind Speed for Drilling Structures	49
5.8	Design Wind Speeds used for Existing Drilling	50
5.9	Deck Acceleration During Design Hurricanes	50
6.1	Values of K and C_m for Various Member Situations.	66
6.2	Safety Factors.	68
6.3	Limiting Angle α for Conical Transitions.	69
7.1	Examples of Joint Classification	76
7.1	Geometric Parameter Validity Range.	79
7.2	Values for Q_u	81
7.3	Values for C_1 , C_2 , C_3	82
7.4	Q_u for Grouted Joints.	84
8.1	Fatigue Life Safety Factors.	88
8.2	Basic Design S-N Curves	90
8.3	Factors on Fatigue Life for Weld Improvement Techniques.	92
9.1	Pile Factors of Safety for Different Loading Conditions	96

Contents

	Page
9.2	Minimum Pile Wall Thickness 102
9.3	Shallow Foundation Safety Factors Against Failure 104
10.2	Guyline Factors of Safety 111
11.1	Structural Steel Plates 114
11.1	Structural Steel Plates (Continued) 115
11.2	Structural Steel Shapes 116
11.3	Structural Steel Pipe 117
11.4	Input Testing Conditions 117
13.1	Impact Testing 123
15.1	Guideline Wall Thickness (in SI Units) 142
15.2	Guideline Wall Thickness (in USC Units) 143
16.1	Recommended Minimum Extent of NDE Inspection 150
17.1	Platform Risk Matrix 158
18.1	Recommended Extent of NDE Inspection-Reused Structure 164
A.1	API 2A-WSD, 21st Edition vs 22nd Edition Cross-reference of Figures 170
A.2	API 2A-WSD, 21st Edition vs 22nd Edition Cross-reference of Tables 175
A.3	API 2A-WSD, 21st Edition vs 22nd Edition Cross-reference of Equations 178
B.7.1	Mean Bias Factors and Coefficients of Variation for K-joints 240
B.7.2	Mean Bias Factors and Coefficients of Variation for Y-joints 240
B.7.3	Mean Bias Factors and Coefficients of Variation for X-joints 241
B.8.1	Equations for SCFs in T/Y-joints 260
B.8.2	Equations for SCFs in X-joints 261
B.8.3	Equations for SCFs in Gap/Overlap K-joints 262
B.8.4	Equations for SCFs in KT-joints 263
B.8.5	Expressions for L_{mp} 265
B.13.1	Average Heat Affected Zone (HAZ) Values 283
B.17.1	Required Tubular Thickness to Locally Absorb Vessel Impact 287

Introduction

This publication serves as a guide for those who are concerned with the design and construction of new fixed offshore platforms and for the relocation of existing platforms used for the drilling, development, production, and storage of hydrocarbons in offshore areas.

In addition, these guidelines are used in conjunction with API 2SIM for the assessment of existing platforms in the event that it becomes necessary to make a determination of the “fitness for purpose” of the structure.

This recommended practice is organized around the framework of the API 2A-WSD, 21st Edition, with the following sections:

- Section 1: Scope;
- Section 2: Normative References;
- Section 3: Terms, Definitions, Acronyms, and Abbreviations;
- Section 4: Planning (API 2A-WSD, 21st Edition, Section 1);
- Section 5: Design Criteria and Procedures (API 2A-WSD, 21st Edition, Section 2);
- Section 6: Structural Steel Design (API 2A-WSD, 21st Edition, Section 3);
- Section 7: Strength of Tubular Joints (API 2A-WSD, 21st Edition, Section 4);
- Section 8: Fatigue (API 2A-WSD, 21st Edition, Section 5);
- Section 9: Foundation Design (API 2A-WSD, 21st Edition, Section 6);
- Section 10: Other Structural Components and Systems (API 2A-WSD, 21st Edition, Section 7);
- Section 11: Material (API 2A-WSD, 21st Edition, Section 8);
- Section 12: Drawings and Specifications (API 2A-WSD, 21st Edition, Section 9);
- Section 13: Welding (API 2A-WSD, 21st Edition, Section 10);
- Section 14: Fabrication (API 2A-WSD, 21st Edition, Section 11);
- Section 15: Installation (API 2A-WSD, 21st Edition, Section 12);
- Section 16: Inspection (API 2A-WSD, 21st Edition, Section 13);
- Section 17: Accidental Loading (API 2A-WSD, 21st Edition, Section 18);
- Section 18: Reuse (API 2A-WSD, 21st Edition, Section 15);
- Section 19: Minimum and Special Structures (API 2A-WSD, 21st Edition, Section 16);
- Annex A: Listing of figures, tables, and equations;
- Annex B: Commentary;
- Bibliography.

The following additional changes to the content of API 2A-WSD not previously noted above have been made:

- API 2A-WSD, 21st Edition, Section 14 (Surveys) and Section 17 (Assessment of Existing Platforms) have been removed in their entirety and now reside in API 2SIM;
- with the publication of API 2FB, the new Section 17 contains only the accidental loading portion of API 2A-WSD, 21st Edition, Section 18;
- Annex A provides a listing of API 2A-WSD, 21st Edition tables, figures, and equations with corresponding 22nd Edition numbers;
- Annex B contains any commentary for the sections;
- Bibliography contains references for all sections.

Planning, Designing, and Constructing Fixed Offshore Platforms— Working Stress Design

1 Scope

This recommended practice is based on global industry best practices and serves as a guide for those who are concerned with the design and construction of new fixed offshore platforms and for the relocation of existing platforms used for the drilling, development, production, and storage of hydrocarbons in offshore areas.

NOTE 1 Specific guidance for hurricane conditions in the Gulf of Mexico and other U.S. offshore areas, previously provided in API 2A-WSD, 21st Edition, Section 2, is now provided in API 2MET.

NOTE 2 Specific guidance for earthquake loading in U.S. offshore areas, previously provided in the API 2A-WSD, 21st Edition, Section 2, is now provided in API 2EQ.

NOTE 3 Specific guidance for soil and foundation considerations in offshore areas, previously provided in API 2A-WSD, 21st Edition, Section 6, is now provided in API 2GEO.

NOTE 4 Specific guidance for the evaluation of structural damage, above and below water structural inspection, fitness-for-purpose assessment, risk reduction and mitigation planning, plus the process of decommissioning has been removed and is now provided in API 2SIM.

NOTE 5 Specific guidance for fire and blast loading, previously provided in the 2A-WSD, 21st Edition, Section 18, is now provided in API 2FB [3].

NOTE 6 Specific guidance for marine operations, supplementing the guidance provided in this document, is now provided in API 2MOP [6]. The provisions in API 2A-WSD shall govern if there are any conflicts.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API Specification 2B, *Fabrication of Structural Steel Pipe*

API Specification 2C, *Specification for Offshore Pedestal-mounted Cranes*

API Recommended Practice 2EQ, *Seismic Design Procedures and Criteria for Offshore Structures*

API Recommended Practice 2GEO, *Geotechnical and Foundation Design Considerations*

API Recommended Practice 2MET, *Derivation of Metocean Design and Operation Conditions*

API Recommended Practice 2N, *Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions*

API Recommended Practice 2SIM, *Structural Integrity Management of Fixed Offshore Structures*

API Bulletin 2TD, *Guidelines for Tie-downs on Offshore Production Facilities for Hurricane Season*

API Bulletin 2U, *Stability Design of Cylindrical Shells*

API Specification 4F, *Drilling and Well Servicing Structures*

AISC 335-89 ¹, *Specification for Structural Steel Buildings—Allowable Stress Design and Plastic Design*, 1989 (included in *AISC Manual of Steel Construction, Allowable Stress Design*, Ninth Edition)

AWS D1.1/D1.1M:2010 ², *Structural Welding Code—Steel*

3 Terms, Definitions, Acronyms, and Abbreviations

For the purposes of this document, the terms, definitions, acronyms, and abbreviations apply.

3.1 Terms and Definitions

3.1.1

fixed platform

A platform extending above and supported by the sea bed by means of piling, spread footings, or other means with the intended purpose of remaining stationary over an extended period.

3.1.2

hot spot stress

HSS

The stress in the immediate vicinity of a structural discontinuity.

NOTE Can also be described as the linear trend of shell bending and membrane stress, extrapolated to the actual weld toe, excluding the local notch effects of weld shape.

3.1.3

manned platform

A platform that is actually and continuously occupied by persons accommodated and living thereon.

3.1.4

mean zero-crossing period

The average time between successive crossings with a positive slope (up crossings) of the zero axis in a time history of water surface, stress, etc.

3.1.5

nominal stress

The stress determined from member section properties and the resultant forces and moments from a global stress analysis at the member end taking into account the existence of thickened or flared stub ends.

3.1.6

operator

The person, firm, corporation, or other organization employed by the owners to conduct operations.

¹ American Institute of Steel Construction, One East Wacker Drive, Suite 700, Chicago, Illinois 60601, www.aisc.org.

² American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.

3.1.7**random waves**

A representation of the irregular surface elevations and associated water particle kinematics of the marine environment.

NOTE Random waves can be represented analytically by a summation of sinusoidal waves of different heights, periods, phases, and directions. For fatigue strength testing, a sequence of sinusoidal stress cycles of random amplitude may be used ^[253].

3.1.8**regular waves**

Unidirectional waves having cyclical water particle kinematics and surface elevation.

3.1.9**sea state**

An oceanographic wave condition that for a specified period of time can be characterized as a stationary random process.

3.1.10**significant wave height**

The average height of the highest one-third of all the individual waves present in a sea state.

NOTE In random seas, the corresponding significant stress range is more consistent with S-N curves than the often misused RMS variance.

3.1.11**S-N curve**

A representation of empirically determined relationships between stress range and number of cycles to failure, including the effects of weld profile and discontinuities at the weld toe.

3.1.12**steady state**

The response of a structure to waves when the transient effects caused by the assumed initial conditions have become insignificant due to damping.

3.1.13**stress concentration factor****SCF**

The SCF for a particular stress component and location on a tubular connection is the ratio of the HSS to the nominal stress at the cross section containing the hot spot.

3.1.14**transfer function**

The ratio of the range of a structural response quantity to the wave height as a function of frequency.

3.1.15**unmanned**

A platform upon which persons may be employed at any one time with no living accommodations or quarters.

3.2 Acronyms and Abbreviations

ALE	abnormal level earthquake
CAFL	constant amplitude fatigue limit
COV	coefficient of variation
CP	cathodic protection
CPT	Cone Penetration Test
CTOD	crack tip opening displacement
DOE	UK Department of Energy
ELE	extreme level earthquake
FE	finite element
GMAW	gas metal arc welding
HAZ	heat-affected zone
HSS	hot spot stress
HSSR	hot spot stress range
IPB	in-plane bending
JIP	joint industry project
LRFD	load and resistance factor design
MT	magnetic particle inspection technique
NDE	nondestructive examination
NDT	nondestructive testing
OPB	out-of-plane bending
OTC	Offshore Technology Conference
OTJTC	Offshore Tubular Joint Technical Committee
PT	liquid penetrant inspection technique
PWHT	postweld heat treatment
QC	quality control
ROV	remotely operated vehicle
RT	radiographic inspection technique
SCF	stress concentration factor
SSSV	subsurface safety valves
UT	ultrasonic inspection technique
VIV	vortex-induced vibration
WSD	working stress design
ZPA	zero-period acceleration

4 Planning

4.1 General

4.1.1 Planning

This publication serves as a guide for those who are concerned with the design and construction of new platforms and for the relocation of existing platforms used for the drilling, development, and storage of hydrocarbons in offshore areas.

In addition, these guidelines shall be used in conjunction with API 2SIM for the assessment of existing platforms in the event that it becomes necessary to make a determination of the fitness-for-purpose of the structure.

Adequate planning should be done before actual design is started in order to obtain a workable and economical offshore structure to perform a given function. The initial planning should include the determination of all criteria upon which the design of the platform is based.

4.1.2 Design Criteria

Design criteria as used herein include all operational requirements and environmental data that could affect the detailed design of the platform.

4.1.3 Codes and Standards

This publication has also incorporated and made maximum use of existing codes and standards that have been found acceptable for engineering design and practices from the standpoint of public safety.

4.2 Operational Considerations

4.2.1 Function

The function for which a platform is designed is usually categorized as drilling, producing, storage, materials handling, living quarters, or a combination of these. The platform configuration should be determined by a study of layouts of equipment to be located on the decks. Careful consideration should be given to the clearances and spacing of equipment before the final dimensions are decided upon.

4.2.2 Location

The location of the platform should be specific before the design is completed. Environmental conditions vary with geographic location; within a given geographic area, the foundation conditions generally vary as do such parameters as design wave heights, periods, and tides.

4.2.3 Orientation

The orientation of the platform refers to its position in the plan referenced to a fixed direction such as true north. Orientation is usually governed by the direction of prevailing seas, winds, currents, and operational requirements.

4.2.4 Water Depth

Information on water depth and tides is needed to select appropriate oceanographic design parameters. The water depth should be determined as accurately as possible so that elevations can be established for boat landings, fenders, decks, and corrosion protection.

4.2.5 Access and Auxiliary Systems

The location and number of stairways and access boat landings on the platform should be governed by safety considerations. A minimum of two accesses to each manned level should be installed and should be located so that escape is possible under varying conditions. Operating requirements should also be considered in stairway locations.

4.2.6 Fire Protection

The safety of personnel and possible destruction of equipment requires attention to fire protection methods. The selection of the system depends upon the function of the platform. Procedures should conform to all federal, state, and local regulations where they exist.

4.2.7 Deck Elevation

Large forces and overturning moments result when waves strike a platform's lower deck and equipment. Unless the platform has been designed to resist these forces, the elevation of the deck should be established to provide adequate clearance above the design maximum crest elevation. Consideration should be given to providing an "air gap" and an additional allowance for local maximum crest elevations, which are higher than the design maximum crest elevation. The deck elevation shall be determined in accordance with 5.3.4.3 and API 2MET.

4.2.8 Wells

Exposed well conductors add environmental forces to a platform and require support. Their number, size, and spacing should be known early in the planning stage. Conductor pipes may or may not assist in resisting the wave force. If the platform is to be set over an existing well with the wellhead above water, information is needed on the dimensions of the tree, size of conductor pipe, and the elevations of the casing head flange and top of wellhead above mean low water. If the existing well is a temporary subsea completion, plans should be made for locating the well and setting the platform properly so that the well can later be extended above the surface of the water. Planning should consider the need for future wells.

4.2.9 Equipment and Material Layouts

Layouts and weights of drilling equipment and material and production equipment are needed in the development of the design. Heavy concentrated loads on the platform should be located so that proper framing for supporting these loads can be planned. When possible, consideration should be given to future operations.

4.2.10 Personnel and Material Handling

Plans for handling personnel and materials should be developed at the start of the platform design, along with the type and size of supply vessels and the anchorage system required to hold them in position at the platform. The number, size, and location of the boat landings should be determined as well.

The type, capacity, number, and location of the deck cranes should also be determined. If equipment or materials are to be placed on a lower deck, then adequately sized and conveniently located hatches should be provided on the upper decks as appropriate for operational requirements. The possible use of helicopters should be established and facilities provided for their use.

4.2.11 Spillage and Contamination

Provision for handling spills and potential contaminants should be provided. A deck drainage system that collects and stores liquids for subsequent handling should be provided. The drainage and collection system should meet appropriate governmental regulations.

4.2.12 Exposure

Design of all systems and components should anticipate extremes in environmental phenomena that may be experienced at the site.

4.3 Environmental Considerations

4.3.1 General Meteorological and Oceanographic Considerations

Experienced specialists should be consulted when defining the pertinent meteorological and oceanographic conditions affecting a platform site. The following sections present a general summary of the information that could be required. Selection of information needed at a site should be made after consultation with both the platform designer and a meteorological-oceanographic specialist. Measured and/or model-generated data should be statistically analyzed to develop the descriptions of normal and extreme environmental conditions as follows.

- a) Normal environmental conditions (conditions that are expected to occur frequently during the life of the structure) are important both during the construction and the service life of a platform.
- b) Extreme conditions (conditions that occur quite rarely during the life of the structure) are important in formulating platform design loadings.

All data used should be carefully documented. The estimated reliability and the source of all data should be noted, and the methods employed in developing available data into the desired environmental values should be defined.

4.3.2 Winds

Wind forces are exerted upon that portion of the structure that is above the water, as well as on any equipment, deck houses, and derricks that are located on the platform. The wind speed may be classified as:

- gusts that average less than 1 min. in duration, and
- sustained wind speeds that average 1 min. or longer in duration.

Wind data should be adjusted to a standard elevation, such as 10 m (33 ft) above mean water level, with a specified averaging time, such as 1 hour. Wind data may be adjusted to any specified averaging time or elevation using standard profiles and gust factors (see 5.3.2).

The spectrum of wind speed fluctuations about the average should be specified in some instances. For example, compliant structures like compliant towers and tension leg platforms in deep water may have natural sway periods in the range of 1 min., in which there is significant energy in the wind speed fluctuations.

The following should be considered in determining appropriate design wind speeds.

For normal conditions:

- the frequency of occurrence of specified sustained wind speeds from various directions for each month or season,
- the persistence of sustained wind speeds above specified thresholds for each month or season,
- the probable speed of gusts associated with sustained wind speeds.

For extreme conditions:

- projected extreme wind speeds of specified directions and averaging times as a function of their recurrence interval should be developed. Data should be given concerning the following:
- the measurement site, date of occurrence, magnitude of measured gusts and sustained wind speeds, and wind directions for the recorded wind data used during the development of the projected extreme winds;
- the projected number of occasions during the specified life of the structure when sustained wind speeds from specified directions should exceed a specific lower bound wind speed.

4.3.3 Waves

Wind-driven waves are a major source of environmental forces on offshore platforms. Such waves are irregular in shape, vary in height and length, and may approach a platform from one or more directions simultaneously. For these reasons, the intensity and distribution of the forces applied by waves are difficult to determine. Because of the complex nature of the technical factors to be considered in developing wave-dependent criteria for the design of platforms, experienced specialists knowledgeable in the fields of meteorology, oceanography, and hydrodynamics should be consulted.

In those areas where prior knowledge of oceanographic conditions is insufficient, the development of wave-dependent design parameters shall include at least the following steps.

- Development of all necessary meteorological data.
- Projection of surface wind fields.
- Prediction of deepwater general seastates along storm tracks using an analytical model.
- Definition of maximum possible seastates consistent with geographical limitations.
- Delineation of bathymetric effects on seastates.

- Introduction of probabilistic techniques to predict seastate occurrences at the platform site against various time bases.
- Development of design wave parameters through physical and economic risk evaluation.

In areas where considerable previous knowledge and experience with oceanographic conditions exist, the foregoing sequence may be shortened to those steps needed to project this past knowledge into the required design parameters.

It is the responsibility of the platform owner to select the design seastate, after considering all of the factors listed in 4.5. In developing seastate data, consideration should be given to the following.

For normal conditions (for both wind seas and swell):

- for each month and/or season, the probability of occurrence and average persistence of various sea states [e.g. waves higher than 3 m (10 ft)] from specified directions in terms of general seastate description parameters (e.g. the significant wave height and the average wave period);
- the wind speeds, tides, and currents occurring simultaneously with the above seastates.

For extreme conditions:

- definition of the extreme seastates should provide an insight as to the number, height, and crest elevations of all waves above a certain height that might approach the platform site from any direction during the entire life of the structure. Projected extreme wave heights from specified directions should be developed and presented as a function of their expected average recurrence intervals. Other data that should be developed include:
- the probable range and distribution of wave periods associated with extreme wave heights;
- the projected distribution of other wave heights, maximum crest elevations, and the wave energy spectrum in the sea state producing an extreme wave height(s);
- the tides, currents, and winds likely to occur simultaneously with the seastate producing the extreme waves;
- the nature, date, and place of the events that produced the historical seastates, for example, Hurricane Camille, August 1969, U.S. Gulf of Mexico was used in the development of the projected values.

4.3.4 Tides

Tides are important considerations in platform design. Tides may be classified as:

- a) astronomical tide,
- b) wind tide, and
- c) pressure differential tide.

The latter two are frequently combined and called storm surge; the sum of the three tides is called the storm tide. In the design of a fixed platform, the storm tide elevation is the datum upon which storm waves are superimposed. The variations in elevations of the daily astronomical tides, however, determine the elevations of the boat landings, barge fenders, the splash zone treatment of the steel members of the structure, and the upper limits of marine growth.

4.3.5 Currents

Currents are important in the design of fixed platforms. They affect:

- the location and orientation of boat landings and barge bumpers, and
- the forces on the platform.

Where possible, boat landings and barge bumpers should be located to allow the boat to engage the platform as it moves against the current.

The most common categories of currents are:

- a) tidal currents (associated with astronomical tides),
- b) circulatory currents (associated with oceanic-scale circulation patterns), and
- c) storm-generated currents.

The vector sum of these three currents is the total current, and the speed and direction of the current at specified elevations is the current profile. The total current profile associated with the sea state producing the extreme waves should be specified for platform design. The frequency of occurrence of total current speed and direction at different depths for each month and/or season may be useful for planning operations.

4.3.6 Ice

In some areas where petroleum development is being carried out, subfreezing temperatures can prevail a major portion of the year, causing the formation of sea ice. Sea ice may exist in these areas as first-year sheet ice, multiyear floes, first-year and multiyear pressure ridges, and/or ice islands. Loads produced by ice features could constitute a dominant design factor for offshore platforms in the most severe ice areas such as the Alaskan Beaufort and Chukchi Seas, and Norton Sound. In milder climates, such as the southern Bering Sea and Cook Inlet, the governing design factor may be seismic or wave induced, but ice features would nonetheless influence the design and construction of the platforms considered.

Research in ice mechanics is being conducted by individual companies and joint industry groups to develop design criteria for arctic and subarctic offshore areas. Global ice forces vary depending on such factors as size and configuration of platform, location of platform, mode of ice failure, and unit ice strength. Unit ice strength depends on the ice feature, temperature, salinity, speed of load application, and ice composition. Forces to be used in design should be determined in consultation with qualified experts.

API 2N outlines conditions that shall be addressed in the design and construction of structures in arctic and subarctic offshore regions.

4.3.7 Active Geologic Processes

4.3.7.1 General

In many offshore areas, geologic processes associated with movement of the near-surface sediments occur within time periods that are relevant to fixed platform design. The nature, magnitude, and return intervals of potential seafloor movements should be evaluated by site investigations and judicious analytical modeling to provide input for determination of the resulting effects on structures and foundations. Because of uncertainties with definition of these processes, a parametric approach to studies may be helpful in the development of design criteria.

4.3.7.2 Earthquakes

Seismic forces should be considered in platform design for areas that are determined to be seismically active. Areas are considered seismically active on the basis of previous records of earthquake activity, both in frequency of occurrence and in magnitude. Seismic activity of an area for purposes of design of offshore structures is rated in terms of possible severity of damage to these structures. The seismic maps for U.S. coastal waters contained in API 2EQ shall be used if no detailed investigation regarding the seismicity of an area has been performed.

4.3.7.3 Faults

In some offshore areas, fault planes may extend to the seafloor with the potential for either vertical or horizontal movement. Fault movement can occur as a result of seismic activity, removal of fluids from deep reservoirs, or long-term creep related to large-scale sedimentation or erosion. Siting of facilities in close proximity to fault planes intersecting the seafloor should be avoided if possible. If circumstances dictate siting structures near potentially active features, the magnitude and time scale of expected movement should be estimated on the basis of geologic study for use in the platform design.

4.3.7.4 Seafloor Instability

Movement of the seafloor can occur as a result of loads imposed on the soil mass by ocean wave pressures, earthquakes, soil self-weight, or combination of these phenomena. Weak, under-consolidated sediments occurring in areas where wave pressures are significant at the seafloor are most susceptible to wave-induced movement and may be unstable under negligible slope angles. Earthquake-induced forces can induce failure of seafloor slopes that are otherwise stable under the existing self-weight forces and wave conditions.

In areas of rapid sedimentation, such as actively growing deltas, low soil strength, soil self-weight, and wave-induced pressures are believed to be the controlling factors for the geologic processes that continually move sediment downslope. Important platform design considerations under these conditions include the effects of large-scale movement of sediment in areas subjected to strong wave pressures, downslope creep movements in areas not directly affected by wave-seafloor interaction, and the effects of sediment erosion and/or deposition on platform performance.

The scope of site investigations in areas of potential instability should focus on identification of metastable geologic features surrounding the site and definition of the soil engineering properties required for modeling and estimating seafloor movements.

Analytical estimates of soil movement as a function of depth below the mudline can be used with soil engineering properties to establish expected forces on platform members. Geologic studies employing historical bathymetric data may be useful for quantifying deposition rates during the design life of the facility.

4.3.7.5 Scour

Scour is removal of seafloor soils caused by currents and waves. Such erosion can be a natural geologic process or can be caused by structural elements interrupting the natural flow regime near the seafloor.

From observation, scour can usually be characterized as some combination of the following.

- a) Local scour—steep-sided scour pits around such structure elements as piles and pile groups, generally as seen in flume models.
- b) Global scour—shallow scoured basins of large extent around a structure, possibly due to overall structure effects, multiple structure interaction, or wave/soil/structure interaction.
- c) Overall seabed movement—movement of sandwaves, ridges, and shoals that would occur in the absence of a structure. This movement can be caused by lowering or accumulation.

The presence of mobile seabed sandwaves, sandhills, and sand ribbons indicates a vigorous natural scour regime. Past bed movement may be evidenced by geophysical contrasts or by variation in density, grading, color, or biological indicators in seabed samples and soundings. Sand or silt soils in water depths less than about 40 m (130 ft) are particularly susceptible to scour, but scour has been observed in cobbles, gravels, and clays; in deeper water, the presence of scour depends on the vigor of currents and waves.

Scour can result in removal of vertical and lateral support for foundations, causing undesirable settlements of mat foundations and overstressing of foundation elements. Where scour is a possibility, it should be accounted for in design and/or its mitigation should be considered. Offshore scour phenomena are described in References [36] and [37].

4.3.7.6 Shallow Gas

The presence of either biogenic or petrogenic gas in the pore water of near-mudline soils is an engineering consideration in offshore areas. In addition to being a potential drilling hazard for both site investigation soil borings and oil well drilling, the effects of shallow gas may be important to engineering of the foundation. The importance of assumptions regarding shallow gas effects on interpreted soil engineering properties and analytical models of geologic processes should be established during initial stages of the design.

4.3.7.7 Marine Growth

Offshore structures accumulate marine growth to some degree in all the world's oceans. Marine growth is generally greatest near the mean water level but in some areas may be significant 60 m (200 ft) or more below the mean water level. Marine growth increases wave forces (by increasing member diameter and surface roughness) and mass of the structure and should be considered in design.

4.3.7.8 Tsunamis

Platforms in shallow water that may be subjected to tsunamis shall be investigated for the effects of the resulting forces.

4.3.7.9 Other Environmental Information

Depending on the platform site, other environmental information of importance includes records and/or predictions with respect to precipitation, fog, wind chill, air temperatures, and sea temperatures. General information on the various types of storms that might affect the platform site should be used to supplement other data developed for normal conditions. Statistics can be compiled giving the expected occurrence of storms by season, direction of approach, etc. Of special interest for construction planning are the duration, the speed of movement and development, and the extent of these conditions. Also of major importance is the ability to forecast storms in the vicinity of a platform.

4.4 Site Investigation—Foundations

4.4.1 Site Investigation Objectives

Knowledge of the soil conditions existing at the site of construction on any sizable structure is necessary to permit a safe and economical design. On-site soil investigations should be performed to define the various soil strata and their corresponding physical and engineering properties. Previous site investigations and experience at the site may permit the installation of additional structures without additional studies.

The initial step for a site investigation is reconnaissance. Information may be collected through a review of available geophysical data and soil boring data available in engineering files, literature, or government files. The purpose of this review is to identify potential problems and to aid in planning subsequent data acquisition phases of the site investigation.

Soundings and any required geophysical surveys should be part of the on-site studies and generally should be performed before borings. These data should be combined with an understanding of the shallow geology of the region to develop the required foundation design parameters. The on-site studies should extend throughout the depth and areal extent of soils that will affect or be affected by installation of the foundation elements.

4.4.2 Seabottom Surveys

The primary purpose of a geophysical survey in the vicinity of the site is to provide data for a geologic assessment of foundation soils and the surrounding area that could affect the site. Geophysical data provide evidence of slumps, scarps, irregular or rough topography, mud volcanoes, mud lumps, collapse features, sand waves, slides, faults, diapirs, erosional surfaces, gas bubbles in the sediments, gas seeps, buried channels, and lateral variations in strata thicknesses. The areal extent of shallow soil layers may sometimes be mapped if good correspondence can be established between the soil boring information and the results from the seabottom surveys.

The geophysical equipment used includes the following:

- a) sub-bottom profiler (tuned transducer) for definition of bathymetry and structural features within the near-surface sediments;
- b) side-scan sonar to define surface features;
- c) boomer or minisparker for definition of structure to depths past a hundred meters (few hundred feet) below the seafloor;

- d) sparker, air gun, water gun, or sleeve exploder for definition of structure at deeper depths and to tie together with deep seismic data from reservoir studies.

Shallow sampling of near-surface sediments using drop, piston, grab samplers, or vibrocore along geophysical track lines may be useful for calibration of results and improved definition of the shallow geology.

See Reference [38] for a more detailed description of commonly used seabottom survey systems.

4.4.3 Soil Investigation and Testing

If practical, the soil sampling and testing program should be defined after a review of the geophysical results. On-site soil investigation should include one or more soil borings to provide samples suitable for engineering property testing and a means to perform in situ testing, if required. The number and depth of borings depend on the soil variability in the vicinity of the site and the platform configuration. Likewise, the degree of sophistication of soil sampling and preservation techniques, required laboratory testing, and the need for in situ property testing are a function of the platform design requirements and the adopted design philosophy.

As a minimum requirement, the foundation investigation for pile-supported structures should provide the soil engineering property data needed to determine the following parameters:

- a) axial capacity of piles in tension and compression,
- b) load-deflection characteristics of axially and laterally loaded piles,
- c) pile driveability characteristics,
- d) mudmat bearing capacity.

The required scope of the soil sampling, in situ testing, and laboratory testing programs is a function of the platform design requirements and the need to characterize active geologic processes that may affect the facility. For novel platform concepts, deepwater applications, platforms in areas of potential slope instability, and gravity-base structures, the geotechnical program should be tailored to provide the data necessary for pertinent soil-structure interaction and pile capacity analyses.

When performing site investigations in frontier areas or areas known to contain carbonate material, the investigation should include diagnostic methods to determine the existence of carbonate soils. Typically, carbonate deposits are variably cemented and range from lightly cemented with sometimes significant void spaces to extremely well-cemented. In planning a site investigation program, there should be enough flexibility in the program to switch between soil sampling, rotary coring, and in situ testing as appropriate. Qualitative tests should be performed to establish the carbonate content. In a soil profile that contains carbonate material (usually in excess of 15 % to 20 % of the soil fraction) engineering behavior of the soil could be adversely affected. In these soils additional field and laboratory testing and engineering may be warranted.

4.5 Selecting the Design Environmental Conditions

Selection of the environmental conditions to which platforms are designed shall be the responsibility of the owner. The design environmental criteria should be developed from the environmental information

described in 4.3, and may also include a risk analysis where prior experience is limited. The risk analysis may include the following:

- historical experience;
- the planned life and intended use of the platform;
- the possible loss of human life;
- prevention of pollution;
- the estimated cost of the platform designed to environmental conditions for several average expected recurrence intervals;
- the probability of platform damage or loss when subjected to environmental conditions with various recurrence intervals;
- the financial loss due to platform damage or loss including lost production, cleanup, replacing the platform and redrilling wells, etc.

As a guide, the recurrence interval for oceanographic design criteria should be several times the planned life of the platform. Experience with major platforms in the U.S. Gulf of Mexico supports the use of 100-year oceanographic design criteria. This is applicable only to new and relocated platforms that are manned during the design event or that are structures where the loss of or severe damage to the structure could result in a high consequence of failure. Consideration may be given to reduced design requirements for the design or relocation of other structures that are unmanned or evacuated during the design event and have either a shorter design life than the typical 20 years or where the loss of or severe damage to the structure would not result in a high consequence of failure. Guidelines to assist in the establishment of the exposure category to be used in the selection of criteria for the design of new platforms are provided in 4.7. Risk analyses may justify either longer or shorter recurrence intervals for design criteria. However, not less than 100-year oceanographic design criteria shall be considered where the design event may occur without warning while the platform is manned and/or when there are restrictions on the speed of personnel removal (e.g. great flying distances).

Section 5 provides guidelines for developing oceanographic design criteria that are appropriate for use with the exposure category levels defined in 4.7. For all new Category L-1 structures located in U.S. waters, the use of nominal 100-year return period is recommended. For all new Category L-2 and L-3 structures located in the U.S. Gulf of Mexico north of 27 °N latitude and west of 86 °W longitude, guidelines for using shorter return criteria are provided.

Where sufficient information is available, the designer may take into account the variation in environmental conditions expected to occur from different directions. When this is considered, an adequate tolerance in platform orientation should be used in the design of the platform and measures shall be employed during installation to ensure the platform is positioned within the allowed tolerance.

Structures should be designed for the combination of wind, wave, and current conditions causing the extreme load, accounting for their joint probability of occurrence (both magnitude and direction). For most template, tower, gravity, and caisson types of platforms, the design fluid dynamic load is predominantly due to waves, with currents and winds playing a secondary role. The design conditions, therefore, consist of the wave conditions and the currents and winds likely to coexist with the design waves. For compliant

structures, response to waves is reduced so that winds and currents become relatively more important. Also, for structures in shallow water and structures with a large deck and/or superstructure, the wind load may be a more significant portion of the total environmental force. This may lead to multiple sets of design conditions including, as an example, for Level L-1 structures:

- the 100-year waves with associated winds and currents, and
- the 100-year winds with associated waves and currents.

Two levels of earthquake environmental conditions are needed to address the risk of damage or structure collapse. These are:

- a) ground motion, which has a reasonable likelihood of not being exceeded at the site during the platform life; and
- b) ground motion for a rare, intense earthquake.

Consideration of the foregoing factors has led to the establishment of the hydrodynamic force guidelines of 5.3.4 and the guidelines for earthquake design of 5.3.6.

4.6 Platform Types

4.6.1 Fixed Platforms

4.6.1.1 General

A fixed platform is defined as a platform extending above the water surface and supported at the seabed by means of piling, spread footing(s), or other means with the intended purpose of remaining stationary over an extended period.

4.6.1.2 Jackets or Templates

These type platforms generally consist of the following:

- completely braced, redundant welded tubular space frame extending from an elevation at or near the sea bed to above the water surface, which is designed to serve as the main structural element of the platform, transmitting lateral and vertical forces to the foundation;
- piles or other foundation elements that permanently anchor the platform to the ocean floor and carry both lateral and vertical loads;
- a superstructure providing deck space for supporting operational and other loads.

4.6.1.3 Towers

A tower platform is a modification of the jacket platform that has relatively few large diameter [e.g. 5 m (15 ft)] legs. Some towers may be floated to location and placed in position by selective flooding. Tower platforms may or may not be supported by piling. Where piles are used, they are driven through sleeves inside or attached to the outside of the legs. The piling may also serve as well conductors. If the tower's support is furnished by spread footings instead of by piling, the well conductors may be installed either inside or outside the legs.

4.6.1.4 Gravity Structures

A gravity structure is one that relies on the weight of the structure rather than piling to resist environmental loads.

4.6.1.5 Minimum Nonjacket and Special Structures

Many structures have been installed and are serving satisfactorily that do not meet the definition for jacket type platforms as defined above. In general, these structures do not have reserve strength or redundancy equal to conventional jacket type structures. For this reason, special recommendations regarding design and installation are provided in Section 19. Minimum structures are defined as structures that have one or more of the following attributes:

- a) structural framing that provides less reserve strength and redundancy than a typical well-braced, three-leg template type platform;
- b) freestanding and guyed caisson platforms that consist of one large tubular member supporting one or more wells;
- c) well conductor(s) or freestanding caisson(s), which are utilized as structural and/or axial foundation elements by means of attachment using welded, nonwelded, or nonconventional welded connections;
- d) threaded, pinned, or clamped connections to foundation elements (piles or pile sleeves);
- e) braced caissons and other structures where a single element structural system is a major component of the platform, such as a deck supported by a single deck leg or caisson.

4.6.1.6 Compliant Towers

A compliant tower is a bottom-founded structure having substantial flexibility. It is flexible enough that applied dynamic forces are resisted in significant part by inertial forces. The result is a reduction in forces transmitted to the supporting foundation. Guyed towers are included in this category as they are normally compliant, unless the guying system is very stiff. Compliant towers are covered in this document only to the extent that the provisions are applicable.

4.6.2 Floating Production Systems

A number of different floating structures are being developed and used as floating production systems (e.g. tension leg platforms, spars, semisubmersibles). Many aspects of this document are applicable to certain aspects of the design of these structures. API 2FPS ^[4] provides general guidance for floating production systems while API 2T ^[7] provides specific advice for TLPs.

4.6.3 Related Structures

Other structures include underwater oil storage tanks, bridges connecting platforms, flare booms, drilling derricks, etc. Specific advice regarding tie-downs for these types of structures is provided in API 2TD.

4.7 Exposure Categories

4.7.1 General

Structures can be categorized by various levels of exposure to determine criteria for the design of new platforms and the assessment of existing platforms that are appropriate for the intended service of the structure.

The levels are determined by consideration of life safety and consequences of failure. Life safety considers the maximum anticipated environmental event that would be expected to occur while personnel are on the platform. Consequences of failure should consider the factors listed in 4.5 and discussed in B.4.7. Such factors include anticipated losses to the owner (platform and equipment repair or replacement, lost production, cleanup), anticipated losses to other operators (lost production through trunklines), and anticipated losses to industry and government.

Categories for life safety are as follows:

- S-1 is manned-nonevacuated,
- S-2 is manned-evacuated,
- S-3 is unmanned.

Categories for consequences of failure are as follows:

- C-1 is high consequence of failure,
- C-2 is medium consequence of failure,
- C-3 is low consequence of failure.

The level to be used for platform categorization is the more restrictive level for either life safety or consequence of failure. Platform categorization may be revised over the life of the structure as a result of changes in factors affecting life safety or consequence of failure.

The exposure category should be determined using the matrix provided in Table 4.1.

Table 4.1—Exposure Category Matrix

Life Safety Category	Consequence Category		
	C-1, High Consequence	C-2, Medium Consequence	C-3, Low Consequence
S-1 manned-nonevacuated	L-1 ^a	L-1 ^a	L-1 ^a
S-2 manned-evacuated	L-1	L-2	L-2
S-3 unmanned	L-1	L-2	L-3
^a Manned-nonevacuated platforms are presently not applicable to the U.S. GoM waters where platforms are normally evacuated ahead of hurricane events. The metocean design criteria in Section 5 have not been verified as adequate for manned-nonevacuated in the U.S. GoM. However, the winter storm, sudden hurricane, and earthquake criteria for the U.S. GoM have been verified as adequate for the manned-nonevacuated situation occurring during those events when platforms in the U.S. GoM waters are not normally evacuated.			

4.7.2 Life Safety

4.7.2.1 General

The determination of the applicable level for life safety should be based on the following descriptions in 4.7.2.2 through 4.7.2.4.

4.7.2.2 S-1, Manned-nonevacuated

The manned-nonevacuated category refers to a platform that is continuously (or nearly continuously) occupied by persons accommodated and living thereon and from which personnel evacuation prior to the design environmental event is either not intended or impractical. A platform shall be categorized as S-1 manned-nonevacuated unless the particular requirements for S-2 or S-3 apply throughout the design service life of the platform.

4.7.2.3 S-2, Manned-evacuated

The manned-evacuated category refers to a platform that is normally manned except during a forecast design environmental event. For categorization purposes, a platform shall not be categorized as a manned-evacuated platform unless all of the following apply:

- a) reliable forecast of a design environmental event is technically and operationally feasible, and the weather between any such forecast and the occurrence of the design environmental event is not likely to inhibit an evacuation;
- b) prior to a design environmental event, evacuation is planned;
- c) sufficient time and resources exist to safely evacuate all personnel from the platform and all other platforms likely to require evacuation for the same storm.

4.7.2.4 S-3, Unmanned

The unmanned category refers to a platform that is not normally manned or a platform that is not classified as either manned-nonevacuated or manned-evacuated. Platforms in this classification may include emergency shelters. However, platforms with permanent quarters are defined as manned and should be classified as manned-nonevacuated or as manned-evacuated as defined above. An occasionally manned platform may be categorized as unmanned only in certain conditions (see B.4.7.2.4).

4.7.3 Consequence of Failure

4.7.3.1 General

As stated in 4.7.1, consequences of failure should include consideration of anticipated losses to the owner, the other operators, and the industry in general. The following descriptions of relevant factors serve as a basis for determining the appropriate level for consequence of failure.

4.7.3.2 C-1 High Consequence

The high consequence of failure category refers to major platforms and/or those platforms that have the potential for well flow of either oil or sour gas in the event of platform failure. In addition, it includes platforms where the shut-in of the oil or sour gas production is not planned or not practical prior to the

occurrence of the design event (such as areas with high seismic activity). Platforms that support major oil transport lines [see B.4.7.3 c)] and/or storage facilities for intermittent oil shipment are also considered to be in the high consequence category. All new U.S. Gulf of Mexico platforms that are designed for installation in water depths greater than 122 m (400 ft) are included in this category unless a lower consequence of failure can be demonstrated to justify a reduced classification.

4.7.3.3 C-2 Medium Consequence

The medium consequence of failure category refers to platforms where production would be shut-in during the design event. All wells that could flow on their own in the event of platform failure shall contain fully functional, subsurface safety valves, which are manufactured and tested in accordance with the applicable API specifications. Oil storage is limited to process inventory and “surge” tanks for pipeline transfer.

4.7.3.4 C-3 Low Consequence

The low consequence of failure category refers to minimal platforms where production would be shut-in during the design event. All wells that could flow on their own in the event of platform failure shall contain fully functional, subsurface safety valves, which are manufactured and tested in accordance with applicable API specifications. These platforms may support production departing from the platform and low volume infield pipelines. Oil storage is limited to process inventory. New U.S. Gulf of Mexico platforms in this category includes caissons or small well protectors with no more than five well completions on or connected to the platform and no more than two conductors at the platform. Total deck area (excluding helideck) is limited to 37 m² (400 ft²) and contains no more than two pieces of production equipment. In addition, platforms in this category are defined as structures in water depths not exceeding 30 m (100 ft).

4.8 Platform Reuse

Existing platforms may be removed and relocated for continued use at a new site. When relocation is considered, the platform should be inspected to ensure that it is in (or can be returned to) an acceptable condition. In addition, it should be reanalyzed and reevaluated for the use, conditions, and loading anticipated at the new site. In general, this inspection, reevaluation, and any required repairs or modification should follow the procedures and provisions for new platforms that are stated in this recommended practice. Additional special provisions regarding reuse are listed in Section 18.

4.9 Platform Assessment

An assessment to determine fitness-for-purpose may be required during the life of a platform. This procedure is normally initiated by a change in the platform usage such as revised manning or loading, by modifications to the condition of the platform such as damage or deterioration, or by a reevaluation of the environmental loading or the strength of the foundation. General industry practices recognize that older, existing structures may not meet current design standards. However, many of these platforms that are in an acceptable condition can be shown to be structurally adequate using a risk-based assessment criteria that considers platform use, location, and the consequences of failure. Guidance on how to assess an existing platform is provided in API 2SIM.

4.10 Safety Considerations

The safety of life and property depends upon the ability of the structure to support the loads for which it was designed and to survive the environmental conditions that may occur. Over and above this overall

concept, good practice dictates use of certain structural additions, equipment, and operating procedures on a platform so that injuries to personnel will be minimized and the risk of fire, blast, and accidental loading (e.g. collision from ships, dropped objects) is reduced. Governmental regulations listed in 4.11 and all other applicable regulations should be met.

4.11 Regulations

Each country has its own set of regulations concerning offshore operations. Listed below are some of the typical rules and regulations that, if applicable, should be considered when designing and installing offshore platforms in U.S. territorial waters. Other regulations may also be in effect. It is the responsibility of the operator to determine which rules and regulations are applicable and should be followed, depending upon the location and type of operations to be conducted.

- a) 33 *Code of Federal Regulations* Parts 140 to 147, *Outer Continental Shelf Activities*, U.S. Coast Guard, Department of Transportation. These regulations stipulate requirements for identification marks for platforms, means of escape, guard rails, fire extinguishers, life preservers, ring buoys, first-aid kits, etc.
- b) 33 *Code of Federal Regulations* Part 67, *Aids to Navigation on Artificial Islands and Fixed Structures*, U.S. Coast Guard, Department of Transportation. These regulations prescribe in detail the requirements for installation of lights and foghorns on offshore structures in various zones.
- c) 30 *Code of Federal Regulations* Part 250, *Oil and Gas and Sulphur Operations in the Outer Continental Shelf*. These regulations govern the marking, design, fabrication, installation, operation, and removal of offshore structures and related appurtenances.
- d) 29 *Code of Federal Regulations* Part 1910, *Occupational Safety and Health Standards*. These regulations provide requirements for safe design of floors, handrails, stairways, ladders, etc. Some of the requirements may apply to components of offshore structures that are located in state waters.
- e) 33 *Code of Federal Regulations* Part 330, *Nationwide Permit Program*, U.S. Corps of Engineers. This document describes requirements for making application for permits for work (e.g. platform installation) in navigable waters. Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act apply to state waters.
- f) *Obstruction Marking and Lighting*, Federal Aviation Administration. This booklet sets forth requirements for marking towers, poles, and similar obstructions. Platforms with derricks, antennae, etc. are governed by the rules set forth in this booklet. Additional guidance is provided by API 2L.
- g) Various state and local agencies (e.g. U.S. Department of Wildlife and Fisheries) require notification of any operations that may take place under their jurisdiction.

Other regulations concerning offshore pipelines, facilities, drilling operations, etc. may be applicable and should be consulted.

5 Design Criteria and Procedures

5.1 General

5.1.1 Dimensional System

All drawings, calculations, etc. should be consistent in a single dimensional system, such as metric (SI) or U.S. customary (USC) units.

5.1.2 Definition of Loads

5.1.2.1 General

The following loads and any dynamic effects resulting from them should be considered in the development of the design loading conditions in 5.2.1.

5.1.2.2 Dead Loads

Dead loads are the weights of the platform structure and any permanent equipment and appurtenant structures that do not change with the mode of operation. Dead loads should include the following:

- a) weight of the platform structure in air, including where appropriate the weight of piles, grout, and ballast;
- b) weight of equipment and appurtenant structures permanently mounted on the platform;
- c) hydrostatic forces acting on the structure below the waterline including external pressure and buoyancy.

5.1.2.3 Live Loads

Live loads are the loads imposed on the platform during its use that may change either during a mode of operation or from one mode of operation to another. Live loads should include the following:

- a) the weight of drilling and production equipment, which can be added or removed from the platform;
- b) the weight of living quarters, heliport, and other life support equipment, life-saving equipment, diving equipment, and utilities equipment, which can be added or removed from the platform;
- c) the weight of consumable supplies and liquids in storage tanks;
- d) the forces exerted on the structure from operations such as drilling, material handling, vessel mooring, and helicopter loadings;
- e) the forces exerted on the structure from deck crane usage. These forces are derived from consideration of the suspended load and its movement as well as dead load.

5.1.2.4 Environmental Loads

Environmental loads are loads imposed on the platform by natural phenomena including wind, current, wave, earthquake, snow, ice, and earth movement. Environmental loads also include the variation in hydrostatic pressure and buoyancy on members caused by changes in the water level due to waves and

tides. Environmental loads should be anticipated from any direction unless knowledge of specific conditions makes a different assumption more reasonable.

5.1.2.5 Construction Loads

Loads resulting from fabrication, loadout, transportation, and installation should be considered in design and are further defined in 5.4.

5.1.2.6 Removal and Reinstallation Loads

For platforms that are to be relocated to new sites, loads resulting from removal, unloading, transportation, upgrading, and reinstallation should be considered in addition to the above construction loads.

5.1.2.7 Dynamic Loads

Dynamic loads are the loads imposed on the platform due to response to an excitation of a cyclic nature or due to reacting to impulsive loads or impact. Excitation of a platform may be caused by waves, wind, earthquake, or machinery. Impact may be caused by a barge or boat berthing against the platform or by drilling operations.

5.2 Loading Conditions

5.2.1 General

Design environmental load conditions are those forces imposed on the platforms by the selected design event, whereas operating environmental load conditions are those forces imposed on the structure by a lesser event that is not severe enough to restrict normal operations, as specified by the operator.

5.2.2 Design Loading Conditions

The platform should be designed for the appropriate loading conditions that produce the most severe effects on the structure. The loading conditions should include environmental conditions combined with appropriate dead and live loads as indicated in Table 5.1.

Table 5.1—Design Loading Conditions

Loading Condition	Description
1	Operating environmental conditions combined with dead loads and maximum live loads appropriate to normal operations of the platform.
2	Operating environmental conditions combined with dead loads and minimum live loads appropriate to the normal operations of the platform.
3	Design environmental conditions with dead loads and maximum live loads appropriate for combining with extreme conditions.
4	Design environmental conditions with dead loads and minimum live loads appropriate for combining with extreme conditions.

Environmental loads, with the exception of earthquake load, should be combined in a manner consistent with the probability of their simultaneous occurrence during the loading condition being considered.

Earthquake load, where applicable, should be imposed on the platform as a separate environmental loading condition.

The operating environmental conditions should be representative of moderately severe conditions at the platform. They should not necessarily be limiting conditions that, if exceeded, require the cessation of platform operations. Typically, a 1-year to 10-year winter storm is used as an operating condition in the Gulf of Mexico. API 2MET or site-specific data developed in accordance with the requirements of API 2MET shall be used for specific values of the associated environmental conditions.

Maximum live loads for drilling and production platforms should consider drilling, production, and workover mode loadings and any appropriate combinations of drilling or workover operations with production.

Variations in supply weights and the locations of movable equipment such as a drilling derrick should be considered to maximize design stress in the platform members.

5.2.3 Temporary Loading Conditions

Temporary loading conditions occurring during fabrication, transportation, installation, or removal and reinstallation of the structure should be considered. For these conditions a combination of the appropriate dead loads, maximum temporary loads, and the appropriate environmental loads should be considered.

5.2.4 Member Loadings

Each platform member should be designed for the loading condition that produces the maximum stress in the member, taking into consideration the allowable stress for the loading condition producing this stress.

5.3 Design Loads

5.3.1 Waves

5.3.1.1 General

The wave loads on a platform are dynamic in nature. For most design water depths presently encountered, these loads may be adequately represented by their static equivalents. For deeper waters or where platforms tend to be more flexible, the static analysis may not adequately describe the true dynamic loads induced in the platform. Correct analysis of such platforms requires a load analysis accounting for the dynamic response of the structure.

5.3.1.2 Static Wave Analysis

5.3.1.2.1 General

The sequence of steps in the calculation of deterministic static design wave forces on a fixed platform (neglecting platform dynamic response and distortion of the incident wave by the platform) is shown graphically in Figure 5.1. The procedure, for a given wave direction, begins with the specification of the design wave height and associated wave period, storm water depth, and current profile. The parameters for U.S. waters specified in API 2MET or site-specific data developed in accordance with the requirements of API 2MET shall be used. The wave force calculation procedure follows these steps.

- 1) An apparent wave period is determined, accounting for the Doppler effect of the current on the wave.

- 2) The two-dimensional wave kinematics are determined from an appropriate wave theory for the specified wave height, storm water depth, and apparent period.
- 3) The horizontal components of wave-induced particle velocities and accelerations are reduced by the wave kinematics factor, which accounts primarily for wave directional spreading.
- 4) The effective local current profile is determined by multiplying the specified current profile by the current blockage factor.
- 5) The effective local current profile is combined vectorially with the wave kinematics to determine locally incident fluid velocities and accelerations for use in Morison's equation.
- 6) Member dimensions are increased to account for marine growth.
- 7) Drag and inertia force coefficients are determined as functions of wave and current parameters, member shape, roughness (marine growth), size, and orientation.
- 8) Wave force coefficients for the conductor array are reduced by the conductor shielding factor.
- 9) Hydrodynamic models for risers and appurtenances are developed.
- 10) Local wave/current forces are calculated for all platform members, conductors, risers, and appurtenances using Morison's equation.
- 11) The global force is computed as the vector sum of all the local forces.

The discussion in the remainder of this section is in the same order as the steps listed above. There is also some discussion on local forces (such as slam and lift) that are not included in the global force.

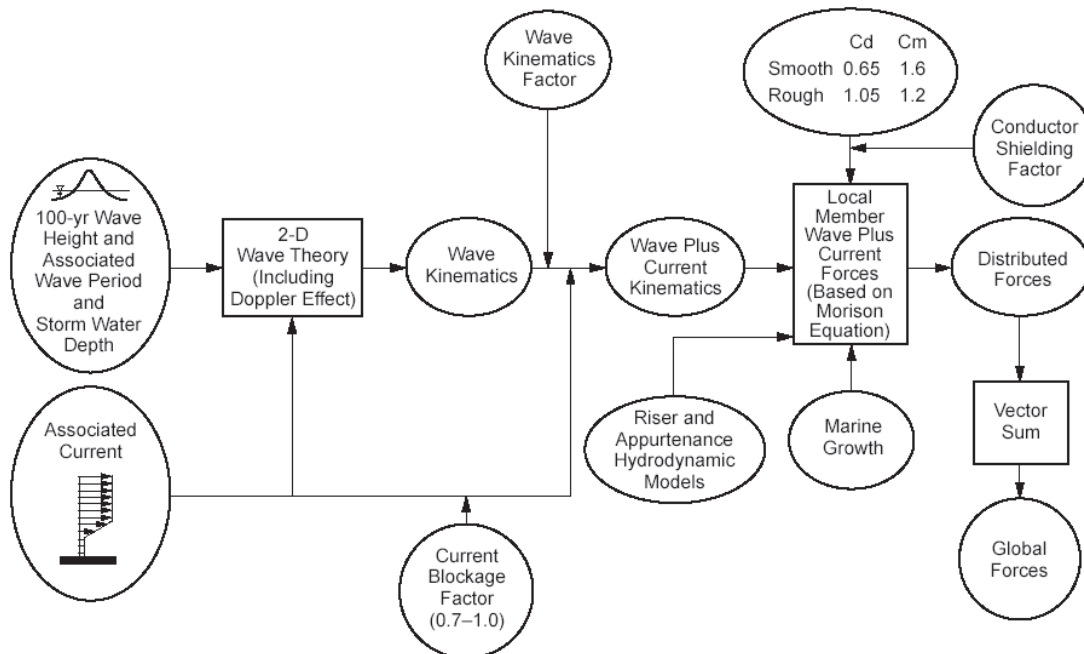


Figure 5.1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

5.3.1.2.2 Apparent Wave Period

A current in the wave direction tends to stretch the wavelength, while an opposing current shortens it. For the simple case of a wave propagating on a uniform in-line current, the apparent wave period seen by an observer moving with the current can be estimated from Figure 5.2, in which T is the actual wave period (as seen by a stationary observer). V_i is the current component in the wave direction, d , is storm water depth (including storm surge and tide), and g is the acceleration of gravity. This figure provides estimates for $d/gT^2 > 0.01$. For smaller values of d/gT^2 , the equation $(T_{app}/T) = 1 + V_i\sqrt{gd}$ can be used. While strictly applicable only to a current that is uniform over the full water depth, Figure 5.2 provides acceptable estimates of T_{app} for “slab” current profiles that are uniform over the top 50 m (165 ft) or more of the water column. For other current profiles, T_{app} (see B.5.3.1.2.2) is generally determined from the iterative solution of a system of simultaneous nonlinear equations. The current used to determine T_{app} should be the free-stream current (not reduced by structure blockage).

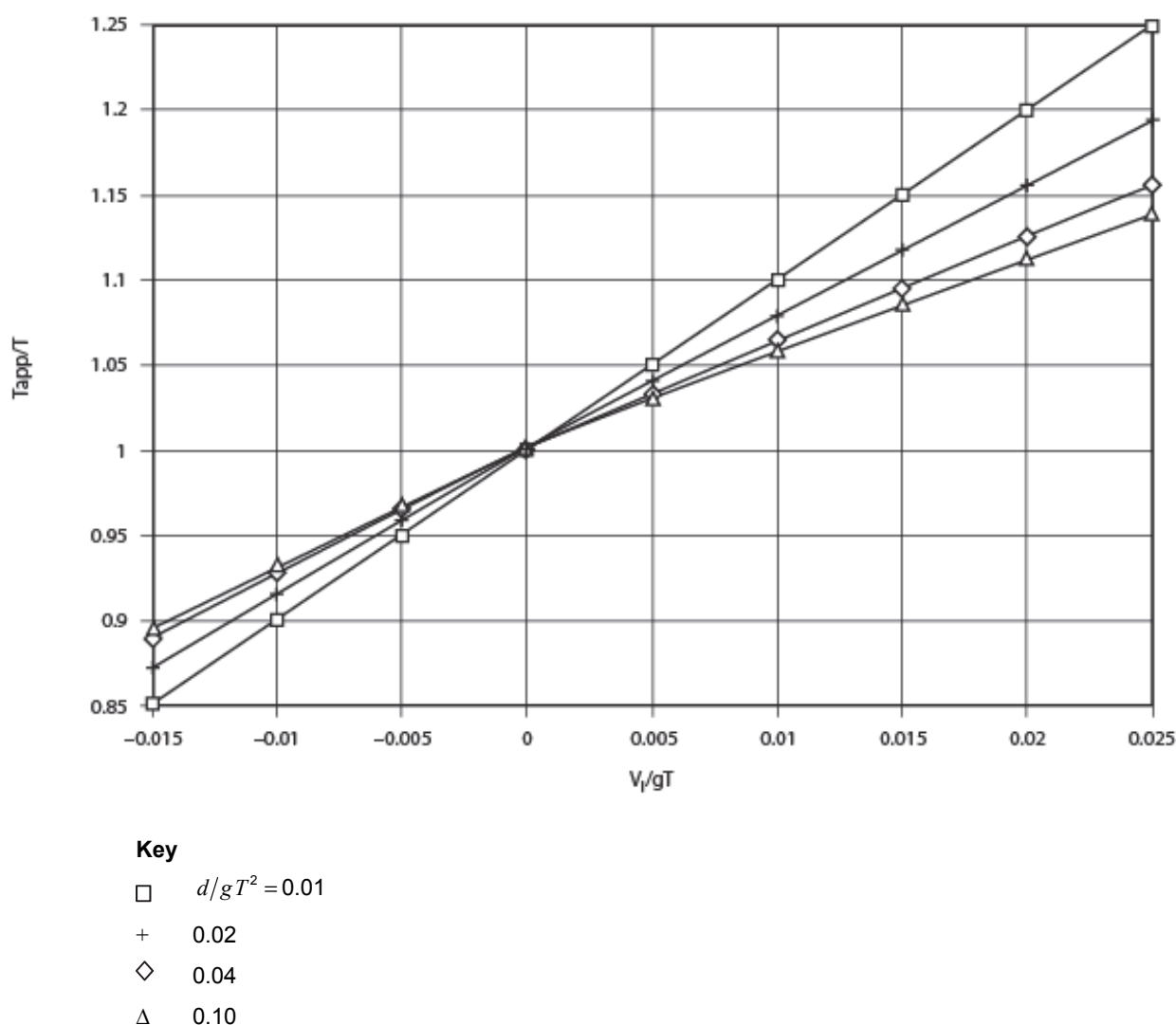


Figure 5.2—Doppler Shift Due to Steady Current

5.3.1.2.3 Two-dimensional Wave Kinematics

For the apparent wave period T_{app} , specified wave height H , and storm water depth, d , two-dimensional regular wave kinematics can be calculated using the appropriate order of stream function wave theory. In many cases, Stokes V wave theory produces acceptable accuracy. Figure 5.3 shows the regions of applicability of Stokes V and various orders of stream function solutions in the H/gT_{app}^2 , d/gT_{app}^2 plane.

Other wave theories, such as extended velocity potential and Chappellear, may be used if an appropriate order of solution is selected.

5.3.1.2.4 Wave Kinematics Factor

The two-dimensional regular wave kinematics from stream function or Stokes V wave theory do not account for wave directional spreading or irregularity in wave profile shape. These “real world” wave characteristics can be approximately modeled in deterministic wave analyses by multiplying the horizontal velocities and accelerations from the two-dimensional regular wave solution by a wave kinematics factor. Wave kinematics measurements support a factor in the range 0.85 to 0.95 for tropical storms and 0.95 to 1.00 for extratropical storms. Particular values within these ranges that shall be used for calculating guideline wave forces are specified for the Gulf of Mexico and for other U.S. waters in API 2MET. Section B.5.3.1.2.4 provides additional guidance for calculating the wave kinematics factor for particular sea states whose directional spreading characteristics are known from measurements or hindcasts.

5.3.1.2.5 Current Blockage Factor

The current speed in the vicinity of the platform is reduced from the specified “free stream” value by blockage. In other words, the presence of the structure causes the incident flow to diverge; some of the incident flow goes around the structure rather than through it, and the current speed within the structure is reduced. Since global platform loads are determined by summing local loads from Morison’s equation, the appropriate local current speed should be used. Table 5.2 gives typical current blockage factors for Gulf of Mexico jacket platforms.

For structures with other configurations or structures with a typical number of conductors, a current blockage factor can be calculated with the method described in B.5.3.1.2.5. Calculated factors less than 0.7 should not be used without empirical evidence to support them. For freestanding or braced caissons the current blockage factor should be 1.0.

Table 5.2—Approximate Current Blockage Factors for Typical Gulf of Mexico Jacket-type Structures

Number of Legs	Heading	Factor
3	all	0.90
4	end-on	0.80
	diagonal	0.85
	broadside	0.80
6	end-on	0.75
	diagonal	0.85
	broadside	0.80
8	end-on	0.70
	diagonal	0.85
	broadside	0.80

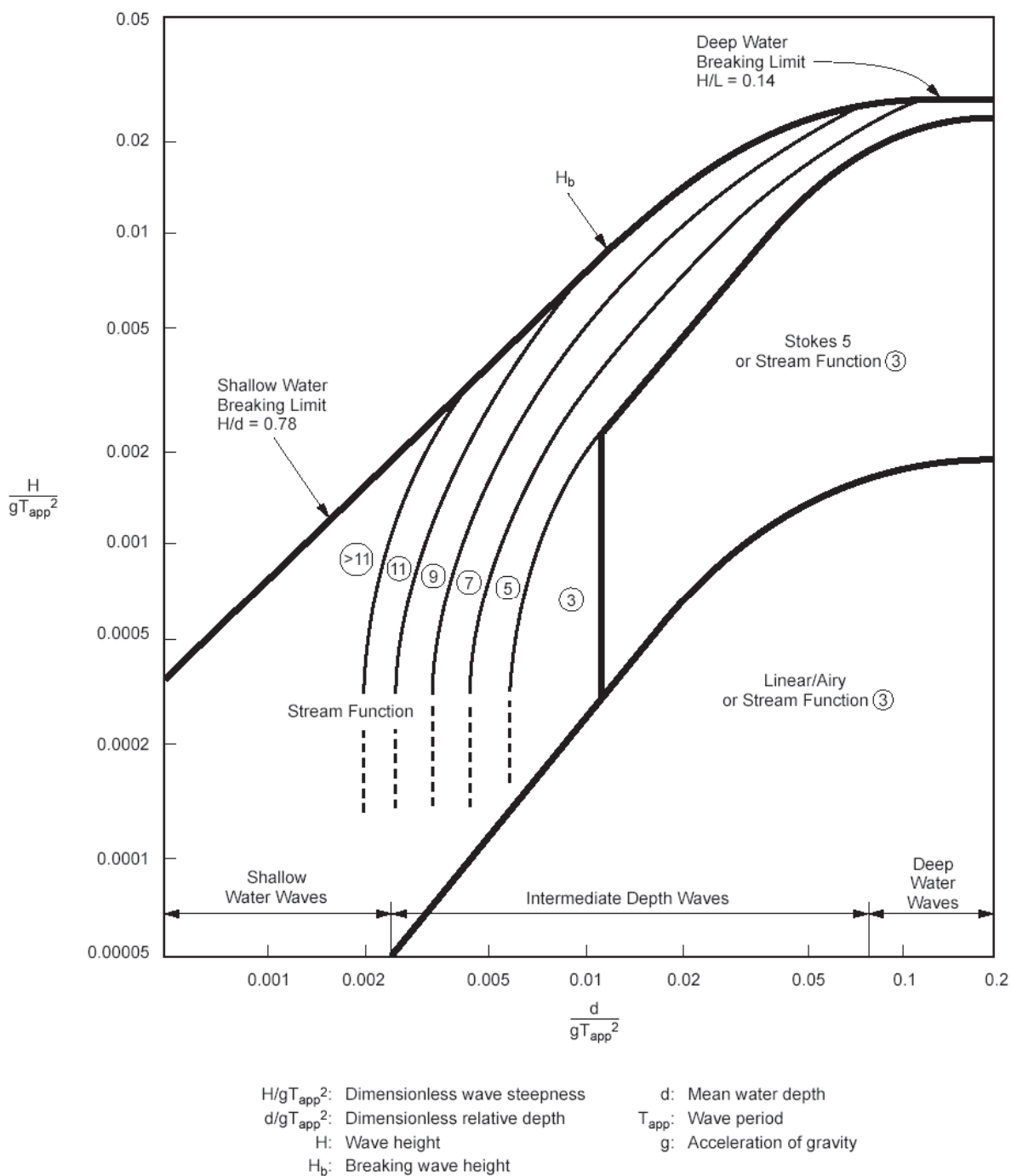


Figure 5.3—Regions of Applicability of Stream Function, Stokes V, and Linear Wave Theory
 (from Atkins, 1990; Modified by API Task Group on Wave Force Commentary)

5.3.1.2.6 Combined Wave/Current Kinematics

Wave kinematics, adjusted for directional spreading and irregularity, should be combined vectorially with the current profile, adjusted for blockage. Since the current profile is specified only to storm mean water level in the design criteria, various methods to stretch (or compress) it to the local wave surface are used. As discussed in B.5.3.1.2.6, “nonlinear stretching” is the preferred method. For slab current profiles such as those specified for U.S. waters in API 2MET, simple vertical extension of the current profile from storm mean water level to the wave surface is a good approximation to nonlinear stretching. For other current profiles, linear stretching is an acceptable approximation. In linear stretching, the current at a point with elevation z , above which the wave surface elevation is η (where z and η are both positive above storm mean water level and negative below), is computed from the specified current profile at elevation z' . The elevations z and z' are linearly related, as follows:

$$(z' + d) = (z + d) d / (d + \eta) \quad (5.1)$$

where

d is the storm water depth.

5.3.1.2.7 Marine Growth

All structural members, conductors, risers, and appurtenances should be increased in cross-sectional area to account for marine growth thickness. Also, elements with circular cross sections should be classified as either “smooth” or “rough” depending on the amount of marine growth expected to have accumulated on them at the time of the loading event. Specific marine growth profiles are provided for U.S. waters in API 2MET. Site-specific data shall be used when available.

5.3.1.2.8 Drag and Inertia Coefficients

Drag and inertia coefficients are discussed in detail in B.5.3.1.2.8. For typical design situations, global platform wave forces can be calculated using the following values for unshielded circular cylinders:

Smooth: $C_d = 0.65$, $C_m = 1.6$

Rough: $C_d = 1.05$, $C_m = 1.2$

These values are appropriate for the case of a steady current with negligible waves or the case of large waves with $U_{mo}T_{app}/D > 30$. Here U_{mo} is the maximum horizontal particle velocity at storm mean water level under the wave crest from the two-dimensional wave kinematics theory, T_{app} is the apparent wave period, and D is platform leg diameter at storm mean water level.

For wave-dominant cases with $U_{mo}T_{app}/D < 30$, guidance on how C_d and C_m for nearly vertical members are modified by “wake encounter” is provided in B.5.3.1.2.8. Such situations may arise with large-diameter caissons in extreme seas or ordinary platform members in lower sea states considered in fatigue analyses.

For members that are not circular cylinders, appropriate coefficients can be found in Reference [39].

5.3.1.2.9 Conductor Shielding Factor

Depending upon the configuration of the structure and the number of well conductors, the wave forces on the conductors can be a significant portion of the total wave forces. If the conductors are closely spaced, the forces on them may be reduced due to hydrodynamic shielding. A wave force reduction factor, to be applied to the drag and inertia coefficients for the conductor array, can be estimated from Figure 5.4, in which S is the center-to-center spacing of the conductors in the wave direction and D is the diameter of the conductors, including marine growth. This shielding factor is appropriate for either steady current with negligible waves or extreme waves, with $U_{mo}T_{app}/S > 5\pi$. For less extreme waves with $U_{mo}T_{app}/S < 5\pi$, as in fatigue analyses, there may be less shielding. Section B.5.3.1.2.9 provides some guidance on conductor shielding factors for fatigue analyses.

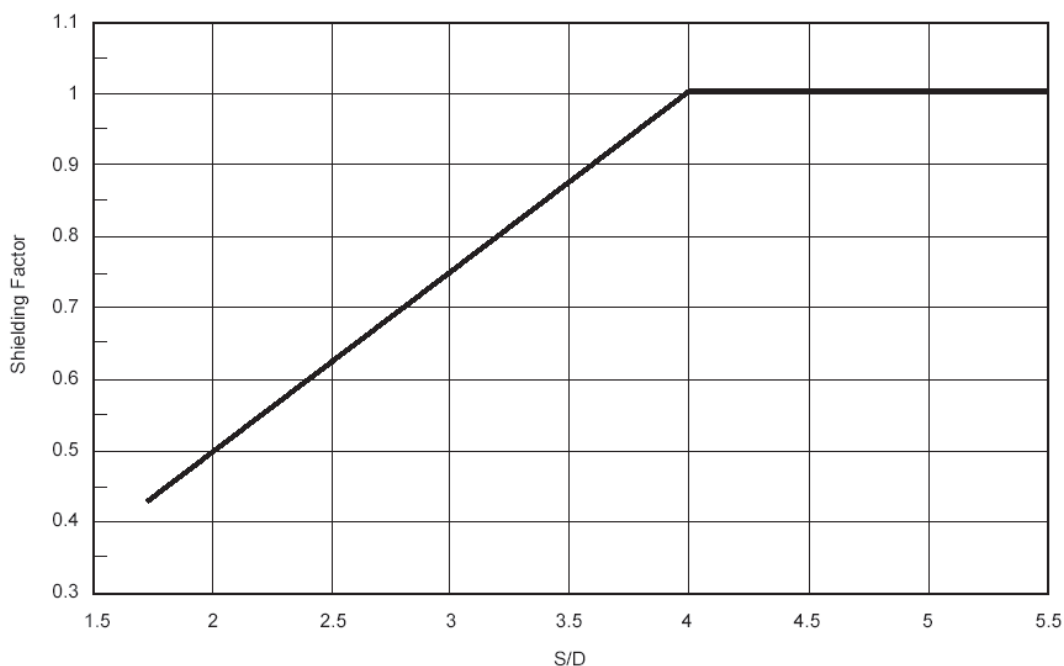


Figure 5.4—Shielding Factor for Wave Loads on Conductor Arrays as a Function of Conductor Spacing

5.3.1.2.10 Hydrodynamic Models for Appurtenances

Appurtenances such as boat landings, fenders or bumpers, walkways, stairways, grout lines, and anodes should be considered for inclusion in the hydrodynamic model of the structure. Depending upon the type and number of appurtenances, they can significantly increase the global wave forces. In addition, forces on some appurtenances may be important for local member design. Appurtenances are generally modeled by nonstructural members, which contribute equivalent wave forces. For appurtenances such as boat landings, wave forces are highly dependent on wave direction because of shielding effects. Additional guidance on the modeling of appurtenances is provided in B.5.3.1.2.10.

5.3.1.2.11 Morison Equation

The computation of the force exerted by waves on a cylindrical object depends on the ratio of the wavelength to the member diameter. When this ratio is large (>5), the member does not significantly

modify the incident wave. The wave force can then be computed as the sum of a drag force and an inertia force, as follows:

$$F = F_D + F_I = C_D \frac{w}{2g} A U |U| + C_m \frac{w}{g} V \frac{\delta U}{\delta t} \quad (5.2)$$

where

- F is the hydrodynamic force vector per unit length acting normal to the axis of the member, N/m (lb/ft);
- F_D is the drag force vector per unit length acting to the axis of the member in the plane of the member axis and U , N/m (lb/ft);
- F_I is the inertia force vector per unit length acting normal to the axis of the member in the plane of the member axis and $\partial U / \partial t$, N/m (lb/ft);
- C_D is the drag coefficient;
- w is the weight density of water, N/m³ (lb/ft³);
- g is the gravitational acceleration, m/s² (ft/s²);
- A is the projected area normal to the cylinder axis per unit length ($= D$ for circular cylinders), m (ft);
- V is the displaced volume of the cylinder per unit length ($= \pi D^2 / 4$ for circular cylinders), m² (ft²);
- D is the effective diameter of circular cylindrical member including marine growth, m (ft);
- U is the component of the velocity vector (due to wave and/or current) of the water normal to the axis of the member, m/s (ft/s);
- $|U|$ is the absolute value of U , m/s (ft/s);
- C_m is the inertia coefficient;
- $\frac{\delta U}{\delta t}$ is the component of the local acceleration vector of the water normal to the axis of the member, m/s² (ft/s²).

Note that the Morison equation, as stated here, ignores the convective acceleration component in the inertia force calculation (see B.5.3.1.2.11). It also ignores lift forces, slam forces, and axial Froude-Krylov forces.

When the size of a structural body or member is sufficiently large to span a significant portion of a wavelength, the incident waves are scattered, or diffracted. This diffraction regime is usually considered to occur when the member width exceeds a fifth of the incident wavelength. Diffraction theory, which computes the pressure acting on the structure due to both the incident wave and the scattered wave, should be used, instead of the Morison equation, to determine the wave forces. Depending on their diameters, caissons may be in the diffraction regime, particularly for the lower sea states associated with

fatigue conditions. Diffraction theory is reviewed in Reference [40]. A solution of the linear diffraction problem for a vertical cylinder extending from the seabottom through the free surface (caisson) can be found in Reference [41].

5.3.1.2.12 Global Structure Forces

Total base shear and overturning moment are calculated by a vector summation of:

- a) local drag and inertia forces due to waves and currents (see 5.3.1.2.11);
- b) dynamic amplification of wave and current forces (see 5.3.1.3)—note that this is preferably represented by a modal inertia load set (due to structure mass and added mass), rather than by simply scaling up the hydrodynamic loads; and
- c) wind forces on the exposed portions of the structure (see 5.3.2).

Local slamming forces can be neglected because they are primarily vertical. Lift forces can be neglected for jacket-type structures because they are not correlated from member to member. Axial Froude-Krylov forces can also be neglected for slender jacket bracing. The wave crest should be positioned relative to the structure so that the total base shear and overturning moment have their maximum values. The following should be kept in mind:

- maximum base shear may not occur at the same wave position as maximum overturning moment;
- in special cases of waves with low steepness and an opposing current, maximum global structure force may occur near the wave trough rather than near the wave crest; and
- maximum local member stresses may occur for a wave position other than that causing the maximum global structure force.

5.3.1.2.13 Local Member Design

Local member stresses are due to both local hydrodynamic forces and loads transferred from the rest of the structure. Locally generated forces include not only the drag and inertia forces modeled by the Morison equation [Equation (5.2)] but also lift forces, axial Froude-Krylov forces, hydrostatic pressure, buoyancy, and weight. Horizontal members near storm mean water level will also experience vertical slam forces as a wave passes. Both lift and slamming forces can dynamically excite individual members, thereby increasing stresses (see B.5.3.1.2.13). Transferred loads are due to the global fluid-dynamic forces and dynamic response of the entire structure. The fraction of total stress due to locally generated forces is generally greater for members higher in the structure; therefore, local lift and slam forces may need to be considered in designing these members. The maximum local member stresses may occur at a different position of the wave crest relative to the structure centerline than that which causes the greatest global wave force on the platform. For example, some members of conductor guide frames may experience their greatest stresses due to vertical drag and inertia forces, which generally peak when the wave crest is far away from the structure centerline.

5.3.1.3 Dynamic Wave Analysis

5.3.1.3.1 General

A dynamic analysis of a fixed platform is indicated when the design sea state contains significant wave energy at frequencies near the platform's natural frequencies. The wave energy content versus frequency

can be described by wave (energy) spectra as determined from measured data or predictions appropriate for the platform site. Dynamic analyses should be performed for compliant towers and tension leg platforms.

5.3.1.3.2 Waves

Use of a random linear wave theory with modified crest kinematics is appropriate for dynamic analysis of fixed platforms. Wave spreading (three-dimensionality) should be considered. Wave group effects may also cause important dynamic responses in compliant structures.

5.3.1.3.3 Currents

Currents associated with the design sea state can affect dynamic loading through the nonlinear drag force term in the Morison equation [Equation (5.2)] and therefore should be considered in dynamic analysis.

5.3.1.3.4 Winds

For analysis of template, tower, gravity, or minimum platforms, global loads due to the sustained wind may be superimposed on the global wave and current load.

For compliant towers and tension leg platforms, the analysis should include the simultaneous action of wind, waves, and current. It may be appropriate to consider wind dynamics.

5.3.1.3.5 Fluid Force on a Member

Equation (5.2) may be used to compute forces on members of template, tower, gravity, or minimum structure platforms. Guidance on selection of drag and inertia coefficients for dynamic analysis is provided in B.5.3.1.2.8. For compliant towers and tension leg platforms, Equation (5.2) should be modified to account for relative velocity by making the following substitution in the drag force term:

replace U and $|U|$ by $(U - \dot{x})$ and $|U - \dot{x}|$, respectively

where

$\dot{x}$ is the component of structural velocity normal to the axis of the member, m/s (ft/s);

U is the component of the velocity vector (due to wave and/or current) of the water normal to the axis of the member, m/s (ft/s) [see Equation (5.2)].

Fluid forces associated with the platform acceleration are accounted for by added mass.

5.3.1.3.6 Structural Modeling

The dynamic model of fixed platforms should reflect the key analytical parameters of mass, damping, and stiffness. The mass should include that of the platform steel, all appurtenances, conductors, and deck loads, the mass of water enclosed in submerged tubular members, the mass of marine growth expected to accumulate on the structure and the added mass of submerged members, accounting for increased member diameter due to marine growth.

Equivalent viscous damping values may be used in lieu of an explicit determination of damping components. In the absence of substantiating information for damping values for a specific structure, a

damping value of 2 % to 3 % of critical for extreme wave analyses and 2 % of critical for fatigue analyses may be used.

The analytical model should include the elastic stiffness of the platform and reflect the structure/foundation interaction. It may be appropriate to consider a stiffer foundation for fatigue analyses than for extreme wave response analyses. However, static p-y data is appropriate for use for an inelastic push over analysis [330]. For guyed towers, these stiffness values should be augmented to account for the guyline system. Analysis procedures should generally account for the dynamic interaction of the tower and guyline system. In general, compliant tower analytical models should include geometric stiffness (large displacement effects). Forces affecting geometric stiffness include gravity loads, buoyancy, the vertical component of the guyline system reaction (where applicable), and the weight of conductors including their contents.

5.3.1.3.7 Analysis Methods

Time history methods of dynamic analysis are preferred for predicting the extreme wave response of template platforms, minimum structures, and compliant towers because these structures are generally drag force dominated. The nonlinear guyline system stiffness also indicates time domain analysis for guyed towers. Frequency domain methods may be used for extreme wave response analysis to calculate the dynamic amplification factor to combine with the static load, provided linearization of the drag force can be justified; for guyed towers, both the drag force and nonlinear guyline stiffness would require linearization. Frequency domain methods are generally appropriate for small wave fatigue analysis.

For member design, stresses may be determined from static analyses that include in an appropriate manner the significant effects of dynamic response determined from separate analyses made according to the provisions of this section.

5.3.2 Wind

5.3.2.1 General

The wind criteria for design should be determined by proper analysis of wind data collected in accordance with 4.3.2. As with wave loads, wind loads are dynamic in nature, but some structures will respond to them in a nearly static fashion. For conventional fixed steel templates in relatively shallow water, winds are a minor contributor to global loads (typically less than 10 %). Sustained wind speeds should be used to compute global platform wind loads, and gust speeds should be used for the design of individual structural elements. The values of wind criteria for different return intervals provided in API 2MET shall be used.

In deeper water and for compliant designs, wind loads can be significant and should be studied in detail. A dynamic analysis of the platform is indicated when the wind field contains energy at frequencies near the natural frequencies of the platform. Such analyses may require knowledge of the wind turbulence intensity, spectra, and spatial coherence. These items are addressed below.

5.3.2.2 Wind Properties

5.3.2.2.1 General

Wind speed and direction vary in space and time. On length scales typical of even large offshore structures, statistical wind properties (e.g. mean and standard deviation of speed) taken over durations of the order of an hour do not vary horizontally, but do change with elevation (profile factor). Within long

durations, there will be shorter durations with higher mean speeds (gusts factor). Therefore, a wind speed value is only meaningful if qualified by its elevation and duration.

5.3.2.2.2 Wind Profiles and Gusts

In SI units, for strong wind conditions (near-neutral stratification) the design wind speed $u(z, t)$ (m/s) at height z (m) above sea level and corresponding to an averaging time period $t \leq t_o = 3600$ s is given by:

$$u(z, t) = U(z) \times \left[1 - 0.41 \times I_u(z) \times \ln \left(\frac{t}{t_o} \right) \right] \quad (5.3)$$

where the 1-hour mean wind speed $U(z)$ (m/s) at level z (m) is given by:

$$U(z) = U_o \times \left[1 + C \times \ln \left(\frac{z}{10} \right) \right] \quad (5.4)$$

where

$$C = 5.73 \times 10^{-2} \times (1 + 0.15 U_o)^{1/2}$$

and where the turbulence intensity $I_u(z)$ at level z (m) is given by:

$$I_u(z) = 0.06 \times (1 + 0.043 \times U_o) \times \left(\frac{z}{10} \right)^{-0.22} \quad (5.5)$$

where U_o (m/s) is the 1-hour mean wind speed at 10 m above sea level.

In USC units, for strong wind conditions the design wind speed $u(z, t)$ (ft/s) at height z (ft) above sea level and corresponding to an averaging time period $t < t_o = 3600$ s is given by:

$$u(z, t) = U(z) \times \left[1 - 0.41 \times I_u(z) \times \ln \left(\frac{t}{t_o} \right) \right] \quad (5.6)$$

where the 1-hour mean wind speed $U(z)$ (ft/s) at level z (ft) is given by:

$$U(z) = U_o \times \left[1 + C \times \ln \left(\frac{z}{32.8} \right) \right] \quad (5.7)$$

where

$$C = 5.73 \times 10^{-2} \times (1 + 0.0457 \times U_o)^{1/2}$$

and where the turbulence intensity $I_u(z)$ at level z (ft) is given by:

$$I_u(z) = 0.06 \times (1 + 0.0131 \times U_o) \times \left(\frac{z}{32.8} \right)^{-0.22} \quad (5.8)$$

where U_o (ft/s) is the 1-hour mean wind speed at 32.8 ft above sea level.

5.3.2.2.3 Wind Spectra

For structures and structural elements for which the dynamic wind behavior is of importance, Equation (5.9) through Equation (5.12) for the 1-point wind spectrum may be used for the energy density of the longitudinal wind speed fluctuations.

In SI units:

$$S(f) = \frac{320 \left(\frac{U_o}{10} \right)^2 \left(\frac{z}{10} \right)^{0.45}}{\left(1 + \tilde{f}^n \right)^{\left(\frac{5}{3n} \right)}} \quad (5.9)$$

$$\tilde{f} = 172 f \left(\frac{z}{10} \right)^{\frac{2}{3}} \left(\frac{U_o}{10} \right)^{-0.75} \quad (5.10)$$

where

n equals 0.468;

$S(f)$ is the spectral energy density at frequency f , in $\text{m}^2/\text{s}^2/\text{Hz}$;

z is the height above sea level, in m;

U_o is the 1-hour mean wind speed at 10 m above sea level, in m/s.

In USC units:

$$S(f) = \frac{3444 \left(\frac{U_o}{32.8} \right)^2 \left(\frac{z}{32.8} \right)^{0.45}}{\left(1 + \tilde{f}^n \right)^{\left(\frac{5}{3n} \right)}} \quad (5.11)$$

$$\tilde{f} = 172 f \left(\frac{z}{32.8} \right)^{\frac{2}{3}} \left(\frac{U_o}{32.8} \right)^{-0.75} \quad (5.12)$$

where

n equals 0.468;

$S(f)$ is the spectral energy density at frequency f , in $\text{ft}^2/\text{s}^2/\text{Hz}$;

z is the height above sea level, in ft;

U_o is the 1-hour mean wind speed at 32.8 ft above sea level, in ft/s.

5.3.2.2.4 Spatial Coherence

Wind gusts have three-dimensional spatial scales related to their durations. For example, 3-s gusts are coherent over shorter distances and therefore affect smaller elements of a platform superstructure than 15-s gusts. The wind in a 3-s gust is appropriate for determining the maximum static wind load on individual members; 5-s gusts are appropriate for maximum total loads on structures whose maximum horizontal dimension is less than 50 m (164 ft); and 15-s gusts are appropriate for the maximum total static wind load on larger structures. The 1-min. sustained wind is appropriate for total static superstructure wind loads associated with maximum wave forces for structures that respond dynamically to wind excitation but that do not require a full dynamic wind analysis. For structures with negligible dynamic response to winds, the 1-hour sustained wind is appropriate for total static superstructure wind forces associated with maximum wave forces.

In frequency domain analyses of dynamic wind loading, it can be conservatively assumed that all scales of turbulence are fully coherent over the entire superstructure. For dynamic analysis of some substructures, it may be beneficial to account for the less-than-full coherence at higher frequencies. The squared correlation between the spectral energy densities of the longitudinal wind speed fluctuations of frequency f between two points in space is described in terms of the 2-point coherence spectrum.

Equation (5.13) through Equation (5.15) may be used for the recommended coherence spectrum between two points (x_i, y_i, z_i) .

In SI units:

- at levels z_1 and z_2 above the sea surface, in m;
- with across-wind positions y_1 and y_2 , in m;
- with along-wind positions x_1 and x_2 , in m.

is given by

$$\text{coh}(f) = \exp \left[-\frac{1}{U_o} \left(\sum_{i=1}^3 A_i^2 \right)^{1/2} \right] \quad (5.13)$$

where

$$A_i = \alpha_i f^{r_i} \Delta_i^{q_i} z_g^{-p_i} \quad (5.14)$$

$$z_g = \sqrt{z_1 z_2} / (10)$$

In USC units:

- at levels z_1 and z_2 above the sea surface, in ft;
- with across-wind positions y_1 and y_2 , in ft;
- with along-wind positions x_1 and x_2 , in ft.

is given by:

$$\text{coh}(f) = \exp \left[-\frac{1}{U_o/3.28} \left(\sum_{i=1}^3 A_i^2 \right)^{1/2} \right] \quad (5.15)$$

where

$$A_i = \alpha_i f^{r_i} \left(\frac{\Delta_i}{3.28} \right)^{q_i} z_g^{-p_i} \quad (5.16)$$

$$z_g = \frac{\sqrt{z_1 z_2}}{32.8}$$

and where the coefficients α , p , q , r and the distances Δ are given in Table 5.3.

Table 5.3—Values Coherence Spectrum Coefficients α , p , q , r , and Δ

i	Δ_i	q_i	p_i	r_i	α_i
1	$ x_2 - x_1 $	1.00	0.4	0.92	2.9
2	$ y_2 - y_1 $	1.00	0.4	0.92	45.0
3	$ z_2 - z_1 $	1.25	0.5	0.85	13.0

5.3.2.3 Wind Speed and Force Relationship

The wind drag force on an object should be calculated as:

$$F = (\rho/2) u^2 C_s A \quad (5.17)$$

where

F is the wind force, in N (lb);

ρ is the mass density of air (kg/m³, 1.22 kg/m³ for standard temperature and pressure) (slug/ft³, 0.0023668 slugs/ft³ for standard temperature and pressure);

u is the wind speed, in m/s (ft/s);

C_s is the shape coefficient;

A is the area of object, in m² (ft²).

5.3.2.4 Local Wind Force Considerations

For all angles of wind approach to the structure, forces on flat surfaces should be assumed to act normal to the surface and forces on vertical cylindrical tanks, pipes, and other cylindrical objects should be assumed to act in the direction of the wind. Forces on cylindrical tanks, pipes, and other cylindrical