CALIFORNIA BUILDING CODE – MATRIX ADOPTION TABLE
CHAPTER 31F – MARINE OIL TERMINALS

(Matrix Adoption Tables are nonregulatory, intended only as an aid to the code user. See Chapter 1 for state agency authority and building applications.)

Adopting agency	BSC	BSC-CG	SFM	HCD			DSA			OSHPD						BSCC	DPH	AGR	DWR	CEC	CA	SL	SLC
				1	2	1/AC	AC	SS	SS/CC	1	1R	2	3	4	5								
Adopt entire chapter																							X
Adopt entire chapter as amended (amended sections listed below)																							
Adopt only those sections that are listed below																							
Chapter / Section																							
2113*A*.9.2																							

The state agency does not adopt sections identified with the following symbol: †

The Office of the State Fire Marshal's adoption of this chapter or individual sections is applicable to structures regulated by other state agencies pursuant to Section 1.11.

CHAPTER 31F [SLC]

MARINE OIL TERMINALS

Division I

SECTION 3101F [SLC] INTRODUCTION

3101F.1 Authority. *The Lempert-Keene-Seastrand oil spill prevention and response act of 1990 (act), as amended, authorizes the California State Lands Commission (SLC) to regulate marine terminals, herein referred to as marine oil terminals (MOTs), in order to protect public health, safety and the environment. The authority for this regulation is contained in Sections 8750 through 8760 of the California Public Resources Code. This act defines "oil" as any kind of petroleum, liquid hydrocarbons, or petroleum products or any fraction or residues thereof, including but not limited to, crude oil, bunker fuel, gasoline, diesel fuel, aviation fuel, oil sludge, oil refuse, oil mixed with waste, and liquid distillates from unprocessed natural gas. The provisions of this chapter regulate onshore and offshore MOTs as defined under this act, including marine terminals that transfer liquefied natural gas (LNG).*

The Marine Environmental Protection Division (Division) administers this code on behalf of the SLC.

3101F.2 Purpose. *The purpose of this code is to establish minimum engineering, inspection and maintenance criteria for MOTs in order to prevent oil spills and to protect public health, safety and the environment. This code does not specifically address terminal siting, systems onboard vessels, processing facilities, or operational requirements. Relevant provisions from existing codes, industry standards, recommended practices, regulations and guidelines have been incorporated directly or through reference, as part of this code.*

Where there are differing requirements between this code and/or references cited herein, the choice of application shall be subject to Division approval.

In circumstances where technologies proposed for use are not covered by this code and/or references cited herein, prevention of oil spills and equivalent or better protection of the public health, safety and the environment must be demonstrated, and the choice of application shall be subject to Division approval.

3101F.3 Applicability. *The provisions of this chapter are applicable to the evaluation of existing MOTs and design of new MOTs in California. Each provision is classified as New (N), Existing (E), or Both (N/E) and shall be applied accordingly. If no classification is indicated, the classification shall be considered to be (N/E).*

Existing (E) requirements apply to MOTs that were in operation on the date this code became effective (February 6, 2006). For these MOTs, equivalent or in-kind replacement of existing equipment, short pipeline sections, or minor modification of existing components shall also be subject to the existing (E) requirements.

New (N) requirements apply to:

1. *A MOT or berthing system (Subsection 3102F.1.3) that commences or recommences operation with a new or modified operations manual after adoption of this code.*
2. *Addition of new structural components or systems at an existing MOT that are structurally independent of existing components or systems.*
3. *Addition of new (nonreplacement) equipment, piping, pipelines, components or systems to an existing MOT.*
4. *Major repairs or substantially modified in-place systems.*
5. *Any associated major installations or modifications.*

3101F.4 Overview. *This Code ensures that a MOT can be safely operated within its inherent structural and equipment-related constraints.*

Section 3102F defines minimum requirements for audit, inspection and evaluation of the structural, electrical and mechanical systems on a prescribed periodic basis, or following a significant, potentially damage-causing event.

Section 3103F, 3104F and 3107F provide criteria for structural loading, deformation and performance-based evaluation considering earthquake, wind, wave, current, seiche and tsunami effects.

Section 3105F provides requirements for the safe mooring and berthing of tank vessels and barges.

Section 3106F describes requirements for geotechnical hazards and foundation analyses, including consideration of slope stability and soil failure.

Section 3108F provides requirements for fire prevention, detection and suppression including appropriate water and foam volumes.

Sections 3109F through 3111F provide requirements for piping/ pipelines, mechanical and electrical equipment and electrical systems.

Section 3112F provides requirements specific to marine terminals that transfer LNG.

Generally, English units are typically prescribed herein; however, System International (SI) units are utilized in Section 3112F and in many of the references.

3101F.5 Spill prevention. *Each MOT shall utilize up-to-date Risk and Hazards Analysis results developed per CCPS "Guidelines for Hazard Evaluation Procedures" [1.1] and [1.2], to identify the hazards associated with operations at the MOT, including operator error, the use of the facility by various types of vessels (e.g. multi-use transfer operations), equipment failure, and external events likely to cause an oil spill.*

If there are changes made to the built MOT or subsequently any new hazard is identified with significant impact, the updated Risk and Hazards Analysis shall be used.

Assessed magnitude of potential oil spill releases and consequences shall be mitigated by implementing appropriate designs using best achievable technologies, subject to Division approval. The residual risks are addressed by operational and administrative means via 2 CCR 2385 [1.3].

Risk and Hazards Analysis requirements specific to marine terminals that transfer LNG are discussed in Section 3112F.2.

3101F.6 Oil spill exposure classification. *Each MOT shall be categorized into one of three oil spill exposure classifications (high, medium or low) as shown in Table 31F-1-1, based on all of the following:*

1. *Exposed total volume of oil (V_T) during transfer.*
2. *Maximum number of oil transfer operations per berthing system (defined in Section 3102F.1.3) per year.*
3. *Maximum vessel size (DWT capacity) that may call at the MOT.*

During a pipeline leak, a quantity of oil is assumed to spill at the maximum cargo flow rate until the ESD is fully effective. The total volume (V_T) of potential exposed oil is equal to the sum of the stored and flowing volumes ($V_s + V_F$) at the MOT, prior to the emergency shutdown (ESD) system(s) stopping the flow of oil. All potential spill scenarios shall be evaluated and the governing scenario clearly identified. The stored volume (V_s) is the non-flowing oil. The flowing volume (V_F) shall be calculated as follows:

$$V_F = Q_C \times \Delta t \times (1/3{,}600) \qquad (1\text{-}1)$$

where:

V_F = *Flowing volume of potential exposed oil [bbl]*

Q_C = *Maximum cargo transfer rate [bbl/hr]*

Δt = *For MOTs that first transferred oil on or before January 1, 2017, Δt may be taken as (ESD time, 30 or 60 seconds). For MOTs that first transfer oil after January 1, 2017, Δt shall be taken as ((ESD closure time) + (time required to activate ESD)) [seconds].*

If spill reduction strategies, (e.g. pipeline segmentation devices, system flexibility and spill containment devices) are adopted, such that the maximum volume of exposed oil during transfer is less than 1,200 barrels, the spill classification of the facility may be lowered.

This classification does not apply to marine terminals that transfer LNG.

3101F.7 Management of Change. *Whenever physical changes are made to the built MOT that significantly impact operations, a Management of Change (MOC) process shall be followed per Section 6.6 of API Standard 2610 [1.4].*

3101F.8 Review requirements.

3101F.8.1 Quality assurance. *All audits, inspections, engineering analyses or design shall be reviewed by a professional having similar or higher qualifications as the person who performed the work, to ensure quality assurance. This review may be performed in-house, and shall include a concluding statement of compliance with this code.*

3101F.8.2 Peer review. *The Division may require peer review of advanced engineering analyses and designs, including, but not limited to, nonlinear dynamic structural analyses, alternative lateral force procedures, complex geotechnical evaluations, subsea pipeline analyses and designs, and fatigue analyses. Peer review shall be performed by an external independent source to maintain the integrity of the process.*

The peer reviewer(s) and their affiliated organization shall have no other involvement in the project, except in a review capacity. The peer reviewer(s) shall be a California registered engineer(s) familiar with regulations governing the work and have technical expertise in the subject matter to a degree of at least that needed for the original work. The peer reviewer(s)' credentials shall be presented to the Division for approval prior to commencement of the review.

Upon completion of the review process, the peer reviewer(s) shall submit a written report directly to the Division that covers all aspects of the review process, including, but not limited to:

1. *Scope, extent and limitations of the review.*
2. *Status of the documents reviewed at each stage (i.e. revision number and date).*
3. *Findings.*
4. *Recommended corrective actions and resolutions, if necessary.*
5. *Conclusions.*
6. *Certification by the peer reviewer(s), including whether or not the final reviewed work meets the requirements of this code.*

TABLE 31F-1-1
MOT OIL SPILL EXPOSURE CLASSIFICATION

SPILL CLASSIFICATION	EXPOSED TOTAL VOLUME OF OIL (V_T) (bbls)	MAXIMUM NUMBER OF TRANSFERS PER BERTHING SYSTEM PER YEAR	MAXIMUM VESSEL SIZE (DWT×1,000)
High	≥ 1200	N.A.	N.A.
Moderate	< 1200	≥ 90	≥ 30
Low	< 1200	< 90	< 30

7. *Formal documentation of important peer review correspondence, including requests for information and written responses.*

The owner and operator shall cooperate in the review process, but shall not influence the peer review. If the original work requires modification after completion of the peer review, the final analyses and designs shall be submitted to the Division.

3101F.8.3 Division review. *The following will be subject to review for compliance with this code by the Division or its authorized representative(s):*

1. *Any audit, inspection, analysis or evaluation of MOTs.*
2. *Any significant change, modification or re-design of a structural, mooring, fire, piping/pipelines, mechanical or electrical system at an MOT, prior to use or reuse.*
3. *Engineering analysis and design for any new MOT prior to construction. Also see Section 3102F.3.3.1.*
4. *Construction inspection team and the construction inspection report(s).*

3101F.9 Alternatives. *In special circumstances where certain requirements of these standards cannot be met, alternatives that provide an equal or better protection of the public health, safety and the environment shall be subject to Division Chief approval with concurrence of the Division's lead engineer in responsible charge.*

3101F.10 Symbols.

DWT = *Dead weight tonnage*

Q_C = *Maximum cargo transfer rate [bbl/hr]*

V_F = *Flowing volume of potential exposed oil [bbl]*

V_S = *Stored volume of potential exposed oil [bbl]*

V_T = *Total volume of potential exposed oil [bbl]*

Δt = *ESD closure and activation time (if applicable) [sec]*

3101F.11 References.

[1.1] Center for Chemical Process Safety (CCPS), 2008, "Guidelines for Hazard Evaluation Procedures", 3rd ed., New York.

[1.2] California Code of Regulations (CCR), Title 14, Division 1, Chapter 3, Oil Spill Contingency Plans (14 CCR 815.01 through 818.03), Section 817.02(c)(1) – Risk and Hazard Analysis.

[1.3] California Code of Regulations (CCR), Title 2, Division 3, Chapter 1, Article 5 – Marine Terminals Inspection and Monitoring (2 CCR 2300 et seq.)

[1.4] American Petroleum Institute (API), 2005, API Standard 2610 (R2010), "Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities," 2nd ed., Washington, D.C.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code. Section 8670.28(a)(7), Government Code.*

Division 2

SECTION 3102F AUDIT AND INSPECTION

3102F.1 General.

3102F.1.1 Purpose. *Section 3102F defines minimum requirements for audit, inspection, and evaluation of the structural, mechanical and electrical components and systems.*

3102F.1.2 Audit and inspections types. *The audit and inspections described in this Chapter (31F) are:*

1. *Annual compliance inspection*
2. *Audits*
3. *Post-event inspection*

Each has a distinct purpose and is conducted either at a defined interval (see Table 31F-2-1 and Section 3102F.3.3), for a significant change in operations, or as a result of a significant, potentially damage-causing event. In the time between audits and inspections, operators are expected to conduct periodic walk-down examinations of the MOT to detect potentially unsafe conditions.

3102F.1.3 Berthing systems. *For the purpose of assigning structural ratings and documenting the condition of mechanical and electrical systems, an MOT shall be divided into independent "berthing systems." A berthing system consists of the wharf and supporting structure, mechanical and electrical components that serve the berth and pipeline systems.*

For example, a MOT consisting of wharves with three berths adjacent to the shoreline could contain three independent "berthing systems" if the piping does not route through adjacent berths. Therefore, a significant defect that would restrict the operation of one berth would have no impact on the other two berths. Conversely, if a T-head Pier, with multiple berths sharing a trestle that supports all piping to the shoreline, had a significant deficiency on the common trestle, the operation of all berths could be adversely impacted. This configuration is classified as a single berthing system.

The physical boundaries of a berthing system may exclude unused sections of a structure. Excluded sections must be physically isolated from the berthing system. Expansion joints may provide this isolation.

3102F.1.4 Records. *All MOTs shall have records reflecting current, "as-built" conditions for all berthing systems. Records shall include, but not be limited to modifications and/or replacement of structural components, electrical or mechanical equipment or relevant operational changes, new construction including design drawings, calculations, engineering analyses, soil borings, equipment manuals, specifications, shop drawings, technical and maintenance manuals and documents.*

Chronological records and reports of annual inspections, audits and post-event inspections and documentation of equipment or structural changes shall be maintained.

Records shall be indexed and be readily accessible to the Division (see 2 CCR Section 2320 (c) (2)) [2.1].

3102F.1.5 Baseline assessment. *If "as-built" or subsequent modification drawings are not available, incomplete or inaccurate, a baseline inspection is required to gather data in sufficient detail for adequate evaluation.*

The level of detail required shall be such that structural member sizes, connection and reinforcing details are documented, if required in the structural analysis. In addition,

TABLE 31F-2-1
MAXIMUM INTERVAL BETWEEN UNDERWATER INSPECTIONS (YEARS)[1]

INSPECTION CONDITION ASSESSMENT RATING (ICAR)[6]	CONSTRUCTION MATERIAL: Unwrapped Timber or Unprotected Steel (no coating or cathodic protection)[4]		CONSTRUCTION MATERIAL: Concrete, Wrapped Timber, Protected Steel or Composite Materials (FRP, plastic, etc.)[4]		CHANNEL BOTTOM OR MUDLINE—SCOUR[4]	
	Benign[2] Environment	Aggressive[3] Environment	Benign[2] Environment	Aggressive[3] Environment	Benign[2] Environment	Aggressive[3] Environment
6 (Good)	6	4	6	5	6	5
5 (Satisfactory)	6	4	6	5	6	5
4 (Fair)	5	3	5	4	6	5
3 (Poor)	4	3	5	4	6	5
2 (Serious)	2	1	2	2	2	2
1 (Critical)	N/A[5]	N/A[5]	N/A[5]	N/A[5]	N/A[5]	N/A[5]

1. *The maximum interval between Underwater Inspections shall be changed as appropriate, with the approval of the Division, based on the extent of deterioration observed on a structure, the rate of further anticipated deterioration or other factors.*
2. *Benign environments include fresh water and maximum current velocities less than 1.5 knots for the majority of the days in a calendar year.*
3. *Aggressive environments include brackish or salt water, polluted water, or waters with current velocities greater than 1.5 knots for the majority of the days in the calendar year.*
4. *For most structures, two maximum intervals will be shown in this table, one for the assessment of construction material (timber, concrete, steel, etc.) and one for scour (last 2 columns). The shorter interval of the two should dictate the maximum interval used.*
5. *MOTs rated "Critical" will not be operational; and Emergency Action shall be required in accordance with Table 31F-2-6.*
6. *ICARs shall be assigned in accordance with Table 31F-2-4.*

the strength and/or ductility characteristics of construction materials shall be determined, as appropriate. Nondestructive testing, partially destructive testing and/or laboratory testing methods may be used.

All fire, piping, mechanical and electrical systems shall be documented as to location, capacity, operating limits and physical conditions in the equipment layout diagram(s).

3102F.2 Annual compliance inspection. *The Division may carry out annual inspections to determine the compliance status of the MOT with this code, based on the terminal's audit and inspection findings and action plan implementation (see Section 3102F.3.9).*

These inspections may include a visual and tactile assessment of structural, mechanical and electrical systems of the topside and underside areas of the dock, including the splash zone. Subject to operating procedures, a boat shall be provided to facilitate the inspection of the dock undersides and piles down to the splash zone.

3102F.3 Audits.

3102F.3.1 Objective. *The objective of the audit is to review structural, mechanical and electrical systems on a prescribed periodic basis to verify that each berthing system is fit for its specific defined purpose. The audit includes above water and underwater inspections, engineering evaluation, documentation and recommended follow-up actions.*

3102F.3.2 Overview. *The audit shall include above water and underwater inspections, and structural, electrical and mechanical systems evaluations, with supporting documentation, drawings and follow-up actions. Structural systems shall include seismic, operational, mooring, berthing and geotechnical considerations. Mechanical systems shall include fire, piping/pipelines and mechanical equipment considerations. The audit is performed by a multidisciplinary team of engineers, qualified inspectors and may include Division representatives.*

The above water inspection involves an examination of all structural, mechanical and electrical components above the waterline. Structural defects and their severity shall be documented, but the exact size and location of each deficiency is typically not required.

The underwater inspection involves an examination of all structural, mechanical and electrical components below the waterline. A rational and representative underwater sampling of piles may be acceptable with Division approval, for cases of limited visibility, heavy marine growth, restricted inspection times because of environmental factors (currents, water temperatures, etc.) or a very large number of piles.

Global operational structural assessment rating(s) (OSAR), global seismic structural assessment rating(s) (SSAR) and global inspection condition assessment rating(s) (ICAR) shall be assigned to each structure and overall berthing system, where appropriate (Table 31F-2-4).

Remedial action priorities (RAP) shall be assigned for component deficiencies (Table 31F-2-5). Recommendations for remediation and/or upgrading shall be prescribed as necessary.

An audit is not considered complete until the audit report is received (in electronic and hard copy formats) by the Division.

3102F.3.3 Schedule.

3102F.3.3.1 Initial audit. *For a new MOT or new berthing system(s), the initial audit of the "as-built" systems(s) shall be performed prior to commencement of operations.*

3102F.3.3.2 Subsequent audits. *A subsequent audit of each terminal shall be completed concurrently with the inspections (see Section 3102F.3.5). The audit team leader shall recommend either: (1) a default subsequent audit interval of 4 years, or (2) an alternate interval, based on assessments of the structural, mechanical and electrical systems, and consideration of:*

1. *The extent of the latest deterioration and/or disrepair,*
2. *The rate of future anticipated deterioration and/or disrepair,*
3. *The underwater inspection guidance provided in Table 31F-2-1, and*
4. *Other specified factors.*

Based on independent assessment of these factors, the Division may accept the audit team leader's recommendation or require a different subsequent audit interval.

If there are no changes in the defined purpose (see Section 3102F.3.6.1) of the berthing system(s), relevant prior analyses may be referenced. However, if there is a significant change in the operations or condition of berthing system(s), a new analysis may be required.

The Division may require an audit, inspection or supplemental evaluations to justify changes in the use of the berthing system(s).

3102F.3.4 Audit team.

3102F.3.4.1 Project manager. *The audit shall be conducted by a multidisciplinary team under the direction of a project manager representing the MOT. The project manager shall have specific knowledge of the MOT and may serve other roles on the audit team.*

3102F.3.4.2 Audit team leader. *The audit team leader shall lead the on-site audit team and shall be responsible for directing field activities, including the inspection of all structural, mechanical and electrical systems. The team leader shall be a California registered civil or structural engineer and may serve other roles on the audit team.*

3102F.3.4.3 Structural inspection team. *The structural inspection shall be conducted under the direction of a registered civil or structural engineer.*

All members of the structural inspection team shall be graduates of a 4-year civil/structural engineering, *or closely related (ocean/coastal) engineering curriculum, and shall have been certified as an Engineer-in-Training; or shall be technicians who have completed a course of study in structural inspections. The minimum acceptable course in structural inspections shall include 80 hours of instruction specifically related to structural inspection, followed by successful completion of a comprehensive examination. An example of an acceptable course is the U.S. Department of Transportation's "Safety Inspection of In- Service Bridges." Certification as a Level IV Bridge Inspector by the National Institute of Certification in Engineering Technologies (NICET) shall also be acceptable [2.2].*

For underwater inspections, the registered civil or structural engineer directing the underwater structural inspection shall also be a commercially trained diver or equivalent and shall actively participate in the inspection, by personally conducting a minimum of 25 percent of the underwater examination [2.2].

Each underwater team member shall also be a commercially trained diver, or equivalent. Divers performing manual tasks such as cleaning or supporting the diving operation, but not conducting or reporting on inspections, may have lesser technical qualifications [2.2].

3102F.3.4.4 Structural analyst. *A California registered civil or structural engineer shall be in responsible charge of the structural evaluations.*

3102F.3.4.5 Electrical inspection team. *A registered electrical engineer shall direct the on-site team performing the inspection and evaluation of electrical components and systems.*

3102F.3.4.6 Mechanical inspection team. *A registered engineer shall direct the on-site team performing the inspection and evaluation of piping/pipeline, mechanical and fire components and systems, except the Fire Protection Assessment in accordance with Section 3108F.2.2.*

3102F.3.4.7 Corrosion specialist. *The corrosion specialist shall be a chemical engineer, corrosion engineer, chemist or other professional with expertise in the types and causes of corrosion, and available means to prevent, monitor and mitigate associated damage. The specialist shall perform the corrosion assessment (Section 3102F.3.6.5) and may be directly involved in corrosion inspection (Section 3102F.3.5.4).*

3102F.3.4.8 Geotechnical analyst. *A California registered civil engineer with a California authorization as a geotechnical engineer shall perform the geotechnical evaluation required for the audit and all other geotechnical evaluations.*

3102F.3.4.9 Division representation. *The Division representative(s) may participate in any audit or inspection as observer(s). The Division shall be notified in advance of audit-related inspections.*

3102F.3.5 Scope of inspections.

3102F.3.5.1 Structural inspections.

3102F.3.5.1.1 Above water structural inspection. *The above water inspection shall include all accessible components above and below deck that are reachable without the need for excavation or extensive removal of materials that may impair visual inspection. The above water inspection shall include, but not be limited to, the following:*

1. *Piles*
2. *Pile caps*
3. *Beams*
4. *Deck soffit*
5. *Bracing*
6. *Retaining walls and bulkheads*
7. *Connections*
8. *Seawalls*
9. *Slope protection*
10. *Deck topsides and curbing*
11. *Expansion joints*
12. *Fender system components*
13. *Dolphins and deadmen*
14. *Mooring points and hardware*
15. *Navigation aids*
16. *Platforms, ladders, stairs, handrails and gangways*
17. *Backfill (sinkholes/differential settlement)*

3102F.3.5.1.2 Underwater structural inspection. *The underwater inspection shall include all components below deck to the mudline, including the slope and slope protection, in areas immediately surrounding the MOT. The water depth at the berth(s) shall be evaluated, verifying the maximum or loaded draft specified in the MOT's Operations Manual (2 CCR 2385) [2.1].*

The underwater structural inspection shall include the Level I, II and III inspection efforts, as shown in Tables 31F-2-2 and 31F-2-3. The underwater inspection levels of effort are described below, per [2.2]:

Level I—Includes a close visual examination, or a tactile examination using large sweeping motions of the hands where visibility is limited. Although the Level I effort is often referred to as a "swim-by" inspection, it must be detailed enough to detect obvious major damage or deterioration due to overstress or other severe deterioration. It should confirm the continuity of the full length of all members and detect undermining or exposure of normally buried elements. A Level I effort may also include limited probing of the substructure and adjacent channel bottom.

Level II—A detailed inspection which requires marine growth removal from a representative sampling of components within the structure. For piles, a 12-inch high band shall be cleaned at designated locations, generally near the low waterline, at the *mudline, and midway between the low waterline and the mudline. On a rectangular pile, the marine growth removal should include at least three sides; on an octagon pile, at least six sides; on a round pile, at least three-fourths of the perimeter. On large diameter piles, 3 ft or greater, marine growth removal should be effected on 1 ft by 1 ft areas at four locations approximately equally spaced around the perimeter, at each elevation. On large solid faced elements such as retaining structures, marine growth removal should be effected on 1 ft by 1 ft areas at the three specified elevations. The inspection should also focus on typical areas of weakness, such as attachment points and welds. The Level II effort is intended to detect and identify damaged and deteriorated areas that may be hidden by surface biofouling. The thoroughness of marine growth removal should be governed by what is necessary to discern the condition of the underlying structural material. Removal of all biofouling staining is generally not required.*

Level III—A detailed inspection typically involving nondestructive or partially-destructive testing, conducted to detect hidden or interior damage, or to evaluate material homogeneity. Level III testing is generally limited to key structural areas, areas which are suspect or areas which may be representative of the underwater structure.

TABLE 31F-2-2
UNDERWATER INSPECTION LEVELS OF EFFORT [2.2]

LEVEL	PURPOSE	DETECTABLE DEFECTS			
		Steel	Concrete	Timber	Composite
I	General visual/tactile inspection to confirm as-built condition and detect severe damage	Extensive corrosion, holes Severe mechanical damage	Major spalling and cracking Severe reinforcement corrosion Broken piles	Major loss of section Broken piles and bracings Severe abrasion or marine borer attack	Permanent deformation Broken piles Major cracking or mechanical damage
II	To detect surface defects normally obscured by marine growth	Moderate mechanical damage Corrosion pitting and loss of section	Surface cracking and spalling Rust staining Exposed reinforcing steel and/or prestressing strands	External pile damage due to marine borers Splintered piles Loss of bolts and fasteners Rot or insect infestation	Cracking Delamination Material degradation
III	To detect hidden or interior damage, evaluate loss of cross-sectional area, or evaluate material homogeneity	Thickness of material Electrical potentials for cathodic protection	Location of reinforcing steel Beginning of corrosion of reinforcing steel Internal voids Change in material strength	Internal damage due to marine borers (internal voids) Decrease in material strength	N/A

TABLE 31F-2-3
SCOPE OF UNDERWATER INSPECTION [2.2]

LEVEL		SAMPLE SIZE AND METHODOLOGY[1]							
		Steel		Concrete		Timber		Composite	Slope Protection, Channel Bottom or Mudline-Scour
		Piles	Bulkheads/ Retaining Walls	Piles	Bulkheads/ Retaining Walls	Piles	Bulkheads/ Retaining Walls	Piles	
I	Sample Size:	100%	100%	100%	100%	100%	100%	100%	100%
	Method:	Visual/Tactile	Visual/Tactile	Visual/Tactile	Visual/Tactile	Visual/Tactile	Visual/Tactile	Visual/Tactile	Visual/Tactile
II	Sample Size:	10%	Every 100 LF	10%	Every 100 LF	10%	Every 50 LF	10%	As necessary
	Method:	Visual: Removal of marine growth in 3 bands	Visual: Removal of marine growth in 1 SF areas	Visual: Removal of marine growth in 3 bands	Visual: Removal of marine growth in 1 SF areas	Visual: Removal of marine growth on 3 bands Measurement: Remaining diameter	Visual: Removal of marine growth in 1 SF areas	Visual: Removal of marine growth in 3 bands	
III	Sample Size:	5%	Every 200 LF	0%	0%	5%	Every 100 LF	0%	Sonar imaging as necessary
	Method:	Remaining thickness measurement; electrical potential measurement; corrosion profiling as necessary	Remaining thickness measurement; electrical potential measurement; corrosion profiling as necessary	N/A	N/A	Internal marine borer infestation evaluation	Internal marine borer infestation evaluation		

1. The minimum inspection sampling size for small structures shall include at least two components.
LF = Linear Feet; SF = Square Feet; N/A = Not Applicable

3102F.3.5.2 Special inspection considerations.

3102F.3.5.2.1 Coated components. *For coated steel components, Level I and Level II efforts should focus on the evaluation of the integrity and effectiveness of the coating. The piles should be inspected without damaging the coating. Level III efforts should include ultrasonic thickness measurements without removal of the coating, where feasible.*

3102F.3.5.2.2 Encased components. *For steel, concrete or timber components that have been encased, the Level I and II efforts should focus on the evaluation of the integrity of the encasement. If evidence of significant damage to the encasement is present, or if evidence of significant deterioration of the underlying component is present, then the damage evaluation should consider whether the encasement was provided for protection and/or structural capacity. Encasements should not typically be removed for an audit.*

For encasements on which the formwork has been left in place, the inspection should focus on the integrity of the encasement, not the formwork. Level I and Level II efforts in such cases should concentrate on the top and bottom of the encasement. For concrete components, if deterioration, loss of bonding, or other significant problems with the encasement are suspected, it may be necessary to conduct a special inspection, including coring of the encasement and laboratory evaluation of the materials.

3102F.3.5.2.3 Wrapped components. *For steel, concrete or timber components that have been wrapped, the Level I and II efforts should focus on the evaluation of the integrity of the wrap. Since the effectiveness of a wrap may be compromised by removal, and since the removal and re-installation of wraps is time-consuming, it should not be routinely done. However, if evidence of significant damage exists, or if the effectiveness of the wraps is in question, then samples should be removed to facilitate the inspection and evaluation. The samples may be limited to particular zones or portions of members if damage is suspected, based on the physical evidence of potential problems. A minimum sample size of three members should be used. A five-percent sample size, up to 30 total members, may be adequate as an upper limit.*

For wrapped timber components, Level III efforts should consist of removal of the wraps from a representative sample of components in order to evaluate the condition of the timber beneath the wrap. The sample may be limited to particular zones or portions of the members if damage is suspected (e.g., at the mudline/ bottom of wrap or in the tidal zone). The sample size should be determined based on the physical evidence of potential problems and the aggressiveness of the environment. A minimum sample size of three members should be used. A five-percent sample size, up to 30 total members, may be adequate as an upper limit.

3102F.3.5.3 Mechanical and electrical inspections. *The mechanical and electrical inspections shall include but not be limited to the following:*

1. *Loading arms*
2. *Cranes and lifting equipment, including cables*
3. *Piping/manifolds and supports*
4. *Oil transfer hoses*
5. *Fire detection and suppression systems*
6. *Vapor control system*
7. *Sumps/sump tanks*
8. *Vent systems*
9. *Pumps and pump systems*
10. *Lighting*
11. *Communications equipment*
12. *Gangways*
13. *Electrical switches and junction boxes*
14. *Emergency power equipment*
15. *Air compressors*
16. *Meters*
17. *Cathodic protection systems*
18. *Winches*
19. *ESD and other control systems*
20. *Ladders*

All alarms, limit switches, load cells, current meters, anemometers, leak detection equipment, etc., shall be operated and/or tested to the extent feasible, to ensure proper function.

Utility, auxiliary and fire protection piping shall have external visual inspections, similar to that defined in Section 10.1 of API RP 574 [2.3] (N/E).

3102F.3.5.4 Corrosion inspection. *During each audit, a comprehensive corrosion inspection shall be performed by a qualified engineer or technician. This inspection shall include all steel and metallic components, and any installed cathodic protection system (CPS). CPS inspection during the audit is not intended to substitute for required testing and maintenance performed on a more frequent schedule per Section 3111F.10. All inspection results shall be documented, and shall be used in the corrosion assessment (Section 3102F.3.6.5).*

Submerged wharf structures and associated cathodic protection equipment (if installed) shall be inspected per [2.2]. Above water structures, ancillary equipment, supports, and hardware shall be visually inspected. Corrosion inspection of utility, auxiliary and fire pipelines shall be done per Section 3102F.3.5.3.

For oil pipelines in an API 570 [2.4] inspection program, a corrosion inspection is not required as part *of the audit; however, the latest inspection results, calculations, and conclusions shall be reviewed, and any significant results shall be included in the corrosion assessment.*

3102F.3.6 Evaluation and assessment.

3102F.3.6.1 Terminal operating limits. *The physical boundaries of the facility shall be defined by the berthing system operating limits, along with the vessel size limits and environmental conditions.*

The audit shall include "Terminal Operating Limits" (TOLs) diagrams, which provide a concise statement of the purpose of each berthing system in terms of operating limits for representative vessel size ranges and mooring configurations approved to call and/or conduct transfer operations at the MOT. This description shall include, the minimum and maximum vessel sizes, including Length Overall (LOA), beam, and maximum draft with associated displacement (see Figure 31F-2-1).

In establishing limits for both the minimum and maximum vessel sizes, due consideration shall be given to water depths, dolphin spacing, fender system limitations, manifold height and hose/loading arm reach, with allowances for tidal fluctuations, surge and drift.

Maximum wind, current or wave conditions, or combinations thereof, shall be clearly defined as limiting conditions for vessels at each berth, both with and without active product transfer.

The TOLs shall be explicitly presented to facilitate implementation by the MOT operator, such as through incorporation in the MOT's Operations Manual (2 CCR 2385 [2.1]). The TOLs shall allow for direct comparison of operating limits and output from monitoring systems and instrumentation (i.e., anemometers, current meters, tension monitoring systems, velocity monitoring systems). Design and implementation considerations shall include, but not be limited to:

1. *Units of measurement (i.e., English vs. System International units)*
2. *Directionality (i.e., current restrictions "to", wind restrictions "from", true or magnetic north)*
3. *Parameters of monitoring systems and instrumentation (i.e., duration/averaging of readings, elevation/depth of readings, distance/location of readings)*

3102F.3.6.2 Mooring and berthing. *Mooring and berthing analyses shall be performed in accordance with Section 3105F. The analyses shall be consistent with the terminal operating limits and the structural configuration of the wharf and/or dolphins and associated hardware.*

Based on inspection results, analyses and engineering judgment, mooring and berthing OSARs shall be assigned on a global basis, independently for each structure and overall berthing system. The OSARs defined in Table 31F-2-4 shall be used for this purpose. The mooring and berthing OSARs document the berthing system(s) fitness-for-purpose.

3102F.3.6.3 Structure. *A structural evaluation, including a seismic analysis, shall be performed in accordance with Sections 3103F through 3107F. Such evaluation shall consider local or global reduction in capacity, as determined from the inspection.*

Based on inspection results, structural analyses and engineering judgment, OSARs (for operational loading) and SSARs shall be assigned on a global basis, independently for each structure, structural system(s) and berthing system(s), as appropriate. The OSARs and SSARs defined in Table 31F-2-4 shall be used for this purpose and document the structural and/or berthing system(s) fitness-for-purpose.

Based on inspection results and engineering judgment, ICARs shall be assigned on a global basis, independently for each above and underwater structure, structural system and berthing system, as appropriate. The ICARs defined in Table 31F-2-4 shall be used for this purpose.

Structural component deficiencies assigned RAPs as per Table 31F-2-5 shall be considered in the OSARs, SSARs and ICARs. The assigned ratings shall remain in effect until all the significant corrective action has been completed to the satisfaction of the Division, or until completion of the next audit.

3102F.3.6.4 Mechanical and electrical systems. *An evaluation of all mechanical and electrical systems and components shall be performed in accordance with Sections 3108F through 3111F of these standards. Forces and imposed seismic displacements resulting from the structural analysis shall be considered in the pipeline stress analyses (Section 3109F.3), and the piping/pipelines shall be assigned SSARs in Table 31F-2-7B. Mechanical and electrical component deficiencies shall be assigned ratings from Table 31F-2-5.*

3102F.3.6.5 Corrosion assessment (N/E). *A comprehensive assessment shall be performed by the corrosion specialist (Section 3102F.3.4.7), to determine the existing and potential corrosion using "as-built" drawings and specifications. This assessment shall comprise all steel and metallic components, including the structure, pipelines, supports and other MOT ancillary equipment. This assessment shall also include prestressed and reinforced concrete structures.*

If cathodic protection is installed to protect wharf structures and/or pipelines, the following records shall be evaluated for each system:

1. *CPS equipment condition and maintenance*
2. *Impressed current readings (as applicable)*
3. *Potential survey results*

TABLE 31F-2-4
ASSESSMENT RATINGS

RATING		DESCRIPTION OF STRUCTURE(S) AND/OR SYSTEMS[4]	
		OSAR[1] and SSAR[2]	ICAR[3]
6	Good	*The capacity of the structure or system meets the requirements of this standard.* *The structure or system should be considered fit-for-purpose. No repairs or upgrades are required.*	*No problems or only minor problems noted. Structural elements may show very minor deterioration, but no overstressing observed.* *No repairs or upgrades are required.*
5	Satisfactory	*The capacity of the structure or system meets the requirements of this standard.* *The structure or system should be considered fit-for-purpose. No repairs or upgrades are required.*	*Limited minor to moderate defects or deterioration observed, but no overstressing observed.* *No repairs or upgrades are required.*
4	Fair	*The capacity of the structure or system is no more than 15 percent below the requirements of this standard, as determined from an engineering evaluation.* *The structure or system should be considered as marginal. Repair and/or upgrade measures may be required to remain operational. Facility may remain operational, provided a plan and schedule for remedial action is presented to and accepted by the Division.*	*All primary structural elements are sound, but minor to moderate defects or deterioration observed. Localized areas of moderate to advanced deterioration may be present, but do not significantly reduce the load bearing capacity of the structure.* *Repair and/or upgrade measures may be required to remain operational. Facility may remain operational, provided a plan and schedule for remedial action is presented to and accepted by the Division.*
3	Poor	*The capacity of the structure or system is no more than 25 percent below the requirements of this standard, as determined from an engineering evaluation.* *The structure or system is not fit-for-purpose. Repair and/or upgrade measures may be required to remain operational. The facility may be allowed to remain operational on a restricted or contingency basis until the deficiencies are corrected, provided a plan and schedule for such work is presented to and accepted by the Division.*	*Advanced deterioration or overstressing observed on widespread portions of the structure, but does not significantly reduce the load bearing capacity of the structure.* *Repair and/or upgrade measures may be required to remain operational. The facility may be allowed to remain operational on a restricted or contingency basis until the deficiencies are corrected, provided a plan and schedule for such work is presented to and accepted by the Division.*
2	Serious	*The capacity of the structure or system is more than 25 percent below the requirements of this standard, as determined from an engineering evaluation.* *The structure or system is not fit-for-purpose. Repairs and/or upgrade measures may be required to remain operational. The facility may be allowed to remain operational on a restricted basis until the deficiencies are corrected, provided a plan and schedule for such work is presented to and accepted by the Division.*	*Advanced deterioration, overstressing or breakage may have significantly affected the load bearing capacity of primary structural components. Local failures are possible and loading restrictions may be necessary.* *Repairs and/or upgrade measures may be required to remain operational. The facility may be allowed to remain operational on a restricted basis until the deficiencies are corrected, provided a plan and schedule for such work is presented to and accepted by the Division.*
1	Critical	*The capacity of the structure or system is critically deficient relative to the requirements of this standard.* *The structure or system is not fit-for-purpose. The facility shall cease operations until deficiencies are corrected and accepted by the Division.*	*Very advanced deterioration, overstressing or breakage has resulted in localized failure(s) of primary structural components. More widespread failures are possible or likely to occur and load restrictions should be implemented as necessary.* *The facility shall cease operations until deficiencies are corrected and accepted by the Division.*

1. OSAR = Operational Structural Assessment Ratings
2. SSAR = Seismic Structural Assessment Ratings
3. ICAR = Inspection Condition Assessment Ratings [2.2]; Ratings shall be assigned comparing the observed condition to the as-built condition.
4. Structural, mooring or berthing systems

TABLE 31F-2-5
COMPONENT DEFICIENCY REMEDIAL ACTION PRIORITIES (RAP)

REMEDIAL PRIORITIES	DESCRIPTION AND REMEDIAL ACTIONS
P1	*Specified whenever a condition that poses an immediate threat to public health, safety or the environment is observed. Emergency Actions may consist of barricading or closing all or portions of the berthing system, evacuating product lines and ceasing transfer operations.* *The berthing system is not fit-for-purpose. Immediate remedial actions are required prior to the continuance of normal operations.*
P2	*Specified whenever defects or deficiencies pose a potential threat to public health, safety and the environment. Actions may consist of limiting or restricting operations until remedial measures have been completed.* *The berthing system is not fit-for-purpose. This priority requires investigation, evaluation and urgent action.*
P3	*Specified whenever systems require upgrading in order to comply with the requirement of these standards or current applicable codes. These deficiencies do not require emergency or urgent actions.* *The MOT may have limitations placed on its operational status.*
P4	*Specified whenever damage or defects requiring repair are observed.* *The berthing system is fit-for-purpose. Repair can be performed during normal maintenance cycles, but not to exceed one year.*
R	*Recommended action is a good engineering/maintenance practice, but not required by these standards.* *The berthing system is fit-for-purpose.*

TABLE 31F-2-6
FOLLOW-UP ACTIONS [2.2]

FOLLOW-UP ACTION	DESCRIPTION
Emergency Action	*Specified whenever a condition which poses an immediate threat to public health, safety or the environment is observed. Emergency Actions may consist of barricading or closing all or portions of the berthing system, limiting vessel size, placing load restrictions, evacuating product lines, ceasing transfer operations, etc.*
Engineering Evaluation	*Specified whenever damage or deficiencies are observed which require further investigation or evaluation to determine appropriate follow-up actions.*
Repair Design Inspection	*Specified whenever damage or defects requiring repair are observed. The repair design inspection is performed to the level of detail necessary to prepare appropriate repair plans, specifications and estimates.*
Upgrade Design and Implementation	*Specified whenever the system requires upgrading in order to comply with the requirements of these standards and current applicable codes.*
Special Inspection	*Typically specified to determine the cause or significance of nontypical deterioration, usually prior to designing repairs. Special testing, laboratory analysis, monitoring or investigation using nonstandard equipment or techniques are typically required.*
Develop and Implement Repair Plans	*Specified when the Repair Design Inspection and required Special Inspections have been completed. Indicates that the structure is ready to have repair plans prepared and implemented.*
No Action	*Specified when no further action is necessary until the next scheduled audit or inspection.*

3102F.3.7 Follow-up actions. *Follow-up actions per Table 31F-2-6 shall be prescribed by the audit team. Multiple follow-up actions may be assigned; however, guidance shall be provided as to the order in which the follow-up actions should be carried out.*

If an assessment rating of “1”, “2” or “3” (Table 31F-2-4) or a RAP of “P1” or “P2” (Table 31F-2-5) or “Emergency Action” using Table 31F-2-6, is assigned to a structure, berthing system or critical component, the Division shall be notified immediately. The Executive Summary Table ES-2 (see Example Table 31F-2-8) shall include implementation schedules for all follow-up and remedial actions. Follow-up and remedial actions and implementation schedules are subject to Division approval.

For action plan implementation between audits, see Section 3102F.3.9.

3102F.3.8 Documentation and reporting. *The audit reports shall be signed and stamped by the audit team leader. The inspection and other reports and drawings shall be signed and stamped by the engineers in responsible charge.*

Each audit and inspection, whether partial or complete, shall be adequately documented. Partial inspections cover only specific systems or equipment examined. The resulting reports shall summarize and reference relevant previous ratings and deficiencies. Inspection reports shall be included in subsequent audits.

The contents of the audit and inspection reports for each berthing system shall, at a minimum, include the following as appropriate:

Executive summary—*a concise narrative of the audit or inspection results and analyses conclusions. It shall include summary information for each berthing system, including an overview of the assigned follow-up actions. The Executive Summary Tables shall also be included (see Example Tables 31F-2-7A through 31F-2-7C and 31F-2-8).*

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Introduction—*a brief description of the purpose and scope of the audit or inspection, as well as a description of the inspection/evaluation methodology used.*

Existing conditions—*a description, along with a summary, of the observed conditions. Subsections shall be used to describe the above water structure, underwater structure, fire, piping/pipeline, mechanical and electrical systems, to the extent each are included in the scope of the audit. Photos, plan views and sketches shall be utilized as appropriate to describe the structure and the observed conditions. Details of the inspection results such as test data, measurements data, etc., shall be documented in an appendix.*

Evaluation and assessment—*assessment ratings shall be assigned to all structures and/or berthing systems. Also, see Section 3102F.3.6. All supporting calculations, as-built drawings and documentation shall be included in appendices as appropriate to substantiate the ratings. However, the results and recommendations of the engineering analyses shall be included in this section. Component deficiencies shall be described and a corresponding RAP assigned.*

Follow-up actions—*Specific follow-up actions (Table 31F-2-6) shall be documented (Table 31F-2-8), and remedial schedules included, for each audited system. Audit team leaders shall specify which follow-up actions require a California registered engineer to certify that the completion is acceptable.*

Appendices—*When appropriate, the following appendices shall be included:*

1. *Background data on the terminal - description of the service environment (wind/waves/currents), extent and type of marine growth, unusual environmental conditions, etc.*
2. *Inspection/testing data*

3. *Mooring and berthing analyses*
4. *Structural and seismic analyses and calculations*
5. *Geotechnical report*
6. *MOT Fire Protection Assessment*
7. *Pipeline stress and displacement analyses*
8. *Mechanical and electrical system documentation*
9. *Corrosion assessment*
10. *Photographs, sketches and supporting data shall be included to document typical conditions and referenced deficiencies, and to justify the assessment ratings and the remedial action priorities RAPs assigned.*

3102F.3.9 Action plan implementation between audits. *The operator is responsible for correction of deficiencies between audits. Prior to implementation, projects shall be submitted for Division review in accordance with Section 3101F.8.3. During project implementation, the Division shall be informed of any significant changes. After project completion, "as-built" documentation, including drawings, calculations and analyses, shall be submitted to the Division.*

Executive Summary Tables shall be updated by the operator and submitted to the Division at least annually.

3102F.4 Post-event notification and inspection. *A post-event inspection is a focused inspection following a significant, potentially damage-causing event such as an earthquake, storm, vessel impact, fire, explosion, construction incident, or tsunami. The primary purpose is to assess the integrity of structural, mechanical and electrical systems. This assessment will determine the operational status and/or any remedial measures required.*

3102F.4.1 Notification and action plan. *Notification as per 2 CCR 2325(e) [2.1] shall be provided to the local area Division field office. The notification shall include, as a minimum:*

1. *Brief description of the event*
2. *Brief description of the nature, extent and significance of any damage observed as a result of the event*
3. *Operational status and any required restrictions*
4. *Statement as to whether a Post-Event inspection will be carried out*

The Division may carry out or cause to be carried out, a post-event inspection. In the interim, the Division may direct a change in the operations manual, per 2 CCR 2385 (f)(3) [2.1].

If a post-event inspection is required, an action plan shall be submitted to the Division within five (5) days after the event. This deadline may be extended in special circumstances. The action plan shall include the scope of the inspection (above water, underwater, electrical, mechanical systems, physical limits, applicable berthing systems, etc.) and submission date of the final report. The action plan is subject to Division approval.

3102F.4.2 Inspection team. *The qualifications of the inspection team shall be the same as those prescribed in Section 3102F.3.4. Division representatives may participate in any post-event inspection, as observers, and may provide guidance.*

3102F.4.3 Scope. *The post-event inspection shall focus on the possible damage caused by the event. General observations of long-term or preexisting deterioration such as significant corrosion-related damage or other deterioration should be made as appropriate, but should not be the focus of the inspection. The inspection shall always include an above-water assessment of structural, mechanical and electrical components.*

The inspection team leader shall determine the need for, and methodology of, an underwater structural assessment, in consultation with the Division. Above water observations, such as shifting or differential settlement, misalignments, significant cracking or spalling, bulging, etc., shall be used to determine whether or not an underwater assessment is required. Similarly, the inspection team leader shall determine, in consultation with the Division, the need for, and methodology of any supplemental inspections (e.g., special inspections (see Section 3102F.3.5.3).

The following information may be important in determining the need for, and methodology of, the post-event inspection:

1. *Earthquakes or vessel or debris impact typically cause damage both above and below the waterline. Following a major earthquake, the inspection should focus on components likely to attract highest lateral loads (batter or shorter piles in the rear of the structure, etc.). In case of vessel or debris impact, the inspection effort should focus on components in the path of the impact mass.*
2. *Major floods or tsunamis may cause undermining of the structure, and/or scouring at the mudline.*
3. *Fire damage varies significantly with the type of construction materials but all types may be adversely affected. Special inspections (sampling and laboratory testing) shall be conducted, as determined by the inspection team leader, in order to determine the nature and extent of damage.*
4. *High wind or wave events often cause damage both above and below the waterline. An underwater inspection may be required if damage is visible above the waterline. Structural damage may be potentially increased if a vessel was at the berth during the event. The effects of high wind may be most prevalent on equipment and connections of such equipment to the structure.*

The methodology of conducting an underwater post-event inspection should be established with due consideration of the structure type and type of damage anticipated. Whereas slope failures or scour may be readily apparent in waters of adequate visibility, overstressing cracks on *piles covered with marine growth will not be readily apparent. Where such hidden damage is suspected, marine growth removal should be performed on a representative sampling of components in accordance with the Level II effort requirements described in Section 3102F.3.5.2. The cause of the event will determine the appropriate sample size and locations.*

3102F.4.4 Post-event ratings. *A post-event rating [2.2] shall be assigned to each berthing system upon completion of the inspection (see Table 31F-2-9). All observations of the above and under water structure, mechanical and electrical components and systems shall be considered in assigning a post-event rating.*

Ratings should consider only damage that was likely caused by the event. Pre-existing deterioration such as corrosion damage should not be considered unless the structural integrity is immediately threatened or safety systems or protection of the environment may be compromised.

Assignment of ratings should reflect an overall characterization of the berthing system being rated. The rating shall consider both the severity of the deterioration and the extent to which it is widespread throughout the facility. The fact that the facility was designed for loads that are lower than the current standards for design should have no influence upon the ratings.

3102F.4.5 Follow-up actions. *Follow-up actions shall be assigned upon completion of the post-event inspection of each berthing system. Table 31F-2-5 specifies remedial action priorities for deficiencies. Table 31F-2-6 specifies various follow-up actions. Multiple follow-up actions may be assigned; however, guidance should be provided as to the order in which the follow-up actions should be carried-out. Follow-up actions shall be subject to Division approval.*

3102F.4.6 Documentation and reporting. *Documentation of the specific attributes of each defect shall not be required during a post-event inspection. However, a narrative description of significant damage shall be used. The description shall be consistent with and shall justify the post-event rating assigned.*

A report shall be prepared and submitted to the Division upon completion of the post-event inspection and shall, at a minimum, include:

1. *Brief description of the facility including the physical limits of the structure, type of construction material(s), and the mechanical and electrical systems present*
2. *Brief description of the event triggering the inspection*
3. *Scope of the inspection (above water, underwater, electrical or mechanical)*
4. *Date of the inspection*
5. *Names and affiliations of inspection team*
6. *Description of the nature, extent and significance of any observed damage resulting from the event*
7. *Photographs should be provided to substantiate the descriptions and justify the condition rating*
8. *Assignment of a post-event rating*
9. *Statement regarding whether the facility is fit to resume operations and, if so, under what conditions*
10. *Assignment of follow-up action(s)*
11. *Inspection data, drawings, calculations and other relevant engineering materials*
12. *Signature and stamp of team leader(s)*

3102F.4.7 Action Plan Report. *Upon completion of all actions delineated in the action plan, a final report shall be submitted to the Division to document the work completed. Supporting documentation such as calculations or other relevant data shall be provided in appendices.*

3102F.5 References.

[2.1] California Code of Regulations (CCR), Title 2, Division 3, Chapter 1, Article 5 – Marine Terminals Inspection and Monitoring (2 CCR 2300 et seq.)

[2.2] Childs, K.M., editor, 2001, "Underwater Investigations - Standard Practice Manual," American Society of Civil Engineers, Reston, VA.

[2.3] American Petroleum Institute (API), 2009, API Recommended Practice 574 (API RP 574), "Inspection Practices for Piping System Components," 3rd ed., Washington, D.C.

[2.4] American Petroleum Institute (API), 2009, API 570, "Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems," 3rd ed., Washington, D.C.

Authority: *Sections 8750 through 8760, Public Resources Code*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

TABLE 31F-2-7A

EXAMPLE	EXECUTIVE SUMMARY TABLE (ES-1A) GLOBAL OPERATIONAL STRUCTURAL ASSESSMENT RATINGS (OSAR)									REV. # MM/YYYY
Berthing system	**Berth(s)[1]**	**Structure(s)[1]**	**Type of analysis[2]**	**OSAR rating[4]**	**Last audit date (MM/YYYY)**	**Next audit due date (MM/YYYY)**	**Last analysis date (MM/YYYY)[5]**	**Repair/ replacement due date (MM/YYYY)[6]**	**Fit-for-purpose (Y/N)**	**Description or comments[7]**
North Wharf	*Berth 1*	*Wharfhead*	*O*	*5*	*08/2008*	*08/2011*	*02/2008*	*N/A*	*Y*	*None*
North Wharf	*Berth 1*	*Mooring Dolphin*	*M*	*3*	*08/2008*	*08/2011*	*05/2008*	*12/2008*	*N*	*Hook capacity inadequate*
North Wharf	*Berth 1*	*Breasting Dolphin*	*B*	*2*	*08/2008*	*08/2011*	*06/2008*	*02/2010*	*N*	*Berthing velocity restrictions required. Velocity monitoring system operational. Fender system to be upgraded.* *See Terminal Operating Limits.*
North Wharf	*Berth 1*	*Overall*	*O*	*4*	*08/2008*	*08/2011*	*02/2008*	*N/A*	*Y*	*None*
North Wharf	*Berth 1*	*Dolphins, Trestles, Catwalks, Bulkhead walls, etc.*			*08/2008*	*08/2011*				
South Wharf	*Berth 2*				*08/2008*	*08/2011*				

TABLE 31F-2-7B

EXAMPLE	EXECUTIVE SUMMARY TABLE (ES-1B) GLOBAL SEISMIC STRUCTURAL ASSESSMENT RATINGS (SSAR)								REV. # MM/YYYY
Berthing system	**Berth(s)[1]**	**Structure(s)[1]**	**SSAR rating[4]**	**Last audit date (MM/YYYY)**	**Next audit due date (MM/YYYY)**	**Last analysis date (MM/YYYY)[5]**	**Repair/ replacement due date (MM/YYYY)[6]**	**Fit-for-purpose (Y/N)**	**Description or comments[7]**
North Wharf	*Berth 1*	*Wharfhead*	*2*	*08/2008*	*08/2011*	*05/2008*	*02/2010*	*N*	*Level 1 – OK; SAP2000 Pushover Analysis* *Level 2 – NG; SAP2000 Pushover Analysis displacements too large and liquefation*
North Wharf	*Berth 1*	*Trestle*	*5*	*08/2008*	*08/2011*	*05/2008*	*N/A*	*Y*	*Level 1 – OK; SAP2000 Linear Analysis* *Level 2 – OK; SAP2000 Linear Analysis*
North Wharf	*Berth 1*	*30" Crude line*	*5*	*08/2008*	*08/2011*	*05/2008*	*N/A*	*Y*	*Level 1 – N/A* *Level 2 – OK; CAESAR Analysis*
North Wharf	*Overall*	*Overall*							
North Wharf	*Berth 1*	*Dolphins, Pipeline, Trestles, Bulkhead walls, etc.*							
South Wharf	*Berth 2*								

TABLE 31F-2-7C

EXAMPLE	**EXECUTIVE SUMMARY TABLE (ES-1C) GLOBAL INSPECTION CONDITION ASSESSMENT RATINGS (ICAR)[8]**							**REV. # MM/YYYY**
Berthing system	**Berth(s)[1]**	**Structure(s)[1]**	**Type of inspection[3]**	**ICAR rating[4,9]**	**Last inspection date (MM/YYYY)[10]**	**Inspection interval (YRS.)**	**Next inspection due date (MM/YYYY)[10]**	**Description or comments[7]**
North Wharf	*Berth 1*	*Wharfhead*	*AW*	*5*	*02/2008*	*3*	*02/2011*	*General satisfactory condition. See RAPs in Table ES-2 for details.*
North Wharf	*Berth 1*	*Wharfhead*	*UW*	*4*	*02/2008*	*5*	*02/2013*	*Pile damage; 10 serve, 15 minor See RAPs in Table ES-2 for details.*
North Wharf	*Berth 1*	*Breasting Dolphin BD-1*	*AW*	*6*	*02/2008*	*3*	*02/2011*	*See RAPs in Table ES-2*
North Wharf	*Berth 1*	*Breasting Dolphin BD-1*	*UW*	*5*	*02/2008*	*5*	*02/2013*	*See RAPs in Table ES-2*
North Wharf	*Berth 1*	*Dolphins, Trestle, Catwalks, Bulkhead walls, etc.*						
South Wharf	*Berth 2*							

These notes apply to Tables 31F-2-7A through 7C:

1. *The term "Overall" shall be input in this field when the assessment ratings are summarized for a berth.*
2. *"Types of Analyses": "O" = Operational Loading Analysis, "M" = Mooring Analysis, "B" = Berthing Analysis*
3. *"Types of Inspections": "AW" = Above Water Inspection, "UW" = Underwater Inspection*
4. *All assessment ratings shall be assigned in accordance with Table 31F-2-4.*
5. *The "Analysis Dates" are defined by the month and year in which the final design package is submitted to the Division.*
6. *The "Repair/Replacement Dates" are defined by the month and year in which the repair/replacement is to be completed and operational.*
7. *The "Description or Comments" shall reference all MOT operating limits. For OSARs, this includes berthing velocity restrictions, load limits, etc. For SSARs, this includes a brief list of the findings for each Seismic Performance Level.*
8. *Inspection findings may trigger a structural reassessment (see Tables 31F-2-7A and 31F-2-7B).*
9. *Ratings shall be assigned comparing the observed condition to the as-built condition.*
10. *The "Inspection Dates" are defined by the month and year in which the last day of formal field inspection is conducted.*

TABLE 31F-2-8

EXAMPLE	EXECUTIVE SUMMARY TABLE (ES-2) COMPONENT DEFICIENCY REMEDIAL ACTION PRIORITIES (RAP)[1]											REV. # MM/YYYY
Berthing system	**Berth(s)**	**Structure(s) or location(s)**	**Deficiency item label[2]**	**Component: deficiency description**	**Remedial action priority (RAP)[3]**	**CBC section reference**	**Audit checklist reference (optional)**	**Description of planned remedial action**	**P.E. review required? (Y/N)[4]**	**Repair/ replacement due date (MM/YYYY)**	**Completion date (MM/YYYY)**	**Description of completed actions**
North Wharf	*Berth 1*	*Wharfhead*	*02.0001.001*	***Piles:** 10 piles have severe damage; 15 piles have minor damage.*	*P2*	*3102F.3.5.2*		*Replace 10 severe piles. Monitor 15 minor piles.*	*Y*	*05/2008*	*04/2008*	*10 piles replaced*
North Wharf	*Berth 1*	*Mooring Dolphin MD-1*	*02.0001.002*	***Curb:** Spalling of concrete curb w/o exposed reinforcement.*	*R*	*3102F.3.5.2*		*Repair concrete curbs.*	*N*	*02/2009*		
North Wharf	*Berth 1*	*Wharfhead*	*08.0001.002*	***International Shore Fire Connection:** Connections available, but not connected.*	*P3*	*3108F.6.3.4*	*8.6.22*	*Install International Shore Fire Connections.*	*N*	*10/2008*		
North Wharf	*Berth 1*	*Wharfhead*	*11.0001.001*	***Conduit Seals near Manifold:** Conduit seals inadequate for Class 1, Division 1 location.*	*P1*	*3111F.2*		*Replace conduit seals with seals adequate for Class 1. Division 1 location within 30 days.*	*Y*	*04/2008*	*04/2008*	*Seals replaced*
North Wharf	*Berth 1*	*Wharfhead*	*11.0001.001*	***Pressurized Instrumentation Panel near Shelter:** Pressure gauge reads "low" and will not hold pressure in Class 1, Division 2 location.*	*P2*	*3111F.2*	*3111F.4.5*	*Repair pressurized instrumentati on panel in Class 1, Division 2 location within 60 days.*	*Y*	*05/2008*	*05/2008*	*Pressurized instrumentation panel could not be repaired and was replaced.*

These notes apply to Table 31F-2-8:

1. *After a deficiency is corrected/completed, the row of text corresponding to that deficiency may be grayed out in subsequent ES-2 tables, and removed entirely in the subsequent audit.*
2. *The "Deficiency Item Labels" shall be assigned in the format shown above with the first series of numbers representing the Code Division/Section number ("XX"), a period (".") for separation, the second series of numbers representing the deficiency item number ("XXXX"), a period (".") for separation, and the third series of numbers representing the ES-2 table revision number ("XXX") in which the deficiency was first reported. Note that the deficiency item numbering will start from "0001" for the first deficiency in each section of the audit, and will increase consecutively in all future ES-2 tables.*
3. *RAPs shall be assigned in accordance with Table 31F-2-5.*
4. *Professional engineering review required in accordance with Section 3102F.3.8 under "Follow-up Actions."*

TABLE 31F-2-9
POST-EVENT RATINGS AND REMEDIAL ACTIONS [2.2]

RATING	SUMMARY OF DAMAGE	REMEDIAL ACTIONS
A	*No significant event-induced damage observed.*	*No further action required. The berthing system may continue operations.*
B	*Minor to moderate event-induced damage observed but all primary structural elements and electrical/mechanical systems are sound.*	*Repairs or mitigation may be required to remain operational. The berthing system may continue operations.*
C	*Moderate to major event-induced damage observed which may have significantly affected the load bearing capacity of primary structural elements or the functionality of key electrical/mechanical systems.*	*Repairs or mitigation may be necessary to resume or remain operational. The berthing system may be allowed to resume limited operations.*
D	*Major event-induced damage has resulted in localized or widespread failure of primary structural components; or the functionality of key electrical/ mechanical systems has been significantly affected. Additional failures are possible or likely to occur.*	*The berthing system may not resume operations until the deficiencies are corrected.*

EXAMPLE

TERMINAL OPERATING LIMITS
Terminal Name & Location
50 to 75 KDWT Vessel Starboard Side

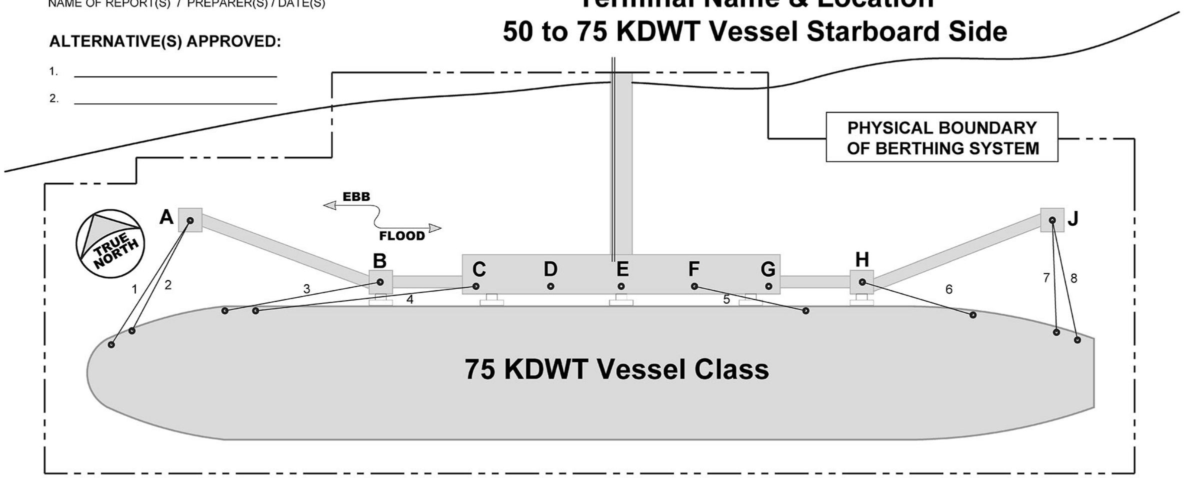
GENERAL INFORMATION

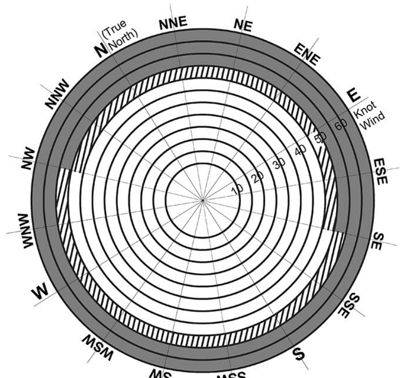
REFERENCE CALCULATION(S):

NAME OF REPORT(S) / PREPARER(S) / DATE(S)

ALTERNATIVE(S) APPROVED:

1. ____________
2. ____________





WIND RESTRICTION DIAGRAM
(WIND DIRECTION FROM)

LEGEND:

OPERATIONAL CONDITION

SURVIVAL CONDITION:
TERMINATE PRODUCT TRANSFER & DISCONNECT PRODUCT LINES

DEPARTURE CONDITION:
DEPART BERTH

ENVIRONMENTAL CONDITION LIMITS

1. WIND RESTRICTION DIAGRAM IS APPLICABLE FOR:
   - MAXIMUM EBB CURRENT: 3.9 KNOTS TOWARDS, 290 DEG TO 310 DEG FROM NORTH
   - MAXIMUM FLOOD CURRENT: 2.6 KNOTS TOWARDS, 110 DEG TO 130 DEG FROM NORTH
   - WAVE PERIOD: T < 4.0 SEC
2. TERMINATE PRODUCT TRANSFER AND DISCONNECT IF CURRENT EXCEEDS MAGNITUDE OR DIRECTION STATED IN NOTE 1.

MOORING DEVICE INFORMATION

MOORING POINT	DEVICE TYPE	CAPACITY (KIPS)
A	DOUBLE HOOK	300 (150 PER HOOK)
B	DOUBLE HOOK	300 (150 PER HOOK)
C	BOLLARD	200
D	BOLLARD	OUT OF SERVICE
E	BOLLARD	200
F	BOLLARD	200
G	BOLLARD	OUT OF SERVICE
H	DOUBLE HOOK	300 (150 PER HOOK)
J	TRIPLE HOOK	450 (150 PER HOOK)

VESSEL DESCRIPTION:

DWT CAPACITY	74,900 LT
MAXIMUM ARRIVAL DISPLACEMENT	75,700 LT
MAXIMUM DRAFT	47.0 FT
MAXIMUM ARRIVAL DRAFT	38.0 FT
MAXIMUM LOA	750.0 FT
MAXIMUM BEAM	105.0 FT

BERTH DESCRIPTION:

MINIMUM WATER DEPTH	40.0 FT @ MLLW
MINIMUM UNDERKEEL CLEARANCE	2.0 FT

BERTHING NOTES:

1. MAXIMUM IMPACT VELOCITY = 0.33 FPS.
2. BERTHING IS NOT ALLOWED AT AN APPROACH ANGLE GREATER THAN 6 DEGREES.
3. NO BERTHING OPERATION WILL TAKE PLACE WITH WIND VELOCITIES GREATER THAN 38 KNOTS (43.7 MPH).

MOORING NOTES:

1. PASSING VESSEL EFFECTS ARE CONSIDERED IN THE MOORING ANALYSIS.
2. MAXIMUM ALLOWED:
   SURGE : +/- 10 FT.
   SWAY : +/- 2.0 FT.
3. STOP OPERATIONS IF A PASSING VESSEL WITH LOA > 250 FT IS WITHIN 300 FT.
4. DO NOT EXCEED ONE LINE PER HOOK.

MOORING LINE DESCRIPTION :

MINIMUM NO. OF LINES	8
NO. OF HEAD LINES	0
NO. OF AFT LINES	0
NO. OF BREAST LINES	2 FORWARD, 2 AFT
NO. OF SPRING LINES	2 FORWARD, 2 AFT
MINIMUM BREAKING LOAD, MBL:	165 KIPS
ACTUAL LINE LOADS NOT TO EXCEED __% OF MBL	

REV. NO. & DATE

FIGURE 31F-2-1

Division 3

SECTION 3103F STRUCTURAL LOADING CRITERIA

3103F.1 General. *Section 3103F establishes the environmental and operating loads acting on the marine oil terminal (MOT) structures and on moored vessel(s). The analysis procedures are presented in Sections 3104F – 3107F.*

3103F.2 Dead loads.

3103F.2.1 General. *Dead loads shall include the weight of the entire structure, including permanent attachments such as loading arms, pipelines, deck crane, fire monitor tower, gangway structure, vapor control equipment and mooring hardware. Unit weights specified in Section 3103F.2.2 may be used for MOT structures if actual weights are not available.*

3103F.2.2 Unit weights. *The unit weights in Table 31F-3-1 may be used for both existing and new MOTs.*

TABLE 31F-3-1
UNIT WEIGHTS

MATERIAL	UNIT WEIGHT (pcf)*
Steel or cast steel	490
Cast iron	450
Aluminum alloys	175
Timber (untreated)	40-50
Timber (treated)	45-60
Concrete, reinforced (normal weight)	145-160
Concrete, reinforced (lightweight)	90-120
Asphalt paving	150

** pounds per cubic foot*

3103F.2.3 Equipment and piping area loads. *The equipment and piping area loads in Table 31F-3-2 may be used, as a minimum, in lieu of detailed as-built data.*

TABLE 31F-3-2
EQUIPMENT AND PIPING AREA LOADS

LOCATION	AREA LOADS (psf)***
Open areas	20*
Areas containing equipment and piping	35**
Trestle roadway	20*

** Allowance for incidental items such as railings, lighting, miscellaneous equipment, etc.*

***35 psf is for miscellaneous general items such as walkways, pipe supports, lighting and instrumentation. Major equipment weight shall be established and added into this weight for piping manifold, valves, deck crane, fire monitor tower, gangway structure and similar ma/or equipment.*

**** pounds per square foot*

3103F.3 Live loads and buoyancy. *The following vertical live loading shall be considered, where appropriate: uniform loading, truck loading, crane loading and buoyancy. Additionally, MOT specific, nonpermanent equipment shall be identified and used in loading computations.*

3103F.4 Earthquake loads.

3103F.4.1 General. *Earthquake loads are described in terms of Peak Ground Acceleration (PGA), spectral acceleration and earthquake magnitude. The required seismic analysis procedures (Tables 31F-4-1 and 31F-4-2) are dependent on the spill classification obtained from Table 31F-1-1.*

3103F.4.2 Design earthquake motion parameters. *The earthquake ground motion parameters of peak ground acceleration, spectral acceleration and earthquake magnitude are modified for site amplification and near fault directivity effects. The resulting values are the Design Peak Ground Acceleration (DPGA), Design Spectral Acceleration (DSA) and Design Earthquake Magnitude (DEM).*

For Site Classes A through E (Section 3103F.4.2.1), peak ground and design spectral accelerations shall be obtained from:

1. *U.S. Geological Survey (USGS) published data as discussed in Section 3103F.4.2.2, or*
2. *A site-specific probabilistic seismic hazard analysis (PSHA) as discussed in Section 3103F.4.2.3.*

Site-specific PSHA is required for Site Class F.

Unless stated otherwise, the DSA values are for 5 percent damping; values at other levels may be obtained as per Section 3103F.4.2.9.

The appropriate probability levels associated with DPGA and DSA for different seismic performance levels are provided in Table 31F-4-1. Deterministic earthquake motions, which are used only for comparison to the probabilistic results, are addressed in Section 3103F.4.2.7.

The evaluation of Design Earthquake Magnitude (DEM), is discussed in Section 3103F.4.2.8. This parameter is required when acceleration time histories (Section 3103F.4.2.10) are addressed or if liquefaction potential (Section 3106F.4) is being evaluated.

3103F.4.2.1 Site classes. *The following Site Classes, defined in Section 3106F.2.1, shall be used in developing values of DSA and DPGA:*

A, B, C, D, E and F

For Site Class F, a site-specific response analysis is required per Section 3103F.4.2.5.

3103F.4.2.2 Earthquake motions from USGS maps. *Earthquake ground motion parameters can be obtained directly from the US Seismic Design Maps tool available at the USGS website (http://earthquake.usgs.gov) for the site condition(s) appropriate for the MOT site and the selected probability of exceedance. For this purpose, select the ASCE/SEI 41 [3.1] as the design code reference document, and specify the appropriate custom parameters, including but not limited to, location, required Probability of Exceedance (in 50 years), and appropriate Site Soil Classification(s) for the MOT* *site. The USGS tool directly provides the peak ground and spectral accelerations for the selected hazard level and site condition(s).*

The alternative method of obtaining earthquake ground motion parameters, from the most current USGS data for selected hazard level and site condition(s), is permitted. If needed, the data for appropriate probability of exceedance may be obtained using the procedure described in Chapter 1 of FEMA 356 [3.2], and corrected for the MOT site as discussed in Section 3103F.4.2.4 or Section 3103F.4.2.5.

3103F.4.2.3 Earthquake motions from site-specific probabilistic seismic hazard analyses. *Site-specific Probabilistic Seismic Hazard Analysis (PSHA) shall use appropriate seismic sources and their characterization, attenuation relationships, probability of exceedance, and site soil conditions. Site-specific PSHA shall be conducted by a qualified California registered civil engineer with a California authorization as a geotechnical engineer per Section 3102F.3.4.8.*

If site-specific PSHA is used for Site Classes A, B, C, D or E, results from the site-specific PSHA shall be compared with those from the USGS published data as described in Section 3103F.4.2.2. If the two sets of values differ significantly, a justification for using the characterization chosen shall be provided. If DPGA and DSA from site-specific PSHA are less than 80 percent of the values from USGS data, a peer review may be required.

3103F.4.2.4 Simplified evaluation of site amplification effects. *When the MOT site class is different from the Site Classes B to C boundary, site amplification effects shall be incorporated in peak ground accelerations and spectral accelerations. This may be accomplished using a simplified method or a site-specific evaluation (Section 3103F.4.2.5).*

For a given site class, the following procedure from Chapter 1 of FEMA 356 [3.2] presents a simplified method that may be used to incorporate the site amplification effects for peak ground acceleration and spectral acceleration computed for the Site Classes B and C boundary.

1. *Calculate the spectral acceleration values at 0.20 and 1.0 second period:*

$$S_{XS} = F_a\, S_S \qquad (3\text{-}1)$$

$$S_{X1} = F_v\, S_1 \qquad (3\text{-}2)$$

where:

F_a = *site coefficient obtained from Table 31F-3-3*

F_v = *site coefficient obtained from Table 31F-3-4*

S_S = *short period (usually at 0.20 seconds) spectral acceleration value (for the boundary of Site Classes B and C) obtained using Section 3103F.4.2.2, or at the period corresponding to the peak in spectral acceleration values when obtained from Section 3103F.4.2.3*

S_1 = *spectral acceleration value (for the boundary of Site Classes B and C) at 1.0 second period*

S_{XS} = *spectral acceleration value obtained using the short period S_s and factored by Table 31F-3-3 for the site class under consideration.*

S_{X1} = *spectral acceleration value obtained using the 1.0 second period S_1 and factored by Table 31F-3-4 for the site class under consideration.*

2. *Set* $PGA_X = 0.4S_{XS}$ (3-3)

where:

PGA_X = *peak ground acceleration corresponding to the site class under consideration.*

When the value of PGA_X is less than the peak ground acceleration obtained following Section 3103F.4.2.2 or Section 3103F.4.2.3, an explanation of the results shall be provided.

3. *PGA_X, S_{XS}, and S_{X1} constitute three spectral acceleration values for the site class under consideration corresponding to periods of 0, S_S (usually 0.2 seconds), and 1.0 second, respectively.*

4. *The final response spectra, without consideration for near-fault directivity effects, values of S_a for the site class under consideration may be obtained using the following equations (for 5 percent critical damping):*

For $0 < T < 0.2T_0$

$$S_a = (S_{XS})(0.4 + 3T/T_0) \qquad (3\text{-}4)$$

where:

T = *Period corresponding to calculated S_a*

T_0 = *Period at which the constant acceleration and constant velocity regions of the design spectrum intersect*

For $0.2T_0 < T < T_0$

$$S_a = S_{XS} \qquad (3\text{-}5)$$

For $T > T_0$

$$S_a = S_{X1}/T \qquad (3\text{-}6)$$

where:

$$T_0 = S_{X1}/S_{XS} \qquad (3\text{-}7)$$

The resulting PGA_X is the DPGA. However, the S_a shall be modified for near-fault directivity effects, per Section 3103F.4.2.6 to obtain the final DSAs.

TABLE 31F-3-3
VALUES OF F_a

SITE CLASS	S_S				
	< 0.25	0.5	0.75	1.0	> 1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	*	*	*	*	*

Note: *Linear interpolation can he used to estimate values of F_a for intermediate values of S_S.*

** Site-specific dynamic site response analysis shall be performed.*

TABLE 31F-3-4
VALUES OF F_V

SITE CLASS	S_1				
	< 0.1	0.2	0.3	0.4	> 0.5
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	*	*	*	*	*

Note: *Linear interpolation can he used to estimate values of F_v for intermediate values of S_1.*

** Site-specific dynamic site response analysis shall be performed.*

3103F.4.2.5 Site-specific evaluation of amplification effects. *As an alternative to the procedure presented in Section 3103F.4.2.4, a site-specific response analysis may be performed. For Site Class F a site-specific response analysis is required. The analysis shall be either an equivalent linear or nonlinear analysis. Appropriate acceleration time histories as discussed in Section 3103F.4.2.10 shall be used.*

In general, an equivalent linear analysis using, for example, SHAKE91 [3.3] is acceptable when the strength and stiffness of soils are unlikely to change significantly during the seismic shaking, and the level of shaking is not large. A nonlinear analysis should be used when the strength and/or stiffness of soils could significantly change during the seismic shaking or significant nonlinearity of soils is expected because of high seismic shaking levels.

The choice of the method used in site response analysis shall be justified considering the expected stress-strain behavior of soils under the shaking level considered in the analysis.

Site-specific site response analysis may be performed using one-dimensional analysis. However, to the extent that MOTs often involve slopes or earth retaining structures, the one-dimensional analysis should be used judiciously. When one-dimensional analysis cannot be justified or is not adequate, two-dimensional equivalent linear or nonlinear response analysis shall be performed. Site-specific response analysis results shall be compared to those based on the simplified method of Section 3103F.4.2.4 for reasonableness.

The peak ground accelerations obtained from this site-specific evaluation are DPGAs and the spectral accelerations are DSAs as long as the near-fault directivity effects addressed in Section 3103F.4.2.6 are appropriately incorporated into the time histories (Section 3103F.4.2.10).

3103F.4.2.6 Directivity effects. *When the site is 15 km (9.3 miles) or closer to a seismic source that can significantly affect the site, near-fault directivity effects shall be reflected in the spectral acceleration values and in the deterministic spectral acceleration values of Section 3103F.4.2.7.*

Two methods are available for incorporating directivity effects:

1. *Directivity effects may be reflected in the spectral acceleration values in a deterministic manner by using well established procedures such as that described in Somerville, et al. [3.4]. The critical seismic sources and their characterization developed as part of the deterministic ground motion parameters (Section 3103F.4.2.7) should be used to evaluate the directivity effects. The resulting adjustments in spectral acceleration values may be applied in the probabilistic spectral acceleration values developed per Section 3103F.4.2.4 or 3103F.4.2.5. Such adjustment can be independent of the probability levels of spectral accelerations.*
2. *Directivity effects may be incorporated in the results of site specific PSHA per Section 3103F.4.2.3. In this case, the directivity effects will also depend on the probability level of spectral accelerations.*

If spectral accelerations are obtained in this manner, the effects of site amplification using either Section 3103F.4.2.4, 3103F.4.2.5 or an equivalent method (if justified) shall be incorporated.

3103F.4.2.7 Deterministic earthquake motions. *Deterministic ground motions from "scenario" earthquakes may be used for comparison purposes. Deterministic peak ground accelerations and spectral accelerations may be obtained using the "Critical Seismic Source" with maximum earthquake magnitude and its closest appropriate distance to the MOT. "Critical Seismic Source" is that which results in the largest computed median peak ground acceleration and spectral acceleration values when appropriate attenuation relationships are used. The values obtained from multiple attenuation relationships should be used to calculate the median peak ground acceleration and spectral acceleration values.*

For comparison, the values of peak ground accelerations and spectral accelerations may be obtained from *the USGS maps, corresponding to the Maximum Considered Earthquake (MCE). In this case, the median values of peak ground acceleration and spectral acceleration values shall be 2/3 (see Section 1.6 of FEMA 356 [3.2]) of the values shown on the USGS maps.*

3103F.4.2.8 Design Earthquake Magnitude. *The Design Earthquake Magnitude used in developing site-specific acceleration time histories (Section 3103F.4.2.10) or liquefaction assessment (Section 3106F.4) is obtained using either of the following two methods:*

1. *The design earthquake may be selected as the largest earthquake magnitude associated with the critical seismic source. The distance shall be taken as the closest distance from the source to the site. The resulting design earthquake shall be associated with all DPGA values for the site, irrespective of probability levels.*
2. *The design earthquake (DEQ) may be obtained for each DPGA or DSA value and associated probability level by determining the corresponding dominant distance and magnitude. These are the values of the distance and magnitude that contribute the most to the mean seismic hazards estimates for the probability of interest. They are usually determined by locating the summits of the 3-D surface of contribution of each small interval of magnitude and distance to the total mean hazards estimate. If this 3-D surface shows several modes with approximate weight of more than 20 percent of the total, several DEQs may be considered, and the DEQ leading to the most conservative design parameters shall be used.*

3103F.4.2.9 Design Spectral Acceleration for various damping values. *Design Spectral Acceleration (DSA) values at damping other than 5 percent shall be obtained by using a procedure given in Chapter 1 of FEMA 356 [3.2], and is denoted as DSA_d. The following procedure does not include near-fault directivity effects.*

For $0 < T < 0.2\,T_0$

$$DSA_d = S_{XS}\,[(5/B_S - 2)\,T/T_0 + 0.4] \qquad (3\text{-}8)$$

For $0.2\,T_0 < T < T_0$

$$DSA_d = DSA/B_S \qquad (3\text{-}9)$$

For $T > T_0$

$$DSA_d = S_1/(B_1\,T) \qquad (3\text{-}10)$$

where:

T = period

T_0 = S_{X1}/S_{XS}

B_S = Coefficient used to adjust the short period spectral response, for the effect of viscous damping.

B_1 = Coefficient used to adjust one-second period spectral response, for the effect of viscous damping

Values of B_S and B_1 are obtained from Table 31F-3-5.

Such a procedure shall incorporate the near-fault directivity effects when the MOT is 15 km (9.3 miles) or closer to a significant seismic source.

TABLE 31F-3-5
VALUES OF B_S AND B_1 [3.2]

DAMPING (%)	B_S	B_1
< 2	0.8	0.8
5	1.0	1.0
10	1.3	1.2
20	1.8	1.5
30	2.3	1.7
40	2.7	1.9
> 50	3.0	2.0

Note: *Linear interpolation should be used for damping values not specifically listed.*

3103F.4.2.10 Development of acceleration time histories. *When acceleration time histories are utilized, target spectral acceleration values shall be initially selected corresponding to the DSA values at appropriate probability levels. For each set of target spectral acceleration values corresponding to one probability level, at least three sets of horizontal time histories (one or two horizontal acceleration time histories per set) shall be developed.*

Initial time histories shall consider magnitude, distance and the type of fault that are reasonably similar to those associated with the conditions contributing most to the probabilistic DSA values. Preferred initial time histories should have their earthquake magnitude and distance to the seismic source similar to the mode-magnitude and mode-distance derived from the PSHA or from appropriate maps. When an adequate number of recorded time histories are not available, acceleration time histories from simulations may be used as supplements.

Scaling or adjustments, either in the frequency domain or in the time domain (preferably), prior to generating acceleration time histories should be kept to a minimum. When the target spectral accelerations include near-fault directivity effects (Section 3103F.4.2.6), the initial time histories should exhibit directivity effects.

When three sets of time histories are used in the analysis, the envelope of the spectral acceleration values from each time history shall be equal to or higher than the target spectral accelerations. If the envelope values fall below the target values, adjustments shall be made to ensure that the spectral acceleration envelope is higher than target spectral accelerations. If the envelope is not higher, then a justification shall be provided.

When seven or more sets of time histories are used, the average of the spectral acceleration values from the *set of time histories shall be equal or higher than the target spectral acceleration values. If the average values fall below the target values, adjustments shall be made to ensure that average values are higher than the target spectral accelerations. If this is not the case, then an explanation for the use of these particular spectral acceleration values shall be provided.*

When three sets of time histories are used in the analysis, the maximum value of each response parameter shall be used in the design, evaluation and rehabilitation. When seven or more sets of time histories are used in the analysis, the average value of each response parameter may be used.

3103F.5 Mooring loads on vessels.

3103F.5.1 General. *Forces acting on a moored vessel may be generated by wind, waves, current, tidal variations, tsunamis, seiches and hydrodynamic effects of passing vessels. Forces from wind and current acting directly on the MOT structure (not through the vessel in the form of mooring and/ or breasting loads) shall be determined in Section 3103F.7.*

The vessel's moorings shall be strong enough to hold during all expected environmental and passing vessel conditions (see Section 3105F), while adequately accommodating changes in draft, surge, sway, yaw and tide.

3103F.5.2 Wind loads. *Wind loads on a vessel, moored at a MOT, shall be determined using procedures described in this section. Wind speed measured at an elevation of 33 feet (10 meters) above the water surface, with duration of 30 seconds shall be used to determine the design wind speed and wind limits for moored vessels. If these conditions are not met, adjustment factors shall be applied per Sections 3103F.5.2.2.*

3103F.5.2.1 Design wind speed. *For new MOTs, the 25-year return period shall be used to establish the design wind speed for each direction. The design wind speed is the maximum wind speed of 30-second duration used in the mooring analysis (see Section 3105F). The 30-second duration wind speed shall be determined from the annual maximum wind data. Average annual summaries cannot be used. Maximum wind speed data for a minimum of eight directions (45-degree increments) shall be obtained. If other duration wind data is available, it shall be adjusted to a 30-second duration, in accordance with Equation (3-12).*

3103F.5.2.2 Wind limits for moored vessels. *Wind loads shall be calculated for each of the load cases identified in Section 3105F.2. Wind velocity limits for moored vessels shall be presented in the Terminal Operating Limits (see Section 3102F.3.6.1 and Figure 31F-2-1) for each of the conditions given below.*

3103F.5.2.2.1 Operational condition. *The operational condition is defined as the wind envelope in which a vessel may conduct transfer operations, as determined from the mooring analysis (Section 3105F). Transfer operations shall cease when the wind exceeds the maximum velocity of the envelope.*

3103F.5.2.2.2 Survival condition. *The survival condition is defined as the state wherein a vessel can remain safely moored at the berth during severe winds; however, loading arms and hoses shall be disconnected (see Sections 3110F.2 and 3110F.3 regarding movement limits of loading arms and hoses, respectfully). The survival condition is the wind zone between the operational condition and the departure condition (defined in Section 3103F.5.2.2). In this wind zone, the vessel must prepare to depart the berth.*

3103F.5.2.2.3 Departure condition. *The departure condition is defined as the wind state above which a vessel can no longer remain safely moored at the berth during severe winds, as determined from the mooring analysis (Section 3105F). For a new MOT, the departure condition threshold is the maximum wind velocity, for a 30-second gust and a 25-year return period, obtained from historical data. If the wind rises above these levels, the vessel must depart the berth.*

3103F.5.2.3 Wind speed corrections. *Wind speed measured at an elevation of 33 feet (10 meters) above the water surface, with duration of 30 seconds shall be used to determine the design wind speed. If these conditions are not met, the following corrections shall be applied.*

The correction for elevation is obtained from the equation:

$$V_w = V_h\left(\frac{33}{h}\right)^{1/7} \quad (3\text{-}11)$$

where:

V_w = *wind speed at elevation 33 ft. (10 m.)*

V_h = *wind speed at elevation h*

h = *elevation above water surface of wind data [feet]*

The available wind duration shall be adjusted to a 30-second value, using the following formula:

$$V_{t\,=\,30\,sec} = \frac{V_t}{c_t} \quad (3\text{-}12)$$

where:

$V_{t\,=\,30\,sec}$ = *wind speed for a 30-second duration*

V_t = *wind speed over a given duration*

c_t = *conversion factor from Figure 31F-3-1*

If wind data is available over land only, the following equation shall be used to convert the wind speed from over-land to over-water conditions [3.5]:

$$V_w = 1.10\,V_L \quad (3\text{-}13)$$

where:

V_w = *over water wind speed*

V_L = *over land wind speed*

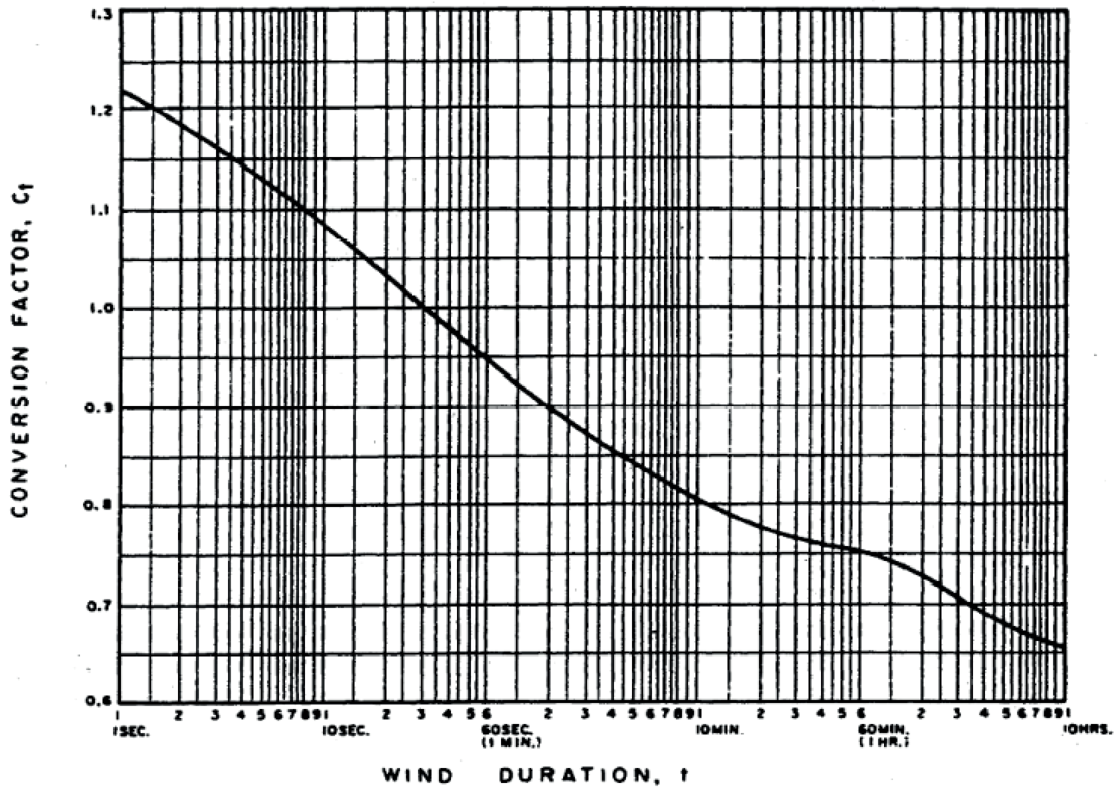


FIGURE 31F-3-1 WIND SPEED CONVERSION FACTOR [3.5]

3103F.5.2.4 Static wind loads on vessels. *The OCIMF MEG3 [3.6] shall be used to determine the wind loads for all tank vessels.*

Alternatively, wind loads for any type of vessel may be calculated using the guidelines in Ferritto et al. [3.7].

3103F.5.3 Current loads.

3103F.5.3.1 Design current velocity. *Maximum ebb and flood currents, annual river runoffs and controlled releases shall be considered when establishing the design current velocities for both existing and new MOTs.*

Local current velocities may be obtained from NOAA [3.8] or other sources, but must be supplemented by site-specific data, if the current velocity is higher than 1.5 knots.

Site-specific data shall be obtained by real time measurements over a one-year period. If this information is not available, a safety factor of 1.25 shall be applied to the best available data until real time measurements are obtained.

If the facility is not in operation during annual river runoffs and controlled releases, the current loads may be adjusted.

Operational dates need to be clearly stated in the definition of the Terminal Operating Limits (see Section 3102F.3.6.1 and Figure 31F-2-1).

3103F.5.3.2 Current velocity adjustment factors. *An average current velocity (V_c) shall be used to compute forces and moments. If the current velocity profile is known, the average current velocity can be obtained from the following equation:*

$$V_c^2 = (1/T)\int_o^t (v_c)^2\, ds \qquad (3\text{-}14)$$

where:

V_c = *average current velocity (knots)*

T = *draft of vessel*

v_c = *current velocity as a function of depth (knots)*

s = *water depth measured from the surface*

If the velocity profile is not known, the velocity at a known water depth shall be adjusted by the factors provided in Figure 31F-3-2 to obtain the equivalent average velocity over the draft of the vessel.

3103F.5.3.3 Static current loads. *The OCIMF MEG3 [3.6] or the UFC 4-159-03 [3.9] procedures shall be used to determine current loads for moored tank vessels.*

3103F.5.3.4 Sea level rise (SLR). *All MOTs shall consider the predicted SLR over the remaining life of the terminal, due to subsidence or climate change combined with maximum high tide and storm surge. Consideration shall include but not be limited to variation in fender locations, additional berthing loads (deeper draft vessels) and any components near the splash zone.*

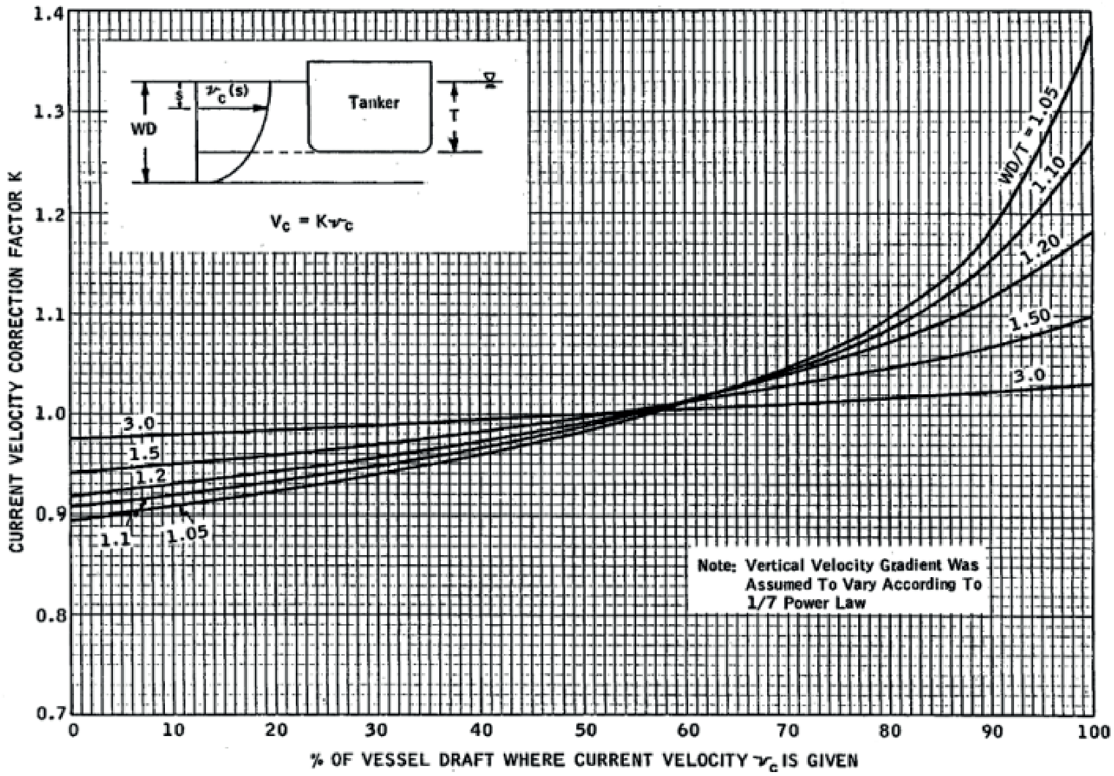


FIGURE 31F-3-2 CURRENT VELOCITY CORRECTION FACTOR (p. 23 [3.6])

3103F.5.4 Wave loads. *When the significant wave period, T_s, is greater than 4 seconds (see Section 3105F.3.1), the transverse wave induced vessel reactions shall be calculated using a simplified dynamic mooring analysis described below.*

The horizontal water particle accelerations shall be calculated for the various wave conditions, taken at the mid-depth of the loaded vessel draft. The water particle accelerations shall then be used to calculate the wave excitation forces to determine the static displacement of the vessel. The Froude-Krylov method discussed in Chakrabarti's Chapter 7 [3.10] may be used to calculate the wave excitation forces, by conservatively approximating the vessel as a rectangular box with dimensions similar to the actual dimensions of the vessel. The horizontal water particle accelerations shall be calculated for the various wave conditions, taken at the mid-depth of the loaded vessel draft. The computed excitation force assumes a 90-degree incidence angle with the longitudinal axis of the vessel, which will result in forces that are significantly greater than the forces that will actually act upon the vessel from quartering seas. A load reduction factor may be used to account for the design wave incidence angle from the longitudinal axis of the ship. The overall excursion of the vessel shall be determined for each of the wave conditions by calculating the dynamic response of the linear spring mass system.

3103F.5.5 Passing vessels. *When required in Section 3105F.3, the sway and surge forces, as well as yaw moment, on a moored vessel, due to passing vessels, shall be established considering the following:*

1. *Ratio of length of moored vessel to length of passing vessel.*
2. *Distance from moored vessel to passing vessel.*
3. *Ratio of midship section areas of the moored and passing vessels.*
4. *Underkeel clearances of the moored and passing vessels.*
5. *Draft and trim of the moored vessel and draft of the passing vessel.*
6. *Mooring line tensions.*

The passing vessel's speed should take into consideration the ebb or flood current. Normal operating wind and current conditions can be assumed when calculating forces due to a passing vessel. Either method of Kriebel [3.11] or Wang [3.12] may be used to determine forces on a moored vessel. Kriebel's recent wave tank study improves on an earlier work of Seelig [3.13].

3103F.5.6 Seiche. *The penetration of long period low amplitude waves into a harbor can result in resonant standing wave systems, when the wave forcing frequency coincides with a natural frequency of the harbor. The resonant standing waves can result in large surge motions if this frequency is close to the natural frequency of the mooring system. Section 3105F.3.3 prescribes the procedure for the evaluation of these effects.*

3103F.5.7 Tsunamis. *A tsunami may be generated by an earthquake or a subsea or coastal landslide, which may induce large wave heights and excessive currents. The large wave or surge and the excessive currents are potentially damaging, especially if there is a tank vessel moored alongside the MOT wharf.*

Tsunamis can be generated either by a distant or near source. A tsunami generated by a distant source (far field event) may allow operators to have an adequate warning for mitigating the risk by allowing the vessels to depart the MOT and go into deep water. For near-field events, with sources less than 500 miles away, the vessel may not have adequate time to depart. Each MOT shall have a "tsunami plan" describing what actions will be performed, in the event of a distant tsunami.

Recent tsunami studies have been completed for both Southern and Northern California. For the Ports of Los Angeles and Long Beach, one of these recent studies focused on near field tsunamis with predicted return periods of 5,000 to 10,000 years [3.14]. These maximum water levels (run-up) would not normally be used for MOT design. However, because the study also provides actual tidal records from recent distant tsunamis, it should be used for design.

The run-up value for Port Hueneme was obtained from an earlier study by Synolakis et al. [3.15].

Run up-values: Port of Los Angeles and Long Beach = 8 ft.

Port Hueneme = 11 ft.

For the San Francisco Bay, a recent study provides the maximum credible tsunami water levels and current speeds. These results are deterministic and are based on the most severe seismic sources that could reasonably impact MOTs in the San Francisco Bay [3.16]. Table 31F-3-6 provides values for the marine oil terminal locations within San Francisco Bay. Water levels could be positive or negative and current velocities may vary in direction. In order to determine the maximum run-up at a MOT, the largest values should be added to the mean high tide. Further details are available in [3.16].

Loads from tsunami-induced waves can be calculated for various structural configurations [3.17]. Tsunami wave heights in shallow water and particle kinematics can also be obtained. Other structural considerations include uplift and debris impact.

TABLE 31F-3-6
TSUNAMI RUN-UP VALUES (ft) AND CURRENT SPEEDS (ft/sec) IN THE SAN FRANCISCO BAY AREA (AFTER [3.16])

S.F. BAY LOCALE	MAXIMUM WATER LEVELS (ft.)	CURRENT VELOCITY (ft/sec)
Richmond, outer	7.5	4.9
Richmond, inner	7.9	8.9
Martinez	2.3	1.3
Selby	2.6	1.6
Rodeo	2.6	2.0
Benicia	2.0	1.0

3103F.6 Berthing Loads.

3103F.6.1 General. *Berthing loads are quantified in terms of transfer of kinetic energy of the vessel into potential energy dissipated by the fender(s). The terms and equations below are based on those in UFC 4-152-01 [3.18] and PIANC [3.19].*

Kinetic energy shall be calculated from the following equation:

$$E_{vessel} = \frac{1}{2} \cdot \frac{W}{g} \cdot V_n^2 \quad (3\text{-}15)$$

where:

E_{vessel} = *Berthing energy of vessel [ft-lbs]*

W = *Total weight of vessel and cargo in pounds [long tons × 2240]*

g = *Acceleration due to gravity [32.2 ft/sec²]*

V_n = *Berthing velocity normal to the berth [ft/sec]*

The following correction factors shall be used to modify the actual energy to be absorbed by the fender system for berthing operations:

$$E_{fender} = F_A \cdot C_b \cdot C_m \cdot E_{vessel} \quad (3\text{-}16)$$

where:

E_{fender} = *Energy to be absorbed by the fender system*

F_A = *Accidental factor accounting for abnormal conditions such as human error, malfunction, adverse environmental conditions or a combination of these factors. For existing berthing systems, F_A may be taken as 1.0. For new berthing systems, F_A shall be determined in accordance with Section 5-1.5.3 of UFC 4-152-01 [3.18] or PIANC Section 4.2.8 [3.19].*

C_b = *Berthing Coefficient*

C_m = *Effective mass or virtual mass coefficient (see Section 3103F.6.6)*

The berthing coefficient, C_b, is given by:

$$C_b = C_e \cdot C_g \cdot C_d \cdot C_c \quad (3\text{-}17)$$

where:

C_e = *Eccentricity Coefficient*

C_c = *Configuration Coefficient*

C_g = *Geometric Coefficient*

C_d = *Deformation Coefficient*

These coefficients are defined in Sections 3103F.6.2 through 3103F.6.5.

The approximate displacement of the vessel (when only partially loaded) at impact, DT, can be determined from an extension of an equation from Gaythwaite [3.20]:

$$DT = 1.25\ DWT(d_{actual}/d_{max}) \quad (3\text{-}18)$$

where:

DWT = *Dead Weight Tonnage (in long tons)*

d_{actual} = *Actual arrival draft of the vessel*

d_{max} = *Maximum loaded vessel draft*

The berthing load shall be based on the fender reaction due to the kinetic berthing energy. The structural capacity shall be established based on allowable concrete, steel or timber properties in the structural components, as defined in Section 3107F.

For fender system selection, Section 3105F.4.5 shall be followed.

3103F.6.2 Eccentricity coefficient (C_e). *During the berthing maneuver, when the vessel is not parallel to the berthing line (usually the wharf face), not all the kinetic energy of the vessel will be transmitted to the fenders. Due to the reaction from the fender(s), the vessel will start to rotate around the contact point, thus dissipating part of its energy. Treating the vessel as a rigid rod of negligible width in the analysis of the energy impact on the fenders leads to the equation:*

$$C_e = \frac{k^2}{a^2 + k^2} \qquad (3\text{-}19)$$

where:

k = Longitudinal radius of gyration of the vessel [ft]

a = Distance between the vessel's center of gravity and the point of contact on the vessel's side, projected onto the vessel's longitudinal axis [ft]

3103F.6.3 Geometric coefficient (C_g). *The geometric coefficient, C_g, depends upon the geometric configuration of the ship at the point of impact. It varies from 0.85 for an increasing convex curvature to 1.25 for concave curvature. Generally, 0.95 is recommended for the impact point at or beyond the quarter points of the ship, and 1.0 for broadside berthing in which contact is made along the straight side [3.18].*

3103F.6.4 Deformation coefficient (C_d). *This accounts for the energy reduction effects due to local deformation of the ships hull and deflection of the whole ship along its longitudinal axis. The energy absorbed by the ship depends on the relative stiffness of the ship and the obstruction. The deformation coefficient varies from 0.9 for a nonresilient fender to nearly 1.0 for a flexible fender. For larger ships on energy-absorbing fender systems, little or no deformation of the ship takes place; therefore, a coefficient of 1.0 is recommended.*

3103F.6.5 Configuration coefficient (C_c). *This factor accounts for the difference between an open pier or wharf and a solid pier or wharf. In the first case, the movements of the water surrounding the berthing vessel is not (or is hardly) affected by the berth. In the second case, the water between the berthing vessel and the structure introduces a cushion effect that represents an extra force on the vessel away from the berth and reduces the energy to be absorbed by the fender system.*

For open berth and corners of solid piers, $C_c = 1.0$

For solid piers with parallel approach, $C_c = 0.8$

For berths with different conditions, C_c may be interpolated between these values [3.18].

3103F.6.6 Effective mass or virtual mass coefficient (C_m). *In determining the kinetic energy of a berthing vessel, the effective or the virtual mass is the sum of vessel mass and hydrodynamic mass. The hydrodynamic mass does not necessarily vary with the mass of the vessel, but is closely related to the projected area of the vessel at right angles to the direction of motion.*

Other factors, such as the form of vessel, water depth, berthing velocity, and acceleration or deceleration of the vessel, will have some effect on the hydrodynamic mass. Taking into account both model and prototype experiments, the effective or virtual mass coefficient can be estimated as:

$$C_m = 1 + 2 \cdot \frac{d_{actual}}{B} \qquad (3\text{-}20)$$

where:

d_{actual} = Actual arrival draft of the vessel

B = Beam of vessel

The value of C_m for use in design should be a minimum of 1.5 and need not exceed 2.0 [3.18].

3103F.6.7 Berthing velocity and angle. *The berthing velocity, V_n, is influenced by a large number of factors such as environmental conditions of the site (wind, current and wave), method of berthing (with or without tugboat assistance), condition of the vessel during berthing (ballast or fully laden) and human factors (experience of the tugboat captain).*

The berthing velocity, normal to berth, shall be in accordance with Table 31F-3-7. Site condition is determined from Table 31F-3-8.

Subject to Division approval, if an existing MOT can demonstrate lower velocities by utilizing velocity monitoring equipment, then such a velocity may be used temporarily until the berthing system is compliant with this Code.

TABLE 31F-3-7
BERTHING VELOCITY V_n (NORMAL TO BERTH)[1]

VESSEL SIZE (DWT)	TUG BOAT ASSISTANCE	SITE CONDITIONS		
		Unfavorable	Moderate	Favorable
≤ 10,000	No	1.31 ft/sec	0.98 ft/sec	0.53 ft/sec
≤ 10,000	Yes	0.78 ft/sec	0.66 ft/sec	0.33 ft/sec
50,000	Yes	0.53 ft/sec	0.39 ft/sec	0.26 ft/sec
≥ 100,000	Yes	0.39 ft/sec	0.33 ft/sec	0.26 ft/sec

1. For vessel sizes not shown, interpolation between velocities may be used.

TABLE 31F-3-8
SITE CONDITIONS

SITE CONDITIONS	DESCRIPTION	WIND SPEED[1]	SIGNIFICANT WAVE HEIGHT	CURRENT SPEED[2]
Unfavorable	*Strong Wind* *Strong Currents* *High Waves*	*> 38 knots*	*> 6.5 ft*	*> 2 knots*
Moderate	*Strong Wind* *Moderate Current* *Moderate Waves*	*≥38 knots*	*≤6.5 ft*	*≤2 knots*
Favorable	*Moderate Wind* *Moderate Current* *Moderate Waves*	*< 38 knots*	*< 6.5 ft*	*< 2 knots*

1. A 30-second duration measured at a height of 33 ft.
2. Taken at 0.5 x water depth

In order to obtain the normal berthing velocity, V_n, an approach angle, defined as the angle formed by the fender line and the longitudinal axis of the vessel must be determined. The berthing angles, used to compute the normal berthing velocity, for various vessel sizes are shown in Table 31F-3-9.

TABLE 31F-3-9
BERTHING ANGLE

VESSEL SIZE (DWT)	ANGLE (degrees)
Barge	*15*
< 10,000	*10*
10,000-50,000	*8*
> 50,000	*6*

3103F.7 Wind and current loads on structures.

3103F.7.1 General. *This section provides methods to determine the wind and current loads acting on the structure directly, as opposed to wind and current forces acting on the structure from a moored vessel.*

3103F.7.2 Wind loads. *Chapter 29 of ASCE/SEI 7 [3.21] shall be used to establish minimum wind loads on the structure. Additional information about wind loads may be obtained from Simiu and Scanlan [3.22].*

3103F.7.3 Current loads. *The current forces acting on the structure may be established using the current velocities, per Section 3103F.5.3.*

3103F.8 Load combinations. *As a minimum, each component of the structure shall be analyzed for all applicable load combinations given in Table 31F-3-10 or Table 31F-3-11, depending on component type. For additional load combinations, see UFC 4-152-01 [3.18].*

The "vacant condition" is the case wherein there is no vessel at the berth. The "mooring and breasting condition" exists after the vessel is securely tied to the wharf. The "berthing condition" occurs as the vessel impacts the wharf, and the "earthquake condition" assumes no vessel is at the berth, and there is no wind or current forces on the structure.

The use of various load types is discussed below:

3103F.8.1 Dead load (D). *Upper and lower bound values of dead load are applied for the vacant condition to check the maximum moment and shear with minimum axial load.*

3103F.8.2 Live load (L). *Typically, the live load on MOTs is small and may be neglected for combinations including earthquake loads. However, in some cases, a higher value of live load may be warranted depending on MOT use, and an appropriate value of live load shall be considered for combinations including earthquake loads.*

3103F.8.3 Buoyancy load (B). *Buoyancy forces shall be considered for any submerged or immersed substructures (including pipelines, sumps and structural components).*

3103F.8.4 Wind (W) and current (C) on the structure. *Wind and currents on the vessel are included in the mooring and breasting condition. The wind and current loads acting on the structure are therefore additional loads that can act simultaneously with the mooring, breasting and/or berthing loads.*

3103F.8.5 Earth pressure on the structure (H). *The soil pressure on end walls, typically concrete cut-off walls, steel sheet pile walls on wharf type structures and/or piles shall be considered.*

3103F.8.6 Mooring line/breasting loads (M). *Mooring line and breasting loads can occur simultaneously or individually, depending on the combination of wind and current. Multiple load cases for operating and survival conditions may be required (see Sections 3103F.5.2 and 3105F.2). In addition, loads caused by passing vessels shall be considered for the "mooring and breasting condition." Refer to Sections 3105F.2 and 3105F.3 for the determination of mooring line and breasting loads.*

3103F.8.7 Berthing load (B_e). *Berthing is a frequent occurrence, and shall be considered as a normal operating load. No increase in allowable stresses shall be applied for ASD.*

3103F.8.8 Earthquake loads (E). *Performance based seismic analysis methodology requires that the actual displacement demand be limited to defined strains in concrete, steel and timber. For the deck and pile evaluation, two cases of dead load (upper and lower bound) shall be considered in combination with the seismic load.*

TABLE 31F-3-10
LRFD LOAD FACTORS FOR LOAD COMBINATIONS [3.18]

LOAD TYPE	VACANT CONDITION		MOORING & BREASTING CONDITION	BERTHING CONDITION	EARTHQUAKE CONDITION[3]	
Dead Load (D)	1.2	0.9	1.2	1.2	1.2 + k[1]	0.9-k[1]
Live Load (L)	1.6	—	1.6[2]	1.0	1.0	—
Buoyancy (B)	1.2	0.9	1.2	1.2	1.2[1]	0.9[1]
Wind on Structure (W)	1.6	1.6	1.6	1.6	—	—
Current on Structure (C)	1.2	0.9	1.2	1.2	1.2	0.9
Earth Pressure on the Structure (H)	1.6	1.6	1.6	1.6	1.6[4]	1.6[4]
Mooring/Breasting Load (M)	—	—	1.6	—	—	—
Berthing Load (B_e)	—	—	—	1.6	—	—
Earthquake Load (E)	—	—	—	—	1.0	1.0

1. k = 0.50 (PGA) The k factor (k=0.5(PGA)) and buoyancy (B) shall be applied to the vertical dead load (D) only, and not to the inertial mass of the structure.
2. The load factor for live load (L) may be reduced to 1.3 for the maximum outrigger float load from a truck crane.
3. For Level 1 and 2 earthquake conditions with strain levels defined in Division 7, the current on structure (C) may not be required.
4. An earth pressure on the Structure factor (H) of 1.0 may be used for pile or bulkhead structures.

TABLE 31F-3-11
SERVICE OR ASD LOAD FACTORS FOR LOAD COMBINATIONS [3.18]

LOAD TYPE	VACANT CONDITION	MOORING & BREASTING CONDITION	BERTHING CONDITION	EARTHQUAKE CONDITION	
Dead Load (D)	1.0	1.0	1.0	1 + 0.7k[1]	1 - 0.7k[1]
Live Load (L)	1.0	1.0	0.75	0.75	—
Buoyancy (B)	1.0	1.0	1.0	1.0	0.6
Wind on Structure (W)	1.0	1.0	0.75	—	—
Current on Structure (C)	1.0	1.0	1.0	—	—
Earth Pressure on the Structure (H)	1.0	1.0	1.0	1.0	1.0
Mooring/Breasting Load (M)	—	1.0	—	—	—
Berthing Load (B_e)	—	—	1.0	—	—
Earthquake Load (E)	—	—	—	0.7	0.7
% Allowable Stress	100	100	100	100[2]	

1. k = 0.5 (PGA)
2. Increase in allowable stress shall not be used with these load combinations unless it can be demonstrated that such increase is justified by structural behavior caused by rate or duration of load. See ASCE/SEI 7 [3.21]

3103F.9 Miscellaneous loads. Handrails and guardrails shall be designed for 25 plf with a 200-pound minimum concentrated load in any location or direction.

3103F.10 Symbols.

a = Distance between the vessel's center of gravity and the point of contact on the vessel's side, projected onto the vessel's longitudinal axis [ft]

A = Site Class A as defined in Table 31F-6-1

B = Beam of vessel

B = Site Class B as defined in Table 31F-6-1

B_1 = Coefficient used to adjust one-second period spectral response, for the effect of viscous damping

B_s = Coefficient used to adjust the short period spectral response, for the effect of visous damping.

C = Site Class C as defined in Table 31F-6-1

C_b = Berthing Coefficient

C_c = Configuration Coefficient

C_g = Geometric Coefficient

C_d = Deformation Coefficient

C_e = Eccentricity Coefficient

C_m = Effective mass or virtual mass coefficient

C_t = Windspeed conversion factor

D = Site Class D as defined in Table 31F-6-1

DSA = Design Spectral Acceleration

DSA_d = DSA values at damping other than 5 percent

DT = Displacement of vessel

DWT = Dead weight tons

d_{actual} = Arrival maximum draft of vessel at berth

d_{max} = Maximum vessel draft (in open seas)

E = Site Class E as defined in Table 31F-6-1

E_{fender} = *Energy to be absorbed by the fender system*

E_{vessel} = *Berthing energy of vessel [ft-lbs]*

F = *Site Class F as defined in Table 31F-6-1*

F_a, F_v = *Site coefficients from Tables 31F-3-3 and 31F-3-4, respectively*

F_A = *Accidental factor accounting for abnormal conditions*

g = *Acceleration due to gravity [32.2 ft/sec^2]*

h = *Elevation above water surface [feet]*

k = *Radius of longitudinal gyration of the vessel [ft]*

K = *Current velocity correction factor (Fig 31F-3-2)*

PGA_X = *Peak ground acceleration corresponding to the site class under consideration.*

s = *Water depth measured from the surface*

S_a = *Spectral acceleration*

S_1 = *Spectral acceleration value (for the boundary of Site Classes B and C) at 1.0 second*

S_S = *Spectral acceleration value (for the boundary of Site Classes B and C) at 0.2 seconds*

S_{X1} = *Spectral acceleration value at 1.0 second corresponding to the period of S_1 and the site class under consideration*

S_{XS} = *Spectral acceleration value at 0.2 seconds corresponding to the period of S_S and the site class under consideration*

T = *Draft of vessel (see Figure 31F-3-2)*

T = *Period [sec]*

T_0 = *Period at which the constant acceleration and constant velocity regions of the design spectrum intersect*

V_c = *Average current velocity [knots]*

v_c = *Current velocity as a function of depth [knots]*

V_h = *Wind speed (knots) at elevation h*

V_L = *Over land wind speed*

V_n = *Berthing velocity normal to the berth [ft/sec]*

v_t = *Velocity over a given time period*

$V_{t=30sec}$ = *Wind speed for a 30 second interval*

V_w = *Wind speed at 33-foot (10 m) elevation [knots]*

W = *Total weight of vessel and cargo inpounds [displacement tonnage × 2240]*

WD = *Water Depth (Figure 31F-3-2)*

3103F.11 References.

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[3.3] Idriss, I.M. and Sun, J.I., 1992, "User's Manual for SHAKE91, A Computer Program for Conducting Equivalent Linear Seismic Response Analyses of Horizontally Layered Soil Deposits," Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA.

[3.4] Somerville, Paul G., Smith, Nancy F., Graves, Robert W., and Abrahamson, Norman A., 1997, "Modification of Empirical Strong Ground Motion Attenuation Relations to Include the Amplitude and Duration Effects of Rupture Directivity," Seismological Research Letters, Volume 68, Number 1, pp.199-222.

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Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 4

SECTION 3104F SEISMIC ANALYSIS AND STRUCTURAL PERFORMANCE

3104F.1 General.

3104F.1.1 Purpose. *The purpose of this section is to establish minimum standards for seismic analysis and structural performance. Seismic performance is evaluated at two criteria levels. Level 1 requirements define a performance criterion to ensure MOT functionality. Level 2 requirements safeguard against major damage, collapse or major oil spill.*

3104F.1.2 Applicability. *Section 3104F applies to all new and existing MOTs. Structures supporting loading arms, pipelines, oil transfer and storage equipment, critical systems and vessel mooring structures, such as mooring and breasting dolphins are included. Catwalks and similar components that are not part of the lateral load carrying system and do not support oil transfer equipment may be excluded.*

3104F.1.3 Configuration classification of MOT structure. *Each MOT structure shall be designated as regular or irregular based on torsional irregularity criteria presented in ASCE/SEI 7 [4.1]. An MOT structure is defined to be irregular when maximum displacement at one end of the MOT structure transverse to an axis is more than 1.2 times the average of the displacement at the two ends of the MOT structure, as described in Figure 31F-4-1. For MOTs with multiple segments separated by expansion joints, each segment shall be designated as regular or irregular using criteria in this section. Expansion joints in this context are defined as joints that separate each structural segment in such a manner that each segment will move independently during an earthquake.*

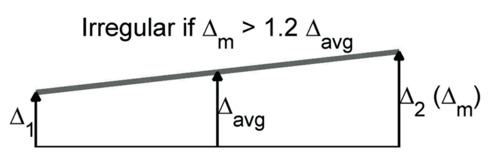


FIGURE 31F-4-1
DEFINITION OF IRREGULAR MOT

3104F.2 Existing MOTs

3104F.2.1 Seismic Performance Criteria. *Two levels of seismic performance shall be considered, except for critical systems (Section 3104F.5.1). These levels are defined as follows:*

Level 1 Seismic Performance:

- *Minor or no structural damage*
- *Temporary or no interruption in operations*

Level 2 Seismic Performance:

- *Controlled inelastic behavior with repairable damage*
- *Prevention of collapse*
- *Temporary loss of operations, restorable within months*
- *Prevention of major spill (≥ 1200 bbls)*

The Level 1 and Level 2 seismic performance criteria are defined in Table 31F-4-1.

3104F.2.2 Basis for evaluation. *Component capacities shall be based on existing conditions, calculated as "best estimates," taking into account the mean material strengths, strain hardening and degradation overtime. The capacity of components with little or no ductility, which may lead to brittle failure scenarios, shall be calculated based on lower bound material strengths. Methods to establish component strength and deformation capacities for typical structural materials and components are provided in Section 3107F. Geotechnical considerations are discussed in Section 3106F.*

3104F.2.3 Analytical procedures. *The objective of the seismic analysis is to verify that the displacement capacity of the structure is greater than the displacement demand, for each performance level defined in Table 31F-4-1. For this purpose, the displacement capacity of each element of the structure shall be checked against its displacement demand including the orthogonal effects of Section 3104F.4.2. The required analytical procedures are summarized in Table 31F-4-2.*

The displacement capacity of the structure shall be calculated using the nonlinear static (pushover) procedure. For the nonlinear static (pushover) procedure, the pushover load shall be applied at the target node defined as the center of mass (CM) of the MOT structure. It is also acceptable to use a nonlinear dynamic procedure for capacity evaluation, subject to peer review in accordance with Section 3101F.8.2.

Methods used to calculate the displacement demand are linear modal, nonlinear static and nonlinear dynamic.

Mass to be included in the displacement demand calculation shall include mass from self-weight of the structure, weight of the permanent equipment, and portion of the live load that may contribute to inertial mass during earthquake loading, such as a minimum of 25% of the floor live load in areas used for storage.

Any rational method, subject to the Division's approval, can be used in lieu of the required analytical procedures shown in Table 31F-4-2.

3104F.2.3.1 Nonlinear static capacity procedure (pushover). *To assess displacement capacity, two-dimensional nonlinear static (pushover) analyses shall be performed; three-dimensional analyses are optional. A model that incorporates the nonlinear load deformation characteristics of all components for the lateral force-resisting system shall be used in the pushover analysis.*

TABLE 31F-4-1
SEISMIC PERFORMANCE CRITERIA[1, 2]

SPILL CLASSIFICATION[3]	SEISMIC PERFORMANCE LEVEL	PROBABILITY OF EXCEEDANCE	RETURN PERIOD
High	*Level 1*	*50% in 50 years*	*72 years*
	Level 2	*10% in 50 years*	*475 years*
Medium	*Level 1*	*65% in 50 years*	*48 years*
	Level 2	*15% in 50 years*	*308 years*
Low	*Level 1*	*75% in 50 years*	*36 years*
	Level 2	*20% in 50 years*	*224 years*

1. For new MOTs, see Section 3104F.3.
2. For marine terminals transferring LNG, return periods of 72 and 475 years shall be used for Levels 1 and 2, respectively.
3. See Section 3101F.6 for spill classification.

TABLE 31F-4-2
MINIMUM REQUIRED ANALYTICAL PROCEDURES

SPILL CLASSIFICATION[1]	CONFIGURATION	SUBSTRUCTURE MATERIAL	DISPLACEMENT DEMAND PROCEDURE	DISPLACEMENT CAPACITY PROCEDURE
High/Medium	*Irregular*	*Concrete/Steel*	*Linear Modal*	*Nonlinear Static*
High/Medium	*Regular*	*Concrete/Steel*	*Nonlinear Static[2]*	*Nonlinear Static*
Low	*Regular/Irregular*	*Concrete/Steel*	*Nonlinear Static*	*Nonlinear Static*
High/Medium/Low	*Regular/Irregular*	*Timber*	*Nonlinear Static*	*Nonlinear Static*

1. See Section 3101F.6 for spill classification.
2. Linear modal demand procedure may be required for cases where more than one mode is expected to contribute to the displacement demand.

Alternatively, displacement capacity of a pile in the MOT structure may be estimated from pushover analysis of an individual pile with appropriate axial load and pile-to-deck connection.

The displacement capacity of a pile from the pushover analysis shall be defined as the displacement that can occur at the top of the pile without exceeding plastic rotation (or material strain) limits, either at the pile-deck hinge or in-ground hinge, as defined in Section 3107F. If pile displacement has components along two axes, as may be the case for irregular MOTs, the pile displacement capacity shall be defined as the resultant of its displacement components along the two axes.

3104F.2.3.1.1 Modeling. *A series of nonlinear pushover analyses may be required depending on the complexity of the MOT structure. At a minimum, pushover analysis of a two-dimensional model shall be conducted in both the longitudinal and transverse directions. The piles shall be represented by nonlinear elements that capture the moment-curvature/rotation relationships for components with expected inelastic behavior in accordance with Section 3107F. The effects of connection flexibility shall be considered in pile-to-deck connection modeling. For prestressed concrete piles, Figure 31F-4-2 may be used. A nonlinear element is not required to represent each pile location. Piles with similar lateral force-deflection behavior may be lumped in fewer larger springs, provided that the overall torsional effects are captured.*

Linear material component behavior is acceptable where nonlinear response will not occur. All components shall be based on effective moment of inertia calculated in accordance with Section 3107F. Specific requirements for timber pile structures are discussed in the next section.

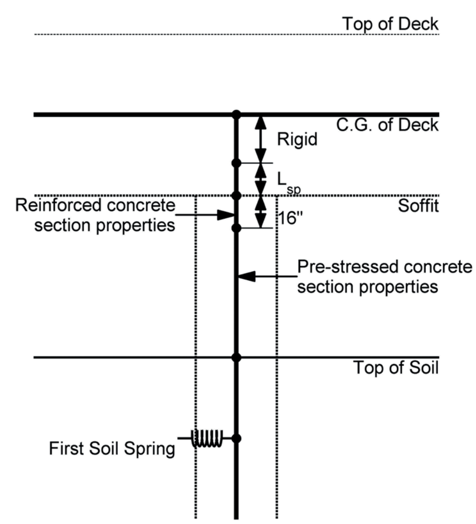


FIGURE 31F-4-2
PILE-DECK CONNECTION MODELING FOR PRESTRESSED CONCRETE PILE (ADAPTED FROM [4.2])

3104F.2.3.1.2 Timber pile supported structures. *For all timber pile supported structures, linear elastic procedures may be used. Alternatively, the nonlinear static procedure may be used to estimate the target displacement demand, Δ_d.*

A simplified single pile model for a typical timber pile supported structure is shown in Figure 31F-4-3. The pile-deck connections may be assumed to be "pinned." The lateral bracing can often be *ignored if it is in poor condition. These assumptions shall be used for the analysis, unless a detailed condition assessment and lateral analysis indicate that the existing bracing and connections may provide reliable lateral resistance.*

A series of single pile analyses may be sufficient to establish the nonlinear springs required for the pushover analysis.

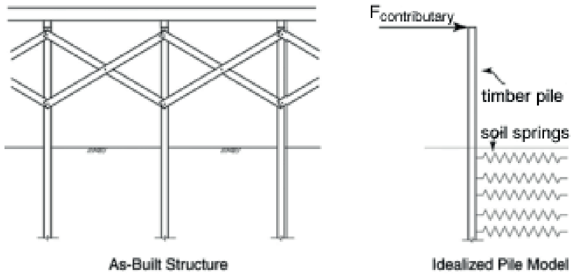


FIGURE 31F-4-3
SIMPLIFIED SINGLE PILE MODEL OF A TIMBER PILE SUPPORTED STRUCTURE

3104F.2.3.2 Nonlinear static demand procedure. *A nonlinear static procedure shall be used to determine the displacement demand for all concrete and steel structures, with the exception of irregular configurations with high or moderate spill classifications. A linear modal procedure is required for irregular structures with high or moderate spill classifications, and may be used for all other classifications in lieu of the nonlinear static procedure.*

In the nonlinear static demand procedure, deformation demand in each element shall be computed at the target node displacement demand. The analysis shall be conducted in each of the two orthogonal directions and results combined as described in Section 3104F.4.2.

The target displacement demand of the structure, Δ_d*, shall be calculated from:*

$$\Delta_d = S_A(T_e^2/4\pi^2) \tag{4-1}$$

where:

T_e = *effective elastic structural period defined in Equation (4-3) or Equation (4-9)*

S_A = *spectral response acceleration corresponding to* T_e

If $T_e < T_0$*, where* T_0 *is the period corresponding to the peak of the acceleration response spectrum, a refined analysis (see Section 3104F.2.3.2.1 or 3104F.2.3.2.2) shall be used to calculate the displacement demand. In the refined analysis, the target node displacement demand may be computed from the Coefficient Method (Section 3104F.2.3.2.1) or the Substitute Structure Method (Section 3104F.2.3.2.2). Both of these methods utilize the pushover curve developed in Section 3104F.2.3.1.*

3104F.2.3.2.1 Coefficient Method. *The Coefficient Method is based on the procedures presented in ASCE/SEI 41 [4.3] and FEMA 440 [4.4].*

The first step in the Coefficient Method requires idealization of the pushover curve to calculate the effective elastic lateral stiffness, k_e*, and effective yield strength,* F_y*, of the structure as shown in Figure 31F-4-4.*

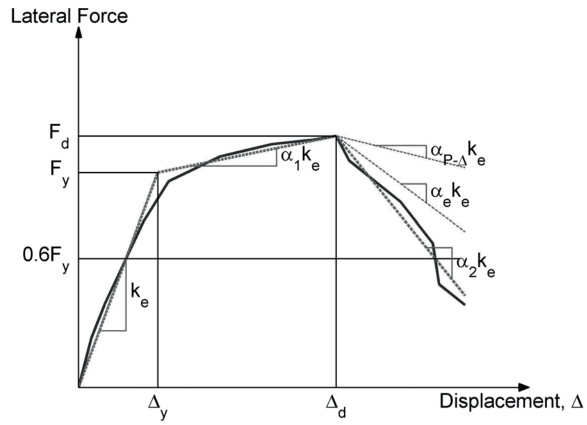


FIGURE 31F-4-4
IDEALIZATION OF PUSHOVER CURVE (ADAPTED FROM [4.3])

The first line segment of the idealized pushover curve shall begin at the origin and have a slope equal to the effective elastic lateral stiffness, k_e*. The effective elastic lateral stiffness,* k_e*, shall be taken as the secant stiffness calculated at the lateral force equal to 60 percent of the effective yield strength,* F_y*, of the structure. The effective yield strength,* F_y*, shall not be taken as greater than the maximum lateral force at any point along the pushover curve.*

The second line segment shall represent the positive post-yield slope ($\alpha_1 k_e$*) determined by a point (*F_d, Δ_d*) and a point at the intersection with the first line segment such that the area above and below the actual curve area approximately balanced. (*F_d, Δ_d*) shall be a point on the actual pushover curve at the calculated target displacement, or at the displacement corresponding to the maximum lateral force, whichever is smaller.*

The third line segment shall represent the negative post-yield slope ($\alpha_2 k_e$*), determined by the point at the end of the positive post-yield slope (*F_d, Δ_d*) and the point at which the lateral force degrades to 60 percent of the effective yield strength.*

The target displacement shall be calculated from:

$$\Delta_d = C_1 C_2 S_A \frac{T_e^2}{4\pi^2} \tag{4-2}$$

where:

S_A = *spectral acceleration of the linear-elastic system at vibration period, which is computed from:*

$$T_e = 2\pi\sqrt{\frac{m}{k_e}} \tag{4-3}$$

where:

m = *seismic mass as defined in Section 3104F.2.3*

k_e = *effective elastic lateral stiffness from idealized pushover*

C_1 = *modification factor to relate maximum inelastic displacement to displacement calculated for linear elastic response. For period less than 0.2 s, C_1 need not be taken greater than the value at T_e = 0.2 s. For period greater than 1.0 s, C_1 = 1.0. For all other periods:*

$$C_1 = 1 + \frac{\mu_{strength} - 1}{aT_e^2} \quad (4\text{-}4)$$

where:

a = *Site class factor*

= *130 for Site Class A or B,*

= *90 for Site Class C, and*

= *60 for Site Class D, E, or F.*

$\mu_{strength}$ = *ratio of elastic strength demand to yield strength coefficient calculated in accordance with Equation (4-6). The Coefficient Method is not applicable where $\mu_{strength}$ exceeds μ_{max} computed from Equation (4-7). $\mu_{strength}$ shall not be taken as less than 1.0.*

C_2 = *modification factor to represent the effects of pinched hysteresis shape, cyclic stiffness degradation, and strength deterioration on the maximum displacement response. For periods greater than 0.7s, C_2 = 1.0. For all other periods:*

$$C_2 = 1 + \frac{1}{800}\left(\frac{\mu_{strength} - 1}{T_e}\right)^2 \quad (4\text{-}5)$$

The strength ratio $\mu_{strength}$ shall be computed from:

$$\mu_{strength} = \frac{mS_A}{F_y} \quad (4\text{-}6)$$

where:

F_y = *effective yield strength of the structure in the direction under consideration from the idealized pushover curve.*

For structures with negative post-yield stiffness, the maximum strength ratio μ_{max} shall be computed from:

$$\mu_{max} = \frac{\Delta_d}{\Delta_y} + \frac{|\alpha_e|^{-h}}{4} \quad (4\text{-}7)$$

where:

Δ_d = *larger of target displacement or displacement corresponding to the maximum pushover force,*

Δ_y = *displacement at effective yield strength*

$$h = 1 + 0.15 \ln T_e \quad (4\text{-}8)$$

α_e = *effective negative post-yield slope ratio which shall be computed from:*

$$\alpha_e = \alpha_{P\text{-}\Delta} + \lambda(\alpha_2 - \alpha_{P\text{-}\Delta}) \quad (4\text{-}9)$$

where:

$\alpha_{P\text{-}\Delta}$, and the maximum negative post-elastic stiffness ratio, α_2, are estimated from the idealized force-deformation curve, and λ is a near-field effect factor equal to 0.8 for sites with 1 second spectral value, S_1 greater than or equal to 0.6g and equal to 0.2 for sites with 1 second spectral value, S_1 less than 0.6g.

3104F.2.3.2.2 Substitute Structure Method. *The Substitute Structure Method is based on the procedure presented in Priestley et al. [4.5] and ASCE/COPRI 61 [4.2]. This method is summarized below.*

1. *Idealize the pushover curve from nonlinear pushover analysis, as described in Section 3104F.2.3.2.1, and estimate the effective yield strength, F_y, and yield displacement, Δ_y.*
2. *Compute the effective elastic lateral stiffness, k_e, as the effective yield strength, F_y, divided by the yield displacement, Δ_y.*
3. *Compute the structural period in the direction under consideration from:*

$$T_e = 2\pi\sqrt{\frac{m}{k_e}} \quad (4\text{-}10)$$

where:

m = *seismic mass as defined in Section 3104F.2.3*

k_e = *effective elastic lateral stiffness in direction under consideration*

4. *Determine target displacement, Δ_d, of the effective linear elastic system from:*

$$\Delta_d = S_A \frac{T_e^2}{4\pi^2} \quad (4\text{-}11)$$

where:

S_A = *the 5 percent damped spectral displacement corresponding to the linear elastic structural period, T_e*

Select the initial estimate of the displacement demand as $\Delta_{d,i} = \Delta_d$.

5. *The ductility level, $\mu_{\Delta,i}$, is found from $\Delta_{d,i}/\Delta_y$. Use the appropriate relationship between ductility and damping, for the component undergoing inelastic deformation, to estimate the effective structural damping, $\xi_{eff,i}$. In lieu of more detailed analysis, Equation (4-12) may be used for concrete and steel piles connected to the deck through dowels embedded in the concrete. Note that the idealized pushover curves in Figure 31F-4-4 shall be utilized in Figure 31F-4-5, which illustrates the iterative procedure.*

$$\xi_{eff,\,i} = 0.05 + \frac{1}{\pi}\left(1 - \frac{1-\alpha_1}{\sqrt{\mu_{\Delta,\,i}}} - \alpha_1\sqrt{\mu_{\Delta,\,i}}\right) \quad (4\text{-}12)$$

where:

α_1 = ratio of second slope over elastic slope (see Figures 31F-4-4 and 31F-4-5)

Equation (4-12) for effective damping was developed by Kowalsky et al. [4.6] for the Takeda hysteresis model of system's force-displacement relationship.

6. *Compute the force, $F_{d,i}$, on the force-deformation relationship associated with the estimated displacement, $\Delta_{d,i}$ (see Figure 31F-4-5).*
7. *Compute the effective stiffness, $k_{eff,i}$, as the secant stiffness from:*

$$k_{eff,\,i} = \frac{F_{d,\,i}}{\Delta_{d,\,i}} \quad (4\text{-}13)$$

8. *Compute the effective period, $T_{eff,i}$, from:*

$$T_{eff,\,i} = 2\pi\sqrt{\frac{m}{k_{eff,\,i}}} \quad (4\text{-}14)$$

where:

m = seismic mass as defined in Section 3104F.2.3

9. *For the effective structural period, $T_{eff,i}$, and the effective structural damping, $\xi_{eff,i}$, compute the spectral acceleration $S_A(T_{eff,i}, \xi_{eff,i})$ from an appropriately damped design acceleration response spectrum.*
10. *Compute the new estimate of the displacement, $\Delta_{d,j}$, from:*

$$\Delta_{d,\,j} = \frac{T_{eff,\,i}^2}{4\pi^2}S_A(T_{eff,\,i}, \xi_{eff,\,i}) \quad (4\text{-}15)$$

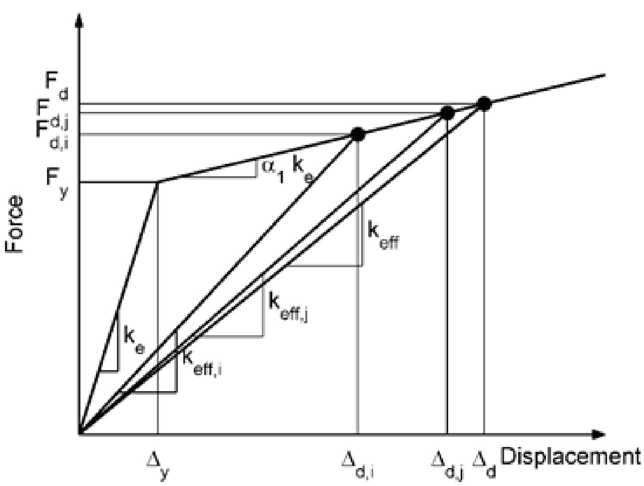


FIGURE 31F-4-5
EFFECTIVE STIFFNESS FOR SUBSTITUTE STRUCTURE METHOD

11. *Repeat steps 5 to 10 with $\Delta_{d,\,i} = \Delta_{d,\,j}$ until displacement, $\Delta_{d,\,j}$, computed in step 10 is sufficiently close to the starting displacement, $\Delta_{d,\,i}$, in step 5 (Figure 31F-4-5).*

3104F.2.3.3 Linear modal demand procedure. *For irregular concrete/steel structures with moderate or high spill classifications, a linear modal analysis is required to predict the global displacement demands. A 3-D linear elastic response analysis shall be used, with effective moment of inertia applied to components to establish lateral displacement demands, to compute displacement components of an element along each axis of the system.*

Sufficient modes shall be included in the analysis such that 90 percent of the participating mass is captured in each of the principal horizontal directions for the structure. For modal combinations, the Complete Quadratic Combination rule shall be used. Multidirectional excitation shall be accounted for in accordance with Section 3104F.4.2.

The lateral stiffness of the linear elastic response model shall be based on the initial stiffness of the nonlinear pushover curve as shown in Figure 31F-4-6 (also see Section 3106F.9). The p-y springs shall be adjusted based on the secant method approach. Most of the p-y springs will typically be based on their initial stiffness; no iteration is required.

If the fundamental period is $T < T_0$, where T_0 is the period corresponding to the peak of the acceleration response spectrum, the displacement demand from the linear modal analysis shall be amplified to account for nonlinear system behavior by an amplification factor. The amplification factor shall be equal to either $C_1 \times C_2$ per Section 3104F.2.3.2.1, or the ratio of the final target displacement and the initial elastic displacement of Equation (4-11) per Section 3104F.2.3.2.2.

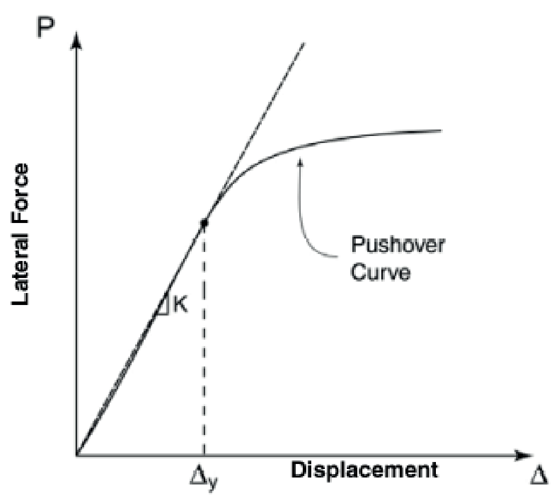


FIGURE 31F-4-6
STIFFNESS FOR LINEAR MODAL ANALYSIS

*3104F.2.3.4 **Nonlinear dynamic analysis.** Nonlinear dynamic time history analysis is optional, and if performed, a peer review is required (see Section 3101F.8.2). Multiple acceleration records shall be used, as explained in Section 3103F.4.2.10. The following assumptions may be made:*

1. *Equivalent "super piles" can represent groups of piles.*
2. *If the deck has sufficient rigidity (both in-plane and out-of plane) to justify its approximation as a rigid element, a 2-D plan simulation may be adequate.*

A time-history analysis should always be compared with a simplified approach to ensure that results are reasonable. Displacements calculated from the nonlinear time history analyses may be used directly in design, but shall not be less than 80 percent of the values obtained from Section 3104F.2.3.2.

*3104F.2.3.5 **Alternative procedures.** Alternative lateral-force procedures using rational analyses based on well-established principles of mechanics may be used in lieu of those prescribed in these provisions. As per Section 3101F.8.2, peer review is required.*

*3104F.3 **New MOTs.** The analysis and design requirements described in Section 3104F.2 shall also apply to new MOTs. However, new MOTs shall comply with the seismic performance criteria for high spill classification, as defined in Table 31F-4-1. Additional requirements are as follows:*

1. *Site-specific response spectra analysis (see Section 3103F.4.2.3).*
2. *Soil parameters based on site-specific and new borings (see Section 3106F.2.2).*

3104F.4 General analysis and design requirements.

*3104F.4.1 **Load combinations.** Earthquake loads shall be used in the load combinations described in Section 3103F.8.*

*3104F.4.2 **Combination of orthogonal seismic effects.** The design displacement demand at an element, δ_d, shall be calculated by combining the longitudinal, δ_x, and transverse, δ_y, displacements in the horizontal plane (Figure 31F-4-7):*

$$\delta_d = \sqrt{\delta_x^2 + \delta_y^2} \quad (4\text{-}16)$$

where:

$$\delta_x = \delta_{xy} + 0.3\delta_{xx} \quad (4\text{-}17)$$

and

$$\delta_y = 0.3\delta_{yx} + \delta_{yy} \quad (4\text{-}18)$$

OR

$$\delta_y = \delta_{yx} + 0.3\delta_{yy} \quad (4\text{-}19)$$

and

$$\delta_x = 0.3\delta_{xy} + \delta_{xx} \quad (4\text{-}20)$$

whichever results in the greater design displacement demand.

*3104F.4.3 **P-Δ Effects.** The P-Δ effect (i.e., the additional moment induced by the total vertical load multiplied by the lateral deck deflection) shall be considered unless the following relationship is satisfied (see Figure 31F-4-8):*

$$\frac{V}{W} \geq 4\frac{\Delta_d}{H} \quad (4\text{-}21)$$

where:

- V = *base shear strength of the structure obtained from a plastic analysis*
- W = *dead load of the frame*
- Δ_d = *displacement demand*
- H = *distance from the location of maximum in-ground moment to center of gravity of the deck*

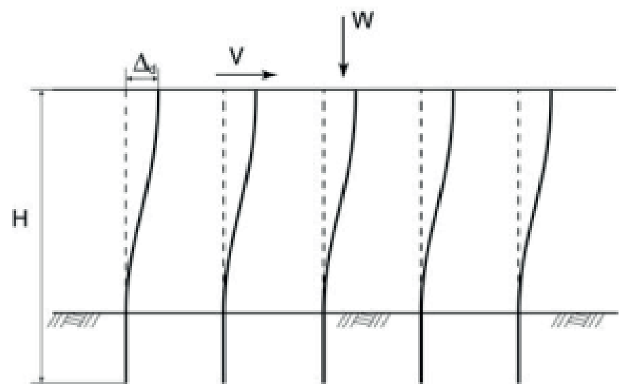


FIGURE 31F-4-8
P-Δ EFFECT

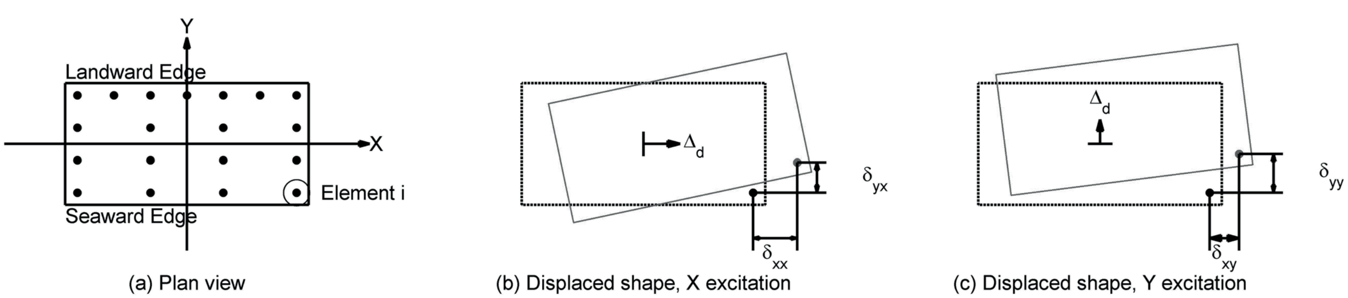


FIGURE 31F-4-7
PLAN VIEW OF WHARF SEGMENT UNDER X AND Y SEISMIC EXCITATIONS

For wharf structures where the lateral displacement is limited by almost fully embedded piles, P-Δ effects may be ignored; however, the individual stability of the piles shall be checked in accordance with Section 3107F.2.5.2.

If the landside batter piles are allowed to fail in a Level 2 evaluation, the remaining portion of the wharf shall be checked for P-Δ effects.

3104F.4.4 Expansion joints. *The effect of expansion joints shall be considered in the seismic analysis.*

3104F.4.5 Shear key forces. *Shear force across shear keys connecting adjacent wharf segments, V_{sk}, (approximate upper bound to the shear key force [4.7]) shall be calculated as follows:*

$$V_{sk} = 1.5(e/L_l)V_{\Delta T} \quad (4\text{-}22)$$

where:

$V_{\Delta T}$ = *total segment lateral force found from a push-over analysis*

L_l = *segment length*

e = *eccentricity between the center of rigidity and the center of mass*

3104F.4.6 Connections. *For an existing wharf, the deteriorated conditions at the junction between the pile top and pile cap shall be considered in evaluating the moment capacity. Connection detail between the vertical pile and pile cap shall be evaluated to determine whether full or partial moment capacity can be developed under seismic action.*

For new MOTs, the connection details shall develop the full moment capacities.

The modeling shall simulate the actual moment capacity (full or partial) of the joint in accordance with Section 3107F.2.7.

3104F.4.7 Batter piles. *Batter piles primarily respond to earthquakes by developing large axial compression or tension forces. Bending moments are generally of secondary importance. Failure in compression may be dictated by the deck-pile connection (most common type), material compression, buckling, or by excessive local shear in deck members adjacent to the batter pile. Failure in tension may be dictated by connection strength or by pile pull out (p. 3-83 of Ferritto et al. [4.7]).*

When the controlling failure scenario is reached and the batter pile fails, the computer model shall be adjusted to consist of only the vertical pile acting either as a full or partial moment frame based on the connection details between the pile top and pile cap. The remaining displacement capacity, involving vertical piles, before the secondary failure stage develops, shall then be established (see Section 3107F.2.8).

Axial p-z curves shall be modeled. In compression, displacement capacity should consider the effect of the reduction in pile modulus of elasticity at high loads and the increase in effective length for friction piles. This procedure allows the pile to deform axially before reaching ultimate loads, thereby increasing the displacement ductility [4.7].

Horizontal nonlinear p-y springs are only applied to batter piles with significant embedment, such as for landside batter piles in a wharf structure. Moment fixity can be assumed for batter piles that extend well above the ground such as waterside batter piles in a wharf structure or batter piles in a pier type structure.

3104F.5 Nonstructural components, nonbuilding structures and building structures. *Nonstructural components, nonbuilding structures and building structures at MOTs shall be assessed for Level 2 seismic performance (see Section 3104F.2.1). Consideration shall be given to the adequacy and condition of supports and attachments (or anchorage), strength, flexibility, relative displacement, P-delta effects, and seismically-induced interaction with other components and structures.*

3104F.5.1 General. *Nonstructural components are mechanical, electrical and architectural components (such as piping/pipelines, loading arms, lifting equipment (winches and cranes), spill prevention equipment, pumps, instrumentation and storage cabinets, and lighting fixtures) that may be required to resist the effects of earthquake.*

Nonbuilding structures (such as gangways, hose towers and racks) are self-supporting structures that carry gravity loads and may be required to resist the effects of earthquake, but are not building structures (such as control rooms). For building structures, see Section 3104F.5.6.

Critical systems are nonstructural components, nonbuilding structures or building structures that shall remain operational or those whose failure could impair emergency operations following an earthquake, to prevent major oil spills and to protect public health, safety and the environment. A seismic assessment of the survivability and continued operation (related to personnel safety, oil spill prevention or response) during a Level 2 earthquake (see Table 31F-4-1) shall be performed for critical systems, including but not limited to, fire protection, emergency shutdown and electrical power systems.

3104F.5.2 Seismic assessment. *For existing (E) nonstructural components, nonbuilding structures and building structures and their supports and attachments, seismic assessment shall be performed in accordance with CalARP [4.8] or ASCE Guidelines [4.9], except for piping/pipelines which shall be evaluated per Section 3109F. If seismic evaluation and/or strengthening are required, it shall be performed in accordance with Section 3104F.5.2.1.*

For new (N) nonstructural components, nonbuilding structures and building structures and their supports and attachments, seismic evaluation and design shall be performed in accordance with Section 3104F.5.2.1, except for piping/pipelines which shall be evaluated per Section 3109F.

3104F.5.2.1 Seismic evaluation, strengthening and design. *For evaluation, strengthening and design of nonstructural components, nonbuilding structures and building structures, seismic forces (demands) shall be obtained from Section 3104F.5. The seismic adequacy* *of nonstructural components shall be demonstrated as specified in ASCE/SEI 7 [4.1]. Structures shall be analyzed in accordance with Section 3107F.5. Supports and attachments shall be assessed in accordance with Sections 3107F.7.*

3104F.5.3 Contribution to global response of MOT structures. *Nonstructural components, nonbuilding structures and building structures permanently attached to MOT structures, including, but not limited to, pipelines, loading arms, hose towers/racks, raised platforms, control rooms and vapor control equipment, may affect the global structural response. In such cases, the seismic characteristics (mass and/or stiffness) of the nonstructural components, nonbuilding structures and building structures shall be considered in computing global seismic response of the MOT structures. If the seismic response of nonstructural components is determined to be out of phase (e.g. pipelines) with the global structural response, then the mass contribution can be neglected in the seismic structural analysis.*

3104F.5.4 Nonstructural components and nonbuilding structures permanently attached to MOT structures. *This section covers nonstructural components and nonbuilding structures having a significant mass and/or importance to the operability and safety of the MOT, and that are permanently attached to MOT structures (e.g., wharves, trestles, dolphins). The weight of nonstructural components and nonbuilding structures shall be included in the dead load of the structure per Section 3103F.2.*

Computation of seismic effects shall consider:

1. *Amplification of acceleration from ground to location of attachment of the nonstructural component or nonbuilding structure to the deck due to flexibility of the MOT structure, and*
2. *Amplification of acceleration due to flexibility of the nonstructural component or nonbuilding structure.*

The following are not covered in this section and shall be assessed using rational approach that includes consideration of strength, stiffness, ductility, and seismic interaction with all other connected components and with the supporting structures or systems, subject to Division approval:

1. *Nonstructural component supported by other nonstructural system permanently attached to MOT structure;*
2. *Nonstructural component or nonbuilding structure supported by other structure permanently attached to MOT structure;*
3. *Nonstructural component or nonbuilding structure attached to multiple MOT structures;*
4. *Nonstructural component or nonbuilding structure attached to structure and ground.*

3104F.5.4.1 Seismic loads. *This section specifies the procedure to compute seismic loads on nonstructural components and nonbuilding structures permanently attached to a MOT structure.*

The following nonstructural components are exempt from the requirements of this section:

1. *Temporary or movable equipment unless part of a critical system (Section 3104F.5.1);*
2. *Mechanical and electrical components that are attached to the MOT structure and have flexible connections to associated piping and conduit; and either:*
   (a) *The component weighs 400 lb or less, the center of mass is located 4 ft or less above the MOT deck, and the component Importance Factor, I_p is equal to 1.0; or*
   (b) *The component weighs 20 lb or less, or in the case of a distributed system, 5 lb/ft or less.*

3104F.5.4.1.1 Simplified Procedure. *The Simplified Procedure may be used to estimate seismic loads on nonstructural components and nonbuilding structures permanently attached to a MOT structure. The Simplified Procedure shall not be used if any of the following apply:*

1. *Mass of the nonstructural component or nonbuilding structure exceeds 25 percent of the combined mass of the MOT structure plus nonstructural component or nonbuilding structure;*
2. *Multiple nonstructural components or nonbuilding structures of similar type (or natural period) when their combined mass exceeds 25 percent of the total mass of the MOT structure plus nonstructural components or nonbuilding structures;*
3. *Concrete/Steel MOT structure with irregular configuration (Section 3104F.1.3 and Table 31F-4-2) and high or medium spill exposure classification.*

The horizontal seismic force, F_p, shall be computed as follows [4.10]:

$$F_p = \frac{1.2 S_{xs} a_p I_p W_p}{R_p} \tag{4-23}$$

$$0.3 S_{xs} I_p W_p \le F_p \le 1.6 S_{xs} I_p W_p$$

where:

S_{xs} = *spectral acceleration in Section 3103F.4.2.4 or Section 3103F.4.2.5*

a_p = *amplification factor for nonstructural component or nonbuilding structure (Table 31F-4-3)*

I_p = *importance factor for nonstructural component or nonbuilding structure (Table 31F-4-4)*

W_p = *weight of the nonstructural component or nonbuilding structure*

R_p = *response modification factor for nonstructural component or nonbuilding structure (Table 31F-4-5)*

Alternatively, when dynamic properties of the MOT structure are available, the horizontal seismic force, F_p, may be computed from [4.10]:

$$F_p = \frac{a_p S_A I_p A_x W_p}{R_p} \quad (4\text{-}24)$$

$$0.3 S_{xs} I_p W_p \leq F_p \leq 1.6 S_{xs} I_p W_p$$

where:

S_A = *spectral acceleration in Section 3103F.4.2.4 or Section 3103F.4.2.5, at the period equal to the elastic fundamental period of the MOT structure, T, in direction under consideration*

A_x = *torsional amplification factor given by:*

$$A_x = \left(\frac{\Delta_m}{1.2\Delta_{avg}}\right)^2 \quad (4\text{-}25)$$

$$1 \leq A_x \leq 3$$

where:

Δ_m = *maximum displacement at one end of the MOT structure transverse to an axis*

Δ_{avg} = *average of the displacements at the extreme points of the MOT structure (see Figure 31F-4-1)*

TABLE 31F-4-3
AMPLIFICATION FACTORS FOR NONSTRUCTURAL COMPONENTS AND NONBUILDING STRUCTURES

COMPONENT OR STRUCTURE	a_p [1, 2]
Rigid components or structures (period less than 0.06 seconds)	*1.0*
Rigidly attached components or structures	*1.0*
Flexible components or structures (period longer than 0.06 seconds)	*2.5*
Flexibly attached components or structures	*2.5*

1. A lower value shall not be used unless justified by detailed dynamic analysis, and shall in no case be less than 1.0.
2. If the fundamental period of the MOT structure, T, and the period of the flexible nonstructural component or nonbuilding structure, T_p, is known, a_p may be estimated from Figure 31F-4-9.

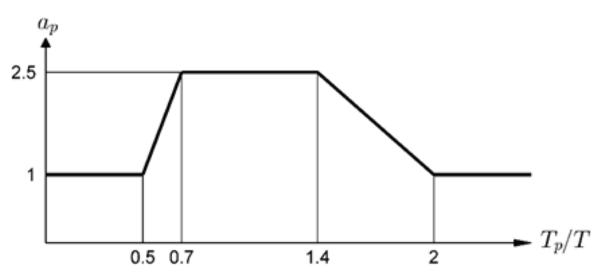


FIGURE 31F-4-9
AMPLIFICATION FACTOR, a_p [4.10]

TABLE 31F-4-4
IMPORTANCE FACTORS FOR NONSTRUCTURAL COMPONENTS AND NONBUILDING STRUCTURES

COMPONENT OR STRUCTURE	I_p
Critical [1, 2]	*1.5*
Other	*1.0*

1. See Section 3104F.5.1 for definition of critical system.
2. A lower value may be utilized, subject to Division approval.

TABLE 31F-4-5
RESPONSE MODIFICATION FACTORS FOR NONSTRUCTURAL COMPONENTS AND NONBUILDING STRUCTURES

COMPONENT OR STRUCTURE	R_p [1]
Loading arms	*3.0*
Piping/pipelines (welded)	*12.0*
Pining/pipelines (threaded or flanged)	*6.0*
Pumps	*2.5*
Skids	*2.5*
Tanks and totes	*2.5*
Light fixtures (or luminaries)	*1.5*
Electrical conduits and cable trays	*6.0*
Mooring hardware	*2.5*
Velocity monitoring equipment	*2.5*
Instrumentation or storage cabinets	*6.0*
Cranes	*2.5*
Gangway (column systems)	*3.0*
Gangways (truss systems)	*Use R_p from frame systems*
Hose towers and racks	*Use R_p from frame systems*
Frame systems:	
Steel special concentrically braced frames	*6.0*
Steel ordinary concentrically braced frames	*3.5*
Steel special moment frames	*8.0*
Steel intermediate moment frames	*4.5*
Steel ordinary moment frames	*3.5*
Lightframe wood sheathed with wood structural panels	*6.5*
Lightframe cold-formed steel sheathed with wood structural panels	*6.5*
Lightframe walls with shear panels of other materials	*2.0*
Other	*Subject to Division approval*

1. A higher value may be utilized, subject to Division approval.

The horizontal seismic force, F_p, in the direction under consideration shall be applied at the center of gravity and distributed relative to the mass distribution of the nonstructural component or nonbuilding structure.

The horizontal seismic force, F_p, shall be applied independently in at least two orthogonal horizontal directions in combination with service or operating loads associated with the nonstructural component or nonbuilding structure, as appropriate. For vertically cantilevered systems, however, F_p shall be assumed to act in any horizontal direction.

The concurrent vertical seismic force, F_v, shall be applied at the center of gravity and distributed relative to the mass distribution of the nonstructural component or nonbuilding structure, as follows:

$$F_v = \pm 0.2 S_{xs} W_p \quad (4\text{-}26)$$

3104F.5.4.1.2 Linear modal demand procedure. *The linear modal demand procedure (Section 3104F.2.3.3) may always be used and shall be used to estimate seismic forces when the Simplified Procedure (Section 3104F.5.4.1.1) is not permitted. The MOT structure and nonstructural components and/or nonbuilding structures shall be modeled explicitly. The seismic forces obtained from the linear modal demand procedure shall be adjusted for appropriate importance factors and response modification factors as specified in Table 31F-4-4 and Table 31F-4-5.*

3104F.5.5 Nonstructural components and nonbuilding structures permanently attached to the ground. *The seismic load shall be computed using the procedures in ASCE/SEI 7 [4.1], except that Level 2 design earthquake motion parameters defined in Section 3103F.4 shall be used in lieu of those specified in ASCE/SEI 7 [4.1].*

3104F.5.6 Building structures. *For buildings permanently attached to MOT structure, Section 3104F.5.4.1 shall be used to compute seismic loads. Computation of seismic effects shall consider:*

1. *Amplification of acceleration from ground to location of attachment of the building to the deck due to flexibility of the MOT structure, and*
2. *Amplification of acceleration due to flexibility of the building.*

For buildings permanently attached to the ground, seismic loads shall be computed using the procedures in ASCE/SEI 7 [4.1], as amended by the local enforcing agency requirements, subject to Division approval.

3104F.6 Symbols.

a = *Site class factor*

a_p = *Amplification factor for nonstructural component or nonbuilding structure*

A_x = *Torsional amplification factor*

C_1 = *Modification factor to relate expected maximum inelastic displacement to displacement calculated for linear elastic response*

C_2 = *Modification factor to represent the effects of pinched hysteresis shape, cyclic stiffness degradation and strength deterioration on the maximum displacement response*

e = *Eccentricity between center of mass and center of rigidity*

$F_{d,i}$ = *Force at step i of iteration*

$F_{d,j}$ = *Force at step j of iteration*

F_p = *Horizontal seismic force on nonstructural component, nonbuilding structure or building structure supported on MOT*

F_v = *Vertical seismic force on nonstructural component, nonbuilding structure or building structure supported on MOT*

F_y = *Effective yield strength*

H = *Distance from maximum in-ground moment to center of gravity of the deck*

I_p = *Importance factor for nonstructural component or nonbuilding structure*

k_e = *Effective elastic lateral stiffness*

$k_{eff,i}$ = *Effective secant lateral stiffness at step i of iteration*

$k_{eff,j}$ = *Effective secant lateral stiffness at step j of iteration*

L_l = *Longitudinal length between wharf expansion joints*

m = *Seismic mass*

R_p = *Response modification factor for nonstructural component or nonbuilding structure*

S_A = *Spectral response acceleration at T*

S_{xs} = *Spectral acceleration in Section 3103F.4.2.4 or Section 3103F.4.2.5*

S_1 = *1-second spectral response acceleration*

T = *Fundamental period of the elastic structure*

T_e = *Effective elastic structural period*

$T_{eff,i}$ = *Effective structural period at step i of iteration*

T_p = *Period of flexible nonstructural component or nonbuilding structure*

T_0 = *Period at peak of the acceleration response spectrum*

V = *Base shear strength of the structure obtained from a plastic analysis*

V_{sk} = *Shear force across shear keys*

$V_{\Delta T}$ = *Total segment lateral force*

W = *Dead load of the frame*

W_p = *Weight of the nonstructural component or nonbuilding structure*

Δ_d = *Target displacement demand*

$\Delta_{d,i}$ = *Target displacement demand at step i of iteration*

$\Delta_{d,j}$ = *Target displacement demand at step j of iteration*

α_1 = *Positive post-yield slope ratio equal to positive post-yield stiffness divided by the effective stiffness*

α_2 = *Negative post-yield slope ratio equal to negative post-yield stiffness divided by the effective stiffness*

α_e = *Effective negative post-yield slope ratio equal to effective post-yield negative stiffness divided by the effective stiffness*

$\alpha_{P\text{-}\Delta}$ = *Negative slope ratio caused by P-Δ effects*

Δ_{avg} = *Average of displacements, Δ_1 and Δ_2, at ends of the MOT transverse to an axis*

Δ_d = *Target displacement*

Δ_m = *Maximum of displacements, Δ_1 and Δ_2, at ends of the MOT transverse to an axis*

Δ_y = *Displacement at yield strength*

Δ_1, Δ_2 = *Displacement at ends of the MOT transverse to an axis*

δ_d = *Design displacement demand at an element*

δ_x = *Displacement of an element in X direction*

δ_y = *Displacement of an element in Y direction*

δ_{xx} = *X displacement under X direction excitation*

δ_{xy} = *X displacement under Y direction excitation*

δ_{yx} = *Y displacement under X direction excitation*

δ_{yy} = *Y displacement under Y direction excitation*

λ = *Near-field effect factor*

μ_{max} = *Maximum strength ratio*

$\mu_{strength}$ = *Ratio of elastic strength demand to yield strength*

$\mu_{\Delta,t}$ = *Initial ductility level*

$\xi_{eff,i}$ = *Effective structural damping at step i of iteration*

3104F.7 References.

[4.1] American Society of Civil Engineers (ASCE), 2016, ASCE/SEI 7-16 (ASCE/SEI 7), "Minimum Design Loads and Associates Criteria for Buildings and Other Structures," Reston, VA.

[4.2] American Society of Civil Engineers (ASCE), 2014, ASCE/COPRI 61-14 (ASCE/COPRI 61), "Seismic Design of Piers and Wharves," Reston, VA.

[4.3] American Society of Civil Engineers (ASCE), 2017, ASCE/SEI 41-17 (ASCE/SEI 41), "Seismic Evaluation and Retrofit of Existing Buildings," Reston, VA.

[4.4] Federal Emergency Management Agency (FEMA), June 2005, FEMA 440, "Improvement of Nonlinear Static Seismic Analysis Procedures," Redwood City, CA.

[4.5] Priestley, M.J.N., Seible, F., Calvi, G.M., 1996, "Seismic Design and Retrofit of Bridges," John Wiley & Sons, Inc., New York.

[4.6] Kowalsky, M.J., Priestley, M.J.N, MacRae, G.A., 1994, "Displacement-Based Design – A Methodology for Seismic Design Applied to Single Degree of Freedom Reinforced Concrete Structures," Report No. SSRP – 94/16, University of California, San Diego.

[4.7] Ferritto, J., Dickenson, S., Priestley N., Werner, S., Taylor, C., Burke, D., Seelig, W., and Kelly, S., 1999, "Seismic Criteria for California Marine Oil Terminals," Vol. 1 and Vol. 2, Technical Report TR-2103-SHR, Naval Facilities Engineering Service Center, Port Hueneme, CA.

[4.8] CalARP Program Seismic Guidance Committee, December 2013, "Guidance for California Accidental Release Prevention (CalARP) Program Seismic Assessments," Sacramento, CA.

[4.9] American Society of Civil Engineers, 2011, "Guidelines for Seismic Evaluation and Design of Petrochemical Facilities," 2nd ed., New York.

[4.10] Goel, R. K., 2017, "Estimating Seismic Forces in Ancillary Components and Nonbuilding Structures Supported on Piers, Wharves, and Marine Oil Terminals," Earthquake Spectra, https://doi.org/10.1193/041017EQS068M.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 5

SECTION 3105F
MOORING AND BERTHING ANALYSIS AND DESIGN

3105F.1 General.

3105F.1.1 Purpose. *This section establishes minimum standards for safe mooring and berthing of vessels at MOTs.*

3105F.1.2 Applicability. *This section applies to onshore MOTs; Figure 31F-5-1 shows typical pier and wharf configurations.*

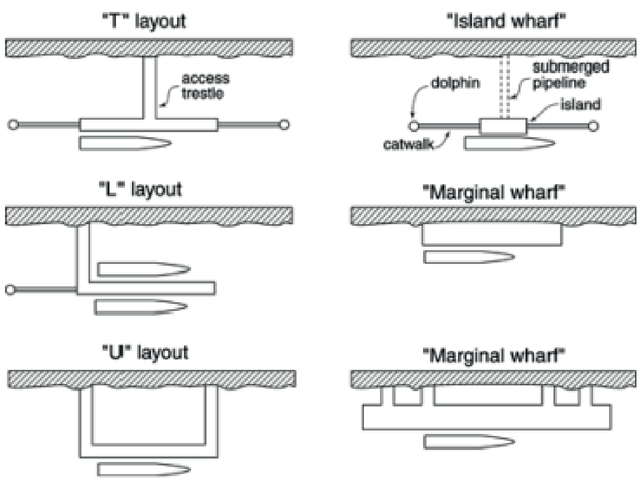


FIGURE 31F-5-1
TYPICAL PIER AND WHARF CONFIGURATIONS

3105F.1.3 Mooring/berthing requirements. *Multiple berth MOTs shall use the same environmental input conditions for each berth unless it can be demonstrated that there are significant differences.*

MOTs shall have the following equipment in operation:

1. *An anemometer (N/E).*
2. *A current meter in high velocity current (>1.5 knots) areas (N/E).*
3. *Remote reading tension load devices in high velocity current (>1.5 knots) areas and/or with passing vessel effects for new MOTs.*
4. *Mooring hardware in accordance with Section 3105F.8 (N/E).*

Berthing systems shall be in accordance with Section 3105F.4 (N/E).

Monitoring systems and instrumentation shall be implemented considering the parameters in Section 3102F.3.6.1, and shall be installed, maintained and calibrated in accordance with Section 3111F.9.3.

3105F.1.4 New MOTs. *Quick release hooks are required at all new MOTs, except for spring line fittings. Quick release hooks shall be sized in accordance with Section 3105F.8 To avoid accidental release, the freeing mechanism shall be activated by a two-step process. Quick release hooks shall be insulated electrically from the mooring structure, and shall be supported so as not to contact the deck.*

Section 3105F.5 and the OCIMF guidelines [5.4] shall be used in designing the mooring layout.

3105F.1.5 Analysis and design of mooring components. *The existing condition of the MOT shall be used in the mooring analysis (see Section 3102F). Structural characteristics of the MOT, including type and configuration of mooring fittings such as bollards, bitts, hooks and capstans and material properties and condition, shall be determined in accordance with Sections 3107F.7 and 3105F.8.*

The analysis and design of mooring components shall be based on the loading combinations and safety factors defined in Sections 3103F.8, 3105F.7 and 3105F.8, and in accordance with ACI 318 [5.1], AISC 325 [5.2] and ANSI/AWC NDS [5.3], as applicable.

3105F.2 Mooring analyses. *A mooring analysis shall be performed for each berthing system, to justify the safe mooring of the various vessels at the MOT. Review of vessels calling at the MOT shall be performed to identify representative vessel size ranges and mooring configurations. Vessels analyzed shall be representative of the upper bound of each vessel size range defined by DWT capacity (see Section 3101F.6). The Terminal Operating Limits (TOLs) shall be generated based on the mooring analyses (see Section 3102F.3.6.1 and Figure 31F-2-1).*

The forces acting on a moored vessel shall be determined in accordance with Section 3103F.5. Mooring line and breasting load combinations shall be in accordance with Section 3103F.8.

Two procedures, manual and numerical, are available for performing mooring analyses. These procedures shall conform to either the OCIMF (MEG 3) [5.4] or UFC 4-159-03 [5.5]. The manual procedure (Section 3105F.2.1) may be used for barges. In order to simplify the analysis for barges (or other small vessels), they may be considered to be solid free-standing walls (Chapter 29 of ASCE/SEI 7 [5.6]). This will eliminate the need to perform a computer assisted mooring analysis.

A new mooring assessment shall be performed when conditions change, such as any modification in the mooring configuration, vessel size or new information indicating greater wind, current or other environmental loads.

The most severe combination of the environmental loads and limiting conditions shall be justified based on site-specific evaluation, and considered in the mooring analyses. At a minimum, the following shall be considered and documented:

1. *Two current directions (maximum ebb and flood; See Section 3103F.5.3)*
2. *Two tide levels (highest high and lowest low)*
3. *Two vessel loading conditions (ballast and maximum draft at the terminal)*

4. *Eight wind directions (45 degree increments)*
5. *Vessel motion limits (as applicable)*
6. *Fender properties*
7. *Mooring hardware capacities*
8. *Minimum mooring line properties (such as MBL of the weakest line permitted for vessel size range)*
9. *Passing vessel forces*

In general, vessels shall remain in contact with the breasting or fendering system. Vessel motion (sway) of up to 2 feet off the breasting structure may be allowed under the most severe environmental loads, unless greater movement can be justified by an appropriate mooring analysis that accounts for potential dynamic effects. The allowable movement shall be consistent with mooring analysis results, indicating that forces in the mooring lines and their supports are within the allowable safety factors. Also, a check shall be made as to whether the movement is within the limitations of the cargo transfer equipment.

The mooring analyses outputs define the wind load and other limitations.

Upon completion of the mooring analyses, the following shall be checked, as applicable:

1. *The fender system compression/deflection performance.*
2. *Anchorage capacity of each mooring hardware component.*
3. *Capacity of supporting structure(s) exceed each mooring line demand.*
4. *Maximum allowable capacities for mooring lines.*
5. *Vessel motion does not exceed the maximum allowable extension limits of the loading arms and/or hoses.*

3105F.2.1 Manual procedure. *Simplified calculations may be used to determine the mooring forces for barges with Favorable Site Conditions (see Table 31F-3-8) and no passing vessel effects (see Section 3105F.3.2), except if any of the following conditions exist (Figures 31F-5-2 and 31F-5-3).*

1. *Mooring layout is significantly asymmetrical*
2. *Horizontal mooring line angles (α) on bow and stern exceed 45 degrees*
3. *Horizontal breast mooring line angles exceed 15 normal to the hull*
4. *Horizontal spring mooring line angles exceed 10 degrees from a line parallel to the hull*
5. *Vertical mooring line angles (θ) exceed 25 degrees*
6. *Mooring lines for lateral loads not grouped at bow and stern*

When the forces have been determined and the distance between the bow and stern mooring points is known, the yaw moment can be resolved into lateral loads at the bow and stern. The total environmental loads on a moored vessel are comprised of the lateral load at the vessel bow, the lateral load at the vessel stern and the longitudinal load. Line pretension loads must be added.

Four load cases shall be considered:

1. *Entire load is taken by mooring lines*
2. *Entire load is taken by breasting structures*
3. *Load is taken by combination of mooring lines and breasting structures*
4. *Longitudinal load is taken only by spring lines*

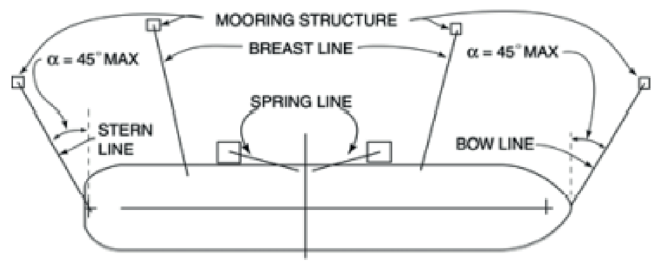


FIGURE 31F-5-2
HORIZONTAL LINE ANGLES [5.4]

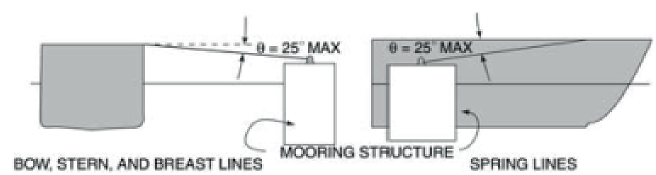


FIGURE 31F-5-3
VERTICAL LINE ANGLES [5.4]

3105F.2.2 Numerical procedure. *A numerical procedure is required to obtain mooring forces for MOTs that cannot use manual procedure. Computer program(s) shall be based on mooring analysis procedures that consider the characteristics of the mooring system, calculate the environmental loads and provide resulting mooring line forces and vessel motions (surge and sway).*

3105F.3 Wave, passing vessel, seiche and tsunami.

3105F.3.1 Wind waves. *MOTs are generally located in sheltered waters such that typical wind waves can be assumed not to affect the moored vessel if the significant wave period, T_s, is less than 4 seconds. However, if the period is equal to or greater than 4 seconds, then a simplified dynamic analysis (See Section 3103F.5.4) is required. The wave period shall be established based on a 1-year significant wave height, H_s. For MOTs within a harbor basin, the wave period shall be based on the locally generated waves with relatively short fetch.*

3105F.3.2 Passing vessels. *These forces generated by passing vessels are due to pressure gradients associated with the flow pattern. These pressure gradients cause the moored vessel to sway, surge, and yaw, thus imposing forces on the mooring lines.*

Passing vessel analysis shall be conducted when all of the following conditions exist (See Figure 31F-5-4):

1. *Passing vessel size is greater than 25,000 DWT.*

2. *Distance L is 500 feet or less*
3. *Vessel speed V is greater than V_{crit}*

where:

$$V_{crit} = 1.5 + \frac{L - 2B}{500 - 2B}\ 4.5(knots) \qquad (5\text{-}1)$$

Exception: *If L ≤ 2B, passing vessel loads shall be considered.*

L and B are shown in Figure 31F-5-4, in units of feet. V is defined as the speed of vessel over land minus the current velocity, when traveling with the current, or the speed of vessel over land plus the current velocity, when traveling against the current.

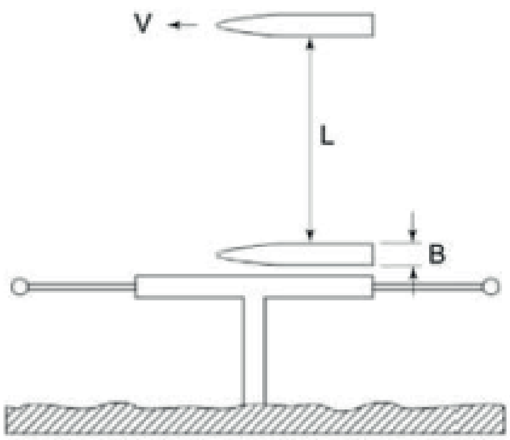


FIGURE 31F-5-4
PASSING VESSEL

When such conditions (1, 2 and 3 above) exist, the surge and sway forces and the yaw moment acting on the moored vessel shall, as a minimum, be established in accordance with Section 3103F.5.5 or by dynamic analysis.

For MOTs located in ports, the passing distance, L, may be established based on channel width and vessel traffic patterns. The guidelines established in Figure 5-17 of UFC 4-150-06 [5.7] for interior channels may be used. The "vertical bank" in Figure 5-17 of UFC 4-150-06 [5.7] shall be replaced by the side of the moored vessel when establishing the distance, "L."

For MOTs, not located within a port, the distance, "L," must be determined from observed traffic patterns.

The following passing vessel positions shall be investigated:

1. *Passing vessel is centered on the moored ship. This position produces maximum sway force.*
2. *The midship of the passing vessel is fore or aft of the centerline of the moored ship by a distance of 0.40 times the length of the moored ship. This position is assumed to produce maximum surge force and yaw moment at the same time.*

The mooring loads due to a passing vessel shall be added to the mooring loads due to wind and current.

3105F.3.3 Seiche. *A seiche analysis is required for existing MOTs located within a harbor basin and which have historically experienced seiche. A seiche analysis is required for new MOTs inside a harbor basin prone to penetration of ocean waves.*

The standing wave system or seiche is characterized by a series of "nodes" and "antinodes." Seiche typically has wave periods ranging from 20 seconds up to several hours, with wave heights in the range of 0.1 to 0.4 ft [5.7].

The following procedure may be used, as a minimum, in evaluating the effects of seiche within a harbor basin. In more complex cases where the assumptions below are not applicable, dynamic methods are required.

1. *Calculate the natural period of oscillation of the basin. The basin may be idealized as rectangular, closed or open at the seaward end. Use Chapter 2 of UFC 4-150-06 [5.7] to calculate the wave period and length for different modes. The first three modes shall be considered in the analysis.*
2. *Determine the location of the moored ship with respect to the antinode and node of the first three modes to determine the possibility of resonance.*
3. *Determine the natural period of the vessel and mooring system. The calculation shall be based on the total mass of the system and the stiffness of the mooring lines in surge. The surge motion of the moored vessel is estimated by analyzing the vessel motion as a harmonically forced linear single degree of freedom spring mass system. Methods outlined in a paper by F.A. Kilner [5.8] can be used to calculate the vessel motion.*
4. *Vessels are generally berthed parallel to the channel; therefore, only longitudinal (surge) motions shall be considered, with the associated mooring loads in the spring lines. The loads on the mooring lines (spring lines) are then determined from the computed vessel motion and the stiffness of those mooring lines.*

3105F.3.4 Tsunami. *Run-up and current velocity shall be considered in the tsunami assessment. Section 3103F.5.7 and Table 31F-3-6 provides run-up values for the San Francisco Bay area, Los Angeles/Long Beach Harbors and Port Hueneme.*

3105F.4 Berthing analysis and design. *The analysis and design of berthing components shall be based on the loading combinations and safety factors defined in Sections 3103F.8 and 3105F.7, and in accordance with ACI 318 [5.1], AISC 325 [5.2], and ANSI/AWC NDS [5.3], as applicable.*

3105F.4.1 Berthing energy demand. *The kinetic berthing energy demand shall be determined in accordance with Section 3103F.6.*

3105F.4.2 Berthing energy capacity. *For existing MOTs, the berthing energy capacity shall be calculated as the area under the force-deflection curve for the combined structure* *and fender system as indicated in Figure 31F-5-5. Fender piles may be included in the lateral analysis to establish the total force-deflection curve for the berthing system. Load-deflection curves for other fender types shall be obtained from manufacturer's data. The condition of fenders shall be taken into account when performing the analysis.*

When batter piles are present, the fender system typically absorbs most of the berthing energy. This can be established by comparing the force-deflection curves for the fender system and batter piles. In this case only the fender system energy absorption shall be considered.

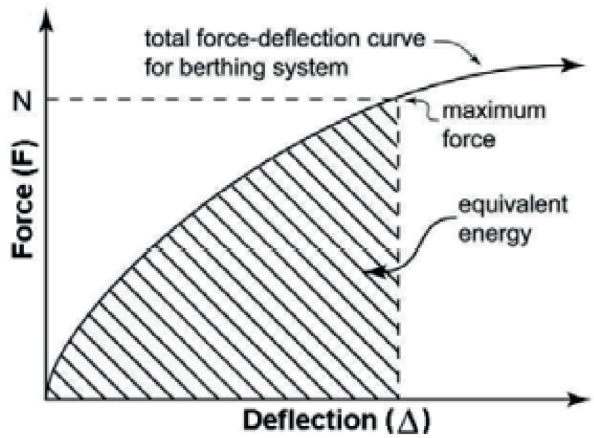


FIGURE 31F-5-5
BERTHING ENERGY CAPACITY

3105F.4.3 Tanker contact length.

3105F.4.3.1 Continuous fender system. *A continuous fender system consists of fender piles, chocks, wales, and rubber or spring fender units.*

The contact length of a ship during berthing depends on the spacing of the fender piles and fender units, and the connection details of the chocks and wales to the fender piles.

The contact length, L_c, can be calculated using rational analysis considering curvature of the bow and berthing angle.

In lieu of detailed analysis to determine the contact length, Table 31F-5-1 may be used. The contact length for a vessel within the range listed in the table can be obtained by interpolation.

TABLE 31F-5-1
CONTACT LENGTH

VESSEL SIZE (DWT)	CONTACT LENGTH
330	25 ft
1,000 to 2,500	35 ft
5,000 to 26,000	40 ft
35,000 to 50,000	50 ft
65,000	60 ft
100,000 to 125,000	70 ft

3105F.4.3.2 Discrete fender system. *For discrete fender systems (i.e., not continuous), one fender unit or breasting dolphin shall be able to absorb the entire berthing energy.*

3105F.4.4 Longitudinal and vertical berthing forces. *The longitudinal and vertical components of the horizontal berthing force shall be calculated using appropriate coefficients of friction between the vessel and the fender. In lieu of as-built data, the values in Table 31F-5-2 may be used for typical fender/vessel materials:*

TABLE 31F-5-2
COEFFICIENT OF FRICTION

CONTACT MATERIALS	FRICTION COEFFICIENT
Timber to Steel	0.4 to 0.6
Urethane to Steel	0.4 to 0.6
Steel to Steel	0.25
Rubber to Steel	0.6 to 0.7
UHMW* to Steel	0.1 to 0.2

**Ultra-high molecular weight plastic rubbing strips.*

Longitudinal and vertical forces shall be determined by:

$$F = \mu N \quad (5\text{-}3)$$

where:

F = longitudinal or vertical component of horizontal berthing force

μ = coefficient of friction of contact materials

N = maximum horizontal berthing force (normal to fender)

3105F.4.5 Design and selection of new fender systems. *For guidelines on new fender designs, refer to UFC 4-152-01 [5.9] and PIANC [5.10]. Velocity and temperature factors, contact angle effects and manufacturing tolerances shall be considered (see Appendices A and B of PIANC [5.10]). Also, see Section 3103F.6.*

3105F.5 Layout of new MOTs. *Guidelines for layout of new MOTs are provided in OCIMF MEG3 [5.4]. The final layout of the mooring and breasting dolphins shall be determined based on the results of the mooring analysis that provides optimal mooring line and breasting forces for the range of vessels to be accommodated.*

3105F.6 Offshore moorings. *Offshore MOT moorings shall be designed and analyzed considering the site water depth, metocean environment and class of vessels calling per OCIMF MEG3 [5.4] or UFC 4-159-03 [5.5].*

3105F.6.1 Mooring analyses. *Analysis procedures shall conform to the OCIMF MEG3 [5.4] or UFC 4-159-03 [5.5], and the following:*

1. *A mooring analysis shall be performed for the range of tanker classes and barges calling at each offshore berth.*
2. *Forces acting on moored vessels shall be determined according to Section 3103F.5 and analysis shall consider all possible vessel movements, contri-*

bution of buoys, sinkers, catenaries affecting mooring line stiffness and anchorages.

3. *Correlation of winds, waves and currents shall be considered. The correlation may be estimated by probabilistic analysis of metocean data.*
4. *The actual expected displacement of the vessels shall be used in the analysis.*
5. *Underwater inspections and bathymetry shall be considered.*
6. *Both fully laden and ballast conditions shall be considered.*
7. *Dynamic analysis shall be used to evaluate moorings performance.*

3105F.6.2 Design of mooring components. *Design of mooring components shall be based on loading combinations and safety factors defined in Sections 3103F.8, 3105F.7 and 3105F.8 and follow the guidelines provided in either the OCIMF MEG3 [5.4] or UFC 4-159-03 [5.5].*

3105F.7 Safety factors for mooring lines. *Safety factors for different material types of mooring lines are given in Table 31F-5-3. The safety factors should be applied to the minimum number of lines specified by the mooring analysis, using the highest loads calculated for the environmental conditions. The minimum breaking load (MBL) of new ropes is obtained from the certificate issued by the manufacturer. If polyamide tails are used in combination with wire mooring lines, the safety factor shall be based on the weaker of the two ropes.*

TABLE 31F-5-3
SAFETY FACTORS FOR ROPES [5.4]

Steel Wire Rope	1.82
Polyamide	2.22
Other Sythetic	2.00
Polyamide Tail for Wire Mooring Lines	2.50
Other Synthetic Tail for Wire Mooring Lines	2.28
Polyamide Tail for Synthetic Mooring Lines	2.75
Other Synthetic Tail for Synthetic Mooring Lines	2.50
Joining Shackles	2.00

3105F.8 Mooring hardware (N/E). *Mooring hardware shall include, but not be limited to, bollards, quick release hooks, other mooring fittings and base bolts. All mooring hardware shall be clearly marked with their safe working loads (or allowable working loads) [5.4]. The certificate issued by the manufacturer normally defines the safe working loads of this hardware.*

3105F.8.1 Quick release hooks. *For new MOTs or berthing systems, a minimum of three quick release hooks are required for each breasting line location for tankers greater than or equal to 50,000 DWT. At least two hooks at each location shall be provided for breasting lines for tankers less than 50,000 DWT. Remote release may be considered for emergency situations.*

All hooks and supporting structures shall withstand the minimum breaking load (MBL) of the strongest line with a safety factor of 1.2 or greater. Only one mooring line shall be placed on each quick release hook (N/E).

For multiple quick release hooks, the minimum horizontal load for the design of the tie-down shall be:

$$F_d = 1.2 \times MBL \times [1 + 0.75\,(n-1)] \qquad (5\text{-}4)$$

where:

F_d = *Minimum factored demand for assembly tie-down.*

n = *Number of hooks on the assembly.*

The capacity of the supporting structures must be larger than F_d (See Section 3107F.6).

3105F.8.2 Other fittings. *Other fittings include cleats, bitts and bollards.*

If the allowable working loads for existing fittings are not available, the values listed in Table 31F-5-4 may be used for typical sizes, bolt patterns and layout. The allowable working loads are defined for mooring line angles up to 60 degrees from the horizontal. The combination of vertical and horizontal loads shall be considered.

TABLE 31F-5-4
ALLOWABLE WORKING LOADS

TYPE OF FITTINGS	NO. OF BOLTS	BOLT SIZE (in)	WORKING LOAD (kips)
30 inch Cleat	4	$1^1/_8$	20
42 inch Cleat	6	$1^1/_8$	40
Low Bitt	10	$1^5/_8$	60 per column
High Bitt	10	$1^3/_4$	75 per column
$44^1/_2$ inch Fit. Bollard	4	$1^3/_4$	70
$44^1/_2$ inch Fit. Bollard	8	$2^1/_4$	200
48 inch Fit. Bollard	12	$2^3/_4$	450

Note: *This table is modified from Table 6-11 of UFC 4-159-03 [5.5]*

3105F.8.3 Base bolts. *Base bolts are subjected to both shear and uplift. Forces on bolts shall be determined using the following factors:*

1. *Height of load application on bitts or bollards.*
2. *Actual vertical angles of mooring lines for the highest and lowest tide and vessel draft conditions, for all sizes of vessels at each particular berth.*
3. *Actual horizontal angles from the mooring line configurations, for all vessel sizes and positions at each particular berth.*
4. *Simultaneous loads from more than one vessel.*

For existing MOTs, the deteriorated condition of the base bolts and supporting members shall be considered in determining the capacity of the fitting.

3105F.9 Symbols.

α = *Horizontal mooring line angles*

Δ = *Deflection*

θ = *Vertical mooring line angles*

B = *Beam of vessel*

DWT = *Dead Weight Tonnage*

F = *Longitudinal or vertical component of horizontal normal berthing force*

F_d = *Minimum factored demand for assembly tie-down*

L = *Distance between passing and moored vessels*

MBL = *Minimum breaking load*

n = *Number of hooks on the assembly*

N = *Maximum horizontal berthing force*

μ = *Coefficient of friction of contact materials*

V = *Ground speed (knots)*

V_c = *Maximum current (knots).*

V_{crit} = *Ground speed (knots) above which passing loads must be considered*

3105F.10 References.

[5.1] American Concrete Institute (ACI), 2014, ACI 318-14 (ACI 318), "Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)," Farmington Hills, MI.

[5.2] American Institute of Steel Construction, Inc. (AISC), 2017, AISC 325-17 (AISC 325), "Steel Construction Manual," 15th ed., Chicago, IL.

[5.3] American Wood Council (AWC), 2017, ANSI/AWC NDS-2018 (ANSI/AWC NDS), "National Design Specification (NDS) for Wood Construction," Washington, D.C.

[5.4] Oil Companies International Marine Forum (OCIMF), 2008, "Mooring Equipment Guidelines (MEG3)," 3rd Ed., London, England.

[5.5] Department of Defense, 3 October 2005 (Change 2, 23 June 2016), Unified Facilities Criteria (UFC) 4-159-03, "Design: Moorings," Washington D.C.

[5.6] American Society of Civil Engineers (ASCE), 2016, ASCE/SEI 7-16 (ASCE/SEI 7), "Minimum Design Loads and Associated Criteria for Buildings and Other Structures," Reston, VA.

[5.7] Department of Defense, 12 December 2001 (Change 1, 19 October 2010), Unified Facilities Criteria (UFC) 4-150-06, "Military Harbors and Coastal Facilities," Washington D.C

[5.8] Kilner F.A., 1961, "Model Tests on the Motion of Moored Ships Placed on Long Waves." Proceedings of 7th Conference on Coastal Engineering, August 1960, The Hague, Netherlands, published by the Council on Wave Research - The Engineering Foundation.

[5.9] Department of Defense, 24 January 2017, Unified Facilities Criteria (UFC) 4-152-01, "Design: Piers and Wharves," Washington D.C.

[5.10] Permanent International Association of Navigation Congresses (PIANC), 2002, "Guidelines for the Design of Fender Systems: 2002," Brussels.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 6

SECTION 3106F GEOTECHNICAL HAZARDS AND FOUNDATIONS

3106F.1 General.

3106F.1.1 Purpose. *This section provides minimum standards for analyses and evaluation of geotechnical hazards and foundations under static and seismic conditions.*

3106F.1.2 Applicability. *The requirements provided herein apply to all new and existing MOTs.*

3106F.1.3 Loading. *The loading for geotechnical hazard assessment and foundation analyses under static and seismic conditions is provided in Sections 3103F and 3104F.*

3106F.2 Site characterization. *Site characterization shall be based on site-specific geotechnical information. If existing information is used, the geotechnical engineer of record shall provide adequate justification.*

3106F.2.1 Site classes. *Each MOT shall be assigned at least one site class. Site Classes A, B, C, D, and E are defined in Table 31F-6-1, and Site Class F is defined by any of the following:*

1. *Soils vulnerable to significant potential loss of stiffness, strength, and/or volume under seismic loading due to liquefiable soils, quick and highly sensitive clays, and/or collapsible weakly cemented soils.*
2. *Peats and/or highly organic clays, where the thickness of peat or highly organic clay exceeds 10 feet.*
3. *Very high plasticity clays with a plasticity index (PI) greater than 75, where the thickness of clay exceeds 25 feet.*
4. *Very thick soft/medium stiff clays with undrained shear strength less than 1,000 psf, where the thickness of clay exceeds 120 feet.*

3106F.2.2 Site-specific information.

1. *Site-specific investigations shall include adequate borings and/or cone penetration tests (CPTs) and other appropriate field methods, to enable the determination of geotechnical parameters.*
2. *Adequate coverage of subsurface data, both horizontally and vertically, shall be obtained to develop geotechnical parameters.*
3. *Exploration shall be deep enough to characterize subsurface materials that are affected by embankment behavior and shall extend to depth of at least 20 feet below the deepest foundation depth.*
4. *During field exploration, particular attention shall be given to the presence of continuous low-strength layers or thin soil layers that could liquefy or weaken during the design earthquake shaking.*
5. *CPTs provide continuous subsurface profile and shall be used to complement exploratory borings. When CPTs are performed, at least one boring shall be performed next to one of the CPT soundings to check that the CPT-soil behavior type interpretations are reasonable for the site. Any difference between CPT interpretation and subsurface condition obtained from borings shall be reconciled.*
6. *Quantitative site soil stratigraphy is required to a depth of 100 feet for assigning a site class (see Table 31F-6-1).*
7. *Laboratory tests may be necessary to supplement the borings and insitu field tests.*

3106F.3 Seismic loads for geotechnical evaluations. *Section 3103F.4 defines the earthquake loads to be used for structural and geotechnical evaluations in terms of design Peak Ground Accelerations (PGA), spectral accelerations and design earthquake magnitude. Values used for analyses are based on Probabilistic Seismic Hazard Analyses (PSHA) using two levels of seismic performance criteria (Section 3104F.2.1 and Table 31F-4-1).*

3106F.4 Liquefaction potential. *The liquefaction potential of the soils in the immediate vicinity of or beneath each MOT, and associated slopes, embankments or rock dikes shall be evaluated for the PGAs associated with seismic performance Levels 1 and 2. Liquefaction potential evaluation should fol-*

TABLE 31F-6-1 SITE CLASSES

SITE CLASS	SOIL PROFILE	AVERAGE VALUES FOR TOP 100 FEET OF SOIL PROFILE[3]		
		Shear Wave Velocity, V_S [ft/sec]	Standard Penetration Test, SPT [blows/ft]	Undrained Shear Strength, S_U [psf]
A	Hard Rock	> 5,000		
B	Rock	2,500 to 5,000		
C	Very Stiff/Very Dense Soil and Soft Rock	1,200 to 2,500	> 50	> 2,000
D	Soft/Dense Soil Profile	600 to 1,200	15 to 50	1,000 to 2,000
E[1, 2]	Soft/Loose Soil Profile	< 600	< 15	< 1,000
F	Defined in Section 3106F.2.1			

1. *Site Class E also includes any soil profile with more than 10 feet of soft clay (defined as a soil with a plasticity index, PI > 20, water content > 40 percent and S_u < 500 psf).*
2. *The plasticity index, P1, and the moisture content shall be determined in accordance with ASTM D4318 [6.1] and ASTM D2216 [6.2], respectively.*
3. *Conversion of CPT data to estimate equivalent V_s, SPT blow count, or S_u is allowed.*

low the procedures outlined in NCEER report [6.3], SCEC [6.4] and CGS Special Publication 117A [6.5].

If liquefaction is shown to be initiated in the above evaluations, the particular liquefiable strata and their thicknesses shall be clearly shown on site profiles. Resulting hazards associated with liquefaction shall be addressed including translational or rotational deformations of slopes or embankment systems and post liquefaction settlement of slopes or embankment systems and underlying foundation soils, as noted below. If such analyses indicate the potential for partial or gross (flow) failure of a slope or embankment, adequate evaluations shall be performed to confirm such a condition exists, together with analyses to evaluate potential slope displacements (lateral spreads). In these situations and for projects where more detailed numerical analyses are performed, a peer review (see Section 3101F.8.2) may be required.

3106F.5 Slope or embankment stability and seismically induced lateral spreading. *Slope or embankment stability related to the MOT facility, shall be evaluated for static and seismic loading conditions.*

3106F.5.1 Static slope stability. *Static stability analysis using conventional limit equilibrium methods shall be performed for site related slope or embankment systems. Live load surcharge shall be considered in analyses based on project-specific information. The long-term static factor of safety of the slope or embankment shall not be less than 1.5.*

3106F.5.2 Pseudo-static seismic slope stability. *Pseudo-static seismic slope or embankment stability analyses shall be performed to estimate the horizontal yield acceleration for the slope for the Level 1 and Level 2 earthquakes. During the seismic event, appropriate live load surcharge shall be considered.*

If liquefaction and/or strength loss of the site soils is likely, the following shall be used in the analyses, as appropriate:

1. *Residual strength of liquefied soils*
2. *Strengths compatible with the pore-pressure generation of potentially liquefiable soils*
3. *Potential strength reduction of clays*

The residual strength of liquefied soils shall be estimated using guidelines outlined in SCEC [6.4] or other appropriate documents as noted in CGS Special Publication 117A [6.5].

Pseudo-static analysis shall be performed without considering the presence of the foundation system. Using a horizontal seismic coefficient of one-half of the PGA, if the estimated factor of safety is greater than or equal to 1.1, then no further evaluation of lateral spreading or kinematic loading from lateral spreading is required.

3106F.5.3 Post-earthquake static slope stability. *The static factor of safety immediately following a design earthquake event shall not be less than 1.1 when any of the following are used in static stability analysis:*

1. *Post-earthquake residual strength of liquefied soils*
2. *Strengths compatible with the pore-pressure generation of potentially liquefiable soils*
3. *Potential strength reduction of clays*

3106F.5.4 Lateral spreading – Free field. *The earthquake–induced lateral deformations of the slope or embankment and associated foundations soils shall be determined for the Level 1 and Level 2 earthquakes using the associated PGA at the ground surface (not modified for liquefaction). If liquefaction and/or strength loss of the site soils is likely, the following shall be used in the analyses, as appropriate:*

1. *Residual strength of liquefied soils*
2. *Strengths compatible with the pore-pressure generation of potentially liquefiable soils*
3. *Potential strength reduction of clays*

The presence of the foundation system shall not be included in the "free field" evaluations.

Initial lateral spread estimates shall be made using the Newmark displacement approach documented in NCHRP Report 611 [6.6] or other appropriate but similar procedures.

3106F.6 Seismically induced settlement. *Seismically induced settlement shall be evaluated. Based on guidelines outlined in SCEC [6.4] or other appropriate documents such as CGS Special Publication 117A [6.5]. If seismically induced settlement is anticipated, the resulting design impacts shall be considered, including the potential development of downdrag loads on piles.*

3106F.7 Earth pressures. *Both static and seismic earth pressures acting on MOT structures shall be evaluated.*

3106F.7.1 Earth pressures under static loading. *The effect of static active earth pressures on structures resulting from static loading of backfill soils shall be considered where appropriate. Backfill sloping configuration, if applicable, and backland loading conditions shall be considered in the evaluations. The loading considerations shall be based on project-specific information. The earth pressures under static loading should be based on guidelines outlined in NAVFAC DM7-02 [6.7] or other appropriate documents.*

3106F.7.2 Earth pressures under seismic loading. *The effect of earth pressures on structures resulting from seismic loading of backfill soils, including the effect of pore-water pressure build-up in the backfill, shall be considered. The seismic coefficients used for this analysis shall be based on the Level 1 and Level 2 earthquake PGA values.*

Evaluation of earth pressures under seismic loading, should be based on NCHRP Report 611 [6.6] or other appropriate methods.

3106F.8 Pile axial behavior.

3106F.8.1 Axial pile capacity. *Axial geotechnical capacity of piles under static loading shall be evaluated using guidelines for estimating axial pile capacities provided in POLB WDC [6.8] or other appropriate documents. A min-*

imum factor of safety of 2.0 shall be achieved on the ultimate capacity of the pile using appropriate MOT loading.

If liquefaction or seismically-induced settlement is anticipated, the ultimate axial geotechnical capacity of piles under seismic conditions shall be evaluated for the effects of liquefaction and/or downdrag forces on the pile. The ultimate geotechnical capacity of the pile during liquefaction shall be determined on the basis of the residual strength of the soil for those layers where the factor of safety for liquefaction is determined to be less than 1.0.

When seismically-induced settlements are predicted to occur during design earthquakes, the downdrag loads shall be computed, and the combination of downdrag load and static load determined. Only the tip resistance of the pile and the side friction resistance below the lowest layer contributing to the downdrag shall be used in the capacity evaluation. The ultimate axial geotechnical capacity of the pile shall not be less than the combination of the seismically induced downdrag force and the maximum static load.

3106F.8.2 Axial springs for piles. *The geotechnical analyst (see Section 3102F.3.4.8) shall coordinate with the structural analyst (see Section 3102F.3.4.4) and develop axial springs (T-z) for piles. The T-z springs may be developed either at the top or at the tip of the pile (see Figure 31F-6-1). If the springs are developed at the pile tip, the tip shall include both the friction resistance along the pile (i.e., side springs [t-z]) and tip resistance at the pile tip (i.e. tip springs [q-w]), as illustrated in Figure 31F-6-1. If T-z springs are developed at the pile top, the appropriate elastic shortening of the pile shall be included in the springs. Linear or nonlinear springs may be developed if requested by the structural analyst.*

Due to the uncertainties associated with the development of axial springs, such as the axial soil capacities, load distributions along the piles and simplified spring stiffnesses, both upper-bound and lower-bound limits shall be estimated and utilized in the analyses.

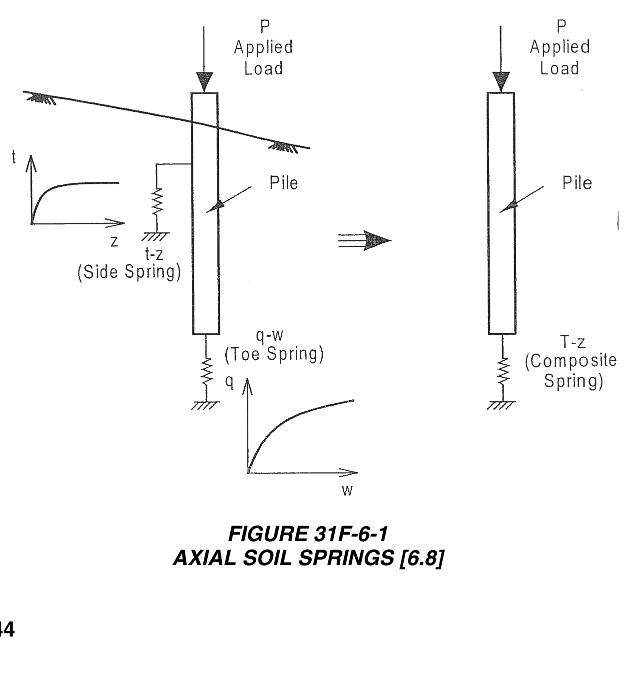


FIGURE 31F-6-1
AXIAL SOIL SPRINGS [6.8]

3106F.9 Soil springs for lateral pile loading. *For design of piles under loading associated with the inertial response of the superstructure, level-ground inelastic lateral springs (p-y) shall be developed. The lateral springs within the shallow portion of the piles (generally within 10 pile diameters below the ground surface) tend to dominate the inertial behavior. Geotechnical parameters for developing lateral soil springs shall follow guidelines provided in API RP 2A-WSD [6.9] or other appropriate documents.*

Due to uncertainties associated with the development of p-y curves for dike structures, upper-bound and lower-bound p-y springs shall be developed for use in superstructure inertial response analyses.

3106F.10 Soil-pile interaction. *Two separate loading conditions for the piles shall be considered:*

1. *Inertial loading under seismic conditions*
2. *Kinematic loading from lateral ground spreading*

Inertial loading is associated with earthquake-induced lateral loading on a structure, while kinematic loading refers to loading on foundation piles from earthquake induced lateral deformations of the slope/ embankment/dike system. Simultaneous application of these loading conditions shall be evaluated with due consideration of the phasing and locations of these loads on foundation elements. The foundation shall be designed such that the structural performance is acceptable when subjected to both inertial and kinematic loadings.

3106F.10.1 Inertial loading under seismic conditions. *The lateral soil springs shall be used in inertial loading response analyses. The evaluation of inertial loading can be performed by ignoring potential slope/embankment/dike system deformations (i.e., one end of the lateral soil spring at a given depth is attached to the corresponding pile node and the other end is assumed fixed).*

3106F.10.2 Kinematic loading from lateral spreading. *Kinematic pile loading from permanent lateral spread ground deformation in deep seated levels of slope/embankment/dike foundation soils shall be evaluated. The lateral deformations shall be restricted such that the structural performance of foundation piles is not compromised.*

The lateral deformation of the embankment or dike and associated piles and foundation soils shall be determined using analytical methods as follows:

1. *Initial estimates of free field lateral spread deformations (in the absence of piles) may be determined using the simplified Newmark sliding block method as described in Section 3106F.5.4. The geotechnical analyst shall provide the structural analyst with level-ground p-y curves for the weak soil layer controlling the lateral spread and soil layers above and below the weak layer. Appropriate overburden pressures shall be used in simplified pushover analyses, to estimate the pile displacement capacities and corresponding pile shear within the weak soil zone.*
2. *For the pushover analysis, the estimated displacements may be uniformly distributed within the thickness of the weak soil layer (i.e., zero at and below the bottom of the layer to the maximum value at and*

> *above the top of the weak layer). The thickness of the weak soil layer used in the analysis (failure zone) shall not be more than five times the pile diameter or 10 feet, whichever is smaller.*

3. *For a simplified analysis (see Figure 31F-6-2), the pile shall be fixed against rotation and translation relative to the soil displacement at some distance above and below the weak soil layer. Between these two points, lateral soil springs are provided, which allow deformation of the pile relative to the deformed soil profile.*

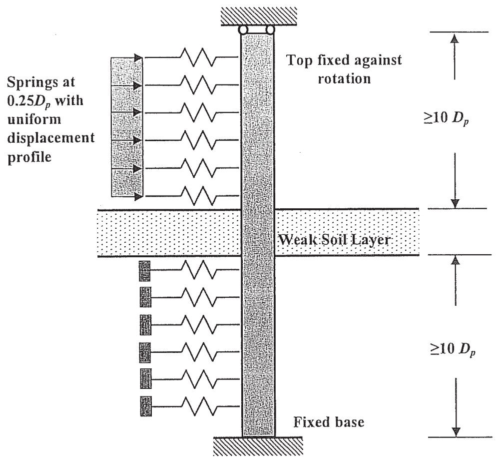


FIGURE 31F-6-2
SLIDING LAYER MODEL [6.8]

3106F.11 Soil-structure interaction – Shallow foundations and underground structures.

3106F.11.1 Shallow foundations. *Shallow foundations shall be assumed to move with the ground. Springs and dashpots may be evaluated as per Gazetas [6.10].*

3106F.11.2 Underground structures. *Buried flexible structures or buried portions of flexible structures including piles and pipelines shall be assumed to deform with estimated ground movement at depth.*

As the soil settles, it shall be assumed to apply shear forces to buried structures or buried portions of structures including deep foundations.

3106F.12 Underwater seafloor pipelines. *Geotechnical evaluations of underwater pipelines shall include static stability of the seafloor ground supporting the pipeline and settlement and lateral deformation of the ground under earthquakes. If the pipeline is buried, the potential for uplift of the pipeline under earthquakes shall also be evaluated.*

3106F.13 Symbols.

A = Site Class A as defined in Table 31F-6-1

B = Site Class B as defined in Table 31F-6-1

C = Site Class C as defined in Table 31F-6-1

CPT = Cone Penetration Test

D = Site Class D as defined in Table 31F-6-1

D_p = *Pile diameter*

E = Site Class E as defined in Table 31F-6-1

F = Site Class F as defined in Table 31F-6-1

P = Applied load

PI = Plasticity index

p-y = Lateral soil spring

S_U = *Undrained shear strength*

SPT = Standard Penetration Test

t-z = Axial soil spring along the side of pile

T-z = Composite axial soil spring at pile tip

q-w = Axial soil spring at pile tip

V_S = *Shear wave velocity*

3106F.14 References.

[6.1] American Society for Testing and Materials (ASTM), 2014, ASTM D4318-10 (ASTM D4318), "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils," West Conshohocken, PA.

[6.2] American Society for Testing and Materials (ASTM), 2014, ASTM D2216-10 (ASTM D2216), "Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass," West Conshohocken, PA.

[6.3] Youd, T.L., Idriss, I.M., Andrus, R.D., Arango, I., Castro, G. Christian, J.T., Dobry, R., Finn, W.D.L., Harder, L.F. Jr., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcuson, W.F., III, Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B., and Stokoe, K.H., II, 2001, "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils," Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Volume 127, No. 10, p. 817-833.

[6.4] Southern California Earthquake Center (SCEC), March 1999, "Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Liquefaction in California," University of Southern California, Los Angeles.

[6.5] California Department of Conservation, California Geological Survey (CGS), 11 September 2008, "Guidelines for Evaluating and Mitigating Seismic Hazards in California," Special Publication 117A, Revised Release.

[6.6] National Cooperative Highway Research Program (NCHRP), 2008, "NCHRP Report 611: Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments," Washington, D.C.

[6.7] Naval Facilities Engineering Command (NAVFAC), 1986, NAVFAC DM7-02, "Foundation and Earth Structures," Alexandria, VA.

[6.8] Port of Long Beach (POLB), 2012 February 29, "Wharf Design Criteria (WDC)," Version 3.0, Long Beach, CA.

[6.9] American Petroleum Institute (API), November 2014, API Recommended Practice 2A-WSD (API RP 2A-WSD), "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design," 22nd ed., Washington, D.C.

[6.10] Gazetas, G., September 1991, "Formulas and Charts for Impedances of Surface and Embedded Foundations," Journal of Geotechnical Engineering, ASCE, Vol. 117, No. 9.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 7

SECTION 3107F STRUCTURAL ANALYSIS AND DESIGN OF COMPONENTS

3107F.1 General.

3107F.1.1 Purpose. *This section establishes the minimum performance standards for structural and nonstructural components. Evaluation procedures for seismic performance, strength and deformation characteristics of concrete, steel and timber components are prescribed herein. Analytical procedures for seismic assessment are presented in Section 3104F.*

3107F.1.2 Applicability. *This section addresses MOT structures constructed using the following structural components:*

1. *Reinforced concrete decks supported by batter and/or vertical concrete piles*
2. *Reinforced concrete decks supported by batter and/or vertical steel piles, including pipe piles filled with concrete*
3. *Reinforced concrete decks supported by batter and/or vertical timber piles*
4. *Timber decks supported by batter or vertical timber, concrete or steel pipe piles*
5. *Retaining structures constructed of steel, concrete sheet piles or reinforced concrete*

Additionally, this section addresses structural and nonstructural components, nonbuilding structures and building structures comprised of steel, concrete or timber.

3107F.2 Concrete deck with concrete or steel piles.

3107F.2.1 Component strength. *The following parameters shall be established in order to compute the component strength:*

1. *Specified concrete compressive strengths*
2. *Concrete and steel modulus of elasticity*
3. *Yield and tensile strength of mild reinforcing and prestressed steel and corresponding strains*
4. *Confinement steel strength and corresponding strains*
5. *Embedment length*
6. *Concrete cover*
7. *Yield and tensile strength of structural steel*
8. *Ductility*

In addition, for "existing" components, the following conditions shall be considered:

9. *Environmental effects, such as reinforcing steel corrosion, concrete spalling, cracking and chemical attack*
10. *Fire damage*
11. *Past and current loading effects, including overload, fatigue or fracture*
12. *Earthquake damage*
13. *Discontinuous components*
14. *Construction deficiencies*

3107F.2.1.1 Material properties. *Material properties of existing components, not determined from testing procedures, and of new components, shall be established using the following methodology.*

The strength of structural components shall be evaluated based on the following values (Section 5.3 of [7.1] and pp. 3-73 and 3-74 of [7.2]):

Specified material strength shall be used for nonductile components (shear controlled), all mechanical, electrical and mooring equipment (attachments to the deck) and for all non seismic load combinations:

$$f'_c = 1.0 f'_c \quad (7\text{-}1a)$$
$$f_y = 1.0 f_y \quad (7\text{-}1b)$$
$$f_p = 1.0 f_p \quad (7\text{-}1c)$$

In addition, these values (7-1a, 7-1b and 7-1c) may be used conservatively as alternatives to determine the nominal strength of ductile components (N).

Expected lower bound estimates of material strength shall be used for determination of moment-curvature relations and nominal strength of all ductile components:

$$f'_c = 1.3 f'_c \quad (7\text{-}2a)$$
$$f_y = 1.1 f_y \quad (7\text{-}2b)$$
$$f_p = 1.0 f_p \quad (7\text{-}2c)$$

Upper bound estimates of material strength shall be used for the determination of moment-curvature relations, to obtain the feasible maximum demand on capacity protected members:

$$f'_c = 1.7 f'_c \quad (7\text{-}3a)$$
$$f_y = 1.3 f_y \quad (7\text{-}3b)$$
$$f_p = 1.1 f_p \quad (7\text{-}3c)$$

where:

f'_c = *Specified compressive strength of concrete*

f_y = *Specified yield strength of reinforcement or specified minimum yield stress steel*

f_p = *Specified yield strength of prestress strands*

"Capacity Design" (Section 5.3 of [7.1]) ensures that the strength at protected components (such as pile caps and decks), joints and actions (such as shear), is greater than the maximum feasible demand (over strength), based on realistic upper bound estimates of plastic hinge flexural strength. An additional series of nonlinear analyses using moment curvature characteristics of pile hinges may be required.

Alternatively, if a moment-curvature analysis is performed that takes into account the strain hardening of the steel, the demands used to evaluate the capacity protected components may be estimated by multiplying the moment-curvature values by 1.25.

Based on a historical review of the building materials used in the twentieth century, guidelines for tensile and yield properties of concrete reinforcing bars and the compressive strength of structural concrete have been established (see Tables 10-2 to 10-4 of ASCE/SEI 41 [7.3]). The values shown in these tables can be used as default properties, only if as-built information is not available and testing is not performed. The values in Tables 31F-7-1 and 31F-7-2, are adjusted according to Equations (7-1) through (7-3).

3107F.2.1.2 Knowledge factor (k). *Knowledge factor, k, shall be applied on a component basis.*

The following information is required, at a minimum, for a component strength assessment:

1. *Original construction records, including drawings and specifications.*
2. *A set of "as-built" drawings and/or sketches, documenting both gravity and lateral systems (Section 3102F.1.5) and any postconstruction modification data.*
3. *A visual condition survey, for structural components including identification of the size, location and connections of these components.*

TABLE 31F-7-1
COMPRESSIVE STRENGTH OF STRUCTURAL CONCRETE (psi)[1]

TIME FRAME	PILING	BEAMS	SLABS
1900-1919	2,500-3,000	2,000-3,000	1,500-3,000
1920-1949	3,000-4,000	2,000-3,000	2,000-3,000
1950-1965	4,000-5,000	3,000-4,000	3,000-4,000
1966-present	5,000-6,000	3,000-5,000	3,000-5,000

1. *Concrete strengths are likely to be highly variable for an older structure.*

TABLE 31F-7-2
TENSILE AND YIELD PROPERTIES OF REINFORCING BARS FOR VARIOUS ASTM SPECIFICATIONS AND PERIODS
(after Table 6-2 of [7.3])

				STRUCTURAL[1]	INTERMEDIATE[1]	HARD[1]			
			GRADE	33	40	50	60	70	75
			Minimum Yield[2] (psi)	33,000	40,000	50,000	60,000	70,000	75,000
ASTM	STEEL TYPE	YEAR RANGE[3]	Minimum Tensile[2] (psi)	55,000	70,000	80,000	90,000	95,000	100,000
A15	Billet	1911-1966		X	X	X			
A16	Rail[4]	1913-1966				X			
A61	Rail[4]	1963-1966					X		
A160	Axle	1936-1964		X	X	X			
A160	Axle	1965-1966		X	X	X	X		
A408	Billet	1957-1966		X	X	X			
A431	Billet	1959-1966							X
A432	Billet	1959-1966					X		
A615	Billet	1968-1972			X		X		X
A615	Billet	1974-1986			X		X		
A615	Billet	1987-1997			X		X		X
A616	Rail[4]	1968-1997					X		
A617	Axle	1968-1997			X		X		
A706	Low-Alloy[5]	1974-1997						X	
A955	Stainless	1996-1997			X		X		X

General Note: An entry "X" indicates that grade was available in those years.

1. *The terms structural, intermediate and hard became obsolete in 1968.*
2. *Actual yield and tensile strengths may exceed minimum values.*
3. *Untilabout 1920, a variety of proprietary reinforcing steels were used. Yield strengths are likely to be in the range from 33,000 psi to 55,000 psi, but higher values are possible. Plain and twisted square bars were sometimes used between 1900 and 1949.*
4. *Rail bars should be marked with the letter "R."*
5. *ASTM steel is marked with the letter "W."*

4. In the absence of material properties, values from limited in-situ testing or conservative estimates of material properties (Tables 31F-7-1 and 31F-7-2).
5. Assessment of component conditions, from an in-situ evaluation, including any observable deterioration.
6. Detailed geotechnical information, based on recent test data, including risk of liquefaction, lateral spreading and slope stability.

The knowledge factor, k, is 1.0 when comprehensive knowledge as specified above is utilized. Otherwise, the knowledge factor shall be 0.75 (see Section 5.2.6 of ASCE/SEI 41 [7.3]).

3107F.2.2 Component stiffness. *Stiffness that takes into account the stress and deformation levels experienced by the component shall be used. Nonlinear load-deformation relations shall be used to represent the component load-deformation response. However, in lieu of using nonlinear methods to establish the stiffness and moment curvature relation of structural components, the equations of Table 31F-7-3 may be used to approximate the effective elastic stiffness, EI_e, for lateral analyses (see Section 3107F.8 for definition of symbols).*

**TABLE 31F-7-3
EFFECTIVE ELASTIC STIFFNESS**

CONCRETE COMPONENT	EI_e/EI_g
Reinforced Pile	$0.3 + N/(f'_c A_g)$
Pile/Deck Dowel Connection[1]	$0.3 + N/(f'_c A_g)$
Prestressed Pile[1]	$0.6 < EI_e/EI_g < 0.75$
Steel Pile	1.0
Concrete w/ Steel Casing	$\frac{E_s I_s + 0.25 E_c I_c}{(E_s I_s + E_c I_c)}$
Deck	0.5

1. The pile/deck connection and prestressed pile may also be approximated as one member with an average stiffness of 0.42 EI_e/EI_g (Ferritto et al, 1999 [7.2])

N = is the axial load level.
E_s = Young's modulus for steel
I_s = Moment of inertia for steel section
E_c = Young's modulus for concrete
I_c = Moment of inertia for uncracked concrete section

3107F.2.3 Deformation capacity of flexural members. *Stress-strain models for confined and unconfined concrete, mild and prestressed steel presented in Section 3107F.2.4 shall be used to perform the moment-curvature analysis.*

The stress-strain characteristics of steel piles shall be based on the actual steel properties. If as-built information is not available, the stress-strain relationship may be obtained per Section 3107F.2.4.2.

For concrete in-filled steel piles, the stress-strain model for confined concrete shall be in accordance with Section 3107F.2.4.1.

Each structural component expected to undergo inelastic deformation shall be defined by its moment-curvature relation. The displacement demand and capacity shall be calculated per Sections 3104F.2 and 3104F.3, as appropriate.

The moment-rotation relationship for concrete components shall be derived from the moment-curvature analysis per Section 3107F.2.5.4 and shall be used to determine lateral displacement limitations of the design. Connection details shall be examined per Section 3107F.2.7.

3107F.2.4 Stress-Strain models.

3107F.2.4.1 Concrete. *The stress-strain model and terms for confined and unconfined concrete are shown in Figure 31F-7-1.*

3107F.2.4.2 Reinforcement steel and structural steel. *The stress-strain model and terms for reinforcing and structural steel are shown in Figure 31F-7-2.*

3107F.2.4.3 Prestressed steel. *The stress-strain model of Blakeley and Park [7.4] may be used for prestressed steel. The model and terms are illustrated in Figure 31F-7-3.*

3107F.2.4.4 Alternative stress-strain models. *Alternative stress-strain models are acceptable if adequately documented and supported by test results, subject to Division approval.*

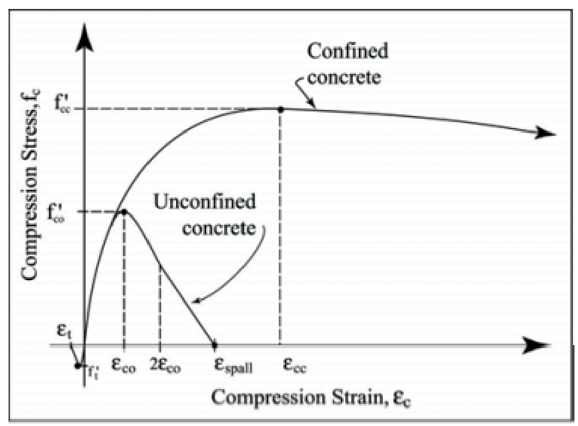


**FIGURE 31F-7-1
STRESS-STRAIN CURVES FOR CONFINED AND UNCONFINED CONCRETE [7.1]**

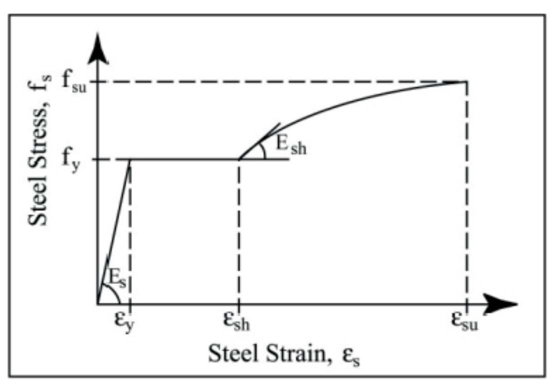


**FIGURE 31F-7-2
STRESS-STRAIN CURVE FOR MILD REINFORCING STEEL OR STRUCTURAL STEEL [7.1]**

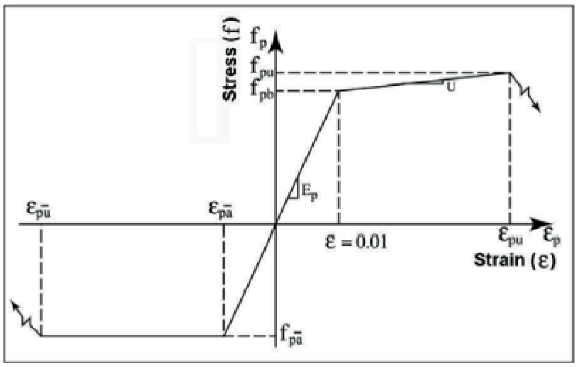


FIGURE 31F-7-3
STRESS-STRAIN CURVE FOR PRESTRESSED STEEL [7.4]

3107F.2.5 Concrete piles.

3107F.2.5.1 General. *The capacity of concrete piles is based on permissible concrete and steel strains corresponding to the desired performance criteria.*

Different values may apply for plastic hinges forming at in-ground and pile-top locations. These procedures are applicable to circular, octagonal, rectangular and square pile cross sections.

3107F.2.5.2 Stability. *Stability considerations are important to pier-type structures. The moment-axial load interaction shall consider effects of high slenderness ratios (kl/r). An additional bending moment due to axial load eccentricity shall be incorporated unless:*

$$e/h \leq 0.10 \quad (7\text{-}4)$$

where:

e = eccentricity of axial load

h = width of pile in considered direction

3107F.2.5.3 Plastic hinge length. *The plastic hinge length is required to convert the moment-curvature relationship into a moment-plastic rotation relationship for the nonlinear pushover analysis.*

The pile's plastic hinge length, L_p (above ground) for reinforced concrete piles, when the plastic hinge forms against a supporting member is:

$$L_p = 0.08L + 0.15 f_{ye} d_b \geq 0.3 f_{ye} d_b \quad (7\text{-}5)$$

where:

L = distance from the critical section of the plastic hinge to the point of contraflexure

d_b = diameter of the longitudinal reinforcement or dowel, whichever is used to develop the connection

f_{ye} = design yield strength of longitudinal reinforcement or dowel, whichever is used to develop the connection (ksi)

If a large reduction in moment capacity occurs due to spalling, then the plastic hinge length shall be:

$$L_p = 0.3 f_{ye} d_b \quad (7\text{-}6)$$

The plastic hinge length, L_p (above ground), for prestressed concrete piles may also be computed from Table 31F-7-4 for permitted pile-to-deck connections as described in ASCE/COPRI 61 [7.5].

When the plastic hinge forms in-ground, the plastic hinge length may be determined using Equation (7-7) [7.5]:

$$L_p = 2D \quad (7\text{-}7)$$

where:

D = pile diameter or least cross-sectional dimension

TABLE 31F-7-4
PLASTIC HINGE LENGTH FOR PRESTRESSED CONCRETE PILES [7.5]

CONNECTION TYPE	L_p AT DECK (in.)
Pile Buildup	$0.15f_{ye}d_b \leq L_p \leq 0.30f_{ye}d_b$
Extended Strand	$0.20f_{pye}d_{st}$
Embedded Pile	0.5D
Dowelled	$0.25f_{ye}d_b$
Hollow Dowelled	$0.20f_{ye}d_b$
External Confinement	$0.30f_{ye}d_b$
Isolated Interface	$0.25f_{ye}d_b$

d_b = diameter of the prestressing strand or dowel, whichever is used to develop the connection (in.)
f_{ye} = design yield strength of prestressing strand or dowel, as appropriate (ksi)
D = pile diameter or least cross-sectional dimension
d_{st} = diameter of the prestressing strand (in.)
f_{pye} = design yield strength of prestressing strand (ksi)

3107F.2.5.4 Plastic rotation. *The plastic rotation is:*

$$\theta_p = L_p \phi_p = L_p (\phi_m - \phi_y) \quad (7\text{-}8)$$

where:

L_p = plastic hinge length

ϕ_p = plastic curvature

ϕ_m = maximum curvature

ϕ_y = yield curvature

The maximum curvature, ϕ_m shall be determined by the concrete or steel strain limit state at the prescribed performance level, whichever comes first.

Alternatively, the maximum curvature, ϕ_m may be calculated as:

$$\phi_m = \frac{\varepsilon_{cm}}{c_u} \quad (7\text{-}9)$$

where:

ε_{cm} = maximum limiting compression strain for the prescribed performance level (Table 31F-7-5)

c_u = neutral-axis depth, at ultimate strength of section

TABLE 31F-7-5
LIMITS OF STRAIN

COMPONENT STRAIN	LEVEL 1	LEVEL 2
MCCS *Pile/deck hinge*	$\varepsilon_c \leq 0.004$	$\varepsilon_c \leq 0.025$
MCCS *In-ground hinge*	$\varepsilon_c \leq 0.004$	$\varepsilon_c \leq 0.008$
MRSTS *Pile/deck hinge*	$\varepsilon_s \leq 0.01$	$\varepsilon_s \leq 0.05$
MRSTS *In-ground hinge*	$\varepsilon_s \leq 0.01$	$\varepsilon_s \leq 0.025$
MPSTS *In-ground hinge*	$\varepsilon_p \leq 0.005$ *(incremental)*	$\varepsilon_p \leq 0.025$ *(total strain)*

MCCS = Maximum Concrete Compression Strain, ε_c
MRSTS = Maximum Reinforcing Steel Tension Strain, ε_s
MPSTS = Maximum Prestressing Steel Tension Strain, ε_p

Either Method A or B may be used for idealization of the moment-curvature curve.

3107F.2.5.4.1 Method A. *For Method A, the yield curvature,* ϕ_y *is the curvature at the intersection of the secant stiffness,* EI_c*, through first yield and the nominal strength, (*$\varepsilon_c = 0.004$*).*

$$\phi_y = \frac{M_y}{EI_c} \qquad (7\text{-}10)$$

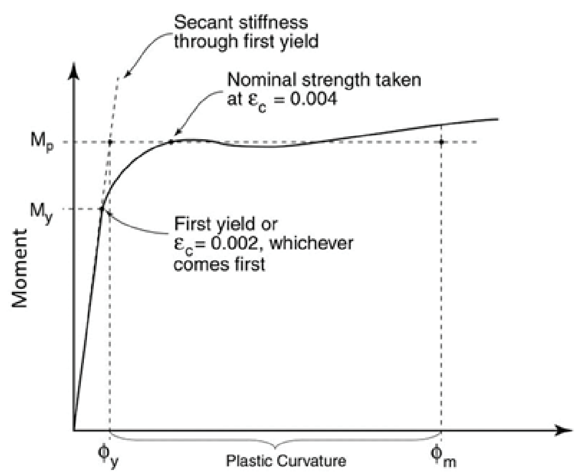


FIGURE 31F-7-4
METHOD A – MOMENT CURVATURE ANALYSIS

3107F.2.5.4.2 Method B. *For Method B, the elastic portion of the idealized moment-curvature curve is the same as in Method A (see Section 3107F.2.5.4.1). However, the idealized plastic moment capacity,* M_p*, and the yield curvature,* ϕ_y*, is obtained by balancing the areas between the actual and the idealized moment-curvature curves beyond the first yield point (see Figure 31F-7-5). Method B applies to moment-curvature curves that do not experience reduction in section moment capacity.*

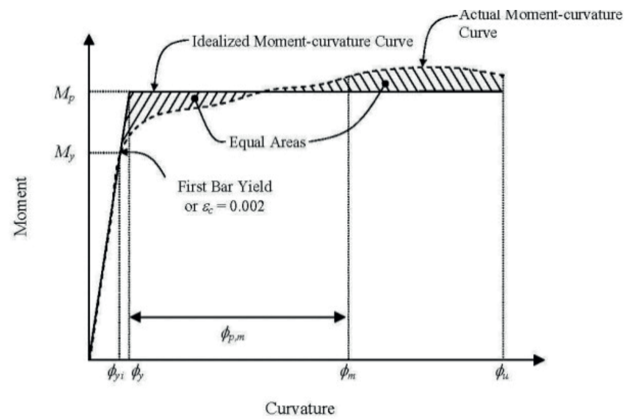


FIGURE 31F-7-5
METHOD B – MOMENT CURVATURE ANALYSIS [7.6]

3107F.2.5.5 Ultimate concrete and steel flexural strains. *Strain values computed in the nonlinear pushover analysis shall be compared to the following limits.*

3107F.2.5.5.1 Unconfined concrete piles: *An unconfined concrete pile is defined as a pile having no confinement steel or one in which the spacing of the confinement steel exceeds 12 inches.*

Ultimate concrete compressive strain:

$$\varepsilon_{cu} = 0.005 \qquad (7\text{-}11)$$

3107F.2.5.5.2 Confined concrete piles: *Ultimate concrete compressive strain [7.1]:*

$$\varepsilon_{cu} = 0.004 + (1.4\rho_s f_{yh} \varepsilon_{sm})/f'_{cc} \geq 0.005 \qquad (7\text{-}12)$$

$$\varepsilon_{cu} \leq 0.025$$

where:

ρ_s = *effective volume ratio of confining steel*

f_{yh} = *yield stress of confining steel*

ε_{sm} = *strain at peak stress of confining reinforcement, 0.15 for grade 40, 0.10 for grade 60*

f'_{cc} = *confined strength of concrete approximated by* $1.5 f'_c$

3107F.2.5.6 Component acceptance/damage criteria. *The maximum allowable concrete strains may not exceed the ultimate values defined in Section 3107F.2.5.5. The limiting values (Table 31F-7-5) apply for each performance level for both existing and new structures. The "Level 1 or 2" refer to the seismic performance criteria (see Section 3104F.2.1).*

For all non-seismic loading combinations, concrete components shall be designed in accordance with the ACI 318 [7.7] requirements.

Note that for existing facilities, the pile/deck hinge may be controlled by the capacity of the dowel reinforcement in accordance with Section 3107F.2.7.

3107F.2.5.7 Shear design. *If expected lower bound of material strength Section 3107F.2.1.1 Equations (7-2a, 7-2b, 7-2c) are used in obtaining the nominal shear strength, a new nonlinear analysis utilizing the upper bound estimate of material strength Section 3107F.2.1.1 Equations (7-3a, 7-3b, 7-3c) shall be used to obtain the plastic hinge shear demand. An alternative conservative approach is to multiply the maximum shear demand,* V_{max} *from the original analysis by 1.4 (Section 8.16.4.4.2 of ATC-32 [7.8]):*

$$V_{design} = 1.4V_{max} \quad (7\text{-}13)$$

If moment curvature analysis that takes into account strain-hardening, an uncertainty factor of 1.25 may be used:

$$V_{design} = 1.25V_{max} \quad (7\text{-}14)$$

Shear capacity shall be based on nominal material strengths, and reduction factors according to ACI 318 [7.7].

As an alternative, the method of Kowalski and Priestley [7.9] may be used. Their method is based on a three-parameter model with separate contributions to shear strength from concrete (V_c)*, transverse reinforcement* (V_s)*, and axial load* (V_p) *to obtain nominal shear strength* (V_n)*:*

$$V_n = V_c + V_s + V_p \quad (7\text{-}15)$$

A shear strength reduction factor of 0.85 shall be applied to the nominal strength, V_n*, to determine the design shear strength. Therefore:*

$$V_{design} \le 0.85V_n \quad (7\text{-}16)$$

The equations to determine V_c*,* V_s *and* V_p *are:*

$$V_c = k\sqrt{f'_c}A_e \quad (7\text{-}17)$$

where:

k = *factor dependent on the curvature ductility* $\mu_\phi = \frac{\phi}{\phi_y}$*, within the plastic hinge region, from Figure 31F-7-6. For regions greater than* $2D_p$ *(see Equation 7-18) from the plastic hinge location, the strength can be based on* $m_f = 1.0$ *(see Ferritto et. al. [7.2]).*

f'_c = *concrete compressive strength*

A_e = $0.8A_g$ *is the effective shear area*

Circular spirals or hoops [7.2]:

$$V_s = \frac{\frac{\pi}{2} A_{sp} f_{yh} (D_p - c - c_o)\cot(\theta)}{s} \quad (7\text{-}18)$$

where:

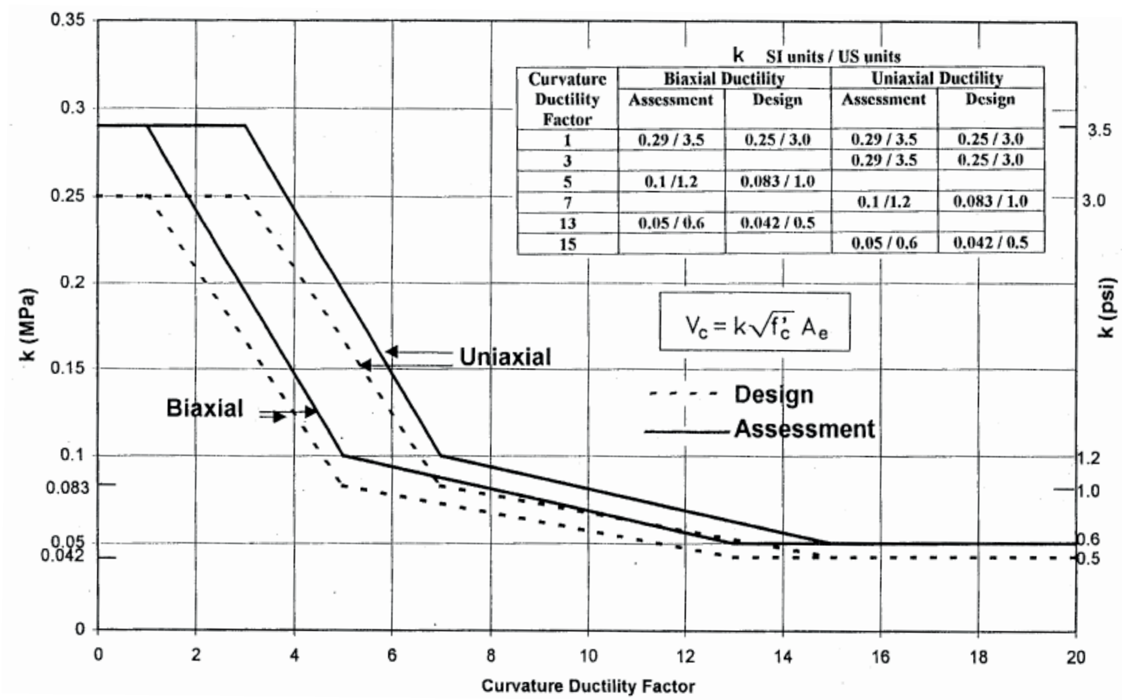
A_{sp} = *spiral or hoop cross section area*

f_{yh} = *yield strength of transverse or hoop reinforcement*

D_p = *pile diameter or gross depth (in case of a rectangular pile with spiral confinement)*

c = *depth from extreme compression fiber to neutral axis (N.A.) at flexural strength (see Figure 31F-7-7)*

c_0 = *distance from concrete cover to center of hoop or spiral (see Figure 31F-7-7)*



Curvature Ductility Factor	Biaxial Ductility Assessment	Biaxial Ductility Design	Uniaxial Ductility Assessment	Uniaxial Ductility Design
1	0.29 / 3.5	0.25 / 3.0	0.29 / 3.5	0.25 / 3.0
3			0.29 / 3.5	0.25 / 3.0
5	0.1 /1.2	0.083 / 1.0		
7			0.1 /1.2	0.083 / 1.0
13	0.05 / 0.6	0.042 / 0.5		
15			0.05 / 0.6	0.042 / 0.5

FIGURE 31F-7-6
CONCRETE SHEAR MECHANISM
(from Fig. 3-30 of [7.2])

θ = angle of critical crack to the pile axis (see Figure 31F-7-7) taken as 30° for existing structures, and 35° for new design

s = spacing of hoops or spiral along the pile axis

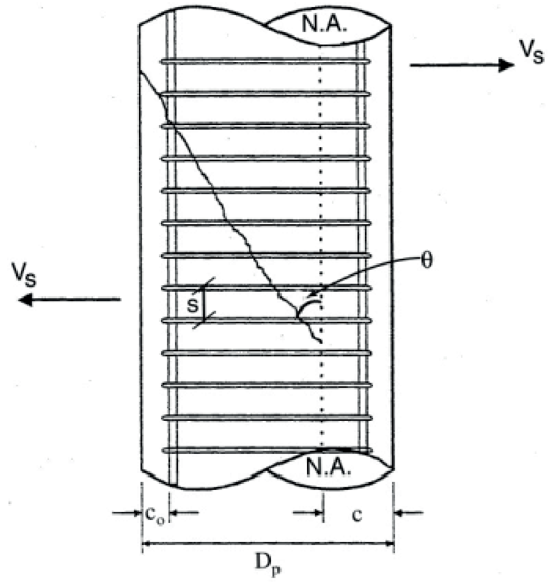


FIGURE 31F-7-7
TRANSVERSE SHEAR MECHANISM

Rectangular hoops or spirals [7.2]:

$$V_s = \frac{A_h f_{yh} (D_p - c - c_o) \cot(\theta)}{s} \qquad (7\text{-}19)$$

where:

A_h = total area of transverse reinforcement, parallel to direction of applied shear cut by an inclined shear crack

Shear strength from axial mechanism, V_p (see Figure 31F-7-8):

$$V_p = \Phi (N_u + F_p) \tan \alpha \qquad (7\text{-}20)$$

where:

N_u = external axial compression on pile including seismic load. Compression is taken as positive; tension as negative

F_p = prestress compressive force in pile

α = angle between line joining centers of flexural compression in the deck/pile and in-ground hinges, and the pile axis

Φ = 1.0 for existing structures, and 0.85 for new design

3107F.2.6 Steel piles.

3107F.2.6.1 General. *The capacity of steel piles is based on allowable strains corresponding to the desired performance criteria and design earthquake.*

3107F.2.6.2 Stability. *Section 3107F.2.5.2 applies to steel piles.*

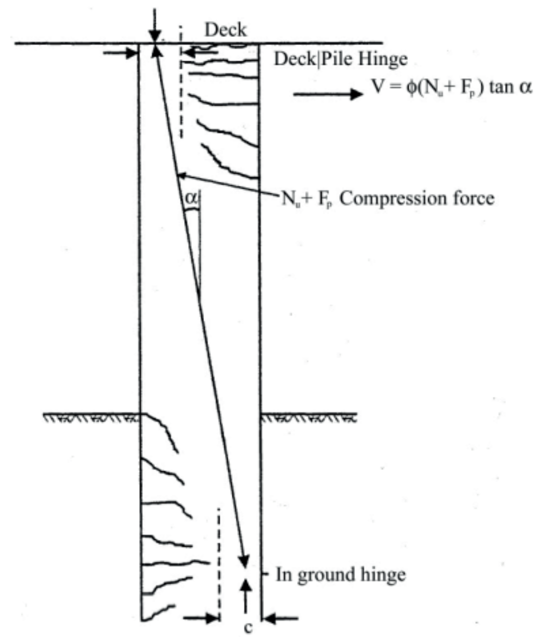


FIGURE 31F-7-8
AXIAL FORCE SHEAR MECHANISM

3107F.2.6.3 Plastic hinge length. *The plastic hinge length, L_p (above ground), for steel piles may be computed from Table 31F-7-6 for pile-to-deck connections.*

When the plastic hinge forms in-ground, the plastic hinge length may be determined using Equation (7-21) [7.5]:

$$L_p = 2D \qquad (7\text{-}21)$$

where:

D = pile diameter

TABLE 31F-7-6
PLASTIC HINGE LENGTH FOR STEEL PILES [7.5]

CONNECTION TYPE	L_p AT DECK (in.)
Embedded Pile	0.5D
Concrete Plug	$0.30 f_{ye} d_b$
Isolated Shell	$0.30 f_{ye} d_b + g$
Welded Embed	0.5D

d_b = diameter of the dowel (in.)
f_{ye} = design yield strength of dowel (ksi)
D = pile diameter (in.)
g = gap distance from bottom of the deck to edge of pipe pile or external confinement (in.)

3107F.2.6.4 Ultimate flexural strain capacity. *The following limiting value applies:*

Strain at extreme-fiber, $\varepsilon_u \leq 0.035$

3107F.2.6.5 Component acceptance/damage criteria. *The maximum allowable strain may not exceed the ultimate value defined in Section 3107F.2.6.4. Table 31F-7-7 provides limiting strain values for each performance level, for both new and existing structures.*

Steel components for noncompact hollow piles ($D_P/t < 0.07 \times E/f_y$) and for all nonseismic loading combinations shall be designed in accordance with AISC 325 [7.10].

TABLE 31F-7-7
STRUCTURAL STEEL STRAIN LIMITS, ε_u

COMPONENTS	LEVEL I	LEVEL 2
Concrete Filled Pipe	0.008	0.030
Hollow Pipe	0.008	0.025

Level 1 or 2 refer to the seismic performance criteria (Section 3104F.2.1)

3107F.2.6.6 Shear design. *The procedures of Section 3107F.2.5.7, which are used to establish V_{design} are applicable to steel piles.*

The shear capacity shall be established from the AISC 325 [7.10]. For concrete filled pipe, Equation (7-15) may be used to determine shear capacity; however, V_{pile} must be substituted for V_s.

$$V_{pile} = (\pi/2)\, t f_{y,\,pile}\, (D_p - c - c_o) \cot\theta \qquad (7\text{-}22)$$

where:

t = *steel pile wall thickness*

$f_{y,pile}$ = *yield strength of steel pile*

c_0 = *distance from outside of steel pipe to center of hoop or spiral*

[All other terms are as listed for Equation (7-18)].

3107F.2.7 Pile/deck connection strength.

3107F.2.7.1 Joint shear capacity. *The joint shear capacity shall be computed in accordance with ACI 318 [7.7]. For existing MOTs, the method [7.1, 7.2] given below may be used:*

1. *Determine the nominal shear stress in the joint region corresponding to the pile plastic moment capacity.*

$$v_j = \frac{0.9 M_o}{\sqrt{2}\, l_{dv}\, D_p^2} \qquad (7\text{-}23)$$

where:

v_j = *Nominal shear stress*

M_o = *Overstrength moment demand of the plastic hinge (the maximum possible moment in the pile) as determined from the procedure of Section 3107F.2.5.7.*

l_{dv} = *Vertical development length, see Figure 31F-7-9*

D_p = *Diameter of pile*

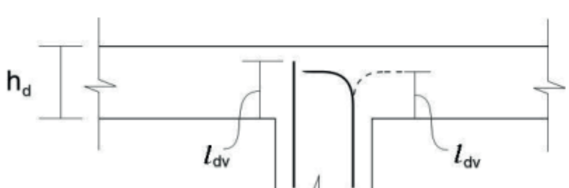


FIGURE 31F-7-9
DEVELOPMENT LENGTH

2. *Determine the nominal principal tension p_t, stress in the joint region:*

$$p_t = \frac{-f_a}{2} + \sqrt{\left(\frac{f_a}{2}\right)^2 + v_j^2} \qquad (7\text{-}24)$$

where:

$$f_a = \frac{N}{(D_p + h_d)^2} \qquad (7\text{-}25)$$

is the average compressive stress at the joint center caused by the pile axial compressive force N and h_d is the deck depth. Note, if the pile is subjected to axial tension under seismic load, the value of N, and f_a will be negative.

If $p_t > 5.0\sqrt{f'_c}$, psi, joint failure will occur at a lower moment than the column plastic moment capacity M_p. In this case, the maximum moment that can be developed at the pile/deck interface will be limited by the joint principal tension stress capacity, which will continue to degrade as the joint rotation increases, as shown in Figure 31F-7-10. The moment capacity of the connection at which joint failure initiates can be established from Equations (7-27) and (7-28).

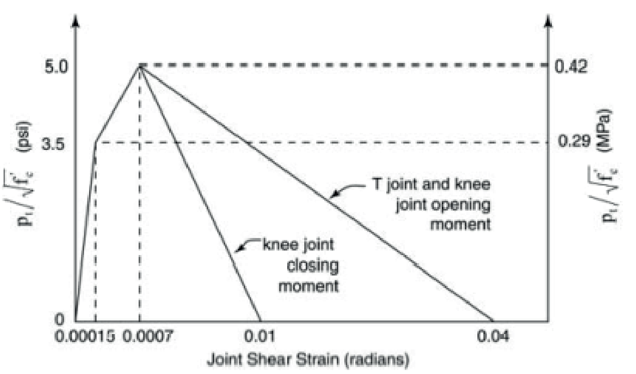


FIGURE 31F-7-10
DEGRADATION OF EFFECTIVE PRINCIPAL TENSION STRENGTH WITH JOINT SHEAR STRAIN (rotation) [7.1, pg. 564]

For $p_t = 5.0\sqrt{f'_c}$, determine the corresponding joint shear stress, v_j:

$$v_j = \sqrt{p_t(p_t - f_a)} \qquad (7\text{-}26)$$

3. *The moment capacity of the connection can be approximated as:*

$$M_c = \left(\frac{1}{0.9}\right)\sqrt{2}\, v_j l_{dv} D_p^2 \le M_o \qquad (7\text{-}27)$$

This will result in a reduced strength and effective stiffness for the pile in a pushover analysis. The maximum displacement capacity of the pile should be based on a drift angle of 0.04 radians.

If no mechanisms are available to provide residual strength, the moment capacity will decrease to zero as the joint shear strain *increases to 0.04 radians, as shown in Figure 31F-7-11.*

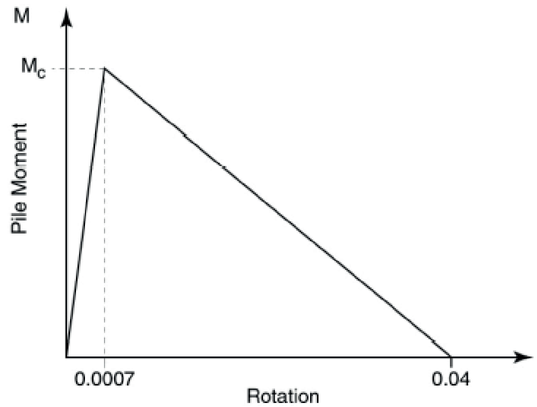


FIGURE 31F-7-11
REDUCED PILE MOMENT CAPACITY

If deck stirrups are present within $h_d/2$ of the face of the pile, the moment capacity, $M_{c,r}$, at the maximum plastic rotation of 0.04 radians may be increased from zero to the following (see Figure 31F-7-12):

$$M_{c,r} = 2A_s f_y(h_d - d_c) + N\left(\frac{D_p}{2} - d_c\right) \qquad (7\text{-}28)$$

where:

A_s = *Area of slab stirrups on one side of joint*

h_d = *See Figure 31F-7-9 (deck thickness)*

d_c = *Depth from edge of concrete to center of main reinforcement*

In addition, the bottom deck steel ($A_{s,\ deckbottom}$) area within $h_d/2$ of the face of the pile shall satisfy:

$$A_{s,\ deckbottom} \geq 0.5 \cdot A_s \qquad (7\text{-}29)$$

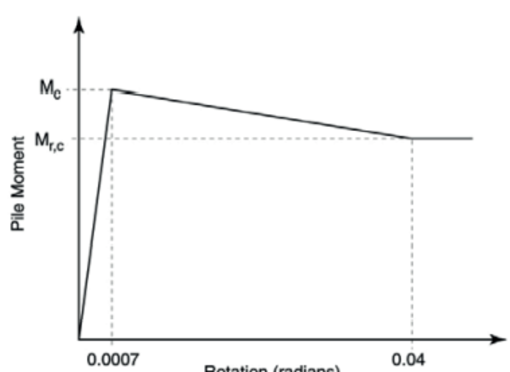


FIGURE 31F-7-12
JOINT ROTATION

4. *Using the same initial stiffness as in Section 3107F.2.5.4, the moment-curvature relationship established for the pile top can now be adjusted to account for the joint degradation.*

The adjusted yield curvature, ϕ'_y, can be found from:

$$\phi'_y = \frac{\phi_y M_c}{M_p} \qquad (7\text{-}30)$$

where:

M_p = *Idealized plastic moment capacity from Method A or B (see Figure 31F-7-4 or 31F-7-5, respectively)*

The plastic curvature, ϕ_p, corresponding to a joint rotation of 0.04 can be calculated as:

$$\phi_p = \frac{0.04}{L_p} \qquad (7\text{-}31)$$

where:

L_p = *Plastic hinge length as determined from Equation (7-5)*

The adjusted ultimate curvature, ϕ'_u, can now be calculated as:

$$\phi'_u = \phi_p + \frac{\phi_y M_{c,r}}{M_p} \qquad (7\text{-}32)$$

where:

M_p = *Idealized plastic moment capacity from Method A or B (see Figure 31F-7-4 or 31F-7-5, respectively)*

$M_{c,r}$ = *0, unless deck stirrups are present as discussed above.*

Examples of adjusted moment curvature relationships are shown in Figure 31F-7-13.

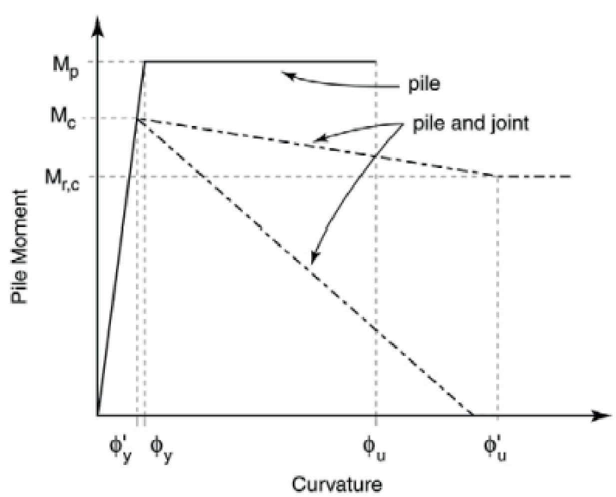


FIGURE 31F-7-13
EQUIVALENT PILE CURVATURE

3107F.2.7.2 Development length. *The minimum development length, l_{dc}, is:*

$$l_{dc} \geq \frac{0.025 \cdot d_b \cdot f_{ye}}{\sqrt{f'_c}} \qquad (7\text{-}33)$$

where:

d_b = *dowel bar diameter*

f_{ye} = *expected yield strength of dowel*

f'_c = *compressive strength of concrete*

In assessing existing details, actual or estimated values for f_{ye} and f'_c rather than nominal strength should be used in accordance with Section 3107F.2.1.1.

When the development length is less than that calculated by the Equation (7-33), the moment capacity shall be calculated using a proportionately reduced yield strength, $f_{ye,r}$, for the vertical pile reinforcement:

$$f_{ye,r} = f_{ye} \cdot \frac{l_d}{l_{dc}} \qquad (7\text{-}34)$$

where:

l_d = *actual development length*

f_{ye} = *expected yield strength of dowel*

3107F.2.8 Batter piles.

3107F.2.8.1 Existing ordinary batter piles. *Wharves or piers with ordinary (not fused, plugged or having a seismic release mechanism) batter piles typically have a very stiff response when subjected to lateral loads in the direction of the batter. The structure often maintains most of its initial stiffness all the way to failure of the first row of batter piles. Since batter piles most likely will fail under a Level 2 seismic event, the following method may be used to evaluate the post-failure behavior of the wharf or pier:*

1. *Identify the failure mechanism of the batter pile-deck connection (refer to Section 3104F.4.7) for typical failure scenarios) and the corresponding lateral displacement.*
2. *Release the lateral load between the batter pile and the deck when the lateral failure displacement is reached.*
3. *Push on the structure until subsequent failure(s) have been identified.*

As an example, following these steps will result in a force-displacement (pushover) curve similar to the one shown in Figure 31F-7-14 for a wharf supported by one row of batter piles.

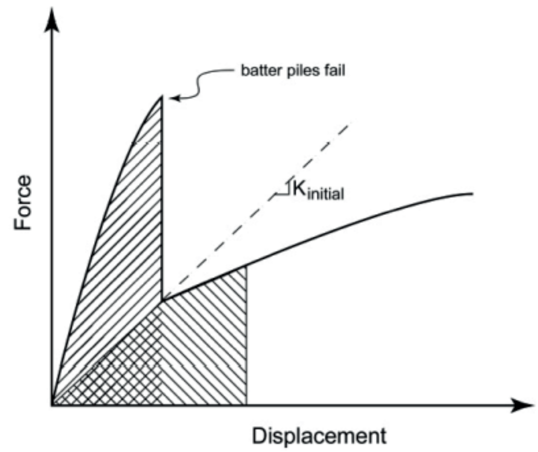


FIGURE 31F-7-14
PUSHOVER CURVE FOR ORDINARY BATTER PILES

When the row of batter piles fail in tension or shear, stored energy will be released. The structure will therefore experience a lateral displacement demand following the nonductile pile failures. If the structure can respond to this displacement demand without exceeding other structural limitations, it may be assumed that the structure is stable and will start to respond to further shaking with a much longer period and corresponding lower seismic demands. The wharf structure may therefore be able to sustain larger seismic demands following the loss of the batter piles than before the loss of pile capacity, because of a much softer seismic response.

The area under the pushover curve before the batter pile failures is compared to the equivalent area under the post failure pushover curve (refer to Figure 31F-7-14). If no other structural limitations are reached with the new displacement demand, it is assumed that the structure is capable of absorbing the energy. It should be noted that even though the shear failure is nonductile, it is expected that energy will be absorbed and the damping will increase during the damage of the piles. The above method is, therefore, considered conservative.

Following the shear failure of a batter pile row, the period of the structure increases such that equal displacement can be assumed when estimating the post-failure displacement demand. The new period may be estimated from the initial stiffness of the post-failure system as shown in Figure 31F-7-14. A new displacement demand can then be calculated in accordance with Section 3104F.2.

3107F.2.8.2 ***Nonordinary batter piles.*** *For the case of a plugged batter pile system, an appropriate displacement force relationship considering plug friction may be used in modeling the structural system.*

For fused and seismic release mechanism batter pile systems, a nonlinear modeling procedure shall be used and peer reviewed (Section 3101F.8.2).

3107F.2.9 Concrete pile caps with concrete deck. *Pile caps and decks are capacity protected components. Use the procedure of Section 3107F.2.5.7 to establish the over strength demand of the plastic hinges. Component capacity shall be based on nominal material strengths, and reduction factors according to ACI 318 [7.7].*

3107F.2.9.1 Component acceptance/damage criteria. *For new pile caps and deck, Level 1 seismic performance shall utilize the design methods in ACI 318 [7.7]; Level 2 seismic performance shall be limited to the following strains:*

Deck/pile cap:	$\varepsilon_c \leq 0.005$
Reinforcing steel tension strain:	$\varepsilon_S \leq 0.01$

For existing pile caps and deck, the limiting strain values are defined in Table 31F-7-5.

Concrete components for all nonseismic loading combinations shall be designed in accordance with ACI 318 [7.7].

3107F.2.9.2 Shear capacity (strength). *Shear capacity shall be based on nominal material strengths; reduction factors shall be in accordance with ACI 318 [7.7].*

3107F.2.10 Concrete detailing. *For new MOTs, the required development splice length, cover and detailing shall conform to ACI 318 [7.7], with the following exceptions:*

1. *For pile/deck dowels, the development length may be calculated in accordance with Section 3107F.2.7.2.*
2. *The minimum concrete cover for prestressed concrete piles shall be three inches, unless corrosion inhibitors are used, in which case a cover of two-and-one-half inches is acceptable.*
3. *The minimum concrete cover for wharf beams and slabs, and all concrete placed against soil shall be three inches, except for headed reinforcing bars (pile dowels or shear stirrups) the cover may be reduced to two-and-one-half inch cover at the top surface only. If corrosion inhibitors are used, a cover of two-and-one-half inches is acceptable.*

3107F.3 Timber piles and deck components.

3107F.3.1 Component strength. *The following parameters shall be established in order to assess component strength:*

New and existing components:

1. *Modulus of rupture*
2. *Modulus of elasticity*
3. *Type and grade of timber*

Existing components only:

1. *Original cross-section shape and physical dimensions*
2. *Location and dimension of braced frames*
3. *Current physical condition of members including visible deformation*
4. *Degradation may include environmental effects (e.g., decay, splitting, fire damage, biological and chemical attack) including its effect on the moment of inertia, I*
5. *Loading and displacement effects (e.g., overload, damage from earthquakes, crushing and twisting)*

Section 3104F.2.2 discusses existing material properties. At a minimum, the type and grade of wood shall be established. The adjusted reference design values per Section 6 of ANSI/AWC NDS [7.11] may be used.

For deck components, the adjusted design stresses shall be limited to the values of ANSI/AWC NDS [7.11]. Piling deformation limits shall be calculated based on the strain limits in accordance with Section 3107F.3.3.3.

The values shown in the ANSI/AWC NDS [7.11] are not developed specifically for MOTs and can be used as default properties only if as-built information is not available, the member is not damaged and testing is not performed. To account for the inherent uncertainty in establishing component capacities for existing structures with limited knowledge about the actual material properties, a reduction (knowledge) factor of k = 0.75 shall be included in the component strength and deformation capacity analyses in accordance with Section 3107F.2.1.2.

The modulus of elasticity shall be based on tests or Section 4 for deck components and Section 6 for timber piles of ANSI/AWC NDS [7.11].

3107F.3.2 Deformation capacity of flexural members. *The displacement demand and capacity of existing timber structures may be established per Section 3104F.2.*

The soil spring requirements for the lateral pile analysis shall be in accordance with Section 3106F.

A linear curvature distribution may be assumed along the full length of a timber pile.

The displacement capacity of a timber pile can then be established per Section 3107F.3.3.2.

3107F.3.3 Timber piles.

3107F.3.3.1 Stability. *Section 3107F.2.5.2 shall apply to timber piles.*

3107F.3.3.2 Displacement capacity. *A distinction shall be made between a pier-type pile, with a long unsupported length and a wharf-landside-type pile with a short unsupported length between the deck and soil. The effective length, L, is the distance between the pinned deck/pile connection and in-ground fixity as shown in Figure 31F-7-15. For pier-type (long unsupported length) vertical piles, three simplified proce-*

dures to determine fixity or displacement capacity are described in UFC 4-151-10 [7.12], UFC 3-220-01 [7.13] and Chai [7.14].

In order to determine fixity in soft soils, another alternative is to use Table 31F-7-8.

The displacement capacity, Δ, for a pile pinned at the top, with effective length, L, (see Table 31F-7-8 and UFC 4-151-10 [7.12]), and moment, M, is:

$$\Delta = \frac{ML^2}{3EI} \quad (7\text{-}35)$$

where:

E = *Modulus of elasticity*

I = *Moment of inertia*

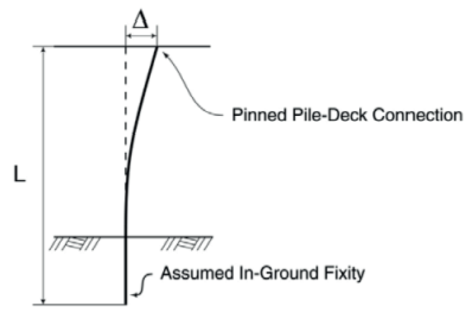


FIGURE 31F-7-15
ASSUMED IN-GROUND FIXITY

TABLE 31F-7-8
DISTANCE BELOW GROUND TO POINT OF FIXITY

PILE EI_g	SOFT CLAYS	LOOSE GRANULAR & MEDIUM CLAYS
< 10^{10} lb in^2	10 feet	8 feet
> 10^{10} lb in^2	12 feet	10 feet

Assuming linear curvature distribution along the pile, the allowable curvature, ϕ_a, can be established from:

$$\phi_a = \frac{\varepsilon_a}{c} \quad (7\text{-}36)$$

where:

ε_a = *allowable strain limit according to Section 3107F.3.3.3*

c = *distance to neutral axis which can be taken as $D_p/2$, where D_p is the diameter of the pile*

The curvature is defined as:

$$\phi = \frac{M}{EI} \quad (7\text{-}37)$$

The maximum allowable moment therefore becomes:

$$M = \frac{2\varepsilon_a}{D_p}EI \quad (7\text{-}38)$$

The displacement capacity is therefore given by:

$$\Delta = \frac{2\varepsilon_a L^2}{3D_p} \quad (7\text{-}39)$$

3107F.3.3.3 Component acceptance/damage criteria. *The following limiting strain values apply for each seismic performance level for existing structures:*

TABLE 31F-7-9
LIMITING STRAIN VALUES FOR TIMBER

EARTHQUAKE LEVEL	MAX. TIMBER STRAIN
Level 1	0.002
Level 2	0.004

For new and alternatively, for existing structures ANSI/AWC NDS [7.11] may be used.

Timber components for all non-seismic loading combinations shall be designed in accordance with ANSI/AWC NDS [7.11].

3107F.3.3.4 Shear design. *To account for material strength uncertainties, the maximum shear demand, V_{max}, established from the single pile lateral analysis shall be multiplied by 1.2:*

$$V_{demand} = 1.2V_{max} \quad (7\text{-}40)$$

The factored maximum shear stress demand τ_{max}, in a circular pile can then be determined:

$$\tau_{max} = \frac{10}{9}\frac{V_{demand}}{\pi \cdot r^2} \quad (7\text{-}41)$$

where:

r = *radius of pile*

For the seismic load combinations, the maximum allowable shear stress, $\tau_{capacity}$, is the design shear strength, τ_{design}, from the ANSI/AWC NDS [7.11] multiplied by a factor of 2.8.

$$\tau_{capacity} = 2.8\tau_{design} \quad (7\text{-}42)$$

The shear capacity must be greater than the maximum demand.

3107F.4 Retaining structures. *Retaining structures constructed of steel or concrete shall conform to AISC 325 [7.10] or ACI 318 [7.7], respectively. For the determination of static and seismic loads on the sheet pile and sheet pile behavior, the following references are acceptable: Ebeling and Morrison [7.15], Strom and Ebeling [7.16], and PIANC TC-7 (Technical Commentary - 7) [7.17]. The applied loads and analysis methodology shall be determined by a California registered geotechnical engineer, and may be subject to peer review.*

3107F.5 Nonbuilding structures and building structures. *The analysis of nonbuilding structures and building structures shall be based on the load combinations defined in Section 3103F.8 with seismic assessment per Section 3104F.5. The component strength in nonbuilding structures and building structures shall be established in accordance with AISC [7.10], ACI-318 [7.7], and ANSI/AWC NDS [7.11], accounting for existing condition with knowledge factors applied, as appropriate. For strength evaluation of supports and attachments, see Section 3107F.7.*

3107F.6 Mooring and berthing components. *Mooring components include bitts, bollards, cleats, pelican hooks, capstans, mooring dolphins and quick release hooks. The maximum mooring line forces (demand) shall be established per Section 3105F. Applicable safety factors to be applied to the demand are provided in Section 3105F.8. Multiple lines may be attached to the mooring component at varying horizontal and vertical angles. Mooring components shall therefore be checked for all mooring analysis load cases.*

Berthing components include fender piles and fenders, which may be camels, fender panels or wales. The maximum berthing forces (demand) on breasting dolphins and fender piles shall be established according to Section 3105F.

Mooring and berthing components analyses shall be based on the load combinations defined in Section 3103F.8 with seismic assessment per Section 3104F.5. The component strength shall account for existing condition with knowledge factors applied, as appropriate. For strength evaluation of supports and attachments, see Section 3107F.7.

Mooring and berthing component capacities may be governed by the strength of the deck, structure and/or soil. Therefore, a check of the deck, structural and geotechnical capacities to withstand component loads shall be performed, as appropriate.

3107F.7 Supports and attachments (or anchorage). *The evaluation of supports and attachments for nonstructural components, nonbuilding structures and building structures shall be based on the load combinations defined in Section 3103F.8 with seismic assessment per Section 3104F.5. The strength of supports and attachments for nonstructural components, nonbuilding structures and building structures shall be assessed in accordance with AISC [7.10], ACI-318 [7.7], and ANSI/AWC NDS [7.11], accounting for existing condition with knowledge factors applied, as appropriate. The following parameters shall be established to calculate strength:*

New and existing components:

1. *Yield and tensile strength of structural steel*
2. *Structural steel modulus of elasticity*
3. *Yield and tensile strength of bolts*
4. *Concrete infill compressive strength*
5. *Concrete infill modulus of elasticity*

Additional parameters for existing components:

1. *Condition of steel including corrosion*
2. *Effective cross-sectional areas*
3. *Condition of embedment material such as concrete slab or timber deck*

The analysis and design shall include the load transfer to supporting deck/pile structures or foundation elements. A check of the deck capacity to withstand support and attachment loads shall be performed for all nonstructural components, nonbuilding structures and building structures.

3107F.8 Symbols.

A_e = *Effective shear area*

A_g = *Uncracked, gross section area*

A_h = *Total area of transverse reinforcement, parallel to direction of applied shear cut by an inclined shear crack*

A_s = *Area of slab stirrups on one side of joint*

$A_{s,\,deckbottom}$ = *Area of bottom deck steel*

A_{sp} = *Spiral or hoop cross section area*

c = *Depth from extreme compression fiber to neutral axis at flexural strength*

c_0 = *Distance from outside of steel pipe to center of hoop or spiral, or distance from concrete cover to center of hoop or spiral*

c_u = *Neutral axis depth at ultimate strength of section*

d_b = *Diameter of the longitudinal reinforcement, prestressing strand or dowel, as appropriate*

d_c = *Depth from edge of concrete to center of main reinforcement*

d_{st} = *Diameter of the prestressing strand (in)*

D = *Pile diameter or least cross-sectional dimension*

D_p = *Pile diameter or gross depth (in case of a rectangular pile with spiral confinement)*

e = *Eccentricity of axial load*

ε_a = *Allowable strain limit*

ε_c = *Concrete compressive strain*

ε_{cm} = *Maximum extreme fiber compression strain*

ε_{cu} = *Ultimate concrete compressive strain*

ε_p = *Prestressing steel tension strain*

ε_s = *Reinforcing steel tension strain*

ε_{sm} = *Strain at peak stress of confining reinforcement*

ε_u = *Ultimate steel strain*

E = *Modulus of elasticity*

E_c = *Modulus of elasticity for concrete*

E_s = *Modulus of elasticity for steel*

f'_c = *Concrete compression strength*

f'_{cc} = *Confined strength of concrete*

F_p = *Prestress compression force in pile*

f_p = *Yield strength of prestressing strand*

f_{pye} = *Design yield strength of prestressing strand (ksi)*

f_y = *Yield strength of steel*

f_{ye} = *Design yield strength of longitudinal reinforcement, prestressing strand or dowel, as appropriate (ksi)*

f_{yh} = *Yield stress of confining steel*

f_{yh} = *Yield strength of transverse or hoop reinforcement*

$f_{y,pile}$ = *Yield strength of steel pile*

$f_{ye,r}$ = *Reduced dowel yield strength*

g = *Gap distance from bottom of the deck to edge of pipe pile or external confinement (in.)*

h = *Width of pile in considered direction*

h_d = *Deck depth*

I = *Moment of inertia*

I_c = *Moment of inertia of uncracked section*

I_e = *Effective moment of inertia*

I_g = *Gross moment of inertia*

I_s = *Moment of inertia for steel section*

k = *Factor dependent on the curvature ductility* $\mu_\phi = \phi/\phi_y$*, within the plastic hinge region*

k = *Knowledge factor*

L = *Distance from the critical section of the plastic hinge to the point of contraflexure (Section 3107F.2.5.3), or effective length (Section 3107F.3.3.2)*

L_p = *Plastic hinge length*

l_{dc} = *Minimum development length*

l_d = *Actual development length*

l_{dv} = *Vertical development length*

M = *Maximum allowable moment*

M_c = *Moment capacity of the connection*

$M_{c,r}$ = *Moment capacity at maximum plastic rotation*

M_o = *Overstrength moment demand of the plastic hinge (Section 3107F.2.7)*

M_p = *Idealized plastic moment capacity from Method A or B (Section 3107F.2.5)*

M_y = *Moment at first yield*

N = *Pile axial compressive force*

N_u = *External axial compression on pile including seismic load*

ρ_s = *Effective volume ratio of confining steel*

p_t = *Nominal principal tension*

r = *Radius of circular pile*

s = *Spacing of hoops or spiral along the pile axis*

t = *Steel pile wall thickness*

Δ = *Displacement capacity*

θ = *Angle of critical crack to the pile axis*

θ_p = *Plastic rotation*

α = *Angle between line joining centers of flexural compression in the deck/pile and in-ground hinges, and the pile axis*

ϕ_a = *Allowable curvature*

ϕ_m = *Maximum curvature*

$\phi_p, \phi_{p,m}$ = *Plastic curvature*

ϕ_u = *Ultimate curvature*

ϕ'_u = *Adjusted ultimate curvature*

ϕ_y = *Yield curvature*

ϕ'_y = *Adjusted yield curvature*

$\tau_{capacity}$ = *Maximum allowable shear stress*

τ_{design} = *Design shear strength*

τ_{max} = *Maximum shear stress*

V_c = *Concrete shear strength*

v_j = *Nominal joint shear stress*

V_{design} = *Design shear strength*

V_{max} = *Maximum shear demand*

V_n = *Nominal shear strength*

V_p = *Contribution to shear strength from axial loads*

V_s = *Transverse reinforcement shear strength*

V_{pile} = *Shear strength of steel pile*

3107F.9 References.

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Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 8

SECTION 3108F FIRE PREVENTION, DETECTION AND SUPPRESSION

3108F.1 General. *This section provides minimum standards for fire prevention, detection and suppression at MOTs. See Section 3101F.3 for definitions of "new" (N) and "existing" (E).*

3108F.2 Hazard assessment and risk analysis.

3108F.2.1 Fire hazard assessment and risk analysis (N/E). *A fire hazard assessment and risk analysis shall be performed, considering the loss of commercial power, earthquake and other relevant events.*

3108F.2.2 Fire Protection Assessment (N/E). *A site-specific Fire Protection Assessment shall be prepared by a registered engineer or a competent fire protection professional. The assessment shall consider the hazards and risks identified per Section 3108F.2.1 and shall include, but not be limited to, the elements of pre-fire planning as discussed in Section 9 of API RP 2001 [8.1] and Chapter 19 of ISGOTT [8.2]. MOT operational and training requirements, as related to fire protection, shall be considered (see 2 CCR 2385 [8.3]). The Fire Protection Assessment shall include goals, resources, organization, strategy and tactics, including the following:*

1. *MOT characteristics (e.g., tanker/manifold, product pipelines, etc.)*
2. *Product types and fire scenarios, including products not regulated by the Division that may impact development of fire scenarios*
3. *Possible collateral fire damage to adjacent facilities*
4. *Firefighting capabilities, including availability of water (flow rates and pressure), foam type and associated shelf life, proportioning equipment, and vehicular access*
5. *The selection of appropriate extinguishing agents*
6. *Calculation of water and foam capacities, as applicable, consistent with area coverage requirements*
7. *Coordination of emergency efforts*
8. *Emergency escape routes*
9. *Requirements for fire drills, training of personnel, and the use of equipment*
10. *Life safety*
11. *Rescue for terminal and vessel personnel*
12. *Cooling water for pipelines and valves exposed to the heat*
13. *Contingency planning when supplemental fire support is not available. Mutual aid agreements can apply to water and land based support.*
14. *Consideration of adverse conditions, such as electrical power failure, steam failure, fire pump failure, an earthquake or other damage to the fire water system.*

The audit team shall review and field verify the firefighting equipment locations and condition to ensure operability.

3108F.2.3 Cargo liquid volatility ratings and fire hazard classifications (N/E). *The cargo liquid volatility ratings are defined in Table 31F-8-1, as either High (H_C) or Low (L_C), depending on the flash point.*

Fire hazard classifications (Low, Medium or High) are defined in Table 31F-8-2, and are based on the cargo liquid volatility ratings and the sum of all stored and flowing volumes (V_T), prior to the emergency shutdown (ESD) system stopping the flow of oil.

The stored (V_S) volume is the sum of the H_C and L_C volumes (V_{SH} and V_{SL}, respectively).

During a leak, a quantity of oil is assumed to spill at the maximum cargo flow rate until the ESD is fully effective. The ESD valve closure time shall conform with 2 CCR 2380 [8.3]. The flowing volume (V_F), calculated in Equation (1-1), is the sum of the H_C and L_C liquid volumes (V_{FH} and V_{FL}, respectively).

3108F.3 Fire prevention.

3108F.3.1 Ignition source control.

3108F.3.1.1 *Protection from ignition by static electricity, lightning or stray currents shall be in accordance with API RP 2003 [8.4](N/E).*

3108F.3.1.2 *Requirements to prevent electrical arcing shall be in conformity with 2 CCR 2341 [8.3] (N/E).*

3108F.3.1.3 *Multi-berth terminal piers shall be constructed so as to provide a minimum of 100 ft between adjacent manifolds (N).*

3108F.3.2 Emergency shutdown (ESD) systems. *Emergency shutdown systems are essential to oil spill and fire prevention. These systems may include, but are not limited to, ESD valves, shore isolation valves (SIVs), automatic pump shutdown, controls, actuators and alarms. The ESD systems shall conform to 2 CCR 2380 [8.3] and 33 CFR 154.550 [8.5], and provide:*

1. *Remote actuation stations strategically located, so that ESD valve(s) may be shut within required times (N).*
2. *Multiple actuation stations installed at strategic locations, so that one such station is located more than 100 ft from areas classified as Class I, Group D, Division 1 or 2 per the California Electrical Code [8.6]. Actuation stations shall be wired in parallel to achieve redundancy and arranged so that fire damage to one station will not disable the ESD system (N).*
3. *Communications or control circuits to synchronize simultaneous closure of the shore isolation valves (SIVs) with the shutdown of loading pumps (N).*

TABLE 31F-8-1
CARGO LIQUID VOLATILITY RATINGS

VOLATILITY RATING	CRITERION	REFERENCE	EXAMPLES
Low (L_C)	Flash Point[1] ≥ 140°F	ISGOTT (Chapter 1), [8.2] —Nonvolatile	#6 Heavy Fuel Oil, residuals, bunker
High (H_C)	Flash Point[1] < 140°F	ISGOTT (Chapter 1), [8.2] —Volatile	Gasoline, JP4, crude oils

1. Flash Point is defined per ISGOTT [8.2].

TABLE 31F-8-2
FIRE HAZARD CLASSIFICATIONS

FIRE HAZARD CLASSIFICATION	STORED VOLUME (bbls)			FLOWING VOLUME (bbls)		CRITERIA (bbls)*
	Stripped	V_{SL}	V_{SH}	V_{FL}	V_{FH}	
LOW	y	n	n	y	y	$V_{FL} \geq V_{FH}$, and $V_T \leq 1200$
LOW	n	y	n	y	n	$V_{SL} + V_{FL} \leq 1200$
MEDIUM	n	n	y	n	y	$V_{SH} + V_{FH} \leq 1200$
MEDIUM	y	n	n	y	y	$V_{FH} > V_{FL}$, and $V_T \leq 1200$
HIGH	y	n	n	y	y	$V_T > 1200$
HIGH	n	y	y	y	y	$V_T > 1200$
HIGH	n	y	n	y	n	$V_{SL} + V_{FL} > 1200$
HIGH	n	n	y	n	y	$V_{SH} + V_{FH} > 1200$

y = yes
n = no
Stripped = product purged from pipeline following product transfer event.
V_{SL} = stored volume of low volatility product
V_{SH} = stored volume of high volatility product
V_{FL} = volume of low volatility product flowing through transfer line during ESD.
V_{FH} = volume of high volatility product flowing through transfer line during ESD.
$V_T = V_{SL} + V_{SH} + V_{FL} + V_{FH}$ = Total Volume (stored and flowing)
* Quantities are based on maximum flow rate, including simultaneous transfers.

4. A manual reset to restore the ESD system to an operational state after each initiation (N).
5. An alarm to indicate failure of the primary power source (N).
6. A secondary (emergency) power source (N).
7. Periodic testing of the system (N/E).
8. Fire proofing of motors and control-cables that are installed in areas classified as Class I, Group D, Division 1 or 2 per the California Electrical Code [8.6]. Fire proofing shall, at a minimum, comply with the recommendations in Section 6 of API RP 2218 [8.7] (N).

3108F.3.2.1 Emergency shutdown (ESD) valves. ESD valves shall conform to the requirements in Section 3109F.5, as applicable, and the following:

1. Be located near the dock manifold connection or loading arm (N/E).
2. Have "Local" and "Remote" actuation capabilities (N).

3108F.3.2.2 Shore isolation valves (SIVs). Shore isolation valve(s) shall conform to the requirements in Section 3109F.5, as applicable, and the following:

1. Be located onshore for each cargo pipeline. All SIVs shall be clustered together, for easy access (N).
2. Be clearly identified together with associated pipeline (N/E).
3. Have adequate lighting (N/E).
4. Be provided with communications or control circuits to synchronize simultaneous closure of the ESD system with the shutdown of loading pumps (N).
5. Have a manual reset to restore the SIV system to an operational state after each shut down event (N).
6. Be provided with thermal expansion relief to accommodate expansion of the liquid when closed. Thermal relief piping shall be properly sized and routed around the SIV, into the downstream segment of the pipeline or into other containment (N/E).
7. SIVs installed in pipelines carrying H_C liquids, or at a MOT with a spill classification "Medium" or "High" (see Table 31F-1-1), shall be equipped with "Local" and "Remote" actuation capabilities. Local control SIVs may be motorized and/or operated manually (N).

3108F.4 Automated fire detection system. An MOT shall have a permanently installed automated fire detection or sensing system (N).

Fire detection systems shall be tested and maintained per the manufacturer or the local enforcing agency requirements.

Specifications shall be retained. The latest testing and maintenance records shall be readily accessible to the Division (N/E).

3108F.5 Fire alarms. *Automatic and manual fire alarms shall be provided at strategic locations. The fire alarm system shall be arranged to provide a visual and audible alarm that can be readily discerned by all personnel at the MOT and vessel personnel involved in the transfer operations. Additionally, visual and audible alarms shall be displayed at the MOT's control center (N/E).*

If the fire alarm system is integrated with the ESD system, the operation shall be coordinated with the closure of SIVs, block valves and pumps to avoid adverse hydraulic conditions (N/E).

Fire alarms shall be tested and maintained in accordance with NFPA 72 [8.8] or the local enforcing agency requirements. Specifications shall be retained. The latest testing and maintenance records shall be readily accessible to the Division (N/E).

3108F.6 Fire suppression. *Table 31F-8-3 gives the minimum provisions for fire-water flow rates and fire extinguishers. The table includes consideration of the fire hazard classification (Low, Medium or High), the cargo liquid volatility rating (Low or High) and the vessel or barge size. The minimum provisions may have to be augmented for multi-berth terminals or those conducting simultaneous transfers, in accordance with the risks identified in the Fire Protection Assessment. For fire water and foam piping and fittings, see Section 3109F.7.*

3108F.6.1 Coverage (N/E). *The fire suppression system shall provide coverage for:*

1. *Marine structures including the pier/wharf and approach trestle*
2. *Terminal cargo manifold*
3. *Cargo transfer system including loading arms, hoses and hose racks*
4. *Vessel manifold*
5. *Sumps*
6. *Pipelines*
7. *Control stations*

3108F.6.2 Fire hydrants. *Hydrants shall be located not greater than 150 ft apart, along the wharf and not more than 300 ft apart on the approach trestle [8.2] (N).*

Additional hose connections shall be provided at the base of fixed monitors and upstream of the water and foam isolation valves. Connections shall be accessible to fire trucks or mutual aid equipment as identified in the Fire Protection Assessment (N/E).

Hydrants and hoses shall be capable of applying two independent water streams covering the cargo manifold, transfer system, sumps and vessel manifold (N/E).

3108F.6.3 Fire water. *The source of fire water shall be reliable and provide sufficient rated capacity as determined in the Fire Protection Assessment. Water-based fire protection systems shall be tested and maintained per California NFPA 25 [8.9], as adopted and amended by the State Fire Marshal, or the local enforcing agency requirements. Specifications shall be retained. The latest testing and maintenance records shall be readily accessible to the Division (N/E).*

1. *All wet systems shall be kept pressurized (jockey pump or other means) (N/E).*
2. *Wet system headers shall be equipped with a low-pressure alarm wired to the control room (N).*

TABLE 31F-8-3
MINIMUM FIRE SUPPRESSION PROVISIONS (N/E)

FIRE HAZARD CLASSIFICATION (From Table 31F-8-2)	VESSEL AND CARGO LIQUID VOLATLITY RATING (From Table 31F-8-1)	MINIMUM PROVISIONS
LOW	Barge with L_C (including drums)	**500 gpm of water** 2 x 20 lb portable dry chemical extinguishers or the equivalent. 2 x 110 lb wheeled dry chemical extinguishers or the equivalent.
	Barge with H_C (including drums) Tankers < 50 KDWT, handling L_C or H_C	**1,500 gpm of water** 2 x 20 lb portable dry chemical extinguishers or the equivalent. 2 x 165 lb wheeled dry chemical extinguishers or the equivalent
MEDIUM	Tankers < 50 KDWT handling L_C	**1,500 gpm of water** 2 x 20 lb portable dry chemical extinguishers or the equivalent. 2 x 165 lb wheeled dry chemical extinguishers or the equivalent.
	Tankers < 50 KDWT, handling H_C	**2,000 gpm of water** 4 x 20 lb portable dry chemical extinguishers or the equivalent. 2 x 165 lb wheeled dry chemical extinguishers or the equivalent.
HIGH	Tankers < 50 KDWT, handling L_C or H_C	**3,000 gpm of water** 4 x 20 lb portable dry chemical extinguishers or the equivalent. 2 x 165 lb wheeled dry chemical extinguishers or the equivalent.
LOW, MEDIUM, HIGH	Tankers > 50 KDWT, handling L_C or H_C	**3,000 gpm of water** 6 x 20 lb portable dry chemical extinguishers or the equivalent. 4 x 165 lb wheeled dry chemical extinguishers or the equivalent.

Notes: L_C and H_C are defined in Table 31F-8-1. KDWT = Dead Weight Tons (Thousands)

3. *Fire pumps shall be installed at a distance of at least 100 ft from the nearest cargo manifold area (N).*
4. *Hose connections for fireboats or tugboats shall be provided on the MOT fire water line, and at least one connection shall be an international shore fire connection at each berth [8.2]. Connections shall be installed at a safe access distance from the sumps, manifolds and loading arms (N/E).*

3108F.6.4 Foam supply (N/E). *Product flammability, foam type, water flow rates and application duration shall be considered in foam supply calculations.*

Fixed foam proportioning equipment shall be located at a distance of at least 100 ft from the sumps, manifolds and loading arms, except where hydraulic limits of the foam delivery system require closer proximity.

MOTs shall have a program to ensure that foam is replaced according to the manufacturer's recommendations.

3108F.6.5 Fire monitor systems. *Fire monitors shall be located to provide coverage of MOT cargo manifolds, loading arms, hoses, and vessel manifold areas. This coverage shall provide at least two independent streams of water/foam. Monitors shall be located to provide an unobstructed path between the monitor and the target area (N/E).*

If the vessel manifold is more than 30 ft above the wharf deck, the following factors shall be considered, in order to determine if monitors located on elevated masts or towers are required (N/E):

1. *Maximum tanker freeboard*
2. *Tidal variations*
3. *Pier/wharf/loading platform elevation*
4. *Winds*
5. *Fire water line pressure*

Sprinklers and/or remotely controlled water/foam monitors shall be installed to protect personnel, escape routes, shelter locations and the fire water system (N).

Isolation valves shall be installed in the fire water and the foam lines in order to segregate damaged sections without disabling the entire system. Readily accessible isolation valves shall be installed 100–150 ft from the manifold and the loading arm/hose area (N).

3108F.6.6 Supplemental fire suppression systems (E). *A supplemental system is an external waterborne or land-based source providing suppressant and equipment. Supplemental systems may not provide more than one-quarter of the total water requirements specified in the Fire Protection Assessment.*

Additionally, supplementary systems shall not be considered in a Fire Protection Assessment, unless available within 20 minutes following the initiation of a fire alarm. Mutual aid may be considered as part of the supplemental system.

3108F.7 Fire systems seismic assessment (N/E). *Fire detection and protection systems, and emergency shutdown systems shall have a seismic assessment per Section 3104F.5. For strength evaluation of supports and attachments, see Section 3107F.7.*

For firewater piping and pipeline systems, see Section 3109F.7.

3108F.8 References.

[8.1] American Petroleum Institute (API), 2012, API Recommended Practice 2001 (API RP 2001), "Fire Protection in Refineries," 9th ed., Washington, D.C.

[8.2] International Chamber of Shipping (ICS), Oil Companies International Marine Forum (OCIMF), International Association of Ports and Harbors (IAPH), 2006, "International Safety Guide for Oil Tankers and Terminals (ISGOTT)," 5th ed., Witherby, London.

[8.3] California Code of Regulations (CCR), Title 2, Division 3, Chapter 1, Article 5 – Marine Terminals Inspection and Monitoring (2 CCR 2300 et seq.)

[8.4] American Petroleum Institute (API), 2008, API Recommended Practice 2003 (API RP 2003), "Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents," 7th ed., Washington, D.C.

[8.5] Code of Federal Regulations (CFR), Title 33, Section 154.550 – Emergency Shutdown (33 CFR 154.550)

[8.6] California Code of Regulations (CCR), Title 24, Part 3, California Electrical Code (Article 500),

[8.7] American Petroleum Institute (API), 2013, API Recommended Practice 2218 (API RP 2218), "Fireproofing Practices in Petroleum and Petrochemical Processing Plants," 3rd ed., Washington, D.C.

[8.8] National Fire Protection Association (NFPA), NFPA 72, "National Fire Alarm and Signaling Code," Quincy, MA. For edition, see California Code of Regulations (CCR), Title 24, Part 2, Chapter 35 – Referenced Standards.

[8.9] National Fire Protection Association (NFPA), California NFPA 25, "Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems," California ed., Quincy, MA. For edition, see California Code of Regulations (CCR), Title 24, Part 2, Chapter 35 – Referenced Standards.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 9

SECTION 3109F PIPING AND PIPELINES

3109F.1 General. *This section provides minimum engineering standards for piping, pipelines, valves, supports and related appurtenances at MOTs. This section applies to piping and pipelines used for transferring:*

1. *Oil (see Section 3101F.1) to or from tank vessels or barges*
2. *Oil within the MOT*
3. *Vapors, including Volatile Organic Compounds (VOCs)*
4. *Inerting or enriching gases to vapor control systems*

Additionally, it also applies to piping or pipelines providing services, which includes stripping, sampling, venting, vapor control and fire water.

See Section 3101F.3 for definitions of "new" (N) and "existing" (E).

3109F.2 Oil piping and pipeline systems. *All pressure piping and pipelines for oil service shall conform to the provisions of API Standard 2610 [9.1], ASME B31.3 [9.2] or B31.4 [9.3] as appropriate, including the following:*

1. *All piping/pipelines shall be documented on current P&IDs (N/E).*
2. *Piping and pipeline systems shall be installed above deck (N).*
3. *The systems shall be arranged in a way not to obstruct access to and removal of other piping components and equipment (N).*
4. *Flexibility shall be achieved through adequate expansion loops or joints (N/E).*
5. *A guide or lateral restraint shall be provided just past the elbow where a pipe changes direction in order to minimize excessive axial stress (N).*
6. *Piping shall be routed to allow for movement due to thermal expansion and seismic displacement, without exceeding the allowable stresses in the supports, and anchor connections (see Section 3109F.3) (N/E).*
7. *Plastic piping shall not be used unless designated for oil service (N/E).*
8. *If a flanged connection exists within 20 pipe diameters from the end of any replaced section, the pipe shall be replaced up to and including the flange.*
9. *Pipelines shall be seamless, electric-resistance-welded or electric-fusion-welded (N).*
10. *Piping greater than 2 inches in diameter shall be butt-welded. Piping 2 inches and smaller shall be socket welded or threaded.*
11. *Pipeline connections directly over the water shall be welded (N). Flanged connections not over water shall have secondary containment (N).*
12. *Pipelines that do not have a valid and certified Static Liquid Pressure Test (SLPT) [9.4] shall be marked "OUT OF SERVICE." Out-of-service piping and pipelines shall be purged, gas-freed and physically isolated from sources of oil.*
13. *If a pipeline is "out-of-service" for 3 or more years, it will require a valid and certified Static Liquid Pressure Test (SLPT) and API 570 inspection [9.4] prior to Division approval for re-use (E).*
14. *New piping and pipeline systems require a valid and certified Static Liquid Pressure Test (SLPT) [9.4] and Division approval, prior to operation.*

3109F.3 Pipeline stress analysis (N/E). *Pipeline stress analysis shall be performed for:*

1. *New piping and pipelines*
2. *Significant rerouting/relocation of existing piping*
3. *Any replacement of "not in-kind" piping*
4. *Any significant rearrangement or replacement of "not in-kind" anchors and/or supports*
5. *Significant seismic displacements calculated from the structural and/or geotechnical assessments*

Pipeline stress analysis shall be performed in accordance with ASME B31.4 [9.3], considering all relevant loads and corresponding displacements determined from the structural analysis and/or geotechnical analysis described in Sections 3104F and 3106F, respectively. Seismic loading of above-grade pipelines may be analyzed in accordance with ASME B31.E [9.5] with seismic loads computed from Section 3104F.5.4.1.

For pipelines spanning between seismically isolated structures (Section 3104F.1.3) and/or varying geotechnical conditions, evaluation of the relative movement of pipelines and supports and varying seismic accelerations shall be considered, including phase differences.

Flexibility analysis for piping, considering supports, shall be performed in accordance with ASME B31.4 [9.3] by using the largest temperature differential imposed by normal operation, start-up, shutdown or abnormal conditions. Thermal loads shall be based upon maximum and minimum local temperatures; heat traced piping shall use the maximum attainable temperature of the heat tracing system.

Section 3106F.12 provides additional considerations for underwater seafloor pipelines.

To determine forces at sliding surfaces, the coefficients of static friction shown in Table 31F-9-1 shall be used.

TABLE 31F-9-1
COEFFICIENTS OF STATIC FRICTION

SLIDING SURFACE MATERIALS	COEFFICIENT OF STATIC FRICTION
Teflon on Teflon	*0.10*
Plastic on Steel	*0.35*
Steel on Steel	*0.40*
Steel on Concrete	*0.45*
Steel on Timber	*0.49*

3109F.4 Piping and pipelines supports and attachments (or anchorage). *Supports and attachments shall conform to ASME B31.3 [9.2], ASME B31.4 [9.3], API Standard 2610 [9.1] and the ASCE Guidelines [9.6] (N).*

A seismic assessment shall be performed for existing supports and attachments using recommendations in Section 7 of CalARP [9.7], as appropriate (E).

For strength evaluation of supports and attachments, see Section 3107F.7. If a pipeline analysis has been performed and support reactions are available, they may be used to determine the forces on the support structure.

3109F.5 Appurtenances.

3109F.5.1 Valves and fittings. *Valves and fittings shall meet the following requirements:*

1. *Conform to ASME B31.3 [9.2], ASME B31.4 [9.3], API Standard 609 [9.8] and ASME B16.34 [9.9], as appropriate, based on their service (N).*
2. *Conform to Section 10 of API Standard 2610 [9.1] (N/E).*
3. *Stems shall be oriented in a way not to pose a hazard in operation or maintenance (N/E).*
4. *Nonductile iron, cast iron, and low-melting temperature metals shall not be used in any hydrocarbon service (N/E).*
5. *Double-block and bleed valves shall be used for manifold valves (N/E).*
6. *Isolation valves shall be fire-safe in accordance with API Standard 607 [9.10] (N).*
7. *Swing check valves shall not be installed in vertical down-flow piping (N/E).*
8. *Pressure relief devices shall be used in any closed piping system that has the possibility of being over pressurized due to temperature increase (thermal relief valves) (N/E).*
9. *Pressure relief devices shall be used in any piping system that has the possibility of being over pressurized due to surging, considering all plausible normal and abnormal operational scenarios in accordance with ASME B31.4 [9.3] (N/E).*
10. *Pressure relief devices shall be sized in accordance with API RP 520 [9.11] (N). Set pressures and accumulating pressures shall be in accordance with API RP 520 [9.11] (N/E).*
11. *Discharge from pressure relief valves shall be directed into lower pressure piping for recycling or proper disposal. Discharge shall never be directed into the open environment, unless secondary containment is provided (N/E).*
12. *Threaded, socket-welded, flanged and welded fittings shall conform to Section 8 of API Standard 2610 [9.1] (N/E).*
13. *ESD valves and SIVs shall also conform to the requirements of Sections 3108F.3.2.1 and 3108F.3.2.2.*

3109F.5.2 Valve actuators (N/E).

1. *Actuators shall have a readily accessible, manually operated overriding device to operate the valve during a power loss.*
2. *Torque switches shall be set to stop the motor closing operation at a specified torque setting.*
3. *Limit switches shall be set to stop the motor opening operation at a specified limit switch setting.*
4. *Critical valves shall be provided with thermal insulation. The insulation shall be inspected and maintained at periodic intervals. Records of thermal insulation inspections and condition shall be maintained for at least 6 years.*
5. *Electrical insulation for critical valves shall be measured for resistance following installation and retested periodically. These records shall be maintained for at least 6 years.*
6. *ESD valve and SIV actuators shall also conform to the requirements of Section 3108F.3.2.*

3109F.6 Utility and auxiliary piping and pipeline systems. *Utility and auxiliary piping includes service for:*

1. *Stripping and sampling*
2. *Vapor control*
3. *Natural gas*
4. *Compressed air, venting and nitrogen*

Stripping and sampling piping shall conform to Section 3109F.2 (N/E).

Vapor return lines and VOC vapor inerting and enriching (natural gas) piping shall conform to 33 CFR 154.2100(b) [9.12] (N/E).

Compressed air, venting and nitrogen piping and fittings shall conform to ASME B31.3 [9.2] (N).

3109F.7 Fire piping and pipeline systems. *Firewater and foam piping and fittings shall meet the following requirements:*

1. *Conform to NFPA 11 [9.13], NFPA 24 [9.14], and ASME B16.5 [9.15] (N/E).*
2. *Fire mains shall be carbon steel pipe (N/E).*
3. *High density polyethylene (HDPE) piping may be used for buried pipelines (N/E).*

4. *Piping and appurtenances shall be color-coded per local jurisdiction requirements or per ASME A13.1 [9.16] (N/E).*
5. *Pipeline stress analysis shall be performed for firewater piping and pipelines per Section 3109F.3 (N/E).*
6. *Firewater piping and pipelines supports and attachments shall be assessed per Section 3109F.4.*
7. *External visual inspection shall be performed per Section 3102F.3.5.3 (N/E).*

3109F.8 References.

[9.1] American Petroleum Institute (API), 2005, API Standard 2610 (R2010), "Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities," 2nd ed., Washington, D.C.

[9.2] American Society of Mechanical Engineers (ASME), 2015, ASME B31.3-2014 (ASME B31.3), "Process Piping," New York.

[9.3] American Society of Mechanical Engineers (ASME), 2012, ASME B31.4-2012 (ASME B31.4), "Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids," New York.

[9.4] California Code of Regulations (CCR), Title 2, Division 3, Chapter 1, Article 5.5 – Marine Terminal Oil Pipelines (2 CCR 2560 et seq.)

[9.5] American Society of Mechanical Engineers (ASME), 2008, ASME B31E, "Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems," New York.

[9.6] American Society of Civil Engineers, 2011, "Guidelines for Seismic Evaluation and Design of Petrochemical Facilities," 2nd ed., New York.

[9.7] CalARP Program Seismic Guidance Committee, December 2013, "Guidance for California Accidental Release Prevention (CalARP) Program Seismic Assessments," Sacramento, CA.

[9.8] American Petroleum Institute (API), 2009, API Standard 609, "Butterfly Valves: Double Flanged, Lug- and Wafer-Type," 7th ed., Washington, D.C.

[9.9] American Society of Mechanical Engineers (ASME), 2013, ASME B16.34-2013 (ASME B16.34), "Valves Flanged Threaded and Welding End," New York.

[9.10] American Petroleum Institute (API), 2010, API Standard 607, "Fire Test for Quarter-Turn Valves and Valves Equipped with Nonmetallic Seats," 6th ed., Washington, D.C.

[9.11] American Petroleum Institute (API), API Recommended Practice 520 P1 and P2 (API 520), "Sizing, Selection, and Installation of Pressure-relieving Devices, Part 1 —Sizing and Selection," 2014, 9th ed., and "Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries – Part 2 – Installation," 2015, 6th ed., Washington, D.C.

[9.12] Code of Federal Regulations (CFR), Title 33, Section 154.2100 – Vapor Control System, General (33 CFR 154.2100)

[9.13] National Fire Protection Association (NFPA), NFPA 11, "Standard for Low-, Medium-, and High-Expansion Foam," Quincy, MA. For edition, see California Code of Regulations (CCR), Title 24, Part 2, Chapter 35 – Referenced Standards.

[9.14] National Fire Protection Association (NFPA), NFPA 24, "Standard for the Installation of Private Fire Service Mains and Their Appurtenances," Quincy, MA. For edition, see California Code of Regulations (CCR), Title 24, Part 2, Chapter 35 – Referenced Standards.

[9.15] American Society of Mechanical Engineers (ASME), 2013, ASME B16.5-2013 (ASME B16.5), "Pipe Flanges and Flanged Fittings," New York.

[9.16] American Society of Mechanical Engineers (ASME), 2007, ASME A13.1-2007 (R2013) (ASME A13.1), "Scheme for the Identification of Piping Systems," New York.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 10

SECTION 3110F
MECHANICAL AND ELECTRICAL EQUIPMENT

3110F.1 General. *This section provides the minimum standards for mechanical and electrical equipment at MOTs.*

See Section 3101F.3 for definitions of "new" (N) and "existing" (E).

3110F.2 Marine loading arms.

3110F.2.1 General criteria. *Marine loading arms and ancillary systems shall conform to ASME B31.3 [10.1], 33 CFR 154.510 [10.2] and OCIMF "Design and Construction Specification for Marine Loading Arms" [10.3]. Each loading arm used for transferring oil shall have a means of being drained or closed before being disconnected.*

The following shall be considered when determining the loading arm maximum allowable extension limits:

1. *Vessel sizes and manifold locations*
2. *Lowest-low water level (datum)*
3. *Highest-high water level*
4. *Maximum vessel surge and sway*
5. *Maximum width of fendering system*

For each loading arm, the maximum allowable movement envelope limits shall comply with 2 CCR 2380 [10.4].

Loading arms and ancillary systems shall have a seismic assessment in accordance with Section 3104F.5. For seismic evaluation, design and strengthening of loading arms and ancillary equipment, seismic loads shall be computed per Section 3104F.5.4.1 and the procedure in Section 8.5.3 of ASCE/COPRI 61 [10.5]. For strength evaluation of supports and attachments, see Section 3107F.7.

3110F.2.2 Electrical and hydraulic power systems.

3110F.2.2.1 Pressure and control systems (N).

1. *Pressure gauges shall be mounted in accordance with ASME B40.100 [10.6].*
2. *The hydraulic drive cylinders shall be mounted and meet either the mounting requirements of NFPA T3.6.7 R3 [10.7] or equivalent.*
3. *In high velocity current (>1.5 knots) areas, all new marine loading arms shall be fitted with quick disconnect couplers and emergency quick release systems in conformance with Sections 6.0 and 7.0 of [10.3]. In complying with this requirement, attention shall be paid to the commentary and guidelines in Part III of reference [10.3].*
4. *Out-of-limit, balance and the approach of out-of-limit alarms shall be located at or near the loading arm console.*

3110F.2.2.2 Electrical components (N). *The following criteria shall be implemented:*

1. *Equipment shall be provided with a safety disconnecting device to isolate the entire electrical system from the electrical mains in accordance with Article 430 of the California Electrical Code [10.8].*
2. *Motor controllers and 3-pole motor overload protection shall be installed and sized in accordance with Article 430 of the California Electrical Code [10.8].*
3. *Control circuits shall be limited to 120 volts and shall comply with Articles 500 and 501 of the California Electrical Code [10.8]. Alternatively, intrinsically safe wiring and controls may be provided in accordance with Article 504 of the California Electrical Code [10.8] and UL Std. No. 913 [10.9].*
4. *Grounding and bonding shall comply with the requirements of Article 430 of the California Electrical Code [10.8] and Section 3111F.*

Section 3111F includes requirements for electrical equipment, wiring, cables, controls and electrical auxiliaries located in hazardous areas.

3110F.2.2.3 Remote operation. *The remote control system, where provided, shall conform to the recommendations of the OCIMF [10.3]. The remote operation shall be facilitated by either a pendant control system or by a hand-held radio controller (N).*

The pendant control system shall be equipped with a plug-in capability to an active connector located either in the vicinity of the loading arms, or at the loading arm outboard end on the triple swivel, and hard-wired into the control console. The umbilical cord running from the triple swivel to the control console shall be attached to the loading arm. Other umbilical cords shall have sufficient length to reach the maximum operational limits (N).

The radio controller if installed shall comply with 2 CCR 2370 [10.4] and 47 CFR Part 15 [10.10] requirements for transmitters operating in an industrial environment (N/E).

3110F.3 Oil transfer hoses (N/E). *Hoses for oil transfer service shall be in compliance with 2 CCR 2380 [10.4] and 33 CFR 154.500 [10.11].*

Hoses with nominal diameters of 6 inches or larger shall have flanges that meet ASME B16.5 [10.12], or hoses with nominal diameters of 6 inches or less may have quick disconnect fittings provided that they meet ASTM F1122 [10.13].

The minimum hose length shall safely accommodate the vessel's size and maximum movements during transfer operations and mooring (see Section 3105F.2).

3110F.4 Lifting equipment: winches and cranes. *Lifting equipment for oil service activities, other activities (if operation or failure could cause an oil release) or spill response,* *shall conform to the provisions in Sections 3110F.4.1 and 3110F.4.2.*

Lifting equipment inspection and maintenance shall conform to ASME B30.4 [10.14], ASME B30.7 [10.15] and ASME HST-4 [10.16], as applicable. Inspections by qualified personnel shall be performed annually. Inspection and maintenance records shall be retained.

3110F.4.1 Winches.

1. *Winches and ancillary equipment shall be suitable for a marine environment (N/E).*
2. *Winches shall be provided with a fail-safe braking system, capable of holding the load under all conditions, including a power failure (N/E).*
3. *Winches shall be fully reversible (N).*
4. *Shock, transient and abnormal loads shall be considered when selecting winch systems (N).*
5. *Winches shall have limit switches and automatic trip devices to prevent over-travel of the drum in either direction. Limit switches shall be tested, and demonstrated to function correctly under operating conditions without inducing undue tensions or slack in the winch cables (N/E).*
6. *Under all operating conditions, there shall be at least two full turns of cable on grooved drums, and at least three full turns on ungrooved drums (N/E).*
7. *Moving winch parts which present caught-in hazards to personnel shall be guarded (N/E).*
8. *Winches shall have clearly identifiable and readily accessible stop controls (N/E).*

3110F.4.2 Cranes (N/E).

1. *Cranes shall not be loaded in excess of the manufacturer's rating except during performance tests.*
2. *Drums on load-hoisting equipment shall be equipped with positive holding devices.*
3. *Under all operating conditions, there shall be at least two full turns of cable on grooved drums, and at least three full turns on ungrooved drums.*
4. *Braking equipment shall be capable of stopping, lowering, and holding a load of at least the full test load.*
5. *When not in use, crane booms shall be lowered to ground level or secured to a rest support against displacement by wind loads or other outside forces.*
6. *Safety systems including devices that affect the safe lifting and handling, such as interlocks, limit switches, load/moment and overload indicators with shutdown capability [10.17], emergency stop switches, radius and locking indicators, shall be provided.*

3110F.5 Shore-to-vessel access for personnel. *This section applies to shore-to-vessel means of access for personnel and equipment provided by the terminal. This includes ancillary structures and equipment, which support, supplement, deploy and maneuver such vessel access systems.*

Shore-to-vessel access for personnel shall conform to 29 CFR 1918.22 [10.18], Sections 19.B and 21.E of USACE EM 385-1-1 [10.19], Chapter 16.4 of ISGOTT [10.20] and the following:

1. *Shore-to-vessel access systems shall be designed to withstand the forces from dead, live, wind, vibration, impact loads and the appropriate combination of these loads. The design shall consider all the critical positions of the system in the stored, maintenance, maneuvering and deployed positions, where applicable (N).*
2. *The minimum live load shall be 50 psf on walkways and 25 plf with a 200 pounds minimum concentrated load in any location or direction on handrails (N).*
3. *The walkway shall be not less than 36 inches in width (N) and not less than 20 inches for existing walkways (E).*
4. *The shore-to-vessel access system shall be positioned so as to not interfere with the safe passage or evacuation of personnel (N/E).*
5. *Guardrails shall be provided on both sides of the access systems with a clearance between the inner most surfaces of the guardrails of not less than 36 inches and shall be maintained for the full length of the walkway (N).*
6. *Guardrails shall be at a height not less than 33 inches above the walkway surface and shall include an intermediate rail located midway between the walkway surface and the top rail (N/E).*
7. *The walkway surface, including self-leveling treads, if so equipped, shall be finished with a safe nonslip footing accommodating all operating gangway inclinations (N/E).*
8. *The undersides of aluminum gangways shall be protected with hard plastic or wooden strips to prevent being dragged or rubbed across any steel deck or component (N/E).*

3110F.6 Oil sumps and ancillary equipment. *Oil sumps and ancillary equipment shall conform to the following:*

1. *Sumps for oil drainage shall be equipped with pressure/vacuum vents, automatic draining pumps and shall be tightly covered (N/E).*
2. *Sumps which provide drainage for more than one berth should be equipped with liquid seals so that a fire on one berth does not spread via the sump (N/E).*
3. *Sumps shall be located at least 25 ft from the manifolds, base of the loading arms or hose towers (N).*
4. *Conduct periodic integrity testing of the sump containers and periodic integrity and leak testing of the related valves and piping.*

3110F.7 Vapor control systems. *Vapor control systems shall conform to 33 CFR 154.2000 through 154.2181 [10.21] and API Standard 2610 [10.22]. The effects of seismic, wind, dead, live and other loads shall be considered in the analysis* *and design of individual tie-downs of components, such as of steel skirt, vessels, controls and detonation arresters.*

3110F.8 Spill prevention equipment and systems maintenance (N/E). *Mechanical and electrical equipment critical to oil spill prevention and safety, such as, but not limited to: mooring line quick release and loading arm quick disconnect systems, shall be maintained and tested as per the manufacturer's recommendations (N/E). The latest records shall be readily accessible to the Division (N/E).*

3110F.9 Pumps (N/E). *Specification information for all MOT pumps providing oil and fire water service to wharf pipeline systems shall be retained. Information shall include, but not be limited to, pump make and model, motor make and model, flow rate, pressure rating and pump performance curves.*

Hydrocarbon pumps that serve the oil transfer operations at the berthing system must be maintained per API Standard 2610 [10.22]. Firewater pumps providing the wharf fire protection shall be maintained in accordance with Section 3108F.6.3.

3110F.10 Mechanical and electrical equipment seismic assessment (N/E)*. Mechanical and electrical equipment shall have a seismic assessment per Section 3104F.5. For strength evaluation of supports and attachments, see Section 3107F.7.*

3110F.11 References.

[10.1] American Society of Mechanical Engineers (ASME), 2015, ASME B31.3-2014 (ASME B31.3), "Process Piping," New York.

[10.2] Code of Federal Regulations (CFR), Title 33, Section 154.510 – Loading Arms (33 CFR 154.510)

[10.3] Oil Companies International Marine Forum (OCIMF), 1999, "Design and Construction Specification for Marine Loading Arms," 3rd ed., Witherby, London.

[10.4] California Code of Regulations (CCR), Title 2, Division 3, Chapter 1, Article 5 – Marine Terminals Inspection and Monitoring (2 CCR 2300 et seq.)

[10.5] American Society of Civil Engineers (ASCE), 2014, ASCE/COPRI 61-14 (ASCE/COPRI 61), "Seismic Design of Piers and Wharves", Reston, VA.

[10.6] American Society of Mechanical Engineers (ASME), 2013, ASME B40.100-2013 (ASME B40.100), "Pressure Gauges and Gauge Attachments," New York.

[10.7] National Fluid Power Association (NFPA), 2009, NFPA T3.6.7 R3-2009 (R2017) (NFPA T3.6.7 R3), "Fluid Power Systems and Products —Square Head Industrial Cylinders - Mounting Dimensions," Milwaukee, WI.

[10.8] California Code of Regulations (CCR), Title 24, Part 3, California Electrical Code.

[10.9] Underwriters Laboratory, Inc., 2013, UL Standard No. 913, "Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, III, Division 1, Hazardous (Classified) Locations," 8th ed., Northbrook, IL.

[10.10] Code of Federal Regulations (CFR), Title 47, Part 15 – Radio Frequency Devices (47 CFR 15)

[10.11] Code of Federal Regulations (CFR), Title 33, Section 154.500 – Hose Assemblies (33 CFR 154.500)

[10.12] American Society of Mechanical Engineers (ASME), 2013, ASME B16.5-2013 (ASME B16.5), "Pipe Flanges and Flanged Fittings," 13th ed., New York.

[10.13] American Society for Testing and Materials (ASTM), 2010, ASTM F1122-04(2010) (ASTM F1122), "Standard Specification for Quick Disconnect Couplings (6 in. NPS and Smaller)," 4th ed., West Conshohocken, PA.

[10.14] American Society of Mechanical Engineers (ASME), 2010, ASME B30.4-2010 (ASME B30.4), "Portal Tower and Pedestal Cranes," 10th ed., New York.

[10.15] American Society of Mechanical Engineers (ASME), 2011, ASME B30.7-2011 (ASME B30.7), "Winches," 11th ed., New York.

[10.16] American Society of Mechanical Engineers (ASME) 1999, ASME HST-1999 (R2010) (ASME HST-4), "Performance Standard for Overhead Electric Wire Rope Hoists," New York.

[10.17] Code of Federal Regulations (CFR), Title 29, Section 1917.46 – Load Indicating Devices (29 CFR 1917.46)

[10.18] Code of Federal Regulations (CFR), Title 29, Section 1918.22 – Gangways (29 CFR 1918.22)

[10.19] US Army Corps of Engineers (USACE), 2008 (05 Jul 11), EM 385-1-1, "Safety and Health Requirements Manual, Sections 19.B and 21.E, Washington, D.C.

[10.20] International Chamber of Shipping (ICS), Oil Companies International Marine Forum (OCIMF), International Association of Ports and Harbors (IAPH), 2010, "International Safety Guide for Oil Tankers and Terminals (ISGOTT)," 5th ed., Witherby, London.

[10.21] Code of Federal Regulations (CFR), Title 33, Sections 154.2000 through 154.2250 – Vapor Control Systems (33 CFR 154.2000 et. seq.)

[10.22] American Petroleum Institute (API), 2005, API Standard 2610 (R2010), "Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities," 2nd ed., Washington, D.C.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 11

SECTION 3111F
ELECTRICAL SYSTEMS

3111F.1 General. *This section provides minimum standards for electrical systems at marine oil terminals.*

Electrical systems include the incoming electrical service and components, the electrical distribution system, branch circuit cables and the connections, including, but not limited to:

1. *Lighting, for operations, security and navigation*
2. *Controls for mechanical and electrical equipment*
3. *Supervision and instrumentation systems for mechanical and electrical equipment*
4. *Grounding and bonding*
5. *Corrosion protection through cathodic protection*
6. *Communications and data handling systems*
7. *Fire detection systems*
8. *Fire alarm systems*
9. *Emergency shutdown systems (ESD)*

All electrical systems shall conform to API RP 540 [11.1] and the California Electrical Code [11.2].

See Section 3101F.3 for definitions of "new" (N) and "existing" (E).

3111F.2 Hazardous area designations and plans (N/E). *Area classifications shall be determined in accordance with API RP 500 [11.3], API RP 540 [11.1] and Articles 500, 501, 504, 505 and 515 of the California Electrical Code [11.2]. A marine oil terminal shall have a current set of scaled plan drawings, with clearly designated areas showing the hazard class, division and group. The plan view shall be supplemented with sections, elevations and details to clearly delineate the area classification at all elevations starting from low water level. The drawings shall be certified by a professional electrical engineer. The plans shall be reviewed, and revised when modifications to the structure, product or equipment change hazardous area identifications or boundaries.*

3111F.3 Identification and tagging. *All electrical equipment, cables and conductors shall be clearly identified by means of tags, plates, color coding or other effective means to facilitate troubleshooting and improve safety, and shall conform to the identification carried out for the adjacent onshore facilities (N). Topics for such identification are found in Articles 110, 200, 210, 230, 384, 480 and 504 of the California Electrical Code [11.2]. Existing electrical equipment (E) shall be tagged.*

Where identification is necessary for the proper and safe operation of the equipment, the marking shall be clearly visible and illuminated (N/E). A coded identification system shall apply to all circuits, carrying low or high voltage power, control, supervisory or communication (N).

3111F.4 Purged or pressurized enclosures for equipment in hazardous locations (N/E). *Purged or pressurized enclosures shall be capable of preventing the entry of combustible gases into such spaces, in accordance with NFPA 496 [11.4]. Special emphasis shall be placed on reliability and ease of operation. The pressurizing equipment shall be electrically monitored and alarms shall be provided to indicate failure of the pressurizing or purging systems.*

Pressurized control rooms shall conform to Chapter 7 of NFPA 496 [11.4].

3111F.5 Electrical service. *Where critical circuits are used for spill prevention, fire control or life safety, an alternative service derived from a separate source and conduit system, shall be located at a safe distance from the main power service. A separate feeder from a double-ended substation or other source backed up by emergency generators will meet this requirement. A stored energy emergency power system (SEEPS) shall be provided for control and supervisory circuits associated with ESD systems (N), see Section 3111F.5.1.*

1. *Electrical, instrument and control systems used to activate equipment needed to control a fire or mitigate its consequences shall be protected from fire and remain operable for 15 minutes in a 2000°F fire, unless designed to fail-safe during fire exposure. The temperature around these critical components shall not exceed 200°F during 15 minutes of fire exposure (N).*
2. *Wiring in fireproofed conduits shall be derated 15 percent to account for heat buildup during normal operation. Type MI (mineral insulated, metal sheathed per the California Electrical Code [11.2]) cables may be used in lieu of fireproofing of wiring (N).*
3. *Emergency cables and conductors shall be located where they are protected from damage caused by traffic, corrosion or other sources (N).*
4. *Allowance shall be made for electrical faults, overvoltages and other abnormalities (N).*

Where solid state motor controls are used for starting and speed control, corrective measures shall be incorporated for mitigating the possible generation of harmonic currents that may affect the ESD or other critical systems (N).

3111F.5.1 Emergency power systems. *Emergency power systems shall be installed (N) and maintained (N/E) per NFPA 110 [11.5]. This does not include stored energy systems. Stored energy emergency power systems (SEEPS) shall be installed (N) when necessary to maintain continuous uninterruptable power to critical systems. SEEPS shall be installed (N) and maintained (N/E) per NFPA 111 [11.6].*

3111F.6 Grounding and bonding (N/E).

1. *All electrical equipment shall be effectively grounded as per Article 250 of the California Electrical Code [11.2]. All noncurrent carrying metallic equipment, structures, piping and other elements shall also be effectively grounded.*

2. *Grounding shall be considered in any active corrosion protection system for on-shore piping, submerged support structures or other systems. Insulation barriers, including flanges or nonconducting hoses shall be used to isolate cathodic protection systems from other electrical/static sources. None of these systems shall be compromised by grounding or bonding arrangements that may interconnect the corrosion protection systems or interfere with them in any way that would reduce their effectiveness.*
3. *Bonding of vessels to the MOT structure is not permitted.*
4. *Whenever flanges of pipelines with cathodic protection are to be opened for repair or other work, the flanges shall be bonded prior to separation.*
5. *Direct wiring to ground shall be provided from all towers, loading arms or other high structures that are susceptible to lightning surges or strikes.*

3111F.7 Equipment specifications (N). *All electrical systems and components shall conform to National Electrical Manufacturers Association (NEMA) standards or be certified by a Nationally Recognized Testing Laboratory (NRTL).*

3111F.8 Illumination (N/E).

3111F.8.1 Illumination Locations. *At a minimum, MOTs shall provide fixed lighting (or luminaires) that illuminates the following areas:*

1. *Transfer connection points on the MOT*
2. *Transfer connection points on any barge moored at the MOT that may transfer oil*
3. *Transfer operations work areas on the MOT*
4. *Transfer operations work areas on any barge moored at the MOT that may transfer oil*
5. *Areas defined in Sections 17.4 and 24.6.4 of ISGOTT [11.7], as appropriate*

Lighting shall be located or shielded so as not to mislead or otherwise interfere with off-site areas as governed by federal, state and local agency requirements.

3111F.8.2 Illumination Levels. *The minimum illumination levels shall be as follows:*

1. *5.0 footcandles (54 lux) at transfer connection points*
2. *1.0 footcandle (11 lux) in transfer operations work and other areas*

Where the illumination appears to the Division to be inadequate, the Division may require verification by instrument of the levels of illumination. The illumination levels shall be verified by measurement at the locations defined in Section 3111F.8.1, if required. All measurements shall be taken on a horizontal plane, 3 feet above the MOT and barge deck or walking surface (33 CFR 154.570 (b) [11.8]).

3111F.8.3 Emergency Power for Illumination (N). *In the event of power supply failure, the emergency power system (Section 3111F.5.1) shall automatically illuminate all of the areas defined in Section 3111F.8.1, and fire pump, hydrant, monitor, foam, and hose connection points on the MOT. The emergency power system shall provide power for a duration of not less than 60 minutes at a level of not less than an average of 0.5 footcandle (5.5 lux).*

3111F.9 Communications, control and monitoring systems.

3111F.9.1 Communication systems (N/E). *Communications systems shall comply with 2 CCR 2370 [11.7] and Section 6 of OCIMF "Guide on Marine Terminal Fire Protection and Emergency Evacuation" [11.9].*

3111F.9.2 Overfill monitoring and controls (N/E). *Overfill protection systems shall conform to Appendix C of API Standard 2350 [11.10]. These systems shall be tested before each transfer operation or monthly, whichever is less frequent. Where vessel or barge overfill sensors and alarms are provided, they shall comply with 33 CFR 154.2102 [11.11].*

All sumps shall be provided with level sensing devices to initiate an alarm to alert the operator at the approach of a high level condition. A second alarm shall be initiated at a high-high level to alert the operator. Unless gravity drainage is provided, sumps must have an automatic pump, programmed to start at a predetermined safe level.

3111F.9.3 Monitoring systems (N/E). *All monitoring systems and instrumentation such as, but not limited to: velocity monitoring systems, tension monitoring systems, anemometers, and current meters, shall be installed, maintained and calibrated per the manufacturer's recommendations. Specifications shall be retained. The latest records shall be readily accessible to the Division.*

3111F.10 Cathodic Protection Systems (CPS) (N/E). *CPS operating, testing, and maintenance criteria for underwater structures shall conform to UFC 3-570-01 [11.12]. Structure-to-electrolyte potential measurements shall be taken at least annually. CPS operating, testing, and maintenance criteria for buried and submerged pipelines shall conform to API 570 [11.13].*

All electrical insulating and isolating devices for protection against static, stray and impressed currents shall be tested in accordance with 2 CCR 2341 and 2380 [11.7].

CPS design criteria and location of anodes, electrical leads and rectifiers shall be documented and retained. Periodic CPS measurements, test data and inspection findings shall be retained.

3111F.11 Electrical systems seismic assessment (N/E). *Electrical systems shall have a seismic assessment per Section 3104F.5. For strength evaluation of supports and attachments, see Section 3107F.7.*

3111F.12 References.

[11.1] American Petroleum Institute (API), 1999, API Recommended Practice 540 (R2004) (API RP 540), "Electrical Installations in Petroleum Processing Plants," 4th ed., Washington, D.C.

[11.2] California Code of Regulations (CCR), Title 24, Part 3, California Electrical Code.

[11.3] American Petroleum Institute (API), 2012 (Errata January 2014), API Recommended Practice 500 (API RP 500), "Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2," 3rd ed., Washington, D.C.

[11.4] National Fire Protection Association (NFPA), 2012, NFPA 496, "Standard for Purged and Pressurized Enclosures for Electrical Equipment," 2013 ed., Quincy, MA.

[11.5] National Fire Protection Association (NFPA), NFPA 110, "Standard for Emergency and Standby Power Systems," Quincy, MA. For edition, see California Code of Regulations (CCR), Title 24, Part 2, Chapter 35 – Referenced Standards.

[11.6] National Fire Protection Association (NFPA), NFPA 111, "Standard on Stored Electrical Energy Emergency and Standby Power Systems," Quincy, MA. For edition, see California Code of Regulations (CCR), Title 24, Part 2, Chapter 35 – Referenced Standards.

[11.7] International Chamber of Shipping (ICS), Oil Companies International Marine Forum (OCIMF), International Association of Ports and Harbors (IAPH), 2006, "International Safety Guide for Oil Tankers and Terminals (ISGOTT)," 5th ed., Witherby, London.

[11.8] Code of Federal Regulations (CFR), Title 33, Section 154.570 – Lighting (33 CFR 154.570)

[11.9] Oil Companies International Marine Forum (OCIMF), 1987, "Guide on Marine Terminal Fire Protection and Emergency Evacuation," 1st ed., Witherby, London.

[11.10] American Petroleum Institute (API), 2012, API Standard 2350, "Overfill Protection for Storage Tanks in Petroleum Facilities," 4th ed., Washington, D.C.

[11.11] Code of Federal Regulations (CFR), Title 33, Section 154.2102 – Facility Requirements for Vessel Liquid Overfill Protection (33 CFR 154.2102)

[11.12] Department of Defense, 28 November 2016, Unified Facilities Criteria (UFC) 3-570-01, "Cathodic Protection," Washington, D.C.

[11.13] American Petroleum Institute (API), 2009, API 570, "Piping Inspection Code: In-service Inspection, Repair, and Alteration of Piping Systems," 3rd ed., Washington, D.C.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*

Division 12

SECTION 3112F REQUIREMENTS SPECIFIC TO MARINE TERMINALS THAT TRANSFER LNG

3112F.1 Purpose and applicability. *Section 3112F provides minimum requirements specific to onshore marine terminals that transfer LNG. Sections 3101F through 3111F are also applicable, as appropriate. Offshore marine terminals that transfer LNG are subject to a case-by-case review and approval by the Division.*

3112F.2 Risk and Hazards Analyses.

1. *Prior to LNG transfer at marine terminal, a hazards identification exercise shall be carried out to isolate potential internal and external events that may cause a spill and/or impact to public health, safety and the environment.*
2. *Hazards analysis shall consider every component, part of a structure, equipment item, and system, whose failure could cause a major accident, result in unacceptable incident escalation beyond the design basis, or adversely affect the potential for the passive and active systems to control or shutdown the facility. Safety Critical Components and Safety Critical Systems shall be identified.*
3. *Consequence models shall be developed for credible scenarios to identify Lower Flammability Limit (LFL) hazard regions. Release diameters shall include, at a minimum, 3mm, 10mm, and 50 mm sizes. Scenarios involving the marine loading arms shall consider a full bore release.*
4. *Consequence models shall develop radiant heat zones from jet and pool fires for the 25 kW/m^2, 12.5 kW/m^2, 5 kW/m^2 and 1.6 kW/m^2 thermal endpoints.*
5. *A Cryogenic Exposure Analysis (CEA) shall be conducted to identify equipment and structures susceptible to cryogenic spray and pool exposure due to LNG releases from different size holes.*
6. *A Facility Essential Systems Survivability Assessment (ESSA) shall be conducted to determine the survivability of the Safety Critical Components.*
7. *Impact on Safety Critical Components and Systems shall be mitigated.*

3112F.3 Specific berthing and mooring considerations. *In addition to the minimum design requirements for berthing and mooring in Sections 3103F, 3105F and 3107F of this code, the following shall be satisfied:*

1. *Wind force and moment coefficients for LNG vessels shall be used in accordance with Appendix A of OCIMF MEG 3 [12.1], as appropriate.*
2. *The limiting environmental criteria for which the LNG carrier may safely remain berthed at the terminal shall be determined using dynamic mooring analysis.*
3. *Real time monitoring and recording of environmental conditions including wind, current and waves shall be conducted to assist in mooring system management.*
4. *Vessel hull pressure shall be considered in fender analyses and design.*

3112F.4 Fire protection. *A Fire and Explosion Hazard Analysis (FEHA) for potential pool fires, jet fires, and flash fires, considering LNG releases from different size holes, as specified in Section 3112F.2, shall be conducted and result in recommendations regarding:*

1. *Type, quantity, and location of fire and gas detection devices to detect potential fires and/or gas releases in a specified time frame*
2. *Fire suppression coverage, including fixed and portable systems, and equipment necessary to allow the design scenarios to be mitigated and/or extinguished*
3. *Design application rates for required fire protection systems*
4. *Firefighting requirements, including an analysis of the capability of response by other facilities, USCG, and federal, state and local agencies*

Critical structural supports and equipment within the fire exposed areas identified in the FEHA shall be provided with passive fire protection designed for the duration identified in the analysis.

Emergency shutdown (ESD) systems shall be provided, in accordance with API RP 14C [12.2] and Section 12.3 of NFPA 59A [12.3], to shut down the flow of LNG to/from the terminal and shut down equipment whose continued operation could add to or prolong an emergency event.

The ESD system shall be of a failsafe design or shall be otherwise installed, located, or protected to minimize the possibility that it becomes inoperative in the event of an emergency or failure at the primary control system. ESD system components that may be exposed to fire effects shall be evaluated to confirm that the actuator operation will not be impaired.

3112F.5 LNG pipelines.

1. *All pipe specified for use in cryogenic service shall be furnished in accordance with Paragraph 323.2.2A and Table A-1 of ASME B31.3 [12.4]. The extreme thickness of insulation on cryogenic piping shall be taken into consideration during piping design.*
2. *All piping materials, including gaskets and thread compounds, shall be selected appropriate to the range of temperatures to which subjected. Piping that may be exposed to the low temperature of LNG or to the heat of an ignited spill, during an emergency where such exposure could result in a failure of the piping, shall comply with at least one of the following:*
   - *(a) Made of material(s) that can withstand both the normal operating temperature and extreme*

temperature to which the piping may be subjected during the emergency

(b) Protected by insulation or other means to delay failure due to extreme temperatures until corrective action can be taken by the operator.

(c) Capable of being isolated and having the flow stopped where piping is exposed only to the heat of an ignited spill during the emergency

3. *LNG pipelines shall be designed for cool-down with liquid nitrogen where the use of LNG is not possible.*
4. *All LNG drains should be located within a containment area or piped to a collection system or containment area.*
5. *LNG lines shall be analyzed for a start-up case where the top of the pipe is 90 degrees F warmer than the bottom of the pipe. The upward bowing of the pipe shall be limited to 1.25 inches.*
6. *Pipe supports, including any insulation systems used to support pipe whose stability is essential, shall be resistant to or protected against fire exposure, escaping cold liquid, or both if they are subject to such exposure.*
7. *Pipe supports for cold lines shall be designed to minimize excessive heat transfer, which can result in piping failure by ice formations or embrittlement of supporting steel. If icing up of piping and components is unavoidable, the weight of the accumulated ice shall be considered during piping and support design.*
8. *Valves shall comply with ASME B31.5 [12.5].*
9. *Cryogenic valves in liquid cryogenic service shall not be installed in vertical lines. Valves in liquid cryogenic service shall be installed in horizontal lines with the stem in the vertical position or at least 45 degrees vertically from the horizontal centerline of the pipe.*
10. *All cryogenic valves (except butterfly valves, check valves and globe valves) shall have a body cavity relief to the "safe" side of the valve. All cryogenic valves with a body cavity relief shall be marked on the exterior of the body with a letter "V" and an arrow pointing to the direction of the venting side.*
11. *Thermal relief valves shall be installed to protect the equipment and piping from over pressuring as a result of ambient heat input to blocked in LNG or other light hydrocarbon liquids.*
12. *Cryogenic subsea pipeline designs shall be qualified by a certifying agency, acceptable to the Division, in a qualification program that demonstrates that the system has been designed, fabricated and can function as intended with safeguards provided as determined to be necessary.*

3112F.6 Mechanical components and systems.

1. *The CEA analysis shall be used to recommend acceptable cryogenic exposure durations for Safety Critical Components to produce CEA drawings.*
2. *ESD system components, which are exposed to cryogenic effects, shall be evaluated to confirm that the actuators will not be impaired by the potential exposures, thereby preventing the components from failing to a safe position.*
3. *Critical structural supports and equipment within the cryogenically exposed areas shall be provided with cryogenic insulation. The cryogenic insulation and passive fire protection shall be designed for sufficient incident duration.*
4. *For marine loading arms in LNG service, ice formation on non-insolated arms and hoses must be taken into account. Mechanisms for venting, apex venting, purging and cool down of the marine loading arms shall be identified on the P&IDs.*
5. *Areas beneath marine arms shall have restricted access during and after product transfer, until there is no longer danger of falling ice.*

3112F.7 References.

[12.1] Oil Companies International Marine Forum (OCIMF), 2008, "Mooring Equipment Guidelines (MEG3)," 3rd ed., London, England.

[12.2] American Petroleum Institute (API), 2001 (Reaffirmed 2007), API Recommended Practice 14C (API RP 14C), "Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms," 7th ed., Washington, D.C.

[12.3] National Fire Protection Association (NFPA), 2012, NFPA 59A, "Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)," 2013 ed., Quincy, MA.

[12.4] American Society of Mechanical Engineers (ASME), 2015, ASME B31.3-2014 (ASME B31.3), "Process Piping," New York.

[12.5] American Society of Mechanical Engineers (ASME), 2013, ASME B31.5-2013 (ASME B31.5), "Refrigeration Piping and Heat Transfer Components," New York.

Authority: *Sections 8750 through 8760, Public Resources Code.*

Reference: *Sections 8750, 8751, 8755 and 8757, Public Resources Code.*