10.0 REFERENCES

References may be obtained from:

Engineering Societies Library (Linda Hall Library), a private library located on the campus of the University of Missouri
5109 Cherry Street
Kansas City, Missouri 64110-2498
1-800-662-1545

1. California Code of Regulations (CCR) Title 19, Division 2 Chapter 4.5.

2. "Guidance for California Accidental Release Prevention (CalARP) Program Seismic Assessments," Prepared for the Administering Agency (AA) Subcommittee Region I Local Emergency Planning Committee (LEPC), Prepared by the CalARP Program Seismic Guidance Committee, January 2004, Approved by Region 1 LEPC, 12/10/03.

3. *Uniform Building Code,* 1997 Edition, International Conference of Building Officials.

4. ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures,* American Society of Civil Engineers, 2006.

5. California Department of Conservation, Division of Mines and Geology, "*Guidelines for Evaluating and Mitigating Seismic Hazards in California,"* Special Publication 117, 1997.

6. ASCE 1997, "Guidelines for Seismic Evaluation and Design of Petrochemical facilities", Task Committee on Seismic Evaluation and Design of Petrochemical Facilities, American Society of Civil Engineers. New York, 1997.

7. Gurbuz, O., Lopez, A., Summers, P., April 1992, "Implementation of the Proposed RMPP Seismic Assessment Guidance to Perform a Structural Seismic Evaluation of Existing Facilities" in *Proceedings of HAZMACON '92,* Session on "New Developments in Earthquake Caused Hazardous Materials Releases," Long Beach, CA.

8. Saunders, K.L. and Hau, G., "Seismic Evaluation Acceptance Guideline for Existing Above Ground Piping Systems", ASME PVP Volume 256-1, 1993.

9. API Standard 650*, Welded Steel Tanks for Oil Storage,* 10th Edition, Addendum 2, November 2001.

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10. ANSI/AWWA D100-96, 1996, *AWWA Standard for Welded Steel Tanks for Water Storage,* American Water Works Association.

11. Veletsos, A.S., Contributor, "Guidelines for the Seismic Design of Oil and Gas Pipeline Systems", ASCE, Committee on Gas and Liquid Fuel Lifelines, NY, NY, 1984.

12. Manos, G.W., August 1986, "Earthquake Tank-Wall Stability of Unbraced Tanks," American Society of Civil Engineers, Journal of Structural Engineering, Vol. 112, No. 8, including Erratum in Journal of Structural Engineering, Vol. 113, No.3, March 1987.

13. Housner, G.W., and Haroun, M.A., 1980, "Seismic Design of Liquid Storage Tanks," ASCE Convention and Exposition, Portland, Oregon, April 14-18, 1980.

14. ACI 350.3-01, Seismic Design of Liquid - Containing Concrete Structures, and Commentary, January 2002.

15. ANSI/ASME B31.3, *ASME Code for Pressure Piping Chemical Plant and Petroleum Refinery Piping*, 2002 Edition.

16. ASCE, Los Angeles Section Geotechnical Group, "Recommended Procedures for Implementation of Division of Mines and Geology Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California", Published by Southern California Earthquake Center (SCEC), June 2002.

17. ASCE, Los Angeles Section Geotechnical Group, "Recommended Procedures for Implementation of Division of Mines and Geology Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction in California", Published by Southern California Earthquake Center (SCEC), March 1999.

18. FEMA 350 "Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings," June 2000.

19. *1998 California Building Code,* California Building Standards Commission.

20. *2001 California Building Code,* California Building Standards Commission.

21. *2007 California Building Code,* California Building Standards Commission.

22. *International Building Code,* 2006 Edition, International Code Council, Inc.

23. National Science and Technology Council, *Tsunami Risk Reduction for the United States: A Framework for Action,* December 2005.

24. Bernard B, Dengler L, and Yim S (editors), 2007, *National Tsunami Research Plan: Report of a Workshop Sponsored by NSF/NOAA.*

This is a preview. Click here to purchase the full publication.

25. ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings,* American Society of Civil Engineers, 2006.

26. API Standard 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks,* Eleventh Edition, 2009.

27. US Department of Energy, *Nuclear Reactors and Earthquakes,* Report No. TID-7024, January 1961.

28. ASME B31-1a-2002, *Power Piping,* American Society of Mechanical Engineers, 2003.

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Table 1. Ductility-Based Reduction Factors (Q) for Existing Structures and Systems

A. STRUCTURES SUPPORTING EQUIPMENT This covers structures whose primary purpose is to support equipment, such as air coolers, spheres, horizontal vessels, exchangers, heaters, vertical vessels and reactors, etc.	**Q**
1. Steel structures	
Ductile moment frame (see Note 8) Use Q=6 if there is a significant departure from the intent of the 1988 (or later) UBC for special moment-resisting frames.	6 or 8
Ordinary moment frame (see Note 8) The following structural characteristics are usually indicative of a Q=2 value (also see Note 6): a. There is a significant strength discontinuity in any of the vertical lateral force resisting elements, i.e., a weak story. b. There are partial penetration welded splices in the columns of the moment resisting frames. c. The structure exhibits "strong girder-weak column" behavior, i.e., under combined lateral and vertical loading, hinges occur in a significant number of columns before occurring in the beams. The following structural characteristics are usually indicative of a Q=4 value (also see Note 6): d. Any of the moment frame elements is not compact. e. Any of the beam-column connections in the lateral force resisting moment frames does not have both: (1) full penetration flange welds; and (2) a bolted or welded web connection. f. There are bolted splices in the columns of the moment resisting frames that do not connect both flanges and the web.	2, 4 or 5
Braced frame The following structural characteristics are usually indicative of a Q=2 value (also see Note 6): a. There is a significant strength discontinuity in any of the vertical lateral force resisting elements, i.e., a weak story (see SEAOC, 1996 Section C104.9). b. The bracing system includes "K" braced bays. Note: "K" bracing is permitted for frames of two stories or less by using Q=2. For frames of more than two stories, "K" bracing must be justified on a case-by-case basis. c. Brace connections are not able to develop the capacity of the diagonals. d. Column splice details cannot develop the column capacity. The following structural characteristics are usually indicative of a Q=4 value (also see Note 6): e. Diagonal elements designed to carry compression have (kl/r) greater than 120. f. The bracing system includes chevron ("V" or inverted "V") bracing that was designed to carry gravity load. g. Tension rod bracing with connections which develop rod strength.	2, 4 or 5
Cantilever column The following structural characteristics are usually indicative of a Q=1.5 value (also see Note 6): a. Column splice details cannot develop the column capacity. b. Axial load demand represents more than 20% of the axial load capacity.	1.5 or 2.5

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Table 1. (continued)

A. STRUCTURES SUPPORTING EQUIPMENT (Continued)	Q
2. Concrete structures	
Ductile moment frame Use Q=6 if there is a significant departure from the intent of the 1988 (or later) UBC for special moment-resisting frames. If shear failure occurs before flexural failure in either beam or column, the frame should be considered an ordinary moment frame.	6 or 8
Intermediate moment frame	4
Ordinary moment frame The following structural characteristics are usually indicative of a Q=1.5 value (also see Note 6): a. There is a significant strength discontinuity in any of the vertical lateral force resisting elements, i.e., a weak story. b. The structure exhibits "strong girder - weak column" behavior, i.e., under combined lateral and vertical loading, hinges occur in a significant number of columns before occurring in the beams. c. There is visible deterioration of concrete or reinforcing steel in any of the frame elements, and this damage may lead to a brittle failure mode. d. Shear failure occurs before flexural failure in a significant number of the columns. The following structural characteristics are usually indicative of a Q=2.5 value (also see Note 6): e. The lateral resisting frames include prestressed (pretensioned or post-tensioned elements) f. The beam stirrups and column ties are not anchored into the member cores with hooks of 135° or more. g. Columns have ties spaced at greater than d/4 throughout their length. Beam stirrups are spaced at greater than d/2. h. Any column bar lap splice is less than $35d_b$ long. Any column bar lap splice is not enclosed by ties spaced $8d_b$ or less. i. Development length for longitudinal bars is less than $24d_b$. j. Shear failure occurs before flexural failure in a significant number of the beams.	1.5, 2.5 or 3.5
Shear wall The following structural characteristics are usually indicative of a Q=1.5 value (also see Note 6): a. There is visible deterioration of concrete or reinforcing steel in any of the frame elements, and this damage may lead to a brittle failure mode. b. There is a significant strength discontinuity in any of the vertical lateral force resisting elements, i.e., a weak story. c. Any wall is not continuous to the foundation. The following structural characteristics are usually indicative of a Q=3 value (also see Note 6): d. The reinforcing steel for concrete walls is not greater than 0.0025 times the gross area of the wall along both the longitudinal and transverse axes. The spacing of reinforcing steel along either axis exceeds 18 inches. e. For shear walls with H/D greater than 2.0, the boundary elements are not confined with either: (1) spirals; or (2) ties at spacing of less than $8d_b$. f. For coupled shear wall buildings, stirrups in any coupling beam are spaced at greater than $8d_b$ or are not anchored into the core with hooks of 135° or more.	1.5, 3 or 5
Cantilever pier/column The following structural characteristics are usually indicative of a Q=1.5 value (also see Note 6): a. There is visible deterioration of concrete or reinforcing steel in any of the elements, and this damage may lead to a brittle failure mode. b. Axial load demand represents more than 20% of the axial load capacity. The following structural characteristics are usually indicative of a Q=2.5 value (also see Note 6): c. The ties are not anchored into the member cores with hooks of 135° or more. d. Columns have ties spaced at greater than d/4 throughout their length. Piers have ties spaced at greater than d/2 throughout their length. e. Any pier/column bar lap splice is less than $35d_b$ long. Any pier/column bar lap splice is not enclosed by ties spaced $8d_b$ or less. f. Development length for longitudinal bars is less than $24d_b$.	1.5, 2.5 or 3.5

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Table 1. (continued)

B. EQUIPMENT BEHAVING AS STRUCTURES WITH INTEGRAL SUPPORTS	Q
1. Vertical vessels/heaters or spheres supported by:	
Steel skirts	2 or 4
The following structural characteristics are usually indicative of a Q=2 value (also see Note 6): a. The diameter (D) divided by the thickness (t) of the skirt is greater than 0.441*E/F_y, where E and F_y are the Young's modulus and yield stress of the skirt, respectively.	
Steel braced legs without top girder or stiffener ring	1.5, 3 or 4
The following structural characteristics are usually indicative of a Q=1.5 value (also see Note 6): a. The bracing system includes "K" braced bays. b. Brace connections are not able to develop the capacity of the diagonals. c. Column splice details cannot develop the column capacity. The following structural characteristics are usually indicative of a Q=3 value (also see Note 6): d. Diagonal elements designed to carry compression have (kl/r) greater than 120. e. The bracing system includes chevron ("V" or inverted "V") bracing that was designed to carry gravity load. f. Tension rod bracing with connections which develop rod strength.	
Steel unbraced legs without top girder or stiffener ring	1.5 or 2.5
The following structural characteristics are usually indicative of a Q=1.5 value (also see Note 6): a. Column splice details cannot develop the column capacity. b. Axial load demand represents more than 20% of the axial load capacity.	
2. Chimneys or stacks	
Steel guyed	4
Steel cantilever	4
Concrete	4

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Table 1. (continued)

C. PIPEWAYS	**Q**
Note: This includes pipeways supporting equipment that does not weigh more than 25% of the other dead loads. For pipeways supporting equipment that weighs more than 25% of the other dead loads, see Section A, STRUCTURES SUPPORTING EQUIPMENT.	
1. Steel	
Ductile moment frame (see Note 8)	8
Ordinary moment frame (see Note 8)	6
Braced frame	6
Cantilever column	4
2. Concrete	
Ductile moment frame	8
Ordinary moment frame	5
Cantilever column	3.5

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Table 1. (continued)

D. GROUND SUPPORTED TANKS (see Notes 4 and 9)	**Q**
1. Anchored	4
2. Unanchored	3
E. FOUNDATIONS (See Note 5)	**Q**
1. Piled	6
2. Spread footings	6
F. ANCHOR BOLTS (see Note 6)	**Q**
1. Anchor bolt yield controls	As for structure
2. Concrete failure or anchor bolt slippage controls, or there is a non-ductile force transfer mechanism between structure and foundation (see Note 7)	1.5
G. PIPING	**Q**
1. Piping in accordance with ASME B31, including in-line components with joints made by welding or brazing.	12
2. Piping in accordance with ASME B31, including in-line components, constructed of high- or limited-deformability materials, with joints made by threading, bonding, compression couplings, grooved couplings or flanges.	6
3. Piping and tubing not in accordance with ASME B31, including in-line components, constructed of high-deformability materials, with joints made by welding or brazing.	9
4. Piping and tubing not in accordance with ASME B31,including in-line components, constructed of high- or limited-deformability materials, with joints made by threading, bonding, compression couplings, grooved couplings or flanges.	4.5
5. Piping and tubing constructed of low-deformability materials, such as cast iron, glass, and nonductile plastics.	3

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Table 1. (continued)

NOTES:

1. The use of the highest Q-factors in each category requires that the elements of the primary load path of the lateral force resisting system have been proportioned to assure ductile rather than brittle system behavior. This can be demonstrated by showing that each connection in the primary load path has an ultimate strength of at least equal to 150% of the load capacity (governed by either yielding or stability) of the element to which the load is transferred. Alternatively, Q-factors should be reduced consistent with the limited ductility of the governing connection and/or the governing connection should be modified as required.

2. A Q-factor different from the tabulated values (higher or lower) may be justified on a case-by-case basis.

3. If more than one of the conditions specified in the table applies, the lowest Q-factor associated with those conditions should be used.

4. Other approved national standards for the seismic assessment of tanks may be used in lieu of these guidelines.

5. These values of Q apply to overturning checks, soil bearing, and pile capacities. For the remaining items including connection between piles and pile caps, use the Q factor for the supported structure.

6. If bolt yielding controls the evaluation of the anchor bolts (as opposed to concrete failure or anchor bolt slippage), and there is a ductile force transfer mechanism between the structure and foundation (such as the use of properly proportioned anchor bolt chairs between skirts or tank shells and the foundation), then the Q-factor to be used for both the evaluation of the anchor bolts and the rest of the structural system corresponds to that for the structural system itself.

   If concrete failure or anchor bolt slippage controls the evaluation of anchor bolts (as opposed to bolt yielding), or there is a non-ductile force transfer mechanism between the structure and foundation, then a Q-factor of 1.5 should be used for the evaluation of the anchor bolts and the rest of the structural system. Also see Note 7.

7. Alternatively, for structures that may contain localized/single features with limited ductility, such as limiting connections or splices, non-compact steel members, high (Kl/r) members and non-ductile anchor bolts, that do not occur at a significant number of locations, the load capacity of the specific limiting feature(s) may be evaluated and/or improved in lieu of using system-wide lower Q-factors that tend to generically penalize all elements of the structural system. The evaluation for these localized features may be performed using a Q-factor equal to 0.4 times the Q-factor normally recommended (i.e., unreduced) for the system. The evaluation for the remainder of the system may then be performed using the Q-factor normally recommended without consideration of the localized feature with limited ductility.

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Table 1. (continued)

8. Figure 1 below shows a common connection detail which has been used in the building industry. In the aftermath of the January, 1994 Northridge, California earthquake, over 100 buildings were found, where cracks occurred in connections based on this detail. This Committee suggests that for determining the connection forces using a Q-value equal to one half (1/2) of Q for the structure system, but not less than 2, where this type of connection is present, unless justified otherwise.

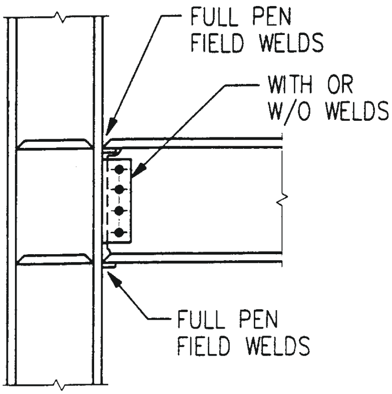

Figure 1: Former Standard Ductile Moment Connection Detail. (As a result of the Northridge Earthquake, this connection was shown to have major problems.)

9. For tanks made of fiberglass or similar materials, non-ductile anchorage and its attachments should be evaluated for a Q equal to 1.5.

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