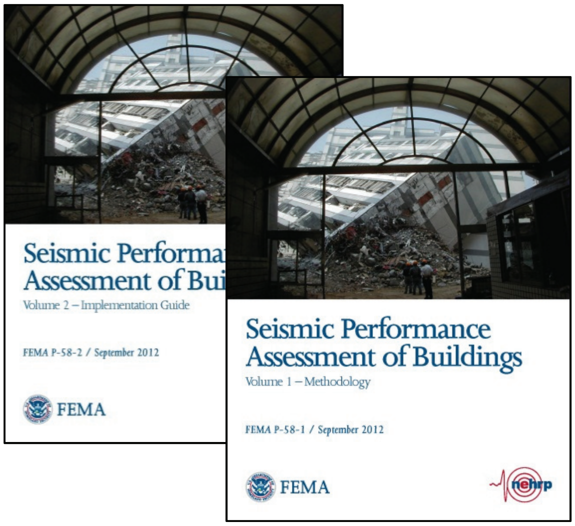

Background Document

FEMA P-58/BD-3.9.28

Fragility of Cooling Towers

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FEMA

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Background Documentation

FEMA P-58 Background Documents are a series of reports documenting the technical background and source information for key aspects of the FEMA P-58 methodology and its implementation. These reports were developed over the course of the 10-year ATC-58/ATC-58-1 Projects funded under FEMA Contracts EMW-2001-RP-0056 and HSFEHQ-06-D-1105.

Background Documents were developed by consultants, serving at various levels within the project hierarchy, reporting the results of: (1) decisions on technical development protocols; (2) focused studies on the development of key aspects of the methodology; (3) documentation of recommended procedures; and (4) collection of available data for the development of structural and nonstructural fragilities. They were initially intended to serve as a record of the technical state-of-knowledge at the time they were produced, and as resources for the development of the eventual project reports. As such, they represent a snapshot in time, and may, or may not, match the technical content, recommended procedures, or data incorporated into the final methodology and its implementation.

This Background Document is intended for the purpose of providing supplemental knowledge to users of the FEMA P-58 methodology. Information contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology. Specifically in the case of certain nonstructural component fragilities, the NISTIR fragility classification numbering scheme was modified over the course of the project, and the fragility classification number assigned in this document might be different from numbers assigned in the final fragility database. Users of information in this document assume all liability arising from such use.

Cover illustration – Primary resource documents for the FEMA P-58 *Seismic Performance Assessment of Buildings, Methodology and Implementation* series of products: FEMA P-58-1, *Volume 1 – Methodology*, and FEMA P-58-2, *Volume 2 – Implementation Guide*.

Keith Porter (02/25/2010)

Fragility of cooling towers

Table 66. Summary results

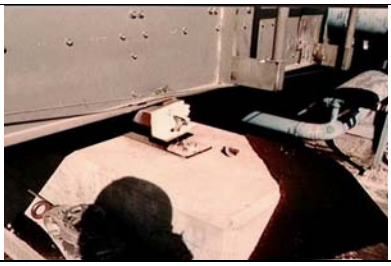
Fragility, damage measures, and consequences for		
Component category:	D3031.021 Cooling tower, well anchored; if vibration isolated, snubbers on isolators and flexibly attached hoses and pipes D5011.012 Cooling tower, with one or more of the following conditions: unanchored, vibration isolated without snubbers, vibration isolated w/ rigidly attached pipes	
Basic composition:	An open box, commonly 8-16 ft tall, commonly mounted on the roof or a mechanical pad outside the building, connected via water pipes to a heat source. A common variety sprays or cascades hot water in contact with outside air. Heat is transferred through evaporation, cooling the water, which is then collected and circulated back to the heat source. Some types used a closed system that transfers heat to air forced over coils. See Figure 28.	
Units:	Ea	
Number of damage states:	1	
If multiple damage states:	Simultaneous with anchorage failure. See Appendix 15	
Author and date:	K Porter 25 Feb 2010	
Damage states, fragilities, and consequences for		
	D3031.021 Cooling tower, well installed	D3031.022 Cooling tower, deficient installation
Description:	Damaged, inoperative	Ditto
Illustration:	N/A	
Demand parameter	Peak floor accel. (geomean, g)	Ditto
Median demand (θ):	2.2g	1.2g
Data dispersion (β_d)	0.4	0.4
Uncertainty (β_u):		
Total dispersion (β):	0.4	0.4
Probability:		
Correlation:		
Repairs required:	Repair attached piping	Remount cooling tower on new restrained isolators
Possible consequences:		
Repair cost (Y/N/?):	Y	Y
Death or injury (Y/N/?):	N	N
Inoperative facility (Y/N/?):	Y	Y
Red tagging (Y/N/?)	N	N
Comments:		

Table 67. Summary supporting information template

Literature summary. See main body for general discussion.	
Number of specimens tested:	19 in eSQUG database (EPRI 2007)
Construction quality:	☐ exceeds ☐ meets ☐ does not meet requirements of: varies
Seismic installation conditions:	Varies. Some observed specimens are mounted on steel columns that are bolted to a concrete plinth. Some are supported on spring isolation mounts, which themselves are sometimes enclosed in heavy steel channels to provide lateral restraint.
Loading protocols applied:	6 earthquakes at 10 sites, including 2 data processing facilities, an office building, a university campus, 2 light manufacturing facilities, 3 power plants, and a petrochemical processing plant
Method for observing demand:	Nearby strong-motion instruments.
Method for observing damage:	Combination of: interviews with facility operators, examination of facility records, & 1st-hand observations by engineers of EQE International, EPRI, or both.

Table 68. Performance of well anchored cooling towers

r, g	Units, M	Failed, m	Comment
0.12	4	0	EPRI (2007) UNO
0.3	1	0	
0.4	2	0	
0.42	1	0	
0.6	2	0	
0.6	1	0	
0.6	2	0	
0.6	3	0	
0.6	1	0	
0.86	2	0	
Sum	19	0	

Table 69. Performance of cooling towers whose vibration isolators lack seismic restraint

r, g	Units, M	Failed, m	Comment
0.86	1	0	eSQUG data (EPRI 2007) UNO. Unit rolled off of isolators & required remounting. However it was operable even after falling from isolator. Failure ignored for ATC-58 because isolator failure is treated analytically.
0.68	1	0	Unit rolled off of isolators & required remounting. No damage to attached piping. Operable once remounted. Failure ignored for ATC-58 because isolator failure is treated analytically.
Sum	2	0	

Table 70. Quality tests

Quality test	D3031.021 Cooling tower, well installed	D3031.022 Cooling tower, deficient install
Passes Lilliefors goodness of fit test? (Type A only)	NA	NA
Are θ and β within 20% of past results? If not discuss.	NA	N
Are $0.2 \leq \beta \leq 0.6$? If not discuss.	Y	Y
Do you believe the demand with 10% failure probability?	Y	Y
Discussion. Johnson et al. (1999) propose θ = 0.6g for unanchored cooling tower, vs. 1.2g here. See Figure 29b.		

Figure 30. Example cooling tower

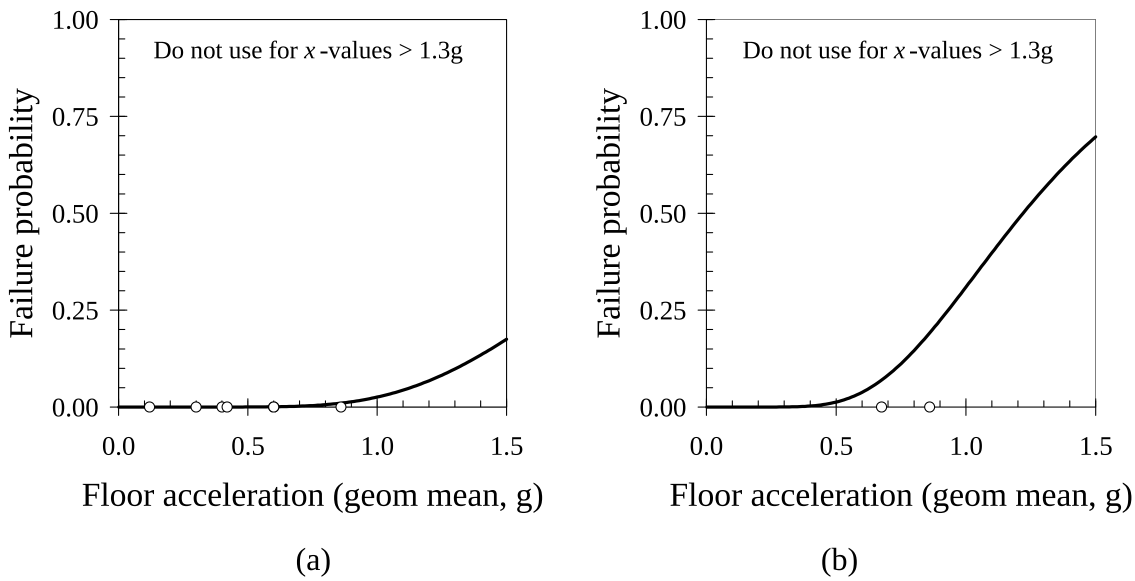


Figure 31. Fragility of (a) well-installed cooling towers, and (b) cooling towers with isolators that lack snubbers. Both specimens in (b) failed by overturning of the isolators, which are treated separately in ATC-58.