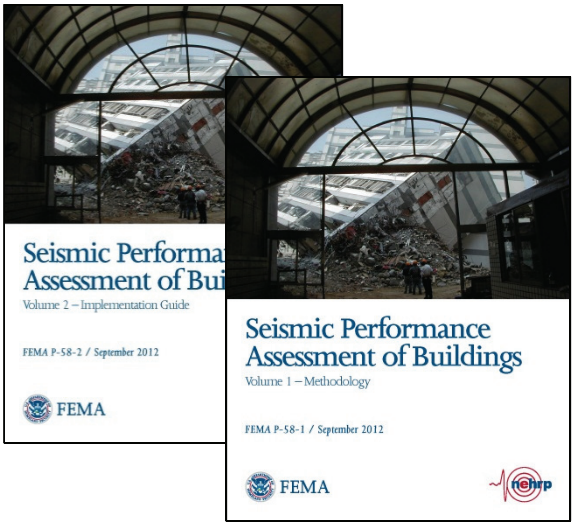

Background Document

FEMA P-58/BD-3.9.16

Fragility of Distribution Panels

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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contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology.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*.

Fragility of distribution panels

Keith Porter (10/05/2009)

Table 1. Summary results

Fragility, damage measures, and consequences for	
Component category:	D5012.030 Distribution panel, unknown or avg installation D5012.031 Distribution panel, well anchored, cabinets within ½ inch are bolted together, no large nearby items that could fall on the panel D5012.032 Distribution panel, 1 deficiency (typ. unanchored)
Basic composition:	Metal cabinet
Units:	ea
Number of damage states:	1
If multiple damage states:	□ ordered; □ mutually exclusive; □ simultaneous
Author and date:	K Porter 05 Oct 2009
Damage states, fragilities, and consequences for D5012.030, average or unknown conditions. For other conditions, see Table 7.	
	DS1
Description:	Inoperative. In the wall-mounted example shown below, loose bus bars in 1 of 6 identical panels contacted and formed a phase-to-phase or ground fault, burning internal components.
Illustration:	See Figure 1
Demand parameter	Peak floor acceleration, geometric mean, g
Median demand (θ)(1):	3.4
Data dispersion (β_d)(2)	0.6
Uncertainty (β_u)(2)	
Total dispersion (β)(1):	0.6
Probability(1):	
Correlation:	0: the single failure with known manufacturer, installation & anchorage conditions seems to have occurred in one of six identical, co-located units
Repairs required:	DNK
Possible consequences:	
Repair cost (Y/N/?):	Y
Death or injury (Y/N/?):	N
Inoperative facility (Y/N/?):	Y
Red tagging (Y/N/?)	N
Comments(2):	

(1) If ordered damage states, leave "probability" blank. If mutually exclusive or simultaneous damage states, provide parameters in DS1 column only, and probabilities of each damage state in "probability." Round θ to 2 significant figures and β to nearest 0.05.

(2) For methods A and B only, provide β_d and β_u and explain in the "comments" row any β_u value that differs from recommendations in Appendix C.

Table 2. Summary supporting information template

Literature summary. See Porter et al. (ND). ERPI (1991) addresses distribution panels in 2 groups: panel boards (wall mounted) and switchboards (floor-mounted, freestanding). No distinction is made here. Interestingly, EPRI (1991) recommends GERS ZPA = 1.5g for panel boards and 2.5g for switchboards.	
Number of specimens tested:	199 specimens total in data set 1, 70 of which also appear in data set 2 (EPRI 2007).
Construction quality:	☐ exceeds ☐ meets ☐ does not meet requirements of:
Seismic installation conditions:	Varies. Of 199 specimens, 67 are known to be anchored and 3 are known to be unanchored, from EPRI (2007)
Loading protocols applied:	15 earthquakes between 1971 and 1992 at 34 sites, mostly industrial facilities, with base acceleration of ~0.2 to 0.85g
Method for observing demand:	Nearby strong-motion instruments
Method for observing damage:	1st-hand observation, interview of facility operators, review of facility records, or a combination, by engineers of EQE International, EPRI, or both.

Table 3. Performance of distribution panels, average (unknown) conditions; data type B

r, g	**Units, *M***	**Failed, *m***	$w = M/\Sigma M$	$y = m/M$	**Φ**
0.20	17	1	0.085	0.059	0.000
0.24	19	0	0.095	0.000	0.000
0.25	39	0	0.196	0.000	0.000
0.26	10	0	0.050	0.000	0.000
0.30	31	0	0.156	0.000	0.000
0.35	7	0	0.035	0.000	0.000
0.37	1	0	0.005	0.000	0.000
0.40	33	2	0.166	0.061	0.000
0.42	14	0	0.070	0.000	0.000
0.50	12	0	0.060	0.000	0.001
0.56	5	0	0.025	0.000	0.001
0.60	5	0	0.025	0.000	0.002
0.65	2	0	0.010	0.000	0.003
0.85	4	0	0.020	0.000	0.011
Sum	199	3			

Table 4. Performance of distribution panels with 0 installation deficiencies

r, g	Units, m	Failed, M	Comment
0.20	1	0	EPRI (2007) UNO
0.20	1	0	
0.20	2	0	
0.20	1	0	
0.24	1	0	
0.24	2	0	
0.24	1	0	
0.25	1	0	
0.25	1	0	
0.25	1	0	
0.25	2	0	
0.26	1	0	
0.26	1	0	
0.30	1	0	
0.30	1	0	
0.30	2	0	
0.30	1	0	
0.30	1	0	
0.35	1	0	
0.35	3	0	
0.40	1	0	
0.40	1	0	
0.40	2	0	
0.40	6	1	Loose bus bars contacted and shorted the unit
0.40	3	0	
0.40	1	0	
0.40	5	0	
0.40	1	0	
0.40	1	0	
0.40	8	0	
0.40	1	0	
0.40	2	0	
0.42	1	0	
0.42	1	0	
0.50	2	0	
0.56	1	0	
0.56	1	0	
0.60	1	0	
0.85	2	0	
1.5	3	0	EPRI (1991)
2.5	5	0	Ditto
3.0	3	0	Ditto
3.3	5	0	Ditto
Sum	67	1	

Table 5. Performance of distribution panels with 1 installation deficieny, typ. lack of anchorage, data type C

r, g	**Units, m**	**Failed, M**	**Comment**
0.42	2	0	
0.85	1	0	Base shifted several inches & plowed up linoleum tile at the base of the unit, but was otherwise undamaged.

Table 6. Quality tests

Quality test	**DS1**	**DS2**	**DS3**
Passes Lilliefors goodness of fit test? (Type A only)	NA		
Are θ and β within 20% of past results? If not discuss.	~Y		
Are $0.2 \le \beta \le 0.6$? If not discuss.	Y		
Do you believe the demand with 10% failure probability?	Y		
Discussion. Johnson et al. (1999) suggest for basic condition, θ = 2.8g, β = 0.4, vs. θ = 3.4g, β = 0.6, so θ is within ~20%, though β is 1.5x previous. Regarding whether I believe demand with 10% failure probability, since the median is so high, and since most of the experience has failure rates of 0-5%, it seems more important whether I believe the estimated failure rates at 0.5-1g. I do, since it is roughly 0% and passes through most of the data.			

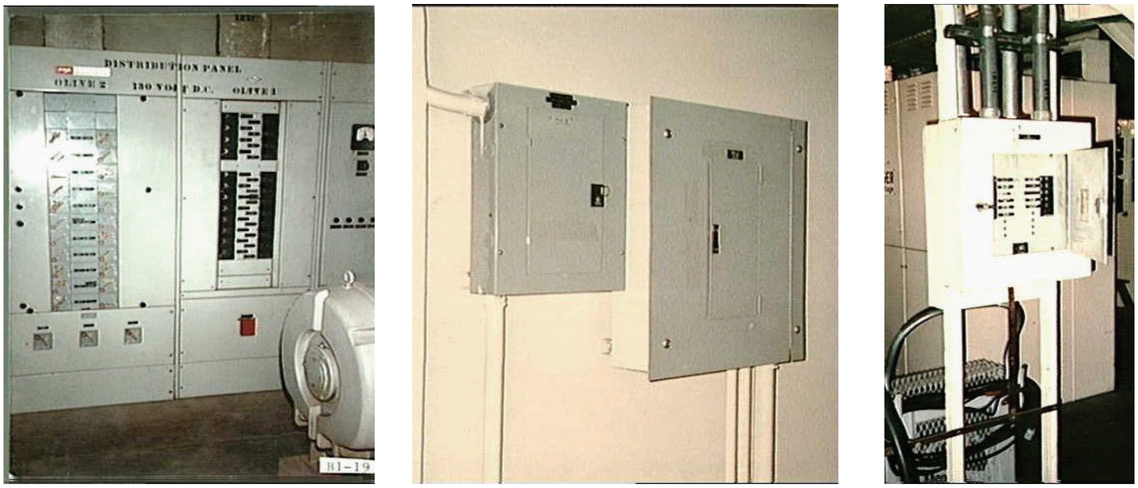
Table 7. Extrapolation to other detailed conditions and to average conditions

Condition (describe)	**From tests?**	**DS1**	
		θ	$\boldsymbol{\beta}$
Best: Anchored at base or to wall (Figure 2c). Before adding GERS data θ = 3.2 and β = 0.6. Method C used here.	Y	4.7	0.4
Moderate: Anchored but adjacent cabinets are within ½ in of each other and not attached, producing the potential for impact and consequent shorting of loose bus bars or damage to sensitive devices such as relays.	N	2.5	0.6
Worst: Unanchored but possibly restrained from overturning etc. by attached conduit or bus duct (Figure 2a)	Y	1.6	0.4
Average or unknown (Figure 2b)	Y	3.4	0.6

Basis for extrapolation. What factors affect θ and β?

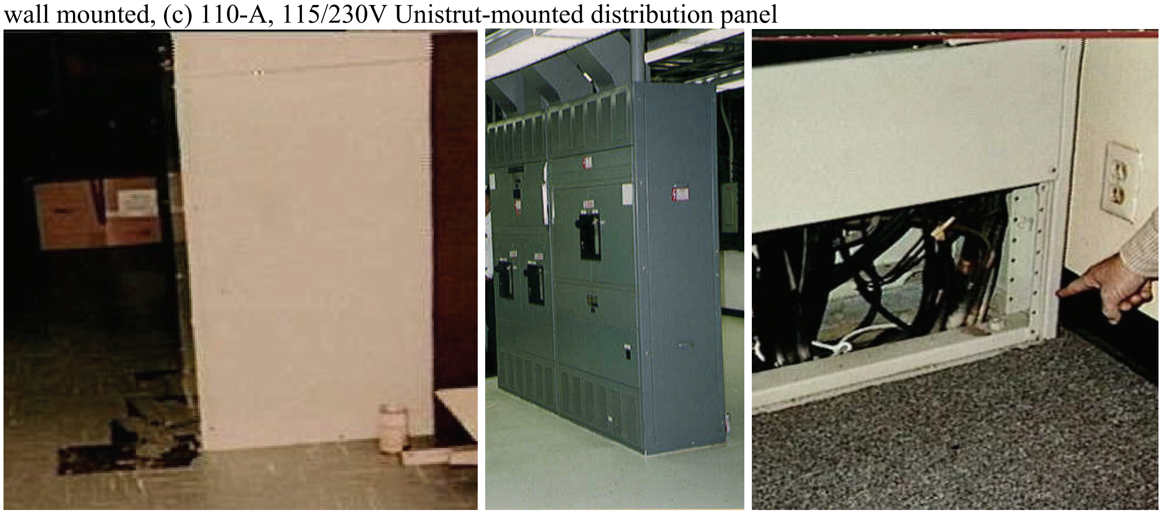
- Johnson et al. (1999) assert that θ is affected by anchorage, the potential for impact, and the potential for large nearby objects to overturn onto the distribution panel.
- β is probably affected by the diversity of distribution panels, as shown in Figure 1.
- These points aside, to create the best-case fragility function, I used method B3 with the data from 67 specimens shown here. Best is the same as average or unknown, implying either that (a) most specimens whose anchorage conditions are unknown were anchored, (b) that restraint by attached conduit is sufficient to prevent overturning & failure, or (c) both.
- Worst case uses method C, since none of the 3 specimens known to be unanchored failed.
- Moderate case takes the average of the medians for best and worst, because of the lack of info. It roughly agrees with Johnson et al. (1999)'s fragility function for "pounding or impact concerns" at the 10^{th} percentile, i.e., they have 10% failure probability at about the same base acceleration: 1.0g for Johnson, 1.15g here. Johnson's θ = 1.9, β = 0.5.

"From tests" means that the tests reported here are believed to represent this condition level



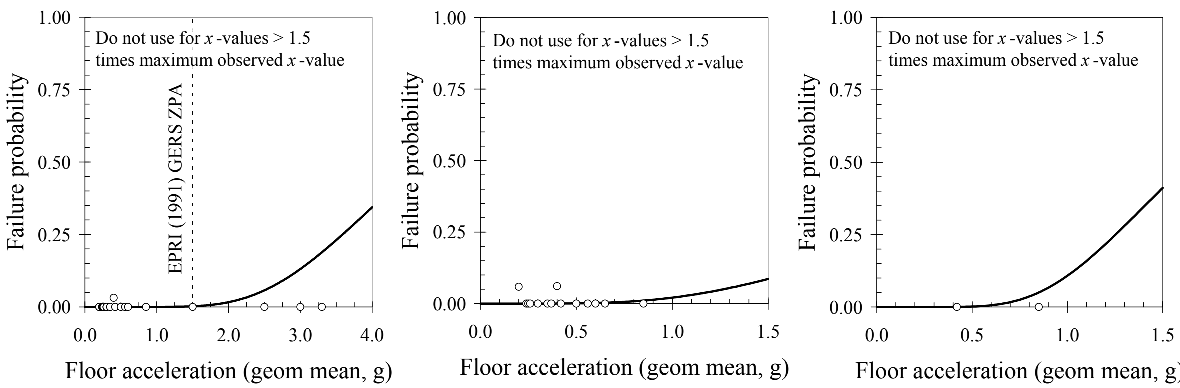
(a) (b) (c)

Figure 1. Some sample distribution panels: (a) floor mounted DC switchboard, 130V (unknown anchorage), (b) wall mounted, (c) 110-A, 115/230V Unistrut-mounted distribution panel



(a) (b) (c)

Figure 2. Variety of installation conditions: (a) base of an unanchored 240V, 400A AC distribution panel that shifted several inches, plowing up linoleum tiles, (b) floor mounted 480V switchboard, unknown floor anchorage but where overhead bus duct connections provide stability against overturning. (c) a 115V, 20A, AC magnetic molded-case circuit-breaker panel, anchored front and back with 3/8-in expansion anchors



(a) (b) (c)

Figure 3. Fragility functions: (a) well anchored, cabinets within ½ inch are bolted together, no large nearby items that could fall on the panel, (b) average or unknown conditions, and (c) 1 installation deficiency, typ. unanchored.

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