

**APPENDIX C:
STRESS-RANGE HISTOGRAM DATA AND REGRESSION**

To determine the appropriate fatigue load for infinite life design, the fatigue-limit-state load with a probability of exceedance of 1:10,000 must be known. The 1:10,000 probability is based on established fatigue tests of steel structures and is the basis for the AASHTO fatigue loads for highway bridges. Statistical analysis was used along with the stress-range histogram data to find the stress-range with a return period of 1:10,000 for each HMLT in the study. The stress range associated with that return period is the maximum threshold for infinite life, or the fatigue-limit-state stress-range (S_{RfIs}).

Viewing plots of the stress-range histogram data, it is easy to see that the distribution is positive skewed or right-tailed. Five different types of positive skewed distributions were evaluated to establish which best represents the stress-range data. Those include:

1. Single parameter exponential distribution
2. Single parameter Rayleigh distribution
3. Single parameter gamma distribution
4. Two-parameter Weibull distribution
5. Two-parameter log-normal distribution

Each of the distributions is commonly used in reliability engineering, time-to-failure estimates or to model variable-load spectrums.

Each of the listed distributions were fit to sample data sets and evaluated using a chi-square goodness-of-fit test. The chi-square values for an expected distribution can be approximated by:

$$\chi^2 \approx \sum_{j=1}^K \frac{(O_j - E_j)^2}{E_j}$$

where K is the number of bins in the sample distribution, O_j and E_j are the number of observed and expected occurrences respectively. In addition, E_j must also be greater than five for the approximation to yield good results. The best possible fit is achieved when the chi-square value is minimized. Further discussion of the chi-square goodness-of-fit test can be found in any elementary statistics textbook.

A spreadsheet was used to calculate the expected distributions fit to the sample data sets. Histogram bin values were set to the maximum value in the range to return the most conservative result. For example, the bin containing values from 1.50 – 2.00 ksi was set at 2.00 ksi. Mean and variance values were calculated for both the observed and expected distributions, and the chi-square values were minimized using an iterative solve routine so that the mean value was not exceeded and the variance was within a reasonable tolerance. Expected values less than five were eliminated from the chi-square analysis, and in some cases, the lower bins (0.50 and 1.00 ksi) were eliminated as well.

Of the five distributions considered, the log-normal appeared to be the most flexible and yielded the best results using the chi-square analysis. The exponential function also yielded promising results, but proved to be unreliable. It is noted that when the stress-range histograms are created, all bins are equally sized at 0.5 ksi, and all values less than 0.25 ksi are disregarded.

Since the exponential distribution is heavily weighted toward the left end, a good fit was difficult to achieve based on the higher stress-range bins.

A summary of the regression data is presented in Table C-1. Included in the table are, S_{Rfls} values, ratio of observed to estimated effective stress-range values (S_{Reff}), ratio of S_{Rfls} to S_{Reff} values, and the distribution parameters used for each regression. Note there is little variation between the lognormal distribution parameters. Following the summary table, histogram and regression data is presented for each HMLT in the long-term study.

ID	GAGE	S_{Rfls}	$(S_{Reff})_{obs}/(S_{Reff})_{est}$	S_{Rfls}/S_{Reff}	μ	σ
		(ksi)			scale	shape
CA-A	CH_3	5.76	1.01	5.26	-0.44	0.59
CA-X	CH_5	4.51	1.01	4.87	-0.54	0.55
IAN-A (MT)	CH_9	6.17	1.02	5.25	-0.39	0.59
IAN-X (MT)	CH_12	5.21	1.00	4.94	-0.39	0.55
IAS-A	CH_2	3.24	1.07	4.07	-0.67	0.50
IAS-X	CH_1	2.87	1.08	3.79	-0.69	0.47
KS-A	CH_2	7.17	1.05	5.62	-0.46	0.65
KS-X	CH_6	7.73	1.05	5.86	-0.49	0.68
ND-A	CH_1	3.54	0.97	4.43	-0.53	0.48
ND-X	CH_5	3.87	0.99	4.44	-0.46	0.49
OKNE-A	CH_3	4.58	1.00	4.75	-0.44	0.53
OKNE-X	CH_5	4.19	0.99	4.61	-0.46	0.51
OKSW-A	CH_8	4.45	1.00	4.70	-0.45	0.52
OKSW-X	CH_6	4.37	0.97	4.95	-0.46	0.53
PA-A	CH_6	2.32	0.99	3.77	-0.77	0.43
PA-X	CH_1	2.23	1.00	3.66	-0.79	0.43
SD-A	CH_6	3.40	1.01	3.95	-0.43	0.44
SD-X	CH_8	3.74	1.02	4.19	-0.44	0.47
CJE-A (FR)	CH_8	4.06	0.99	4.54	-0.46	0.50
CJE-X (FR)	CH_6	4.68	0.98	4.82	-0.41	0.53
CJE-A (MT)	CH_4	4.57	1.00	4.66	-0.40	0.52
CJE-X (MT)	CH_6	4.67	0.99	4.78	-0.42	0.53
CJW-A (FR)	CH_8	5.10	0.95	5.23	-0.42	0.55
CJW-X (FR)	CH_6	5.45	0.96	5.21	-0.37	0.56
CJW-A (MT)	CH_1	3.97	1.03	4.20	-0.40	0.48
CJW-X (MT)	CH_3	3.95	1.02	4.22	-0.41	0.48
		MEAN	1.01	4.74	-0.48	0.53
		SD	0.04	0.56	0.08	0.06

Table C-1: Summary of histogram regression data

CA					
CH_3			CH_5		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	5,709,572	5,693,343	0.50	6,941,887	6,946,798
1.00	2,425,372	2,354,272	1.00	2,278,048	2,245,993
1.50	670,942	740,062	1.50	520,897	554,635
2.00	240,364	244,409	2.00	148,661	147,759
2.50	95,163	87,843	2.50	46,795	43,848
3.00	40,153	34,231	3.00	16,163	14,377
3.50	17,827	14,321	3.50	6,194	5,139
4.00	8,154	6,370	4.00	2,437	1,978
4.50	3,703	2,988	4.50	1,040	811
5.00	1,714	1,467	5.00	444	352
5.50	820	750	5.50	223	160
6.00	391	397	6.00	98	76
6.50	171	217	6.50	46	37
7.00	85	122	7.00	22	19
7.50	38	71	7.50	12	10
8.00	19	42	8.00	2	5
8.50	4	25	8.50	3	3
9.00	5	15	9.00	3	2
9.50	2	10	9.50	2	1
10.00	0	6	10.00	0	1
N =	9,214,499	9,180,161	N =	9,962,977	9,962,004
MEAN =	0.79	0.77	MEAN =	0.71	0.68
VAR =	0.23	0.24	VAR =	0.14	0.16
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.44	scale, μ =		-0.54
shape, σ =		0.59	shape, σ =		0.55
1:10,000 S_R =		5.76	1:10,000 S_R =		4.51

Table C-2: Histogram data for CA HMLT

IA-N (MT)					
CH_9			CH_12		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	1,076,392	1,088,881	0.50	1,384,229	1,445,823
1.00	541,157	503,504	1.00	674,206	659,654
1.50	136,412	170,350	1.50	173,229	198,285
2.00	51,506	59,488	2.00	58,150	60,598
2.50	23,266	22,373	2.50	19,999	19,978
3.00	11,246	9,060	3.00	7,273	7,133
3.50	5,720	3,919	3.50	2,901	2,739
4.00	2,775	1,796	4.00	1,117	1,121
4.50	1,418	865	4.50	441	485
5.00	718	435	5.00	219	221
5.50	363	228	5.50	105	105
6.00	180	123	6.00	51	52
6.50	92	69	6.50	23	26
7.00	36	39	7.00	15	14
7.50	21	23	7.50	13	8
8.00	7	14	8.00	6	4
8.50	3	8	8.50	4	2
9.00	2	5	9.00	3	1
9.50	3	3	9.50	0	1
10.00	1	2	10.00	0	0
N =	1,851,318	1,861,185	N =	2,321,984	2,396,250
MEAN =	0.82	0.81	MEAN =	0.79	0.79
VAR =	0.27	0.28	VAR =	0.20	0.22
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.39	scale, μ =		-0.39
shape, σ =		0.59	shape, σ =		0.55
1:10,000 S_R =		6.17	1:10,000 S_R =		5.21

Table C-3: Histogram data for IA-N HMLT

IA-S					
CH_2 (A)			CH_1 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	1,242,007	1,378,793	0.50	1,737,889	1,974,418
1.00	413,028	279,344	1.00	526,030	335,782
1.50	48,405	44,326	1.50	49,762	43,341
2.00	8,727	8,000	2.00	7,446	6,449
2.50	2,052	1,681	2.50	1,403	1,136
3.00	621	404	3.00	290	232
3.50	195	109	3.50	86	54
4.00	84	32	4.00	21	14
4.50	22	10	4.50	4	4
5.00	5	4	5.00	4	1
5.50	2	1	5.50	0	0
6.00	0	1	6.00	0	0
6.50	0	0	6.50	0	0
7.00	0	0	7.00	0	0
7.50	0	0	7.50	0	0
8.00	0	0	8.00	0	0
N =	1,715,148	1,712,706	N =	2,322,935	2,361,431
MEAN =	0.66	0.58	MEAN =	0.64	0.56
VAR =	0.08	0.09	VAR =	0.07	0.08
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.67	scale, μ =		-0.69
shape, σ =		0.50	shape, σ =		0.47
1:10,000 S_R =		3.15	1:10,000 S_R =		2.70

Table C-4: Histogram data for IA-S HMLT

KS					
CH_2 (A)			CH_6 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	9,304,897	8,668,964	0.50	8,588,207	7,588,056
1.00	3,707,481	3,597,360	1.00	3,028,591	3,051,489
1.50	1,150,277	1,277,013	1.50	951,677	1,109,972
2.00	481,190	485,001	2.00	451,585	437,203
2.50	225,442	200,306	2.50	235,457	187,784
3.00	115,619	89,195	3.00	129,408	86,956
3.50	61,554	42,357	3.50	73,138	42,895
4.00	34,475	21,244	4.00	41,767	22,317
4.50	18,991	11,165	4.50	22,648	12,149
5.00	10,557	6,110	5.00	11,965	6,876
5.50	6,121	3,463	5.50	6,477	4,025
6.00	3,574	2,024	6.00	3,594	2,427
6.50	2,161	1,216	6.50	1,985	1,502
7.00	1,282	749	7.00	1,106	952
7.50	722	471	7.50	618	616
8.00	511	302	8.00	353	406
8.50	298	198	8.50	216	272
9.00	198	131	9.00	125	185
9.50	146	89	9.50	68	128
10.00	80	61	10.00	46	90
10.50	52	42	10.50	31	64
11.00	34	29	11.00	7	46
11.50	31	21	11.50	8	33
12.00	24	15	12.00	3	24
12.50	11	11	12.50	3	18
13.00	2	8	13.00	2	13
13.50	4	6	13.50	1	10
14.00	0	4	14.00	0	8
14.50	3	3	14.50	1	6
15.00	1	2	15.00	0	4
N =	15,125,738	14,407,558	N =	13,549,087	12,556,526
MEAN =	0.83	0.78	MEAN =	0.83	0.77
VAR =	0.34	0.33	VAR =	0.39	0.35

LOGNORMAL PARAMETERS		LOGNORMAL PARAMETERS	
scale, μ =	-0.46	scale, μ =	-0.49
shape, σ =	0.65	shape, σ =	0.68
1:10,000 S_R =	7.17	1:10,000 S_R =	7.73

Table C-5: Histogram data for KS HMLT

ND					
CH_1 (A)			CH_5 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	6,892,012	7,486,010	0.50	7,049,652	7,834,863
1.00	2,356,556	2,185,377	1.00	3,010,680	2,790,452
1.50	279,754	406,895	1.50	535,481	599,378
2.00	47,859	80,302	2.00	90,322	132,481
2.50	11,029	17,836	2.50	19,187	32,348
3.00	3,287	4,448	3.00	5,023	8,755
3.50	1,044	1,229	3.50	1,555	2,601
4.00	404	371	4.00	674	838
4.50	162	121	4.50	374	290
5.00	63	42	5.00	180	107
5.50	21	16	5.50	112	42
6.00	8	6	6.00	79	17
6.50	3	3	6.50	47	7
7.00	2	1	7.00	15	3
7.50	0	0	7.50	4	1
8.00	1	0	8.00	0	1
8.50	0	0	8.50	0	0
9.00	0	0	9.00	0	0
9.50	0	0	9.50	0	0
10.00	0	0	10.00	0	0
N =	9,592,205	10,182,658	N =	10,713,385	11,402,184
MEAN =	0.66	0.66	MEAN =	0.71	0.71
VAR =	0.08	0.12	VAR =	0.11	0.14
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.53	scale, μ =		-0.46
shape, σ =		0.48	shape, σ =		0.49
1:10,000 S_R =		3.54	1:10,000 S_R =		3.87

Table C-6: Histogram data for ND HMLT

OK-NE					
CH_3 (A)			CH_5 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	3,588,444	3,772,603	0.50	4,180,501	4,470,905
1.00	1,540,060	1,498,432	1.00	1,703,737	1,644,162
1.50	333,963	391,568	1.50	343,375	388,409
2.00	88,453	105,532	2.00	69,156	95,041
2.50	29,793	31,088	2.50	22,710	25,607
3.00	11,365	10,025	3.00	7,693	7,607
3.50	4,282	3,508	3.50	2,638	2,467
4.00	1,650	1,318	4.00	957	864
4.50	688	527	4.50	367	323
5.00	301	222	5.00	152	128
5.50	135	99	5.50	79	54
6.00	51	46	6.00	24	23
6.50	19	22	6.50	16	11
7.00	11	11	7.00	9	5
7.50	5	6	7.50	2	2
8.00	4	3	8.00	3	1
8.50	1	2	8.50	0	1
9.00	2	1	9.00	0	0
9.50	0	0	9.50	1	0
10.00	1	0	10.00	1	0
N =	5,599,228	5,815,012	N =	6,331,421	6,635,610
MEAN =	0.74	0.74	MEAN =	0.72	0.72
VAR =	0.16	0.18	VAR =	0.13	0.15
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.44	scale, μ =		-0.46
shape, σ =		0.53	shape, σ =		0.51
1:10,000 S_R =		4.58	1:10,000 S_R =		4.19

Table C-7: Histogram data for OK-NE HMLT

OK-SW					
CH_8 (A)			CH_6 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	6,453,571	6,822,178	0.50	11,172,707	11,686,171
1.00	2,728,795	2,650,316	1.00	4,681,966	4,475,379
1.50	569,287	671,749	1.50	1,041,721	1,166,600
2.00	157,688	175,776	2.00	258,342	316,519
2.50	46,288	50,381	2.50	61,529	94,178
3.00	14,075	15,841	3.00	18,070	30,716
3.50	5,541	5,414	3.50	6,749	10,874
4.00	2,368	1,990	4.00	2,628	4,134
4.50	1,155	780	4.50	1,177	1,672
5.00	513	323	5.00	498	714
5.50	248	140	5.50	233	320
6.00	124	64	6.00	145	149
6.50	57	30	6.50	81	72
7.00	28	15	7.00	42	36
7.50	12	7	7.50	30	19
8.00	5	4	8.00	14	10
8.50	1	2	8.50	12	5
9.00	3	1	9.00	8	3
9.50	4	1	9.50	10	2
10.00	0	0	10.00	4	1
10.50	1	0	10.50	4	1
11.00	0	0	11.00	0	0
11.50	0	0	11.50	3	0
12.00	0	0	12.00	0	0
N =	9,979,764	10,395,012	N =	17,245,973	17,787,576
MEAN =	0.73	0.73	MEAN =	0.73	0.73
VAR =	0.15	0.17	VAR =	0.14	0.18
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.45	scale, μ =		-0.46
shape, σ =		0.52	shape, σ =		0.53
1:10,000 S_R =		4.45	1:10,000 S_R =		4.61

Table C-8: Histogram data for OK-SW HMLT

PA					
CH_6 (A)			CH_1 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	353,553	356,125	0.50	608,287	607,784
1.00	38,713	37,022	1.00	56,817	56,950
1.50	2,001	3,024	1.50	4,085	4,238
2.00	171	301	2.00	497	390
2.50	23	37	2.50	71	45
3.00	7	6	3.00	5	6
3.50	6	1	3.50	1	1
4.00	0	0	4.00	1	0
4.50	0	0	4.50	1	0
5.00	0	0	5.00	0	0
N =	394,474	396,516	N =	669,765	669,414
MEAN =	0.56	0.51	MEAN =	0.55	0.50
VAR =	0.03	0.05	VAR =	0.03	0.05
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, $\mu =$		-0.77	scale, $\mu =$		-0.79
shape, $\sigma =$		0.43	shape, $\sigma =$		0.43
1:10,000 $S_R =$		2.32	1:10,000 $S_R =$		2.23

Table C-9: Histogram data for PA HMLT

SD					
CH_6 (A)			CH_8 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	12,140,254	14,312,237	0.50	13,059,585	15,065,526
1.00	5,969,213	5,313,489	1.00	6,480,006	5,650,686
1.50	668,263	965,906	1.50	785,478	1,175,699
2.00	139,248	174,102	2.00	193,212	247,092
2.50	38,507	34,558	2.50	70,015	57,105
3.00	11,132	7,650	3.00	24,067	14,624
3.50	3,365	1,875	3.50	7,621	4,116
4.00	1,065	503	4.00	2,242	1,260
4.50	382	146	4.50	713	415
5.00	128	46	5.00	254	146
5.50	51	15	5.50	95	54
6.00	15	5	6.00	32	21
6.50	5	2	6.50	33	9
7.00	4	1	7.00	19	4
7.50	0	0	7.50	15	2
8.00	1	0	8.00	10	1
8.50	0	0	8.50	16	0
9.00	0	0	9.00	11	0
9.50	0	0	9.50	4	0
10.00	0	0	10.00	13	0
10.50	0	0	10.50	10	0
11.00	0	0	11.00	0	0
N =	18,971,633	20,810,538	N =	20,623,451	22,216,759
MEAN =	0.71	0.72	MEAN =	0.72	0.72
VAR =	0.10	0.11	VAR =	0.12	0.13
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.43	scale, μ =		-0.44
shape, σ =		0.45	shape, σ =		0.47
1:10,000 S_R =		3.40	1:10,000 S_R =		3.74

Table C-10: Histogram data for SD HMLT

WY-CJE (FR)					
CH_8 (A)			CH_6 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	11,849,383	12,723,654	0.50	17,537,265	18,961,046
1.00	4,828,050	4,627,947	1.00	8,622,158	7,998,910
1.50	854,983	1,055,066	1.50	1,897,431	2,160,400
2.00	168,980	248,468	2.00	516,232	595,448
2.50	46,904	64,503	2.50	140,571	178,381
3.00	17,127	18,498	3.00	39,303	58,299
3.50	6,920	5,803	3.50	12,832	20,623
4.00	3,230	1,969	4.00	5,721	7,822
4.50	1,549	716	4.50	2,805	3,153
5.00	779	276	5.00	1,507	1,341
5.50	454	112	5.50	814	597
6.00	235	48	6.00	460	278
6.50	111	21	6.50	192	134
7.00	73	10	7.00	114	67
7.50	34	5	7.50	69	34
8.00	21	2	8.00	34	18
8.50	4	1	8.50	13	10
9.00	3	1	9.00	5	5
9.50	1	0	9.50	2	3
10.00	3	0	10.00	2	2
10.50	0	0	10.50	0	1
11.00	1	0	11.00	0	1
11.50	0	0	11.50	0	0
12.00	0	0	12.00	0	0
N =	17,778,845	18,747,100	N =	28,777,530	29,986,573
MEAN =	0.71	0.71	MEAN =	0.76	0.76
VAR =	0.12	0.15	VAR =	0.15	0.18
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.46	scale, μ =		-0.41
shape, σ =		0.50	shape, σ =		0.53
1:10,000 S_R =			4.06		
1:10,000 S_R =			4.68		

Table C-11: Histogram data for WY-CJE HMLT - no strokes

WY-CJE (MT)					
CH_4 (A)			CH_6 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	2,728,506	3,000,090	0.50	3,700,862	3,959,577
1.00	1,415,012	1,294,493	1.00	1,748,643	1,654,735
1.50	293,983	344,143	1.50	389,196	445,588
2.00	75,554	92,585	2.00	103,993	122,690
2.50	22,660	27,019	2.50	31,366	36,750
3.00	7,874	8,602	3.00	10,995	12,015
3.50	3,098	2,966	3.50	4,215	4,253
4.00	1,437	1,098	4.00	1,798	1,614
4.50	543	432	4.50	753	651
5.00	265	180	5.00	373	277
5.50	145	78	5.50	157	124
6.00	65	36	6.00	66	57
6.50	31	17	6.50	32	28
7.00	15	8	7.00	11	14
7.50	11	4	7.50	4	7
8.00	5	2	8.00	2	4
8.50	4	1	8.50	1	2
9.00	0	1	9.00	1	1
9.50	1	0	9.50	1	1
10.00	1	0	10.00	0	0
N =	4,549,210	4,771,755	N =	5,992,470	6,238,388
MEAN =	0.76	0.76	MEAN =	0.76	0.76
VAR =	0.16	0.18	VAR =	0.16	0.18
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.40	scale, μ =		-0.42
shape, σ =		0.52	shape, σ =		0.53
1:10,000 S_R =		4.57	1:10,000 S_R =		4.67

Table C-12: Histogram data for WY-CJE HMLT - mitigated

WY-CJW (FR)					
CH_8 (A)			CH_6 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS X_j	COUNT O_j	COUNT E_j	BINS X_j	COUNT O_j	COUNT E_j
0.50	13,386,927	14,708,363	0.50	15,198,811	16,768,463
1.00	7,689,332	6,275,463	1.00	9,326,427	7,933,380
1.50	1,493,498	1,826,709	1.50	2,222,138	2,489,956
2.00	314,752	547,424	2.00	623,350	792,399
2.50	87,468	178,076	2.50	168,522	271,094
3.00	31,189	62,961	3.00	49,419	100,126
3.50	13,272	23,994	3.50	18,038	39,660
4.00	6,580	9,763	4.00	8,697	16,709
4.50	3,346	4,207	4.50	4,572	7,430
5.00	1,775	1,905	5.00	2,807	3,465
5.50	1,066	902	5.50	1,776	1,685
6.00	635	444	6.00	1,182	850
6.50	324	226	6.50	729	443
7.00	213	119	7.00	484	238
7.50	105	64	7.50	407	132
8.00	68	36	8.00	282	74
8.50	44	20	8.50	187	43
9.00	40	12	9.00	86	25
9.50	34	7	9.50	70	15
10.00	27	4	10.00	84	9
10.50	29	3	10.50	55	6
11.00	22	2	11.00	59	4
11.50	8	1	11.50	43	2
12.00	2	1	12.00	28	2
12.50	2	0	12.50	11	1
13.00	0	0	13.00	7	1
N =	23,030,758	23,640,706	N =	27,628,271	28,426,213
MEAN =	0.77	0.77	MEAN =	0.81	0.81
VAR =	0.15	0.21	VAR =	0.18	0.24
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.42	scale, μ =		-0.37
shape, σ =		0.55	shape, σ =		0.56
1:10,000 S_R = 5.10			1:10,000 S_R = 5.45		

Table C-13: Histogram data for WY-CJW HMLT - no strakes

WY-CJW (MT)					
CH_1 (A)			CH_3 (X)		
OBS. HISTOGRAM		LOGNORM EST.	OBS. HISTOGRAM		LOGNORM EST.
BINS	COUNT	COUNT	BINS	COUNT	COUNT
X_j	O_j	E_j	X_j	O_j	E_j
0.50	749,499	862,795	0.50	803,662	922,177
1.00	405,194	367,339	1.00	423,119	381,903
1.50	69,568	84,015	1.50	69,531	86,430
2.00	16,152	19,057	2.00	16,416	19,508
2.50	4,689	4,697	2.50	5,006	4,797
3.00	1,731	1,272	3.00	1,620	1,298
3.50	737	376	3.50	703	384
4.00	282	120	4.00	281	123
4.50	128	41	4.50	111	42
5.00	41	15	5.00	38	15
5.50	15	6	5.50	21	6
6.00	9	2	6.00	12	2
6.50	4	1	6.50	6	1
7.00	3	0	7.00	1	0
7.50	1	0	7.50	1	0
8.00	0	0	8.00	0	0
8.50	0	0	8.50	0	0
9.00	0	0	9.00	0	0
9.50	0	0	9.50	0	0
10.00	0	0	10.00	0	0
N =	1,248,053	1,339,739	N =	1,320,528	1,416,688
MEAN =	0.75	0.75	MEAN =	0.75	0.75
VAR =	0.14	0.15	VAR =	0.13	0.14
LOGNORMAL PARAMETERS			LOGNORMAL PARAMETERS		
scale, μ =		-0.40	scale, μ =		-0.41
shape, σ =		0.48	shape, σ =		0.48
1:10,000 S_R =		3.97	1:10,000 S_R =		3.95

Table C-14: Histogram data for WY-CJW HMLT- mitigated