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INL Snow Load Methodology White Paper

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Modified approach to DOE-STD-1020-2016

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1. Purpose

The purpose of this paper is to provide clarification for applying winter precipitation requirements and guidance as provided in Department of Energy Standard (DOE-STD)-1020-2016 and Nuclear Regulatory Commission (NRC) NUREG-0800. Two snow load methodologies are presented, with selection of the preferred approach for use at Idaho National Laboratory (INL).

2. Application of DOE-STD-1020-2016

DOE-STD-1020-2016, Section 7.4.2, reads:

"For winter precipitation loads, the NRC criteria in NUREG-0800, Section 2.3.1, Regional Climatology (Revision 3), shall be used to determine the extreme structural loads for PDC-3, PDC-4, and PDC-5 SSCs. The NRC criteria state that the extreme winter precipitation loads are based on the weight of the 100-year snowpack at ground level, plus the weight of the 48-hour probable maximum winter precipitation at ground level for the month corresponding to the selected snowpack. Depending on the location of the site, the 48-hour maximum event may not necessarily be in the form of frozen precipitation."

Note that Table 7-2 below (taken from DOE-STD-1020-2016, Section 7.4.2) applies when evaluating structures for the effects of loads resulting from precipitation.

Table 7-2: Return Period (Years) for Design Basis Precipitation Structural Loads

SSC Category	PDC-1	PDC-2	PDC-3	PDC-4	PDC-5
Return Period (Years)	100	200	2,500	6,250	*

*Extreme precipitation flooding and structural loads are not evaluated.

Thus, according to DOE-STD-1020-2016, Section 7.4.2, the extreme precipitation loading (weight of snow and ice on the roofs of safety-related structures) for precipitation design category (PDC)-3 through 5, is the sum of 100-year snow load and the 48-hour probable maximum winter precipitation (PMWP). Note, PMWP is a methodology used for nuclear power plants that is not graded by recurrence interval like Table 7-2. Therefore, applying the PMWP means that all PDC-3 through PDC-5 facilities would have the same extreme winter precipitation load; this appears to conflict with Section 7.5.4, "Precipitation-Related Hazard Design Criteria," which directs use of the graded approach in Table 7-2. Since PDC-3, -4, and -5 facilities do not pose the same risk to the public and/or environment, DOE normally allows for a graded approach for increasing risk. In short, the NRC NUREG-0800 method does not provide a graded-approach for the return-period as with DOE-STD-1020-2016, Table 7-2 and compliance with both is problematic. The INL suggests a graded approach using the standard as described in Section 4, "Methodology," of this document.

3. Application of NRC NUREG-0800

NRC NUREG-0800 leads INL to use Hydrometeorological Report (HMR)-57 for the 48-hour PMWP methodology. The underlying data used to determine the PMWP from HMR-57 leads to under-estimation of extreme snow events. The PMWP calculated from HMR-57 should be a bounding, maximum possible event; however, from the Method 1 and Method 2 calculation tables (see below), the PMWP, for INL, is exceeded for recurrence intervals much shorter than those contemplated for commercial nuclear power plants.

4. Methodology

4.1 Clarification of DOE-STD-1020-2016

It is suggested to use one of the following two modified approaches. Method 1 uses the probabilistic precipitation values for PDC-1 and PDC-2. Then, for PDC-3 and PDC-4, the values are calculated from adding the 100-year snow load and the 48-hour PMWP. Method 2 also uses the probabilistic precipitation values for PDC-1 and PDC-2. However, the second method differs for PDC-3 and PDC-4 by using the total load as calculated from the 100-year snow load plus the annual exceedance probability (AEP) snow load at each PDC. Each of these methods are described below. As noted in DOE-STD-1020-2016, Table 7-2, extreme precipitation flooding and structural loads are not evaluated for PDC-5.

An extreme precipitation hazard analysis was performed and documented in the "INL Site-Wide Extreme Precipitation Analysis Technical Report," herein referred to as the DTN Report. This report provides a modern precipitation frequency analysis with L-Moment statistics and stochastic storm transposition.

For Method 1, the extreme precipitation values for PDC-1 and PDC-2 are obtained from the snow load mean-frequency curve from the DTN Report, Section 10.3, Table 30. The values for PDC-3 and PDC-4 are calculated by adding the 100-year snow load (mean-frequency curve value for PDC-1 from DTN Report, Section 10.3, Table 30) and the 48-hour PMWP from the DTN Report, Section 10.5. According to the report, the PMWP was been calculated to be between 40 to 46 lbs/ft^2. Method 1 incorporates the low-end value (40 lbs/ft^2) as part of the PDC-3 calculation and the high-end value (46 lbs/ft^2) as part of the PDC-4 calculation. The 40 to 46 lbs/ft^2 range of the PMWP was used to grade the approach consistent with the intent of DOE-STD-1020-2016. This range was used in the Method 1 table (below) for PDC-3 and PDC-4. Mean values from Table 30 were used.

Table 1: Method 1 Snow Pack values

PDC-1	
100 yr Snow	28.2 lbs/ft^2
PDC-2	
200 yr Snow	32.6 lbs/ft^2
PDC-3	
48-hr PMWP (low)	40 lbs/ft^2
100-yr Snow	28.2 lbs/ft^2
Total	68.2 lbs/ft^2
PDC-4	
48-hr PMWP (hi)	46 lbs/ft^2
100-yr Snow	28.2 lbs/ft^2
Total	74.2 lbs/ft^2

For Method 2, the extreme precipitation loading values for PDC-1 and PDC-2 are taken from the respective snow loads (mean-frequency curve values from DTN Report, Section 10.3, Table 30). For the overall PDC-3 and PDC-4, the extreme precipitation loading values are calculated by adding the 100-year snow load (taken from the mean-frequency curve value for PDC-1 from the DTN Report, Section 10.3, Table 30) and the DTN AEP snow load for 2,500 years and 6,250 years.

Table 30: Ground snow load quantile estimates for the location of the Idaho Falls 46W station.

Ground Snow Load (lbs/ft^2) for Location of the Idaho Falls 46W Station									
AEPs	1:50	PDC 1 1:100	PDC 2 1:200	1:500	1:1,000	1:1,250	PDC 3 1:2,500	1:5,000	PDC 4 1:6,250
Mean-Frequency Curve	24.0	28.2	32.6	38.9	44.0	45.6	51.1	56.8	58.7
Median-Frequency Curve	22.3	26.0	29.8	35.1	39.2	40.6	44.9	49.3	50.8

Table 2: Method 2 Snow Pack values

PDC-1		Percent Difference Between Method 1 and Method 2
100 yr Snow	28.2 lbs/ft^2	0%
PDC-2		
200 yr Snow	32.6 lbs/ft^2	0%
PDC-3		
48-hr PMWP (low)	40 lbs/ft^2	
100-yr Snow	28.2 lbs/ft^2	
Total	68.2 lbs/ft^2	+14%
PDC-4		
48-hr PMWP (hi)	46 lbs/ft^2	
100-yr Snow	28.2 lbs/ft^2	
Total	74.2 lbs/ft^2	+15%

These two methods each apply varying levels of risk based on the PDC and both use extreme precipitation analysis results that were specifically calculated for the INL Site. Applying a risk-based approach and using site-specific criteria for the INL provides existing facilities and new infrastructure projects with realistic design criteria with a low likelihood of exceedance.

To contrast Method 1 and Method 2, the Probable Maximum Precipitation (PMP) methodology is decades old and should be supplanted by the DTN precipitation-frequency analysis. The DTN snow loads calculated are greater than the probable maximum snow load. Separately, the statistics of the sequence of any PDC being preceded by the 100-year snow fall is not known and is treated the same in both Methods, which is the sum of both events. Application of the DTN precipitation-frequency values for PDC 1 through 4 would be conservative and preferable.

4.2 Application of the NRC Prescribed Methodology

NRC NUREG-0800 and subsequent use of HMR-57 are applicable to the INL. The PMP using HMR-57 shows that its underlying data leads to under-estimation of extreme snow events. The PMP from HMR-57 should be a bounding, maximum possible event; however, from the DTN analysis, it is exceeded for recurrence intervals much shorter than those contemplated for commercial nuclear power plants. Consistent with industry experience, the PMP HMR's are subject to over or under estimation of the hazard, and in INL's case, the PMP is an under-estimation. INL subcontractor DTN utilized current methodologies and the resulting probabilistic method should be favored over the HMR PMP because it applies contemporary science, includes a larger weather data set, and is more defensible.

5. Conclusions and Recommendations

Method 1 clarifies what is outlined in DOE-STD-1020-2016, Section 7.4.2, for calculating extreme winter precipitation loads. Method 1 meets the intent of DOE-STD-1020-2016 by providing results for all PDCs using the mean-frequency curve values for PDC-1 and PDC-2. Method 1, also supports higher risk for PDC-3 and PDC-4, by using the 100-year snow load (mean-frequency curve value for PDC-1) and respectively adds the low and high values for the 48-hour probable maximum ground snow load. The likelihood of the 100-year snow load and the 48-hour probable maximum ground snow load occurring in the same year or as back-to-back storms is extremely low and the risk is especially low for PDC-1 and PDC-2 facilities. Therefore, Method 1 provides compliant loads that are tailored specifically for the INL but are less desirable when compared with Method 2.

As shown in the calculations for Methods 1 and 2, Method 2 provides a slightly more conservative and accurate snow loads than Method 1 for PDC-3 and PDC-4. The Method 2 results are also based on modern precipitation-frequency analysis and is more accurate and desirable. Therefore, Method 2 is recommended for use at the INL PDC-1 through PDC-4 facilities.

6. References

DOE-STD-1020-2016, "Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities."

NRC NUREG-0800, March 2007, "U.S. Nuclear Regulatory Commission Standard Review Plan 2.3.1 Regional Climatology," Revision 3.

VDR-796825, DTN/MGS Technical Report September 2020, "INL Site-Wide Extreme Precipitation Analysis."

HMR-57, "Probable Maximum Precipitation - Pacific Northwest States. Columbia River (including portions of Canada), Snake River and Pacific Coastal Drainages," NOAA, 1994.