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To: Reliability Committee

From: System Design Task Force

Re: Ambient Temperatures and Wind Velocities for Thermal Rating Calculations in Planning Procedure No. 7

At the April 5, 2005 Reliability Committee meeting, a draft of ISO Planning Procedure No. 7 – Procedures for Determining and Implementing Transmission Facility Ratings in New England was presented for review and comment. This new planning procedure describes methodologies and procedures for:

1. The collaborative development of ratings for (a) transmission equipment connected at 69kV and above on the electric power system in New England and (b) all generator step up transformers attached to generators of 1 MW or greater that participate in the Energy Market; and
2. The provision for reviewing the ratings of individual transmission facilities prior to their permanent implementation by ISO New England (the "ISO").

During discussions of weather variables used to determining transmission equipment ratings, several RC members inquired whether using a single weather location for all of New England was appropriate and questioned how the weather data was developed. To answer these two questions, the SDTF with the assistance of Doug James, consultant to ISO New England, has prepared the attached report.

In summary, the effect of using Hartford area temperatures in calculating New England equipment ratings is nearly identical to the effect of using the average of the temperatures for the eight New England locations[1] for which such data is available today. Further, the available temperature data does not indicate a need for, not does it provide a basis for, dividing New England into ambient temperature zones for determining equipment ratings.

[1] The eight New England weather collection locations are: Boston, MA; Bridgeport, CT; Burlington, VT; Concord, NH; Portland, ME; Providence, RI; Windsor Locks (Hartford Area), CT; and Worcester, MA.

Ambient Temperatures and Wind Velocities
For Thermal Rating Calculations

Transmission equipment thermal (current carrying) ratings are calculated based on estimates and approximations of environmental conditions, the most influential being ambient temperature and, where applicable, wind velocity. Historically, the approach used in New England, as elsewhere, has been to determine a set of “benchmark” environmental conditions and to quantify other factors such as maximum allowable equipment temperatures, clearance limitations, annealing and loss of both physical and insulation strength and cycling of equipment loadings. These are combined to calculate seasonal ratings for the different types of equipment. These factors, including the “benchmark” ambient temperatures and wind velocities, were initially established in 1971 with NEPOOL’s adoption of the Capacity Ratings Procedures. Three equipment types were recognized: 1) Overhead Conductors, 2) Power and Current Transformers and 3) All Other Line Terminal Equipment. The current “benchmark” ambient temperatures and wind velocities, as adopted by NEPOOL, are provided in Table 1 of Appendix A of Planning Procedure 7, Procedures for Determining and Implementing Transmission Facility Ratings in New England (PP-7) [Reference 1]. These “benchmark” values and their derivations are described below, where Table 1 of Appendix A has been separated into three tables, 1a, 1b and 1c for convenience of discussion:

I. Overhead Conductors

<u>“Benchmark” Values</u>

Table 1a

	Ambient Temperature		Wind Velocity
	Normal	Emergency	
Summer	38 °C (100 °F)	38 °C (100 °F)	3 fps
Winter	10 °C (50 °F)	10 °C (50 °F)	3 fps

<u>Wind Velocity and Summer Ambient Temperatures</u>

The initial release of the Capacity Rating Procedures cited summer ambient temperatures of 100 °F (38 °C) and a summer wind velocity 2 fps. This was consistent with the recommendations of Section 125.23 of Chapter 220 of the Code of Massachusetts Regulations, Installation and Maintenance of Transmission Lines (220 CMR 125.23) [Reference 2] which, in addressing vertical clearances of wires above ground, rails or water, states “In computing conductor temperature, an ambient air temperature of 100°F and a transverse wind of two feet per second should be used.” (Note: Section 125.10 states that when a rule is of an advisory nature, the word “should” is used; mandatory rules use the word “shall”.)

In 1978, under direction of the NEPOOL Planning Committee, the Conductor Rating Working Group (CRWG) of the System Design Task Force (SDTF) completed an investigation of summer weather conditions affecting overhead conductor ratings. Specifically, the coincidence of low velocity wind values with high ambient air temperatures was researched with particular regard to whether the design guidelines of 220 CMR 125.23 were realistic or valid. A direct correlation between wind velocity and ambient temperature was observed. The major conclusion was that, with an ambient air temperature of 100°F, the “wind velocity of two feet per second used to calculate ampacity ratings of overhead transmission lines should be raised to at least three feet per second." The working group's December 1978 report, An Analysis of Wind Temperature Data and Their Effect of Current Carrying Capacity On Overhead Conductors (SDTF-19) [Reference 3] was the basis for an August 22, 1979 CRWG meeting with the Chief Engineer of the Massachusetts DPU and a representative of the New England Conference of Public Utilities Commissioners. CRWG Chairman R. Haskins summarized the meeting in a September 7, 1979 letter to the SDTF chairman, R. Duncan [Reference 4], indicating the DPU Chief Engineer agreed that Massachusetts utilities would be justified in changing the wind speed used from two to three feet per second. A September 27, 1979 letter [Reference 5] was sent to the Massachusetts DPU informing them, on behalf of the NEPOOL companies operating in Massachusetts, "…our engineering judgment dictates that a 3 feet per second wind velocity be used for summer ratings." This letter also mentioned that winter weather data was being analyzed to determine if changes should be implemented during that period.

While this second analysis focused initially on only the winter period, it was soon expanded to consider the entire year since a different analysis technique was introduced. In their August 1983 report, An Analysis of Wind Temperature Data and Their Effect On Current Carrying Capacity of Overhead Conductors (SDTF-20) [Reference 6], which superseded their earlier report by the same title, the CRWG concluded, "…all factors considered, 3 feet per second appears to be a reasonable wind velocity assumption for the rating of transmission lines in New England on a year-round basis." The Capacity Rating Procedures were revised accordingly in August 1984.

Winter Ambient Temperatures

The winter ambient temperatures used in determining overhead conductor ratings, 50°F/10°C, are the same as for All Other Line Terminal Equipment, discussed in Section III, below.

II. Power and Current Transformers

"Benchmark" Values

Table 1b

	Ambient Temperature		Wind Velocity
	Normal	Emergency	
Summer	25 °C (77°F)	32 °C (90°F)	N/A
Winter	5°C (41°F)	10 °C (50 °F)	N/A

Ambient Temperature

Section 6 of the IEEE Guide for Loading Mineral-Oil-Immersed Transformers (C57.91) [Reference 7] recommends using approximated ambient temperatures from data "for the sections of the country where the transformer is located," and where "the ambient temperature seen by the transformer is the air in contact with its radiators or heat exchangers." In determining normal ratings, "average daily temperatures for the month involved, averaged over several years" should be used, while the "average of the maximum daily temperatures for [the] month involved" should be used in determining emergency ratings. Because aging at higher than average temperature is not fully compensated by decreased aging at lower than average temperature, the Guide also recommends the use of a 5°C adder to be conservative. It is further stated that, "With this margin the approximated 24 h average temperature will not be exceeded on more than a few days per month and, where it is exceeded, the additional loss of life will not be serious."

The "benchmark" ambient temperatures indicated in the above Table 1b are consistent with the recommendations for determining ambient temperatures set forth in C57.91 including the recommended 5°C adder. When the Table 1b temperatures were developed in 1971, ambient temperatures from Hartford, Connecticut area temperature statistics for the years 1905 to 1970 were compared to similar statistics of several other New England locations. It was concluded that the Hartford area data was representative of New England (see Section IV, below, for further discussion on this subject). A summary of this data is presented as Table 2 in Appendix A of PP-7 and is repeated below:

Table 2
(Also Table 2 of PP-7 Appendix A)
Hartford, CT Area Temperature Data
1905-1970

	Average of the Daily Maximums [1]		Average of the Monthly Maximums [2]		Daily Mean [3]	
	°F	ºC	°F	ºC	°F	ºC
January	35.1	1.7	54.0	12.2	27.2	-2.7
February	36.1	2.3	53.0	11.7	27.7	-2.4
March	45.5	7.5	66.1	18.9	36.9	2.7
April	58.0	14.4	79.0	26.1	48.0	9.0
May	69.6	20.9	86.9	30.5	58.6	14.8
June	78.3	24.6	92.0	33.3	67.8	19.9
July	83.2	28.4	94.0	34.4	70.8	21.6
August	82.5	28.1	91.0	32.8	70.8	21.6
September	77.1	25.1	87.0	30.6	62.2	16.8
October	63.9	17.7	81.0	27.2	51.1	10.6
November	50.5	10.3	66.0	18.9	42.0	5.5
December	38.0	3.3	57.0	13.9	30.4	-0.9

[1]This is the average of the daily maximum temperatures for each month.
[2] This is the average of the monthly maximum temperature over 65 years.
[3] This is the average of the daily maximum and minimum temperatures over the month.

Per C57.91, normal ambient temperatures are derived from the Daily Mean temperatures of the above Table 2, Column 3 and emergency ambient temperatures are derived from the Average of the Daily Maximum temperatures of Column 1.

However, because seasonal (rather than monthly) ratings are used in New England, weighted averages of temperatures appropriate to the summer and winter periods are used instead of monthly temperatures as suggested by C57.91. In determining summer and winter ratings, temperature data for the spring and fall transition months of April, May and October are not considered. Thus:

Winter temperatures are equally weighted over the 5-month period, November – March.
For Normal ratings (using the Daily Mean column, ºC):

(5.5-0.9-2.7-2.4+2.7)/5=0.44; add 5ºC = 5.44ºC; round to 5ºC as indicated in Table 1b.

For Emergency ratings (using the Average of the Daily Maximums column, ºC): (10.3+3.3+1.7+2.3+7.5)/5=5.02; add 5ºC = 10.02ºC; round to 10ºC as indicated in Table 1b.

Summer temperatures are determined by equal weighting of the temperatures for the four months of June through September (these are the months in which summer peak loads have occurred).

For Normal ratings (using the Daily Mean column, ºC): (19.9+21.6+21.6+16.8)/4=19.98; add 5ºC = 24.98ºC; round to 25ºC as indicated in Table 1b.

For Emergency ratings (using the Average of the Daily Maximums column, ºC): (24.6+28.4+28.1+25.1)/4=26.55; add 5ºC = 31.55ºC; round to 32ºC as indicated in Table 1b.

Independent, freestanding current transformers are similar in construction to distribution transformers and Section 6 of the IEEE Guide for Loading Mineral-Oil-Immersed Transformers (C57.91) [Reference 7] is applied. Thus the ambient temperatures are the same as for power transformers. Bushing current transformers are rated on a different basis as described in Appendix H of PP-7 [Reference 8].

Wind Velocity

Wind velocity is not a factor in power transformer or current transformer rating calculations.

III. Other Line Terminal Equipment

"Benchmark" Values

Table 1c

	Ambient Temperature		Wind Velocity*
	Normal	Emergency	
Summer	28°C (82°F)	28°C (82°F)	3 fps
Winter	10°C (50°F)	10°C (50°F)	3 fps

* wind velocity affects busses and interconnecting cables only

Ambient Temperature

Seasonal normal and emergency ratings of line terminal equipment other than transformers and current transformers are based on conservative weighted averages of daily maximum temperatures. Specifically, the average of the daily maximum ambient temperatures for the warmest month representative of the season are used. Again, temperature data for the spring and fall transition months of April, May and October are not considered. Thus, from Column 1 of Table 2, the July average daily maximum ambient temperature of 28°C (rounded from 28.4°C) is used for summer. Likewise, the November average daily maximum ambient temperature of 10°C (rounded from 10.3°C) is used for winter.

Wind Velocity

Wind velocity affects the rating calculations of bare, outdoor, non-enclosed busses and interconnecting cables in the same manner as overhead conductor calculations (indeed, the same algorithms are used). Therefore, the same wind velocity is used, based on the same references [References 3 and 6]. Rating calculations for other line terminal equipment are not influenced by wind.

IV. Reassessment of Ambient Temperatures Using Expanded Data Sample

As indicated above, the original "benchmark" ambient temperatures were developed in 1971 using Hartford, Connecticut area temperature statistics for the years 1905 to 1970. It was reported that, following comparisons to similar statistics for several other New England locations, it was concluded that the Hartford area data was representative of New England. Temperature data for the Hartford, Connecticut area and seven other locations throughout New England for the years 1975 – 2004 was recently acquired from the ISO System Planning Department and both the "benchmark" ambient temperature values and the appropriateness of using Hartford Area temperatures as being representative of all New England were reassessed.

Consistency of Hartford, CT Temperature Data, 1905-1970 vs. 1975-2004

Table 3 presents data for the period 1975-2004. As might be expected, it compares favorably with the 1905-1970 data of Table 2, above. The largest difference in the Average of the Daily Maximums is 1.6ºC (for September) with the average difference for the year being 0.1ºC. The Daily Mean differs by as much as 1.8ºC (for February) with the average difference for the year being 0.7ºC.

Table 3
Hartford, CT Area Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	33.6	0.9	53.9	12.2	26.3	-3.2
February	38.9	3.8	56.4	13.6	31.0	-0.6
March	47.1	8.4	69.1	20.6	38.1	3.4
April	59.1	15.1	82.8	28.2	49.2	9.6
May	69.9	21.0	88.8	31.5	59.3	15.2
June	78.6	25.9	92.7	33.7	68.4	20.2
July	82.6	28.1	92.2	33.5	72.6	22.5
August	82.1	27.8	93.8	34.3	72.4	22.4
September	74.4	23.5	86.4	30.2	64.6	18.1
October	61.6	16.4	78.6	25.9	51.7	11.0
November	50.5	10.3	68.6	20.3	42.3	5.7
December	40.3	4.6	61.3	16.3	32.9	0.5

[1] This is the average of the daily maximum temperatures for each month.
[2] This is the average of the monthly maximum temperature over 30 years.
[3] This is the average of the daily maximum and minimum temperatures over the month.

Further, there is no advantage in combining the data to create a larger sample, as there would be no practical impact on the benchmark ambient temperatures. This is illustrated in Table 4 below. Tables 1a, 1b and 1c have been combined (as in Table 1 of Appendix A of PP-7) and expanded to include recalculated ambient temperatures using the 25 years of data presented in Table 3. Only the ambient temperatures for transformers and current transformers differ (by but 1ºC). Thus, combining the data would result in "benchmark" ambient temperatures the same as those using the 1905-1970 data.

Table 4
Ambient Temperatures For Determining Equipment Ratings, °C
Comparing Results Using 1905-1970 vs. 1975-2004 Temperature Data For the Hartford, CT Area

	Overhead Conductors[1]				Transformers & CTs				Other Equipment			
	1905-1970		1975-2004		1905-1970		1975-2004		1905-1970		1975-2004	
	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer
W	10	10	10	10	5	10	**6**	**11**	10	10	10	10
S	-	-	-	-	25	32	**26**	**31**	28	28	28	28

[1] The summer ambient temperature for rating overhead conductors is 38°C/100°F in conformance with Massachusetts 220 CMR 125.23 [Reference 2] as described in Section I.

Representative Ambient Temperature for New England

The Hartford area temperature data for 1905-1970 that was used in establishing the original benchmark ambient temperatures appears in Table 2. However, the temperature data for other New England locations that was used to support the conclusion that the Hartford area data was representative of New England is no longer available. Instead, 1975-2004 temperature statistics provided by the ISO-NE System Planning Department for the following eight New England locations were analyzed:

- Boston, MA
- Bridgeport, CT
- Burlington, VT
- Concord, NH
- Portland, ME
- Providence, RI
- Windsor Locks (Hartford Area), CT
- Worcester, MA

This data, in the format of Tables 2 and 3, is found in Section VI of this report.

Both the favorable direct comparison of Hartford area data in Tables 2 (1905-1970 data) and 3 (1975-2004 data) and the consistency in result indicated in Table 4 suggest that the 1975-2004 data statistics can be applied to determine if the Hartford area temperatures are representative of New England.

Table 5, below, presents an equally weighted average of the temperature data for the above eight locations. Table 6 indicates the temperature differences found when the Table 5 (New England) values are subtracted from Table 3 (Hartford Area) values. The Hartford area Average of the Daily Maximum temperatures average about 1ºC warmer in the winter and 1 ½ ºC warmer in the summer while the difference in the Daily Mean temperatures is less than 1ºC both summer and winter. The effect of these differences is illustrated in Table 7 and supports the continued use of the 1905-1970 Hartford area ambient temperatures as being representative of all New England. Table 7 also supports the conclusion that the longstanding ambient temperature recommendations of Table 1 should remain unchanged.

Table 5
(Table 3 of PP-7 Appendix A)
New England Temperature Data (Eight Locations[4])
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	32.3	0.2	52.0	11.1	25.0	-3.9
February	36.9	2.7	54.8	12.7	29.2	-1.5
March	44.1	6.7	65.8	18.8	36.1	2.3
April	55.5	13.0	78.5	25.8	46.7	8.2
May	66.3	19.0	85.2	29.6	57.1	13.9
June	75.4	24.1	90.1	32.3	66.6	19.2
July	79.9	26.6	91.2	32.9	71.2	21.8
August	79.4	26.3	90.7	32.6	70.9	21.6
September	72.2	22.3	85.2	29.5	63.6	17.5
October	59.7	15.4	76.7	24.8	51.0	10.6
November	48.9	9.4	66.8	19.3	41.6	5.4
December	39.3	4.0	58.9	15.0	32.2	0.1

[1] This is the average of the daily maximum temperatures for each month.
[2] This is the average of the monthly maximum temperature over 30 years.
[3] This is the average of the daily maximum and minimum temperatures over the month.
[4] Based on eight New England locations of Hartford/Windsor Locks and Bridgeport in CT, Boston and Worcester in MA, Burlington VT, Providence RI, Concord NH and Portland ME.

Table 6
Temperature Data Difference: Hartford Area
Temperatures (Table 3) less New England Temperatures (Table 5)
1975-2004

	Average of the Daily Maximums		Average of the Monthly Maximums		Daily Mean	
	°F	ºC	°F	ºC	°F	ºC
January	1.3	0.7	1.9	1.1	1.3	0.7
February	2.0	1.1	1.6	1.0	1.8	0.9
March	3.0	1.7	3.3	1.8	2.0	1.1
April	3.7	2.1	4.3	2.4	2.6	1.4
May	3.6	2.0	3.6	1.9	2.2	1.3
June	3.2	1.8	2.6	1.5	1.9	1.0
July	2.7	1.5	1.0	0.6	1.4	0.7
August	2.7	1.5	3.1	1.7	1.5	0.8
September	2.3	1.2	1.2	0.7	1.0	0.6
October	2.0	1.0	2.0	1.1	0.7	0.4
November	1.6	0.9	1.8	1.0	0.7	0.4
December	1.0	0.6	2.4	1.3	0.7	0.4

Table 7
Ambient Temperatures For Determining Equipment Ratings, °C
Comparing Results of Hartford Area vs. Averaged Temperature Data for 8 Locations (1975-2004)[1]

	Overhead Conductors[2]				Transformers & CTs				Other Equipment			
	Hartford Area		8 Location Average		Hartford Area		8 Location Average		Hartford Area		8 Location Average	
	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer
W	10	10	**9**	**9**	**6**	**11**	**6**	10	10	10	**9**	**9**
S	-	-	-	-	**26**	**31**	25	**30**	28	28	**27**	**27**

[1] **Bold** font indicates a difference from the current ambient temperature values based on Hartford Area data for 1905-1970 and found in Tables 1a, 1b and 1c, above.
[2] The summer ambient temperature for rating overhead conductors is 38°C/100°F in conformance with Massachusetts 220 CMR 125.23 [Reference 2] as described in Section I.

<u>Using Common Ambient Temperatures and Wind Velocities In Establishing Ratings for All NE</u>

Since its initial adoption of the Capacity Rating Procedures, NEPOOL has encouraged using a common set of ambient temperatures and wind velocities for calculating equipment ratings. Only by applying uniform environmental assumptions as well as a common methodology, will the same equipment be consistently assigned the same rating. This is of particular interest with overhead lines having differing line section and/or terminal ownership. At the same time, the resulting ratings must also balance maximum transmission system capability with acceptable levels of risk to equipment and system reliability. This balance is managed in two ways:

- Ratings are calculated based on the “benchmark” environmental assumptions discussed in this report. Then, as real-time operating conditions warrant, more specific equipment ratings, calculated over a range of ambient temperatures and can be provided by the equipment owner, for activation by system operators.

- The “benchmark” assumptions, along with the methodologies appended to PP-7, are offered as a “best practice.” Where other assumptions or methodologies can be demonstrated to be justified in a particular area, situation or circumstance, such assumptions or methodologies may be acknowledged by the ISO as an accepted alternative rating practice and may influence future consideration of modifications to that “best practice”.

Table 7, above, indicates that the effect of using Hartford area temperatures in calculating New England equipment ratings is nearly identical to the effect of using the average of the temperatures for the eight New England locations for which such data is available. Similar comparisons can be made to determine how representative the currently recommended set of ambient temperatures assumptions is of those for the 8-location average and for each specific location. These comparisons are presented in Table 8, below. As might be expected, the temperature variations at the 8 locations give rise to differences from the current “benchmark” ambient temperature assumptions. A bold font is used to call attention to differences of two degrees Centigrade or more from those “benchmarks”.

Table 8
Ambient Temperatures For Determining Equipment Ratings, °C[1]
Comparing Results Using Current Representative New England Temperature Values[2],
Averaged Temperature Data for 8 Locations (1975-2004)[3],
And Temperature Data for the 8 Individual Locations (1975-2004)[4]

	Overhead Conductors				Transformers & CTs				Other Equipment			
	Summer[6]		Winter		Summer		Winter		Summer		Winter	
	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer	Nor	Emer
Current NE	38	38	10	10	25	32	5	10	28	28	10	10
8 Location Avg	-	-	9	9	25	30	6	10	27	27	9	9
Boston, MA	-	-	11	11	26	**30**	**7**	11	27	27	11	11
Bridgeport, CT	-	-	11	11	26	**30**	**8**	11	27	27	11	11
Burlington, VT	-	-	**7**	**7**	24	**30**	**3**	**7**	**26**	**26**	**7**	**7**
Concord, NH	-	-	9	9	24	**30**	4	9	27	27	9	9
Portland, ME	-	-	**8**	**8**	24	**28**	4	9	**25**	**25**	**8**	**8**
Providence, RI	-	-	11	11	26	**30**	**7**	**12**	**30**	27	11	11
Windsor L, CT[5]	-	-	10	10	26	31	6	11	28	28	10	10
Worcester, MA	-	-	**8**	**8**	25	**29**	5	9	**25**	**25**	**8**	**8**

[1] **Bold** font indicates a difference of 2 or more degrees C from the current ambient temperature values based on Hartford Area data for 1905-1970 and found in Tables 1a, 1b and 1c, above. **Bold Underlined** font indicates a difference of 3 and 4 degrees C.
[2] From Tables 1a, 1b and 1c
[3] From Table 7
[4] Determined as described in Sections 1, II and III using data from Tables A-1 through A
[5] Windsor Locks is the same location as Hartford Area
[6] The summer ambient temperature for rating overhead conductors is 38°C/100°F in conformance with Massachusetts 220 CMR 125.23 [Reference 2] as described in Section I.

It can be seen that the largest differences are for Burlington, VT, Portland, ME and Worcester, MA where ambient temperatures are consistently cooler than the average New England ambients (these locations account for 11 of the 12 temperature differences of 3 and 4 degrees). Because these three locations are not differentiated from the others by geography, a simple Northern New England/Southern New England division using two sets of representative ambient temperature assumptions is not appropriate (particularly since Concord, NH fits comfortably with the average temperature assumptions). Indeed, Table 8 does not provide a basis for dividing New England into ambient temperature zones for determining equipment ratings. Further, any alteration of the single ambient temperature/wind velocity combination presently in use must consider the high degree of correlation between these parameters as described in references 3 and 6. An option available in PP-7 allows equipment owners to evaluate the “best practice” environmental factors in light of their specific circumstances and to justify differences accordingly. This option provides sufficient flexibility to allow a balance of commonality of application, efficiency and risk.

It should also be noted that this single “benchmark” approach to ambient temperature/wind speed rating parameters is not unique to New England. New York and in PJM both use similar ambient temperatures and the readily available documentation indicates they are similarly applied. For example, both appear to use 10 ºC (winter) and 35 ºC (summer) for calculating overhead conductor ratings.

As an illustration of the effect of changes in ambient temperatures on overhead conductor ratings, summer and winter ratings were calculated for two typical conductors, one operating at 115 kV and one operating at 345 kV, with all other factors held constant at values appropriate for the season. Given the greatest temperature range in Table 8 above is 3 to 4 ºC, winter ratings were found to increase 1.9% and summer ratings increased about 3.7%, both with reduced ambient temperature.

V. References

1. Appendix A (General Rating Parameters) of ISO New England Planning Procedure No. 7, “Procedures for Determining and Implementing Transmission Facility Ratings in New England” (PP-7).

2. Section 125.23 of Chapter 220 of the Code of Massachusetts Regulations, “Installation and Maintenance of Transmission Lines” (220 CMR 125.23).

3. “An Analysis of Wind Temperature Data and Their Effect of Current Carrying Capacity On Overhead Conductors” (SDTF-19), December 29, 1978, by the Conductor Rating Working Group of the NEPOOL System Design Task Force.

4. September 7, 1979 letter from R. E. Haskins, Conductor Rating Working Group Chairman, to R. O. Duncan, System Design Task Force Chairman.

5. September 27, 1979 letter from J. R. Smith, NEPLAN Director, to William White, Chief Engineer, Massachusetts Department of Public Utilities.

6. “An Analysis of Wind Temperature Data and Their Effect On Current Carrying Capacity of Overhead Conductors” (SDTF-20), August 1983, by the Conductor Rating Working Group of the NEPOOL System Design Task Force.

7. ANSI/IEEE C57.91-1995, “IEEE Guide for Loading Mineral-Oil-Immersed Transformers”

8. Appendix H (Current Transformers) of ISO New England Planning Procedure No. 7, Procedures for Determining and Implementing Transmission Facility Ratings in New England (PP-7).

VI. Appendix

Table A-1
Boston, MA Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	35.4	1.9	55.3	12.9	28.9	-1.7
February	38.1	3.4	56.3	13.5	31.4	-0.3
March	45.3	7.4	66.9	19.4	38.6	3.6
April	55.2	12.9	78.5	25.8	48.2	9.0
May	65.8	18.8	87.0	30.6	58.3	14.6
June	75.4	24.1	91.6	33.1	67.7	19.9
July	80.8	27.1	94.8	34.9	73.5	23.1
August	79.0	26.1	92.3	33.5	72.2	22.3
September	71.6	22.0	86.9	30.5	64.6	18.1
October	60.8	16.0	78.0	25.6	53.9	12.2
November	51.2	10.7	69.6	20.9	44.8	7.1
December	40.9	4.9	60.7	16.0	34.5	1.4

Table A-2
Bridgeport, CT Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	36.2	2.3	53.8	12.1	30.0	-1.1
February	40.1	4.5	56.2	13.5	33.7	1.0
March	46.2	7.9	65.3	18.5	39.2	4.0
April	56.3	13.5	75.0	23.9	48.9	9.4
May	66.1	18.9	83.8	28.8	58.6	14.8
June	75.5	24.2	88.8	31.5	68.4	20.2
July	80.3	26.8	91.6	33.1	73.3	22.9
August	79.8	26.5	90.1	32.3	73.5	23.0
September	73.6	23.1	83.0	28.3	66.7	19.3
October	62.2	16.8	77.3	25.2	54.7	12.6
November	52.2	11.2	66.2	19.0	45.4	7.4
December	42.8	6.0	59.8	15.4	36.6	2.5

Table A-3
Burlington, VT Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	26.0	-3.3	48.6	9.2	18.5	-7.5
February	31.3	-0.4	51.8	11.0	23.0	-5.0
March	39.6	4.2	64.3	18.0	31.5	-0.3
April	53.0	11.6	77.4	25.2	43.8	6.6
May	66.7	19.3	83.4	28.6	56.9	13.8
June	75.7	24.3	89.9	32.2	66.2	19.0
July	79.1	26.1	89.7	32.0	69.8	21.0
August	78.8	26.0	89.6	32.0	69.4	20.8
September	71.2	21.8	86.2	30.1	62.0	16.6
October	56.6	13.7	74.9	23.8	48.2	9.0
November	44.6	7.0	65.1	18.4	38.2	3.5
December	34.2	1.2	54.4	12.5	27.5	-2.5

Table A-4
Concord, NH Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	29.7	-1.3	48.7	9.3	20.9	-6.1
February	35.4	1.9	54.6	12.5	26.0	-3.3
March	43.2	6.2	66.2	19.0	33.5	0.8
April	56.1	13.4	81.6	27.5	44.9	7.2
May	67.4	19.7	87.8	31.0	55.6	13.1
June	76.6	24.8	90.8	32.7	65.5	18.6
July	80.6	27.0	90.9	32.7	69.6	20.9
August	80.8	27.1	91.4	33.0	69.6	20.9
September	72.9	22.7	87.2	30.7	61.4	16.3
October	59.4	15.2	78.3	25.7	48.0	8.9
November	47.4	8.6	67.6	19.8	38.5	3.6
December	37.3	3.0	58.4	14.7	28.6	-1.9

Table A-5
Portland, ME Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	30.3	-0.9	47.7	8.7	22.3	-5.4
February	34.9	1.6	51.1	10.6	26.8	-2.9
March	41.4	5.2	61.9	16.6	33.8	1.0
April	52.3	11.3	74.6	23.6	43.7	6.5
May	62.3	16.8	82.3	28.0	53.6	12.0
June	72.0	22.2	88.8	31.5	63.4	17.4
July	77.1	25.1	89.7	32.0	68.5	20.3
August	77.3	25.1	89.8	32.1	68.5	20.3
September	69.9	21.1	84.8	29.3	61.4	16.3
October	57.6	14.2	74.4	23.6	48.6	9.2
November	46.7	8.2	63.4	17.5	39.3	4.1
December	38.2	3.5	56.3	13.5	30.6	-0.8

Table A-6
Providence, RI Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	36.6	2.6	56.9	13.8	29.3	-1.5
February	40.8	4.9	57.2	14.0	33.3	0.7
March	47.1	8.4	66.9	19.4	39.0	3.9
April	57.2	14.0	79.8	26.5	48.7	9.3
May	67.2	19.5	85.2	29.6	58.1	14.5
June	76.1	24.5	91.2	32.9	67.7	19.8
July	81.3	27.4	92.8	33.8	72.9	22.7
August	80.4	26.9	91.6	33.1	72.5	22.5
September	73.7	23.1	84.3	29.1	65.5	18.6
October	61.8	16.6	77.4	25.2	53.1	11.7
November	51.8	11.0	68.2	20.1	44.2	6.8
December	43.0	6.1	61.6	16.4	35.7	2.1

Table A-7
Windsor Locks, CT Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	33.6	0.9	53.9	12.2	26.3	-3.2
February	38.9	3.8	56.4	13.6	31.0	-0.6
March	47.1	8.4	69.1	20.6	38.1	3.4
April	59.1	15.1	82.8	28.2	49.2	9.6
May	69.9	21.0	88.8	31.5	59.3	15.2
June	78.6	25.9	92.7	33.7	68.4	20.2
July	82.6	28.1	92.2	33.5	72.6	22.5
August	82.1	27.8	93.8	34.3	72.4	22.4
September	74.4	23.5	86.4	30.2	64.6	18.1
October	61.6	16.4	78.6	25.9	51.7	11.0
November	50.5	10.3	68.6	20.3	42.3	5.7
December	40.3	4.6	61.3	16.3	32.9	0.5

Table A-8
Worcester, MA Temperature Data
1975-2004

	Average of the Daily Maximums [2]		Average of the Monthly Maximums [3]		Daily Mean [4]	
	°F	ºC	°F	ºC	°F	ºC
January	30.5	-0.8	51.4	10.8	23.9	-4.5
February	35.6	2.0	54.6	12.5	28.6	-1.9
March	42.7	5.9	66.1	19.0	35.1	1.7
April	54.4	12.4	78.2	25.7	45.8	7.7
May	64.8	18.2	83.6	28.6	56.2	13.4
June	73.1	22.9	86.7	30.4	65.1	18.4
July	77.1	25.1	88.0	31.1	69.2	20.7
August	76.9	24.9	86.9	30.5	69.4	20.8
September	69.9	21.1	82.7	28.1	62.4	16.9
October	57.2	14.0	74.3	23.5	49.8	9.9
November	46.8	8.2	65.6	18.6	40.3	4.6
December	37.4	3.0	58.9	14.9	31.2	-0.4

[1]This is the average of the daily maximum temperatures for each month.
[2] This is the average of the monthly maximum temperature over 30 years.
[3] This is the average of the daily maximum and minimum temperatures over the month.

DAJames
6/7/05