R. R. Sgarro
Manager-Nuclear Regulatory Affairs

PPL Bell Bend, LLC
38 Bomboy Lane, Suite 2
Berwick, PA 18603
Tel. 570.802.8102 FAX 570.802.8119
rrsgarro@pplweb.com

July 30, 2009

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

BELL BEND NUCLEAR POWER PLANT
RESPONSE TO RAI NO. 25 QUESTION 1
BNP-2009-164 Docket No. 52-039

References: 1) M. Canova (NRC) to R. Sgarro (PPL Bell Bend, LLC), Bell Bend COLA – Request for Information No. 25 (RAI No. 25) – RHEB-2852, email dated July 10, 2009

The purpose of this letter is to respond to Question 1 in the request for additional information (RAI) identified in the referenced NRC correspondence to PPL Bell Bend, LLC (PPL). This RAI Question addresses the Ice Effects of the Essential Service Water Emergency Makeup System (ESWEMS) Retention Pond in the Final Safety Analysis Report (FSAR), as submitted in Part 2 of the Bell Bend Nuclear Power Plant Combined License Application (COLA).

The enclosure provides our response to RAI No. 25, Question 02.04.07-1. A new regulatory commitment has been created to update the FSAR in a future revision.

If you have any questions, please contact the undersigned at 570.802.8102.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on July 30, 2009

Respectfully,

Rocco R. Sgarro

Enclosures: As stated

RRS/kw

D079
NRO

cc: (w/o Enclosures)

Mr. Samuel J. Collins
Regional Administrator
U.S. Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, PA 19406-1415

Mr. Michael Canova
Project Manager
U.S. Nuclear Regulatory Commission
11545 Rockville Pike, Mail Stop T7-E18
Rockville, MD 20852

Enclosure 1

Response to NRC Request for Additional Information Set No. 25, Question 02.04.07-1
Bell Bend Nuclear Power Plant

Question 02.04.07-1

In accordance with the requirements of 10 CFR 100.20(c)(2), and 10 CFR 52.79(a)(1)(iii), the staff reviewed the Final Safety Analysis Report (FSAR), Chapter 2.4.7, Ice Effects. Information is necessary to determine if the Essential Service Water Emergency Makeup System (ESWEMS) and other systems have adequately accounted for the accumulation of ice in the storage volume of the pond and the use of the operational system. The staff identified additional information needs related to the storage capacity of ESWEMS, sources of frazil ice accumulation, and referenced operational controls. The staff requests additional information including:

(1) information to include detailed technical bases, and storage calculations included in "Ice Thickness Calculation BBNPP," dated May 12, 2008, to support the conclusion that the 27-day storage capacity of the ESWEMS pond conservatively includes ice thickness;

(2) supporting information regarding the potential for frazil ice accumulation at the ESWEMS intakes, including the data range and other information for local frazil ice formation;

(3) information regarding the operational control (Technical Specification 3.7-8 in Part 4) that was referenced in the site audit discussion of the cooling tower basins and freezing conditions; and

(4) at least two years of additional historical data from the SSES meteorological tower, including wet bulb temperatures, dry bulb temperatures, total insolation (if available), and wind speeds.

Response

(1) RIZZO 2008 calculation package "Ice Thickness Calculation BBNPP" dates May 12, 2008, is provided in Attachment 1. Black & Veatch (B&V) calculation package "ESWEMS Retention Pond Sizing Calculation #161642.51.2001", provides additional information to support the conclusion that the 27-day storage capacity of the ESWEMS includes ice thickness. B&V calculation package is provided in Attachment 2. The ESWEMS pond volume as defined in the B&V calculation, takes into account the thickness of ice cover estimated to be 20.732 in which translates into a volume of 9.832 acre-ft.

(2) According to USACE (1991), frazil ice often occurs in open water at night under clear conditions and cold temperatures (-6°C). The process begins when the water temperature is at or just below the freezing point (pure water is 0°C). The atmosphere will then rapidly cool and water at the air/water interface will begin to freeze under a process called *nucleation,* forming small ice crystals. Turbulence will mix the ice crystals through the entire flow depth, where frazil ice can accumulate on underwater objects.

As per this RAI, further analysis was considered to evaluate whether frazil ice presents a risk to the water intake of the Essential Service Water Emergency Makeup System (ESWEMS) at the Bell Bend Nuclear Power Plant (BBNPP). Under the unlikely scenario

that frazil ice forms in the ESWEMS pond, this analysis focused on the potential for mixing of frazil ice crystals formed at the surface to sufficient depths to cause a concern for the water intake system. In this analysis, the mixing depth was calculated based on several wind speed recurrence intervals. The mixing depth can be estimated by calculating a wave base which can be defined as the depth below the mean water surface where the fluid motion as a result of the waves is considered negligible. Based upon the calculated wave base, the maximum mixing depth as a result of the 1,000-year recurrence wind speed (118 mph) is limited to 3.7 ft. The ESWEMS water intake system is approximately 30 ft deep, therefore under the most extreme wind recurrence interval, the sustained speeds are not sufficient to provide a deep enough mixing zone to mix frazil ice to the depth of the intake system.

Calculations to support the mixing zone results can be found in RIZZO (2009) "Frazil Ice Analysis for BBNPP ESWEMS Pond-Response to RAI#25", which can be found in Attachment 3.

(3) Technical Specification 3.7.8 defines surveillance requirements (SR) for the ESWEMS Pond. SR 3.7.8.8 requires a surveillance on a 24 hour basis to assure that the average water temperature of the ESWEMS Pond is less than or equal to 95°F. In addition, SR 3.7.8.9 requires a surveillance on a 24 hour basis to verify water level of the ESWEMS Pond is greater than or equal to 644 ft msl. Both of these surveillance requirements will ensure that the ESWEMS remains operable.

(4) Historical data from the SSES meteorological tower are found in Revision 1 of the BBNPP FSAR. Tables 2.3-85 through 2.3-92 present onsite temperature statistics. Table 2.3-93 presents onsite relative humidity statistics. Table 2.3-97 presents wet bulb temperatures at National Weather Service sites in the area. Tables 2.3-28 and 2.3-29 present annual joint frequency distribution tables of wind speed and direction as a function of atmospheric stability class for the 10-m and 60-m tower levels, respectively. The SSES met tower does not measure solar radiation/insolation.

COLA Impact

The Bell Bend FSAR Section 2.4.7 will be updated as follows, in a future COLA revision:

2.4.7.5 Frazil Ice

Research on the properties of frazil ice indicates that the nature and quantities of ice produced depends on the rate of cooling within a critical temperature range. Frazil ice forms when the water temperature is below 32°F (0°C), the rate of super cooling is greater than 0.018°F (-17.8°C) per hour in turbulent flows, and there is no surface ice sheet to prevent the cooling (USACE, 1991) (Griffen, 1973). This type of ice, which is in the shape of discoids and spicules (Griffen, 1973), typically forms in shallow flowing water, such as in rivers and lakes, when the flow velocity is approximately 2 ft/s (0.6 m/s) or higher (IAHR, 1970).

Under the unlikely scenario that frazil ice forms in the ESWEMS pond, analysis focused on the potential for mixing of frazil ice crystals formed at the surface to sufficient depths to cause a concern for the ESWEMS intake system. In this analysis, the mixing depth was calculated based on several wind speed recurrence intervals. The mixing depth was estimated by calculating a wave base which can be defined as the depth below the mean water surface where the fluid motion as a result of the waves is considered negligible.

Based upon the calculated wave base, the maximum mixing depth as a result of the 1,000-yr recurrence wind speed (118 mph; 52.8 m/s) is limited to 3.7 ft (1.13m). The ESWEMS water intake system is approximately 30 ft deep (9.14m), therefore under the most extreme wind recurrence interval, the sustained speeds are not sufficient to provide a deep enough mixing zone to mix frazil ice to the depth of the ESWEMS intake system.

The ESWEMS Retention Pond arrangement with pump intakes approximately 30 ft (9 m) below the surface prevents any interruption of emergency water supply to the ESWS.

Furthermore, neither frazil ice nor anchor ice have been observed in the intake structure of the existing SSES Units 1 and 2 since the start of operation. There is no public record of frazil or anchor ice obstructing other water intakes in the Susquehanna River. As a result, frazil ice or anchor ice is unlikely to occur to an extent that will affect the function of the makeup water intakes. The operating floor of the CWS Makeup Water Intake Structure is at elevation 528 ft (161 m) msl. Therefore, formation of frazil and anchor ice is not expected to impact operation of the intake system.

2.4.7.6 Surface Ice Sheet

Ice may form on the surface of the BBNPP ESWEMS Retention Pond during severe winter periods. Ice formation, however, does not affect the operation of the ESWEMS Retention Pond for the following reason: when the ESWS operates with such ice cover, water from the pond is withdrawn at a point approximately 24.5 ft (7.5 m) below the ice formation. Sufficient water volume is provided in the pond to preclude ice from reaching the pump intake during post- accident operation. This arrangement prevents any interruption of emergency water supply to the ESWS. Thus, there is no possibility for pump blockage by ice.

Technical Specification 3.7.8 in COLA Part 4, defines two surveillance requirements (SR) regarding the ESWEMS pond. SR 3.7.8.8 requires a surveillance on a 24-hour basis to assure that the average water temperature of the ESWEMS Pond is less than or equal to 95F. In addition, SR 3.7.8.9 requires a surveillance on a 24-hour basis to verify water level of the ESWEMS Pond is greater than or equal to 644 ft msl. Both of these surveillance requirements will ensure that the ESWEMS remains operable.

The pond structures at the water surface are in contact with surface ice that can form during prolonged subfreezing periods. Ice expansion and wind drag on the ice surface exert forces on these structures. The following sections address the approach used in evaluating the ice thickness and the forces on the ESWEMS Pumphouse and the pond outlet structure caused by the presence of ice.

Response to NRC Request for Additional Information Set No. 25
(RAI Set No. 25 Question #1)
Bell Bend Nuclear Power Plant
Berwick, Pennsylvania

Attachment 1 – RIZZO 2008 calculation package "Ice Thickness Calculation BBNPP"

FAM= Fehmida Mesania Fehmida Mesania
DW= David Wallner David Wallner

Purpose:

Estimate ice thickness on the Susquehanna River and the BBNPP ESW Emergency Makeup Retention Pond based on ambient air temperature data.

Assumptions:

Ambient air temperature was retrieved in hourly format. Sorting of data was necessary to estimate daily average Accumulated Freezing Degree-Days (AFDD).

References:

USACE, 2004. Method to Estimate River Ice Thickness Based on Meteorological Data, ERDC/CRREL Technical Note 04-3, U.S. Army Corps of Engineers, June 2004.
http://www.crrel.usace.army.mil/library/technicalnotes/TN04-3.pdf

INPUT: PPL, 2008. SSES Unit 1 & 2 Met tower data, 2001 to 2007.

Methodology:

Determination of the ice thickness in the ESW Emergency Makeup Retention Pond is based on the analysis of monthly Accumulated Freezing Degree-Days (AFDD), defined as the summation of the difference between 32°F (0 °C) and all recorded daily air temperatures below freezing (or the average daily temperature obtained from hourly data on record) for the months of December, January and February.

The maximum ice thickness that could form in the Susquehanna River and the ESW Emergency Makeup Retention Pond was estimated using historic air temperature data from the nearby SSES Unit 1 & 2 meteorological tower for the period of 2001 through 2007. SSES Unit 1 & 2 is located within a 5-mile radius from the BBNPP site.

Surface ice thickness (t_i) can be estimated as a function of Accumulated Freezing Degree-Days (AFDD) using the modified Stefan equation (**USACE, 2004**), where C is a coefficient usually ranging between 0.3 and 0.6 and AFDD is in °F days. For the Missouri River, a coefficient of 0.15 was used in Equation 1 to provide a conservative estimation of the ice thickness ("average river with snow condition", Table 1, **USACE, 2004**). A value of 0.7 was used to estimate the ice thickness in the ESWE Makeup Retention Pond ("average lake with snow condition", Table 1, **USACE, 2004**)

Equation 1 $t_i = C\,(AFDD)^{0.5}$

Accumulated Freezing Degree-Days are obtained for each winter month (December, January, and February) by summing the Freezing Degree-Days (FDD) for each month, which is the difference between the freezing point (32°F (0°C)) and the average daily air temperature (T_a) :

Equation 2 $FDD = (32 - T_a)$

Calculation:

Using Microsoft Excel, daily air temperature was sorted by day and Freezing Degree-Days (FDD) for each day were estimated using Equation 2, which is the difference between the freezing point (32°F (0°C)) and the average daily air temperature (T_a).

Based on Equation 1, a spreadsheet using Microsoft Excel was created to determine ice thickness in the ESW Emergency Makeup Retention Pond and the Missouri River based on the analysis of the total number of degree days below freezing.

Excel file is available under:
G:\DJW\Berwick FSAR 2.4.7 \ Summary_Susquehanna_met_data.xls

Results:

Table 1 summarizes the estimated monthly average Accumulated Freezing Degree-Days (AFDDs) and their corresponding ice thickness estimates from 2001-2007 for the Susquehanna River. Table 2 summarizes the monthly average AFDD and corresponding ice thickness from 2001-2007 for the ESW Emergency Makeup Retention Pond. As indicated in Table 1, the monthly average AFDD is 190.4 °F occurring in January with the corresponding ice thickness estimated to be approximately 2.07 in (5.26 cm) on the Susquehanna River. Table 2 shows that the ESW Emergency Makeup Retention Pond average ice thickness occurring in January is estimated to be approximately 9.66 in (24.54 cm).

Table 1 Estimated Average Monthly Ice Thickness, Susquehanna River 2001-2007

Month	AFDD (°F)	Ice Thickness (in)	Ice Thickness (cm)
January	190.4	2.07	5.26
February	125.1	1.68	4.27
December	88.1	1.41	3.58
Average	134.5	1.72	4.37

Table 2 Estimated Average Monthly Ice Thickness, ESW Emergency Makeup Retention Pond 2001-2007

Month	AFDD (°F)	Ice Thickness (in)	Ice Thickness (cm)
January	190.4	9.66	24.54
February	125.1	7.83	19.89
December	88.1	6.57	16.69
Average	134.5	8.02	20.37

Conclusions:

The results generated by the Excel spreadsheet are correct and can be used in the BBNPP FSAR Section 2.4.7 to evaluate ice effects.

ATTACHMENT A
EXCEL Spreadsheet

Summary_Susquehanna_met_data.xls

By FAM Date 05-12-08

Chkd. By [illegible] Date 6/10/08

Date Time	Date	TEMP10M (oF)	FDD	12/31/2000	period
1/1/01 0:00	1/1/01	25.2	6.8	1/1/2001	
1/1/01 1:00	1/1/01	25.4	6.6	1/2/2001	
1/1/01 2:00	1/1/01	25.5	6.5	1/3/2001	
1/1/01 3:00	1/1/01	25.2	6.8	1/4/2001	
1/1/01 4:00	1/1/01	24.9	7.1	1/5/2001	
1/1/01 5:00	1/1/01	23.6	8.4	1/6/2001	
1/1/01 6:00	1/1/01	22.5	9.5	1/7/2001	
1/1/01 7:00	1/1/01	21.3	10.7	1/8/2001	
1/1/01 8:00	1/1/01	21.2	10.8	1/9/2001	
1/1/01 9:00	1/1/01	20.3	11.7	1/10/2001	
1/1/01 10:00	1/1/01	18.9	13.1	1/11/2001	
1/1/01 11:00	1/1/01	22.2	9.8	1/12/2001	
1/1/01 12:00	1/1/01	23.9	8.1	1/13/2001	
1/1/01 13:00	1/1/01	25.9	6.1	1/14/2001	
1/1/01 14:00	1/1/01	28.2	3.8	1/15/2001	
1/1/01 15:00	1/1/01	30.2	1.8	1/16/2001	
1/1/01 16:00	1/1/01	31.2	0.8	1/17/2001	
1/1/01 17:00	1/1/01	31.2	0.8	1/18/2001	
1/1/01 18:00	1/1/01	30.1	1.9	1/19/2001	
1/1/01 19:00	1/1/01	28.7	3.3	1/20/2001	
1/1/01 20:00	1/1/01	28.1	3.9	1/21/2001	
1/1/01 21:00	1/1/01	26.1	5.9	1/22/2001	
1/1/01 22:00	1/1/01	24.6	7.4	1/23/2001	
1/1/01 23:00	1/1/01	22.6	9.4	1/24/2001	
1/2/01 0:00	1/2/01	21.4	10.6	1/25/2001	
1/2/01 1:00	1/2/01	20.7	11.3	1/26/2001	
1/2/01 2:00	1/2/01	20.0	12.0	1/27/2001	
1/2/01 3:00	1/2/01	18.6	13.4	1/28/2001	
1/2/01 4:00	1/2/01	16.2	15.8	1/29/2001	
1/2/01 5:00	1/2/01	14.0	18.0	1/30/2001	
1/2/01 6:00	1/2/01	11.9	20.1	1/31/2001	
1/2/01 7:00	1/2/01	12.6	19.4	2/1/2001	
1/2/01 8:00	1/2/01	13.2	18.8	2/2/2001	
1/2/01 9:00	1/2/01	13.6	18.4	2/3/2001	
1/2/01 10:00	1/2/01	14.4	17.6	2/4/2001	
1/2/01 11:00	1/2/01	17.5	14.5	2/5/2001	
1/2/01 12:00	1/2/01	18.8	13.2	2/6/2001	
1/2/01 13:00	1/2/01	19.0	13.0	2/7/2001	
1/2/01 14:00	1/2/01	20.3	11.7	2/8/2001	
1/2/01 15:00	1/2/01	21.5	10.5	2/9/2001	

start line	height	average	min	max	FDD
2	24	25.29	18.9	31.2	6.71
26	24	18.41	11.9	22.4	13.59
50	24	21.11	16.2	27.4	10.89
74	24	26.14	19.5	31.6	5.86
98	24	23.05	15.1	28.2	8.95
122	24	29.71	27.2	33.2	2.29
146	24	29.75	23.3	38.7	2.25
170	24	29.13	25.3	33.7	2.87
194	24	25.22	21.3	31.5	6.78
218	24	26.03	21	31.3	5.97
242	24	32.23	26	41.5	-0.23
266	24	25.88	16.3	37.7	6.12
290	24	25.66	16.8	39	6.34
314	24	27.30	18.4	37.2	4.70
338	24	34.98	32.3	37.8	-2.98
362	24	36.27	33.7	39.5	-4.27
386	24	34.66	33.4	35.5	-2.66
410	24	32.62	30.7	34.8	-0.62
434	24	33.70	32.2	35.1	-1.70
458	24	30.89	26	33.4	1.11
482	24	22.47	19	28.3	9.53
506	24	18.21	5.3	30.2	13.79
530	24	17.34	4.9	31.4	14.66
554	24	25.02	16.4	36.7	6.98
578	24	29.79	23.3	33.2	2.21
602	24	22.19	13.4	29.5	9.81
626	24	29.98	25.8	35.3	2.02
650	24	28.35	24.7	31.2	3.65
674	24	23.63	10.7	33.5	8.37
698	24	34.56	29.7	39.9	-2.56
722	24	36.81	32.7	41.2	-4.81
746	24	37.75	35.6	41.3	-5.75
770	24	34.46	24.7	41.2	-2.46
794	24	23.80	20.9	27.9	8.20
818	24	27.59	16.3	37.2	4.41
842	24	31.93	30.2	32.8	0.07
866	24	35.40	32.6	39.7	-3.40
890	24	36.76	31.4	40.3	-4.76
914	24	31.93	23.6	40	0.07
938	24	41.31	34.6	53.6	-9.31

By Fam Date 05-12-08
Chkd. By DW Date 6/10/08

12/1/2000 period	start line	height	average	min		SUM FDD
1/1/2001	2	31	27.63	17.34		155.42
2/1/2001	33	28	32.15	16.31		77.22
3/1/2001	61	31	35.16	26.20		25.51
4/1/2001	92	30	49.38	37.27		0.00
5/1/2001	122	31	60.06	49.82		0.00
6/1/2001	153	30	68.37	52.22		0.00
7/1/2001	183	31	68.51	59.33		0.00
8/1/2001	214	31	72.60	63.72		0.00
9/1/2001	245	30	60.51	48.88		0.00
10/1/2001	275	31	52.80	39.77		0.00
11/1/2001	306	30	46.57	32.65		0.00
12/1/2001	336	31	37.14	19.67		56.74
1/1/2002	367	31	34.07	21.83		60.67
2/1/2002	398	28	35.55	22.47		30.02
3/1/2002	426	31	40.18	21.88		30.10
4/1/2002	457	30	51.55	31.67		0.33
5/1/2002	487	31	56.96	42.65		0.00
6/1/2002	518	30	68.29	58.65		0.00
7/1/2002	548	31	72.98	62.50		0.00
8/1/2002	579	31	72.83	59.55		0.00
9/1/2002	610	30	64.74	54.78		0.00
10/1/2002	640	31	50.17	33.71		0.00
11/1/2002	671	30	38.32	2.31		58.64
12/1/2002	701	31	29.79	16.78		131.33
1/1/2003	732	31	22.68	8.16		305.98
2/1/2003	763	28	26.29	8.84		200.15
3/1/2003	791	31	37.41	14.65		71.24
4/1/2003	822	30	48.38	31.27		1.45
5/1/2003	852	31	54.22	12.28		24.74
6/1/2003	883	30	64.86	52.06		0.00
7/1/2003	913	31	70.82	63.85		0.00
8/1/2003	944	31	71.07	61.42		0.00
9/1/2003	975	30	63.06	49.64		0.00
10/1/2003	1005	31	48.93	37.90		0.00
11/1/2003	1036	30	39.64	-10.80		87.51
12/1/2003	1066	31	32.26	23.73		74.60
1/1/2004	1097	31	21.02	2.91		381.40
2/1/2004	1128	29	29.36	14.80		107.50
3/1/2004	1157	31	40.28	25.98		11.82
4/1/2004	1188	30	50.33	31.75		0.25

By fm Date 05-12-08
Chkd. By [illegible] Date 6/10/08

	1	2	3	4	5	6	7	8	9	10	11	12
2001	155.425	77.22083	25.5125	0	0	0	0	0	0	0	0	56.74167
2002	60.66667	30.02083	30.09583	0.333333	0	0	0	0	0	0	58.6375	131.3333
2003	305.9792	200.1542	71.2375	1.454166	24.74167	0	0	0	0	0	87.5125	74.59583
2004	381.4	107.5	11.82083	0.245833								

By Fm Date 05-12-08

Chkd. By AW Date 6/10/08

						147.9625							
							0						
								0					
									0				
										0			
											0		
												2.433333	
													117.5792
2005	263.9958												
		85.05833											
			68.0125										
				0									
					44.05								
						0							
							0						
								0					
									0				
										104.1208			
											20.69167		
													162.1208
2006	45.57917												
		98.47083											
			19.39583										
				0									
					42.97917								
						0							
							0						
								0					
									0				
										0			
											0		
													18.06667
2007	119.4833												
		276.9625											
			82.47083										
				20.79583									
					34.42917								
						0							
							0						
								0					
									0				

By FAM Date 05-12-08
Chkd. By [illegible] Date 6/10/0[illegible]

1.620833
3.575
56.34583

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Sum FDD	190.4	125.1	44.1	3.3	42.0	0.0	0.0	0.0	0.0	15.1	24.7	88.1
Susquehanna River Ice thickness (in)	2.07	1.68	1.00	0.27	0.97	0.00	0.00	0.00	0.00	0.58	0.75	1.41
UHS ice thickness (in)	9.66	7.83	4.65	1.26	4.54	0.00	0.00	0.00	0.00	2.72	3.48	6.57

Response to NRC Request for Additional Information Set No. 25
(RAI Set No. 25 Question #1)
Bell Bend Nuclear Power Plant
Berwick, Pennsylvania

Attachment 2 – B&V "ESWEMS Retention Pond Sizing Calculation #161642.51.2001"

BLACK & VEATCH
Building a world of difference.

CALCULATION COVER SHEET

Client Name:	Unistar	Project No.:	161642
Project Name:	Bell Bend UHS	Calculation No.:	161642.51.2001
Calculation Title:	ESWEMS Retention Pond Sizing	File No.:	51.2000
		Page	1 of 116

Calculation Type	☐ Preliminary	☒ Final	
Seismic Classification	☒ I	☐ II	
Quality Classification	☒ S	☐ R	☐ G

Objective Determine the volume of water necessary to provide 27 days of make-up water to the Essential Service Water System (ESWS) of the proposed US-EPR at the Bell Bend site.

Unverified Assumptions Requiring Subsequent Verification

No.	Assumption	Verified By	Date
1	The ground water depth is 20 feet. See assumption 2 below.		
2	The coefficient of permeability is 10^{-8} m/s. The 3 ft. liner thickness is a function of the coefficient of permeability. See assumption 3 below.		

Refer to page 7 of this calculation for additional assumptions.

This Section Used for Computer Calculations

Software Program Name/Number: N/A Version:

Number of Pages:

Evidence of or reference to computer program verification, if applicable:

Bases or reference thereto supporting application of the computer program to the physical problem:

Review and Approval

Rev.	Prepared By: Print and Sign	Prepared By: Date	DVR No.*	Approved By: Print and Sign	Approved By: Date
0	David B. Schwenk	6/26/08	DVR-0011	A. D. Boehelman	6/26/08

Revision Description
Initial Issue.

*Indicate Design Verification Review (DVR) Checklist number.

This calculation supersedes Calculation Number:

This calculation is superseded by Calculation Number:

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1.0 Purpose and Scope

The purpose of this calculation is to determine the volume of water necessary in a makeup pond to provide 27 days of make-up to the ESWS at the Bell Bend Nuclear Power Plant. The proposed unit is a US-EPR, which already has a 3 day make-up supply in its ESWS cooling tower basins; therefore, this makeup pond only needs to furnish 27 days to meet the NRC requirement of 30 days. The total volume will include the makeup requirements of the US-EPR unit (i.e. evaporation and drift from the ESWS cooling towers); 30 days of seepage; the volume required to provide the Net Positive Suction Head (NPSH) for the make-up pumps; and the greater of either 30 days of evaporation, or the volume of water lost to an ice cover.

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3.0 Summary and Conclusion

Pond Volume at Normal Water Level:	$3.34 \times 10^6\ ft^3$
Minimum Volume:	$2.03 \times 10^6\ ft^3$
Minimum Depth:	12 ft.
Margin over Minimum Volume at Normal Water Level:	64.81%

4.0 Design

4.1 Design Inputs

Define units and constants for MathCad

Bars	$bar := 10^5 Pa$	Ref. 6, Table A-2M
Millibars	$mb := bar \cdot 10^{-3}$	
Celcius	$degC := K$	
Fahrenheit	$degF := \frac{5}{9} K$	
Gallons per Minute	$gpm := 1 \frac{gal}{min}$	
Langley	$langley := 1 \frac{tcal}{cm^2}$	Ref. 17

Inputs

Time period of ESW Makeup	$t := 27day$	Ref. 12
Time period post-accident (for evaporation and seepage)	$t_s := 30day$	Ref. 11
Pond At-Grade Width	$w_g := 400ft$	Assumption 1
Pond At-Grade Length	$l_g := 700ft$	Assumption 1
Pond Water Depth	$d := 17ft$	Assumption 1

Side Slope	$S_{slope} := \frac{1}{3}$	Assumption 1
Radius of Corner Fillets @ the pond bottom	$r_2 := 20ft$	Assumption 1
Pond Excavation Total Depth	$d_t := 22ft$	Assumption 1
Cooling Tower Circulating Water Flow	$Q_T := 19000gpm$	Ref. 14
Drift loss, % of Circulating Flow	$r_T := 0.0010\%$	Ref. 14
Latent Heat of Fusion of Ice	$L_{ice} := 333.4 \frac{J}{gm}$	Ref. 2, Page 45
High Air Temperature for Pond Evaporation	$T_a := 52.42degF$	Ref. 15, Attachment 3
Water Vapor Pressure @ T_a	$e_a := 3.12mb$	Ref. 15, Attachment 3
Water Vapor Pressure @ Average Dewpoint Temperature for 30 Day Period	$e_s := 13.42mb$	Ref. 15, Attachment 3
Solar Insulation	$R_{sun} := 5.51 \frac{kW \cdot hr}{m^2 \cdot day}$	Ref. 7
	$R_{sun} = 474.092 \frac{langley}{day}$	
Average Windspeed	$U_p := 20.3 \frac{mi}{hr}$	Ref. 9
	$U_p = 487.2 \frac{mi}{day}$	

Density of Ice @ 0C	$\rho_{ice} := 916.59 \frac{kg}{m^3}$	Ref. 8, Table 39.17
Specific Weight of Water @ 39 F	$\gamma_{H2O} := 62.426 \frac{lbf}{ft^3}$	Ref. 16
Atmospheric Pressure	$P_{atm} := 14.7psi$	
Vapor Pressure of Water @ 94F	$P_{94VP} := .7914psi$	Ref. 6, Table A-12
Vapor Pressure of Water @ 96F	$P_{96VP} := .8416psi$	Ref. 6, Table A-12
Temperature of Ice/Water Interface	$T_i := 0degC$	
Minimum Average Daily Low Air Temperature	$T_{min} := -6.92degC$	Attachment 2
Time frame of Ice Formation	$t_{ice} := 31day$	Attachment 2
Volume of water for ESWEMS makeup	$V_{uhs} := 1.115 \cdot 10^7 gal$	Ref. 10
Depth of water table	$d_{wt} := 20ft$	Assumption 2
Thickness of clay liner	$t_{liner} := 3ft$	Assumption 3
Coefficient of permeability for clay	$k := 10^{-8} \frac{m}{s}$	Assumption 3

4.2 Design Margins

Client Margin: No specific client margin is applied.
Safety Margin: No specific safety margin is applied.
Design Margin: No specific design margin is applied.
Operation Margin: No specific operation margin is applied.
Other Margin: No other margins are applied.

4.3 Acceptance Criteria

The retention pond is sized to meet the requirements of Reg. Guide 1.27.

5.0 Assumptions

1. The pond excavation will be 700 feet long, 400 feet wide, 22 feet deep, the side slope will be 3:1, the corner radius on the bottom of the pond will be 20 feet, and the normal water depth will be 17 feet to be identical in size to the ESWEMS pond at the Callaway Nuclear Station, Unit 2.
2. Based off of Reference 18 and Reference 19, the ground water depth is conservatively set at 20 feet. This is dependent on the final revision of Reference 19.
3. Based off of Reference 5, the coefficient of permeability of the liner will be 10^{-8} m/s. This property will need to be verified by an ITAAC commitment. To ensure an acceptable seepage rate, the 3 foot thickness of the liner is based off of this property. The liner thickness is a function of the coefficient of permeability.

6.0 Analysis

6.1 Total UHS Required Volume

The total UHS Required Volume will consist of the water for ESWEMS makeup and water lost to drift in the cooling towers. The volume of water lost to drift is calulated as follows:

$$V_{drift} := Q_T \cdot r_T \cdot t \qquad V_{drift} = 987.525\,ft^3 \qquad V_{drift} = 0.023\,acre \cdot ft$$

Where V_{drift} is volume of drift, Q_T is flowrate of circulation water through the cooling tower, r_T is % drift loss, and t is days

Total UHS Required Volume is then calculated as follows:

$$V_{UHS} = V_{uhs} + V_{drift}$$

6.2 NPSH Available

Net positive suction head will be calculated at a water elevation of zero feet above the eye of the pump. If a vertical pump is used, then there will be no additional head requirements from a suction pipe due to the eye of the pump being submerged to an elevation near the bottom of the retention pond.

Per Reference 13, the following equation is used to determine available NPSH:

$$NPSH_A = \frac{P_{atm} - P_{VP}}{\gamma_{H2O}}$$

Where $NPSH_A$ is available net positive suction head, P_{atm} is atmopheric pressure, γ_{H2O} is the specific weight of water, and P_{VP} is the vapor pressure of water.

6.3 Seepage Volume

The rate of seepage from the make-up pond is a function of the composition of the pond liner and the surface area of the wetted surface. The composition of the pond liner will be clay with a permeability of 10^{-8} m/s, and this will be validated with an ITAAC commitment following construction. The volume will be calculated based on the wetted surface area of the pond, the discharge velocity through the liner, and the time period post accident. The wetted surface area will include the rectangle at the bottom of the pond plus the rectangles that make up each side of the pond (two (2) on each side for a total of four (4)) and the surface area of a truncated cone to account for the corners. See Figure 1 for clarification.

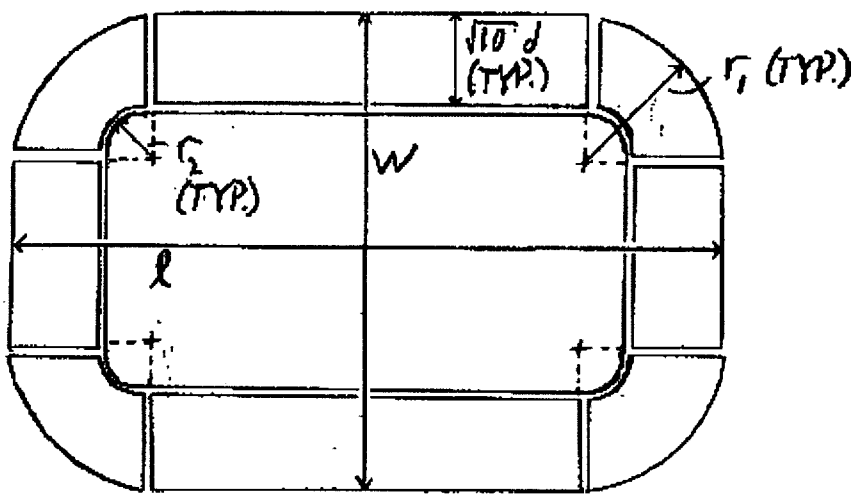


Figure 1

The equation for the surface area of a truncated cone is of the following form:

$$SA_{truncated} = \pi(r_1 \cdot s_1 - r_2 \cdot s_2)$$

Where: r_1 = major radius (surface of water)

r_2 = minor radius (bottom of pond)

s_n = slant height of cone with radius $r_n = [r_n^2 + (r_n \times S_{slope})^2]^{.5}$

The major radius of the conical sections is defined by the following equation:

$$r_1 := \frac{d}{S_{slope}} + r_2 \qquad r_1 = 71\,ft$$

To determine the surface area of the proposed pond, the dimensions of the normal water surface will need to be calculated as follows:

$$d_{fb} := d_t - d \qquad d_{fb} = 5\,ft$$

Where d_{fb} is freeboard depth, d_t is pond excavation total depth, and d is pond water depth.

$$l := l_g - 2\frac{d_{fb}}{S_{slope}} \qquad l = 670\,ft$$

$$w := w_g - 2\frac{d_{fb}}{S_{slope}} \qquad w = 370\,ft$$

Where: l_g and w_g = At grade length and width, respectively
d_{fb} = Depth of freeboard
S_{slope} = Side Slope

The wetted surface area of the proposed pond is then calculated by the following, where l, w, and d represent surface length, surface width, and depth, respectively:

$$SA := \left[\left(l - 2\cdot\frac{d}{S_{slope}}\right)\cdot\left(w - 2\cdot\frac{d}{S_{slope}}\right) - 4r_2^{\,2} + \left[\left(l - 2\cdot\frac{d}{S_{slope}} - 2r_2\right) + \left(w - 2\cdot\frac{d}{S_{slope}} - 2r_2\right)\right]\cdot 2\cdot 10^{.5}d \ldots \right.$$
$$\left. + \pi\left[r_2^{\,2} + \left[r_1\cdot\left[r_1^{\,2} + \left(r_1\cdot S_{slope}\right)^2\right]^{.5} - r_2\left[r_2^{\,2} + \left(r_2\cdot S_{slope}\right)^2\right]^{.5}\right]\right]\right]$$

$$SA = 2.485\times 10^5\,ft^2$$

The discharge velocity through the liner is calculated by the following equation:

$$v = k\cdot i$$ Ref. 5, Page 72

Where: v = discharge velocity
k = coefficient of permeabilty
i = hydraulic gradient

The hydraulic gradient is the rate of loss of total head through the soil and is calculated by the following equation:

$$i = -\lim_{\Delta s\to 0}\frac{\Delta h}{\Delta s} = \frac{d}{ds}h$$ Ref. 5, Page 72

Where: Δh = head loss through the soil
Δs = macroscopic flow distance through the soil

For this calculation, the value of i will be conservatively set as:

$$i := -\frac{(d_{fb} - d_{wt})}{t_{liner}} \qquad i = 5$$

Where: d_{fb} = depth of freeboard
d_{wt} = depth to water table
t_{liner} = thickness of clay liner

The volume of seepage is then calculated by the equation:

$$V_{seepage} = v \cdot SA \cdot t_s$$

6.4 Evaporation or Freezing Volume

Since evaporation and an ice cover can not occur simultaneously, this calculation will only factor into the total volume the worst of the two cases. Similarly, since frazil ice can only occur in open water, it can not occur simultaneously with an ice cover, and it is assumed that the volume of water lost to an ice cover will be substantially greater than the volume of water lost to frazil ice because frazil ice is a mixture of ice and water. It is therefore assumed that the volume of water lost to any potential frazil ice formation, such as could occur in a partial ice cover, will be bounded by the calculation for the volume of water lost to a full ice cover.

The equation for depth of water lost daily to evaporation is:

$$R_{evap} := \frac{\left[e^{\left[\left[\frac{(T_a)}{degF} - 212\right]\left(0.1024 - 0.01066 \cdot \ln\left(R_{sun} \cdot \frac{day}{langley}\right)\right)\right]} - 0.0001 \ldots + 0.0105\left(\frac{e_s}{in_Hg} - \frac{e_a}{in_Hg}\right)^{.88} \cdot \left(0.37 + 0.0041 U_p \cdot \frac{day}{mi}\right) \right]}{\left[(0.015) + \left[\frac{(T_a)}{degF} + 398.36\right]^{-2} \cdot 6.8554 \cdot 10^{10} \cdot e^{\left[\frac{-7482.6}{\frac{(T_a)}{degF} + 398.36}\right]} \right]} \cdot \frac{in}{day}$$

Ref. 3, Page 1.190 Equation 3.12

$$R_{evap} = 0.32 \frac{in}{day}$$

Where: R_{evap} = depth of water lost per day
T_a = High Air Temperature for Pond Evaporation
e_s = water vapor pressure at the saturation (dew point) temperature
e_a = water vapor pressure at T_a
R_{sun} = solar radiation
U_p = Average wind speed for 30 day period

The total evaporation is dependent on the surface area of the pond. This calculation will assume the pond is at its maximum operating level, which is the most conservative approach. The maximum operating level is the at grade level minus the depth of freeboard. The inputs for the parameters listed above are the worst case gleened from the data analyzed from Reference 15, Reference 7, and Reference 9. The lowest day of average relative humidity from Reference 15 is combined with the highest average monthly insolation from Reference 7, and the 1% exceedance extreme annual windspeed from Reference 9 to create a synthetic day for worst case pond evaporation. The windspeed from Reference 9 is more conservative than the average monthly windspeeds found in Reference 7. This synthetic day is then repeated for 30 consecutive days to create a conservative 30 day period.

The total volume of water lost to an ice cover is dependent on the maximum surface area of the pond and maximum depth of the ice. The maximum depth of the ice is dependent on the thermal conductivity of ice, the temperature difference between the ice/water interface and the ambient air, the time period of ice formation, the density of ice, and the latent heat of fusion of ice. The time period of ice formation is the period before the design basis event occurs. Historic climactic data found in References 20, 21, and 22 was analyzed to determine the average monthly daily lows. Only the winter months of November, December, January, February, and March were analyzed because freezing temperatures are only expected during those months. This analysis is displayed in Attachment 2., and the coldest average daily low temperature at BBNPP between 1961 and 2005 occured during the month of January, so the time period of ice formation used in the maximum ice thickness calculation will be 31 days. The depth of ice is defined by the following equation from Reference 2, page 234:

$$h_{ice} = \left(\frac{2 \cdot k_i \left(T_i - T_{min} \right) t_{ice}}{\rho_{ice} \cdot L_{ice}} \right)^{.5}$$

The thermal conductivity of ice, k_i, is defined by the following equation, also from Reference 2, page 47:

$$k_i = 2.21 - 0.011\left(T_{min}\right)$$

This method is conservative for the following reasons. First, the volume of ice is greater than the associated volume of water; therefore, the volume of water lost to ice will be less than the volume of ice formed. Second, the minimum temperature used in the analysis is the average daily low, which means the temperature will rise throughout the day, thus slowing (or in some cases reversing) the formation of ice. Third, per Reference 2, the equation for the depth of ice assumes heat transfer across the ice/water interface is negligible. In reality, heat will conduct from the water to the ice, slowing the formation of ice.

6.5 Total Volume

The total volume of the pond will be the area inside the liner. If ITAAC testing indicates the liner needs to be thicker than 3 feet, the entire excavation should increase in size accordingly. The total volume of the proposed Unit 2 pond will include a trapezoidal cross section extrusion for the main body of the pond, two (2) other trapezoidal cross section extrusions for the ends of the pond, and four (4) quarter truncated conical sections for the corners of the pond.

The volume of a trapezoidal extrusion is the area of the cross section times the length of the extrusion. The area of the cross section is as follows:

$$A_{trapezoid} = \frac{1}{2}(b_1 + b_2)h$$

Where:
b_n is the length of the base
h is the height of the trapezoid.

The volume of a truncated cone is the difference in the volume of two similar cones:

$$V_{conic} = V_{cone1} - V_{cone2}$$

The volume of a cone is as follows:

$$V_{cone} = \frac{\pi}{3}r^2 \cdot d$$

Where:
r is the axis
d is the depth of the cone.

It can be determined that:

$$V_{conic} = \frac{\pi}{3}\left(r_1^2 + r_2^2 + r_1 \cdot r_2\right) \cdot d$$

The minimum volume is the UHS volume plus the volumes calculated in sections 6.2, 6.3, and 6.4. The pond margin is calculated by the following equation:

$$\frac{V_{total} - V_{min}}{V_{min}}$$

7.0 Calculation and Results

7.1 Total UHS Required Volume

The total UHS required volume is as follows:

$V_{UHS} := V_{uhs} + V_{drift}$ $\quad V_{UHS} = 1.492 \times 10^{6}\,ft^{3}$ $\quad V_{UHS} = 34.241\,acre \cdot ft$

7.2 NPSH Available

The saturation vapor pressure for 95 degree F water will be determined by averaging the vapor pressure at 94 and 96 degrees F from existing saturation tables in Reference 6.

$$P_{VP} := \frac{P_{94VP} + P_{96VP}}{2}$$

$$P_{VP} = 0.816\,psi$$

The NPSH available is determined by the following equation:

$$NPSH_A := \frac{P_{atm} - P_{VP}}{\gamma H2O}$$

$$NPSH_A = 32.026\,ft$$

Based on this analysis, no additional pond volume is needed to account for NPSH if a submerged vertical pump with a required NPSH less than 32 feet is used.

7.3 Seepage Volume

The discharge velocity through the liner is calculated by the following equation:

$v := k \cdot i$ $\quad v = 5 \times 10^{-8}\,\frac{m}{s}$

The seepage volume is as follows:

$$V_{seepage} := v \cdot SA \cdot t_s$$

$V_{seepage} = 1.057 \times 10^{5}\,ft^{3}$ $\quad V_{seepage} = 2.426\,acre \cdot ft$

7.4 Evaporation or Freezing Volume

7.4.1 Evaporation

Maximum Surface Area

$$A_{max} := w \cdot l$$

$$A_{max} = 2.479 \times 10^5\,ft^2$$

Evaporation Volume

$$V_{evap} := A_{max} \cdot R_{evap} \cdot t_s$$

$$V_{evap} = 1.983 \times 10^5\,ft^3 \qquad V_{evap} = 4.553\,acre \cdot ft$$

7.4.2 Freezing

Thermal Conductivity of Ice

$$k_i := 2.21 \frac{W}{m \cdot degC} - 0.011 \frac{W}{m \cdot degC^2}(T_{min})$$

$$k_i = 2.286 \frac{W}{m \cdot degC}$$

Thickness of Ice Cover

$$h_{ice} := \left[\frac{\left[2 \cdot k_i \cdot (T_i - T_{min})\, t_{ice}\right]}{\rho_{ice} \cdot L_{ice}}\right]^{.5}$$

$$h_{ice} = 20.732\,in$$

Volume of Ice

$$V_{ice} := A_{max} \cdot h_{ice}$$

$$V_{ice} = 4.283 \times 10^5\,ft^3 \qquad V_{ice} = 9.832\,acre \cdot ft$$

Since the volume of water lost to evaporation is less than the volume of water lost to ice cover, the total volume required in the make-up pond will account for an ice cover.

7.5 Available Usable Pond Volume

7.5.1 First Trapezoidal Extrusion

The area of a trapezoid is one half the sum of the bases times the height:

$$A_{trapezoid1} := \frac{1}{2}\left[w + \left(w - 2\cdot\frac{d}{S_{slope}}\right)\right]\cdot d$$

The volume is found by multiplying the Area by the length of the extrusion as follows:

$$V_{trapezoidal1} := A_{trapezoid1}\cdot\left(l - 2\cdot r_1\right)$$

$$V_{trapezoidal1} = 2.863 \times 10^6\,ft^3$$

7.5.2 Second Trapezoidal Extrusions

$$A_{trapezoid2} := \frac{1}{2}\cdot\left(r_2 + r_1\right)\cdot d$$

The total trapezoidal volume is found by multiplying two times the area, to account for both ends, by the length of the extrusion as follows:

$$V_{trapezoidal2} := 2A_{trapezoid2}\cdot\left(w - 2\cdot r_1\right)$$

$$V_{trapezoidal2} = 3.527 \times 10^5\,ft^3$$

7.5.3 Volume of Corners

The volume of the corners is found by calculating the volume of a truncated cone, to account for all four corners, with its major radius at water level and its minor radius at the bottom of the pond. The volume is as follows:

$$V_{conic} := \frac{\pi}{3}\cdot\left(r_1^{\,2} + r_2^{\,2} + r_1\cdot r_2\right)\cdot d$$

$$V_{conic} = 1.221 \times 10^5\,ft^3$$

7.5.4 Total Pond Volume

The total pond volume is then:

$$V_{total} := V_{trapezoidal1} + V_{trapezoidal2} + V_{conic}$$

$$V_{total} = 3.34 \times 10^6\,ft^3 \qquad V_{total} = 76.635\,acre \cdot ft$$

The minimum required pond volume is then:

$$V_{min} := V_{UHS} + V_{ice} + V_{seepage}$$

$$V_{min} = 2.03 \times 10^6\,ft^3 \qquad V_{min} = 46.499\,acre \cdot ft$$

A summary table of pond water depth to corresponding pond volume and margin is shown in Attachment 1. The volumes for First Trapezoidal, Second Trapezoidal, Cone Volumes and Margin are calculated using the equations described in Section 6.5 above.

8.0 Attachments

Attachment 1: Pond Volume to Depth Table (1 page)
Attachment 2: Mean Monthly Daily Lows, 1961-2005 (97 pages)
Attachment 3: Design Conditions for Wilkes-Barre (1 page)

Attachment 1:
Pond Volume to Depth Table

Depth (ft)	Freeboard (ft)	Elevation (MSL)	Total Volume (ft^3)	Total Volume (acre-ft)	First Trapezoidal Volume (ft^3)	Second Trapezoidal Volume (ft^3)	Cone Volume (ft^3)	Margin
0	22	653	0.000E+00	0.000	0.000E+00	0.000E+00	0.000E+00	-100.00%
1	21	654	1.543E+05	3.543	1.431E+05	9.804E+03	1.455E+03	-92.38%
2	20	655	3.137E+05	7.201	2.893E+05	2.098E+04	3.343E+03	-84.51%
3	19	656	4.780E+05	10.973	4.388E+05	3.352E+04	5.721E+03	-76.40%
4	18	657	6.474E+05	14.863	5.914E+05	4.742E+04	8.646E+03	-68.04%
5	17	658	8.220E+05	18.870	7.471E+05	6.270E+04	1.217E+04	-59.42%
6	16	659	1.002E+06	22.997	9.060E+05	7.934E+04	1.636E+04	-50.54%
7	15	660	1.187E+06	27.244	1.068E+06	9.736E+04	2.127E+04	-41.41%
8	14	661	1.377E+06	31.614	1.233E+06	1.167E+05	2.694E+04	-32.01%
9	13	662	1.573E+06	36.106	1.402E+06	1.375E+05	3.345E+04	-22.35%
10	12	663	1.774E+06	40.723	1.573E+06	1.596E+05	4.084E+04	-12.42%
11	11	664	1.980E+06	45.465	1.748E+06	1.831E+05	4.918E+04	-2.22%
12	10	665	2.193E+06	50.335	1.926E+06	2.079E+05	5.851E+04	8.25%
13	9	666	2.410E+06	55.333	2.107E+06	2.342E+05	6.890E+04	19.00%
14	8	667	2.634E+06	60.461	2.292E+06	2.617E+05	8.040E+04	30.03%
15	7	668	2.863E+06	65.719	2.479E+06	2.907E+05	9.307E+04	41.33%
16	6	669	3.098E+06	71.110	2.670E+06	3.210E+05	1.070E+05	52.93%
17	5	670	3.338E+06	76.635	2.863E+06	3.527E+05	1.221E+05	64.81%
18	4	671	3.585E+06	82.294	3.060E+06	3.858E+05	1.387E+05	76.98%
19	3	672	3.837E+06	88.089	3.260E+06	4.202E+05	1.566E+05	89.44%
20	2	673	4.096E+06	94.022	3.464E+06	4.560E+05	1.759E+05	102.20%
21	1	674	4.360E+06	100.094	3.670E+06	4.932E+05	1.968E+05	115.26%
22	0	675	4.631E+06	106.306	3.880E+06	5.317E+05	2.192E+05	128.62%

At grade length:	700
At grade width:	400
Slope:	0.33
Bottom Radius:	20
Minimum Volume: (ft^3)	2.03E+06

Month/ Year	Dry Bulb (F)	Dry Bulb (C)
Jan-61	12.07	-11.07
Feb-61	21.35	-5.92
Mar-61	27.65	-2.42
Nov-61	33.83	1.02
Dec-61	23.64	-4.65
Jan-62	17.05	-8.30
Feb-62	18.15	-7.70
Mar-62	28.24	-2.09
Nov-62	30.05	-1.08
Dec-62	17.23	-8.21
Jan-63	16.19	-8.78
Feb-63	10.96	-11.69
Mar-63	30.43	-0.87
Nov-63	38.85	3.80
Dec-63	19.03	-7.20
Jan-64	20.64	-6.31
Feb-64	16.61	-8.55
Mar-64	28.80	-1.78
Nov-64	34.50	1.39
Dec-64	26.19	-3.23
Jan-65	17.13	-8.26
Feb-65	20.90	-6.17
Mar-65	27.83	-2.32
Nov-65	33.75	0.97
Dec-65	28.25	-2.08
Jan-66	18.31	-7.61
Feb-66	21.09	-6.06
Mar-66	31.13	-0.48
Nov-66	35.88	2.15
Dec-66	25.79	-3.45
Jan-67	26.82	-2.88
Feb-67	16.35	-8.69
Mar-67	28.02	-2.21
Nov-67	30.55	-0.80
Dec-67	26.03	-3.32

Month	Group #1	Group #2	Total Average (F)	Total Average (C)
January	18.34	20.75	19.54	-6.92
February	20.08	22.48	21.28	-5.96
March	29.04	29.33	29.19	-1.56
November	34.56	35.13	34.84	1.58
December	24.27	25.89	25.08	-3.84

Month/ Year	Dry-Bulb (F)	Dry-Bulb (C)	Group #1	Group #2	Total Average (F)	Total Average (C)
Jan-68	13.44	-10.31				
Feb-68	16.83	-8.43				
Mar-68	32.05	0.03				
Nov-68	35.46	1.92				
Dec-68	21.48	-5.85				
Jan-69	19.84	-6.75				
Feb-69	21.23	-5.99				
Mar-69	27.40	-2.55				
Nov-69	33.72	0.95				
Dec-69	21.51	-5.83				
Jan-70	11.63	-11.32				
Feb-70	18.49	-7.50				
Mar-70	26.19	-3.23				
Nov-70	35.94	2.19				
Dec-70	23.00	-5.00				
Jan-71	13.59	-10.23				
Feb-71	21.37	-5.91				
Mar-71	26.73	-2.93				
Nov-71	33.14	0.63				
Dec-71	28.02	-2.21				
Jan-72	21.54	-5.81				
Feb-72	16.91	-8.38				
Mar-72	24.93	-3.93				
Nov-72	31.30	-0.39				
Dec-72	28.27	-2.07				
Jan-73	21.87	-5.63				
Feb-73	16.82	-8.43				
Mar-73	34.50	1.39				
Nov-73	34.49	1.38				
Dec-73	25.18	-3.79				
Jan-74	22.01	-5.55				
Feb-74	17.07	-8.29				
Mar-74	27.35	-2.58				
Nov-74	36.56	2.53				
Dec-74	30.14	-1.03				
Jan-75	25.76	-3.47				
Feb-75	26.34	-3.14				
Mar-75	28.29	-2.06				
Nov-75	40.17	4.54				
Dec-75	25.31	-3.72				
Jan-76	14.53	-9.71				
Feb-76	26.67	-2.96				
Mar-76	32.85	0.47				
Nov-76	31.42	-0.32				
Dec-76	15.50	-9.16				
Jan-77	8.81	-12.88				
Feb-77	19.43	-6.99				
Mar-77	31.83	-0.09				
Nov-77	37.81	3.23				
Dec-77	23.68	-4.62				
Jan-78	17.96	-7.80				

Month/ Year	Dry-Bulb (F)	Dry-Bulb (C)	Group #1	Group #2	Total Average (F)	Total Average (C)
Feb-78	12.82	-10.66				
Mar-78	25.90	-3.39				
Nov-78	32.38	0.21				
Dec-78	22.58	-5.23				
Jan-79	18.43	-7.54				
Feb-79	9.36	-12.58				
Mar-79	31.67	-0.18				
Nov-79	38.87	3.82				
Dec-79	29.00	-1.66				
Jan-80	21.87	-5.63				
Feb-80	17.58	-8.01				
Mar-80	28.19	-2.12				
Nov-80	31.27	-0.40				
Dec-80	17.82	-7.88				
Jan-81	12.51	-10.83				
Feb-81	26.90	-2.84				
Mar-81	28.68	-1.85				
Nov-81	34.71	1.51				
Dec-81	24.54	-4.14				
Jan-82	11.68	-11.29				
Feb-82	21.28	-5.95				
Mar-82	27.61	-2.44				
Nov-82	36.55	2.53				
Dec-82	29.62	-1.32				
Jan-83	21.91	-5.60				
Feb-83	21.78	-5.68				
Mar-83	31.55	-0.25				
Nov-83	36.13	2.30				
Dec-83	21.55	-5.81				
Jan-84	16.62	-8.54				
Feb-84	30.04	-1.09				
Mar-84	23.91	-4.49				
Nov-84	32.77	0.43				
Dec-84	31.38	-0.34				
Jan-85	15.27	-9.30				
Feb-85	22.29	-5.40				
Mar-85	29.65	-1.30				
Nov-85	38.85	3.80				
Dec-85	20.67	-6.29				
Jan-86	20.85	-6.20				
Feb-86	21.16	-6.02				
Mar-86	30.58	-0.79				
Nov-86	30.19	-1.00				
Dec-86	27.74	-2.36				
Jan-87	18.88	-7.29				
Feb-87	17.22	-8.21				
Mar-87	29.47	-1.41				
Nov-87	32.80	0.45				
Dec-87	27.32	-2.60				
Jan-88	14.08	-9.95				

Month/ Year	Dry-Bulb (F)	Dry-Bulb (C)	Group #1	Group #2	Total Average (F)	Total Average (C)
Feb-88	20.45	-6.42				
Mar-88	29.19	-1.56				
Nov-88	35.79	2.11				
Dec-88	22.53	-5.26				
Jan-89	24.39	-4.23				
Feb-89	21.43	-5.88				
Mar-89	28.41	-2.00				
Nov-89	32.22	0.12				
Dec-89	11.94	-11.15				
Jan-90	28.68	-1.85				
Feb-90	24.35	-4.25				
Mar-90	31.40	-0.33				
Nov-90	35.60	2.00				
Dec-90	29.04	-1.65				
Jan-91	20.42	-6.43				
Feb-91	26.11	-3.28				
Mar-91	32.03	0.02				
Nov-91	34.35	1.30				
Dec-91	26.30	-3.16				
Jan-92	21.95	-5.58				
Feb-92	23.34	-4.81				
Mar-92	26.93	-2.82				
Nov-92	35.96	2.20				
Dec-92	26.27	-3.18				
Jan-93	25.98	-3.35				
Feb-93	14.90	-9.50				
Mar-93	25.49	-3.62				
Nov-93	33.44	0.80				
Dec-93	23.63	-4.65				
Jan-94	11.06	-11.64				
Feb-94	15.88	-8.95				
Mar-94	27.59	-2.45				
Nov-94	39.31	4.06				
Dec-94	29.30	-1.50				
Jan-95	27.02	-2.77				
Feb-95	18.36	-7.58				
Mar-95	31.20	-0.44				
Nov-95	29.03	-1.65				
Dec-95	20.71	-6.27				
Jan-96	17.90	-7.83				
Feb-96	22.21	-5.44				
Mar-96	24.74	-4.03				
Nov-96	30.87	-0.63				
Dec-96	30.39	-0.90				
Jan-97	19.81	-6.77				
Feb-97	26.68	-2.96				
Mar-97	29.87	-1.18				
Nov-97	32.27	0.15				
Dec-97	27.23	-2.65				
Jan-98	30.14	-1.03				

Month/ Year	Dry-Bulb (F)	Dry-Bulb (C)	Group #1	Group #2	Total Average (F)	Total Average (C)
Feb-98	29.18	-1.57				
Mar-98	33.81	1.00				
Nov-98	36.30	2.39				
Dec-98	29.74	-1.25				
Jan-99	21.58	-5.79				
Feb-99	25.43	-3.65				
Mar-99	28.39	-2.01				
Nov-99	39.07	3.93				
Dec-99	27.48	-2.51				
Jan-00	18.97	-7.24				
Feb-00	24.31	-4.27				
Mar-00	34.48	1.38				
Nov-00	32.87	0.48				
Dec-00	17.94	-7.81				
Jan-01	21.61	-5.77				
Feb-01	24.21	-4.33				
Mar-01	27.61	-2.44				
Nov-01	39.13	3.96				
Dec-01	31.55	-0.25				
Jan-02	27.90	-2.28				
Feb-02	27.82	-2.32				
Mar-02	31.94	-0.04				
Nov-02	34.57	1.43				
Dec-02	24.13	-4.37				
Jan-03	15.81	-9.00				
Feb-03	20.07	-6.63				
Mar-03	28.97	-1.68				
Nov-03	37.70	3.17				
Dec-03	26.32	-3.15				
Jan-04	14.06	-9.96				
Feb-04	20.17	-6.57				
Mar-04	32.61	0.34				
Nov-04	35.93	2.19				
Dec-04	25.65	-3.53				
Jan-05	17.87	-7.85				
Feb-05	22.96	-5.02				
Mar-05	24.55	-4.14				
Nov-05	36.17	2.31				
Dec-05	22.55	-5.25				

	Min of Dry-Bulb Temperature (F)	YEAR					
MONTH	DAY HOUR	61.00	62.00	63.00	64.00	65.00	Grand Total
1.00	1.00	28.04	19.94	6.98	12.02	24.08	6.98
	2.00	21.92	8.06	17.96	26.96	24.08	8.06
	3.00	21.02	19.94	23.00	24.98	19.94	19.94
	4.00	14.00	21.02	23.00	33.98	21.92	14.00
	5.00	10.04	19.04	21.92	24.08	17.96	10.04
	6.00	21.02	33.08	24.98	21.92	25.34	21.02
	7.00	33.08	35.96	23.00	24.98	17.96	17.96
	8.00	17.96	24.98	30.92	15.98	37.04	15.98
	9.00	8.96	12.92	32.00	33.98	31.28	8.96
	10.00	8.96	8.06	26.06	17.96	23.36	8.06
	11.00	14.00	5.00	35.06	19.04	21.02	5.00
	12.00	21.02	5.00	35.96	8.96	22.64	5.00
	13.00	15.98	8.96	17.96	5.00	28.94	5.00
	14.00	28.04	12.92	10.04	1.94	1.94	1.94
	15.00	28.04	37.04	12.02	-5.98	-2.92	-5.98
	16.00	26.06	24.08	6.08	8.96	6.08	6.08
	17.00	17.96	10.94	15.08	21.92	-5.08	-5.08
	18.00	17.06	8.06	24.98	19.94	6.26	6.26
	19.00	12.02	8.96	21.02	15.08	8.06	8.06
	20.00	1.94	19.04	33.98	35.06	20.30	1.94
	21.00	-7.96	12.92	8.06	35.96	21.92	-7.96
	22.00	-9.94	30.92	6.98	30.92	24.98	-9.94
	23.00	-2.02	19.94	10.94	28.04	19.94	-2.02
	24.00	8.06	15.08	-5.08	33.98	19.94	-5.08
	25.00	-4.00	28.94	-2.92	33.08	26.06	-4.00
	26.00	-2.02	24.98	8.06	26.06	24.08	-2.02
	27.00	6.98	17.96	12.92	26.06	19.04	6.98
	28.00	3.02	14.00	3.92	15.08	15.08	3.02
	29.00	8.06	12.02	-7.06	10.04	5.90	-7.06
	30.00	-0.04	6.98	17.06	21.02	1.94	-0.04
	31.00	6.98	1.94	6.98	12.92	1.94	1.94
2.00	1.00	-4.00	12.92	1.04	28.94	12.92	-4.00
	2.00	-11.02	10.04	26.06	17.06	14.36	-11.02
2.00	3.00	-4.00	24.98	5.00	12.02	6.98	-4.00
	4.00	23.00	28.94	-0.04	10.04	3.92	-0.04
	5.00	12.92	33.08	19.04	30.02	3.02	3.02
	6.00	6.98	12.02	19.04	26.96	26.06	6.98
	7.00	6.08	3.92	14.00	33.08	44.06	3.92
	8.00	5.00	8.96	-9.04	23.00	37.94	-9.04
	9.00	12.02	26.06	3.92	15.98	30.92	3.92
	10.00	30.02	-0.94	24.98	14.00	33.08	-0.94
	11.00	12.02	-9.04	28.94	12.92	37.04	-9.04
	12.00	12.92	10.94	21.02	10.94	41.72	10.94
	13.00	26.06	6.98	15.98	19.94	23.90	6.98
	14.00	30.92	21.02	12.02	24.08	19.04	12.02
	15.00	30.92	21.02	3.92	17.06	15.08	3.92
	16.00	19.94	19.04	-2.92	21.92	24.98	-2.92
	17.00	17.06	21.02	-4.00	14.00	24.08	-4.00
	18.00	35.06	14.00	19.94	14.00	26.96	14.00
	19.00	35.06	23.00	28.04	24.98	9.68	9.68
	20.00	26.96	23.00	30.02	21.92	6.98	6.98

	21.00	26.06	14.00	3.92	12.92	24.26	3.92
	22.00	33.08	26.96	-0.94	6.98	10.94	-0.94
	23.00	35.96	28.04	-0.04	-2.02	6.08	-2.02
	24.00	39.92	17.06	17.96	12.92	12.02	12.02
	25.00	44.96	15.08	8.96	1.94	26.78	1.94
	26.00	30.92	28.04	3.02	17.96	19.22	3.02
	27.00	33.98	33.98	1.04	8.06	17.06	1.04
	28.00	28.94	33.98	15.98	6.08	26.06	6.08
	29.00				24.08		24.08
3.00	1.00	24.08	10.94	14.00	19.94	21.92	10.94
	2.00	30.02	6.98	21.02	28.94	23.00	6.98
	3.00	35.96	6.98	17.96	35.06	26.06	6.98
	4.00	33.98	10.94	30.92	30.92	35.96	10.94
	5.00	39.02	23.00	35.06	39.92	36.68	23.00
	6.00	41.00	30.92	33.08	30.92	33.98	30.92
	7.00	33.98	24.98	23.00	32.00	35.06	23.00
	8.00	28.04	17.96	24.98	33.08	37.04	17.96
	9.00	24.08	21.92	30.02	35.96	35.96	21.92
	10.00	15.08	26.06	28.04	26.06	30.02	15.08
3.00	11.00	12.02	30.02	21.02	23.00	23.00	12.02
	12.00	26.96	32.00	33.08	21.92	19.94	19.94
	13.00	26.96	33.98	35.96	26.06	21.02	21.02
	14.00	32.00	32.00	28.04	33.08	24.08	24.08
	15.00	33.08	33.98	23.00	35.06	32.00	23.00
	16.00	15.98	28.04	26.96	30.92	30.92	15.98
	17.00	8.96	30.92	37.94	28.94	28.94	8.96
	18.00	6.98	26.96	30.92	19.94	32.90	6.98
	19.00	28.94	28.04	23.00	19.04	28.04	19.04
	20.00	24.98	37.04	30.02	24.08	18.68	18.68
	21.00	19.94	35.96	26.06	32.00	10.94	10.94
	22.00	28.04	32.00	30.02	32.00	12.02	12.02
	23.00	30.02	32.00	24.98	30.92	35.96	24.98
	24.00	32.00	26.06	26.96	32.00	30.02	26.06
	25.00	30.92	32.00	39.92	39.02	30.02	30.02
	26.00	28.94	30.92	46.94	33.08	32.00	28.94
	27.00	33.98	30.92	42.08	28.94	28.76	28.76
	28.00	44.06	32.00	42.08	24.98	24.98	24.98
	29.00	37.94	39.02	35.06	28.04	36.68	28.04
	30.00	28.04	51.98	39.02	21.02	24.98	21.02
	31.00	21.02	39.02	42.08	15.98	21.02	15.98
4.00	1.00	32.00	35.06	44.96	17.96	24.08	17.96
	2.00	26.96	32.00	42.98	21.92	28.22	21.92
	3.00	26.96	26.06	60.08	28.94	26.06	26.06
	4.00	30.02	23.00	33.08	24.08	26.96	23.00
	5.00	28.04	30.92	28.04	23.00	28.04	23.00
	6.00	35.06	44.96	26.96	35.96	33.08	26.96
	7.00	32.00	48.02	37.94	37.94	39.02	32.00
	8.00	28.04	41.00	28.04	39.02	42.08	28.04
	9.00	21.92	33.98	35.96	30.92	39.92	21.92
	10.00	30.92	37.04	30.92	30.02	39.92	30.02
	11.00	33.98	39.02	35.96	35.96	35.96	33.98
	12.00	30.02	35.06	39.02	37.04	46.76	30.02
	13.00	30.92	35.06	37.94	42.98	37.94	30.92

	14.00	32.00	35.06	37.94	55.94	37.94	32.00
	15.00	33.08	30.92	35.06	39.92	37.04	30.92
	16.00	37.04	28.94	30.92	35.06	39.20	28.94
4.00	17.00	30.02	28.04	50.00	44.96	37.04	28.04
	18.00	32.00	32.00	50.00	55.94	35.06	32.00
	19.00	33.08	35.96	42.08	46.04	35.96	33.08
	20.00	28.04	32.00	51.08	39.92	37.94	28.04
	21.00	35.96	33.98	46.04	37.94	37.94	33.98
	22.00	42.98	51.98	37.04	39.02	45.32	37.04
	23.00	46.04	42.98	33.08	46.04	39.92	33.08
	24.00	48.92	37.04	37.94	39.02	35.06	35.06
	25.00	57.92	41.00	33.98	37.94	37.58	33.98
	26.00	44.96	48.02	33.98	35.96	37.04	33.98
	27.00	37.94	57.92	33.08	44.06	44.96	33.08
	28.00	39.92	64.94	35.06	51.08	44.06	35.06
	29.00	35.96	64.94	42.08	44.96	37.94	35.96
	30.00	32.00	55.04	48.92	42.08	44.96	32.00
5.00	1.00	37.04	48.02	33.08	46.94	48.92	33.08
	2.00	37.04	46.04	37.04	44.06	51.98	37.04
	3.00	39.92	44.06	35.06	37.04	60.08	35.06
	4.00	37.04	48.92	48.92	42.98	56.66	37.04
	5.00	37.94	48.02	55.04	51.08	51.08	37.94
	6.00	39.92	50.00	42.08	46.94	46.04	39.92
	7.00	48.02	44.06	42.08	51.98	46.04	42.08
	8.00	59.00	39.92	57.92	64.04	46.58	39.92
	9.00	57.92	37.94	64.04	66.92	55.94	37.94
	10.00	48.02	33.98	51.08	55.94	62.96	33.98
	11.00	42.08	42.98	39.02	51.08	57.20	39.02
	12.00	51.98	39.02	39.02	46.94	53.06	39.02
	13.00	57.92	48.92	37.04	57.92	49.46	37.04
	14.00	60.08	50.00	48.92	46.04	39.92	39.92
	15.00	60.08	59.00	51.08	46.04	44.06	44.06
	16.00	51.08	57.02	44.06	48.02	57.92	44.06
	17.00	44.06	53.96	53.96	55.04	57.74	44.06
	18.00	48.02	64.94	55.04	51.08	51.98	48.02
	19.00	48.02	64.04	51.08	53.06	50.00	48.02
	20.00	46.94	60.08	53.96	46.94	53.06	46.94
	21.00	44.96	59.00	44.96	39.02	48.92	39.02
	22.00	48.02	46.04	48.02	51.98	57.92	46.04
	23.00	44.06	51.08	39.92	60.08	60.44	39.92
5.00	24.00	46.94	62.06	32.00	62.96	53.96	32.00
	25.00	55.04	59.00	42.08	60.98	55.94	42.08
	26.00	41.00	57.02	46.94	51.08	66.92	41.00
	27.00	39.92	51.98	41.00	55.04	66.92	39.92
	28.00	41.00	53.96	53.06	46.04	63.32	41.00
	29.00	44.96	51.98	57.92	44.96	48.02	44.96
	30.00	41.00	62.06	55.94	39.02	42.08	39.02
	31.00	39.92	66.02	53.06	50.00	41.00	39.92
6.00	1.00	57.02	60.08	50.00	53.96	51.98	50.00
	2.00	64.94	55.04	53.06	50.00	57.02	50.00
	3.00	51.98	46.94	57.02	46.94	50.72	46.94
	4.00	42.98	53.06	64.04	44.06	42.98	42.98
	5.00	53.96	60.98	64.04	41.00	48.02	41.00

	6.00	60.98	57.92	62.96	50.00	55.04	50.00
	7.00	53.96	48.02	60.08	57.92	66.92	48.02
	8.00	62.96	51.08	57.92	60.98	73.04	51.08
	9.00	66.02	53.06	62.06	60.08	69.08	53.06
	10.00	64.94	62.06	66.02	60.98	64.94	60.98
	11.00	60.98	66.92	62.06	51.08	57.02	51.08
	12.00	66.02	60.08	50.00	48.92	51.98	48.92
	13.00	62.06	57.02	50.00	64.94	55.04	50.00
	14.00	55.04	55.94	51.98	66.02	51.62	51.62
	15.00	46.94	57.02	51.98	60.98	46.04	46.04
	16.00	41.00	51.08	46.04	48.92	48.02	41.00
	17.00	46.04	55.94	48.92	46.04	51.98	46.04
	18.00	51.98	66.02	51.08	48.92	53.06	48.92
	19.00	55.94	68.00	55.04	64.04	53.96	53.96
	20.00	60.98	62.06	62.06	66.92	57.02	57.02
	21.00	64.94	60.08	50.00	66.92	64.94	50.00
	22.00	60.98	59.00	46.94	68.00	69.08	46.94
	23.00	55.94	64.04	50.00	62.96	64.94	50.00
	24.00	55.04	64.94	50.00	69.08	61.34	50.00
	25.00	51.08	60.98	55.04	57.02	53.06	51.08
	26.00	53.06	59.00	53.96	51.08	46.94	46.94
	27.00	55.04	51.98	60.98	64.04	57.02	51.98
	28.00	57.02	55.04	64.94	51.08	62.96	51.08
	29.00	59.00	57.92	68.00	57.92	73.94	57.92
6.00	30.00	69.98	60.08	66.92	66.92	59.90	59.90
7.00	1.00	62.06	62.96	64.94	66.92	51.08	51.08
	2.00	64.94	50.00	66.92	66.02	53.96	50.00
	3.00	64.94	53.96	60.08	66.02	62.06	53.96
	4.00	57.02	55.04	53.96	60.98	57.02	53.96
	5.00	51.98	50.00	53.96	59.00	66.02	50.00
	6.00	53.06	55.94	51.08	55.04	57.92	51.08
	7.00	55.04	57.02	51.98	51.98	55.94	51.98
	8.00	59.00	62.06	55.04	62.96	66.92	55.04
	9.00	53.06	64.04	46.04	60.08	64.94	46.04
	10.00	51.08	57.92	50.00	55.04	65.66	50.00
	11.00	55.04	55.04	55.94	59.00	60.98	55.04
	12.00	62.96	66.02	55.94	66.92	51.98	51.98
	13.00	64.04	64.04	60.08	62.96	55.94	55.94
	14.00	68.00	60.08	62.96	64.04	69.98	60.08
	15.00	68.00	57.92	64.04	62.06	64.04	57.92
	16.00	66.02	57.02	60.08	60.98	57.02	57.02
	17.00	68.00	62.06	62.06	62.06	66.92	62.06
	18.00	62.96	60.08	66.92	69.08	66.38	60.08
	19.00	62.06	59.00	68.00	69.98	58.64	58.64
	20.00	66.92	57.92	66.02	71.06	48.02	48.02
	21.00	66.92	66.02	62.96	69.98	48.02	48.02
	22.00	68.00	59.00	62.06	71.96	57.02	57.02
	23.00	71.06	60.98	64.04	69.08	64.58	60.98
	24.00	69.98	57.92	62.06	66.92	71.06	57.92
	25.00	71.06	53.06	64.04	64.04	73.94	53.06
	26.00	66.92	57.02	66.02	66.92	64.04	57.02
	27.00	62.96	51.08	64.94	68.00	62.96	51.08
	28.00	62.06	53.06	69.98	69.08	57.02	53.06

	29.00	69.98	64.94	69.98	69.98	53.06	53.06
	30.00	69.98	64.04	64.94	60.98	59.00	59.00
	31.00	69.08	68.00	55.04	51.98	55.04	51.98
8.00	1.00	64.94	64.04	64.94	51.98	62.06	51.98
	2.00	64.94	57.02	64.94	68.00	63.68	57.02
	3.00	64.04	57.02	62.96	59.00	59.00	57.02
	4.00	62.06	66.02	69.08	53.06	53.96	53.06
	5.00	66.02	64.04	64.04	62.96	62.06	62.06
8.00	6.00	66.02	71.06	57.02	51.98	64.94	51.98
	7.00	62.06	66.02	66.92	50.00	69.08	50.00
	8.00	60.08	60.98	62.96	64.04	71.06	60.08
	9.00	64.04	60.08	59.00	53.96	71.60	53.96
	10.00	68.00	57.92	60.08	48.92	68.00	48.92
	11.00	64.94	55.04	53.96	64.04	62.06	53.96
	12.00	66.92	51.08	55.94	62.06	57.02	51.08
	13.00	57.02	60.98	68.00	53.96	62.60	53.96
	14.00	50.00	60.98	59.00	48.92	62.06	48.92
	15.00	60.08	55.94	50.00	50.00	64.94	50.00
	16.00	59.00	57.02	57.92	51.08	69.98	51.08
	17.00	50.00	62.96	62.06	60.98	66.02	50.00
	18.00	53.06	50.00	55.04	59.00	73.04	50.00
	19.00	57.92	51.08	46.94	55.04	69.26	46.94
	20.00	62.06	69.98	64.04	48.92	58.46	48.92
	21.00	59.00	64.04	60.08	53.96	53.96	53.96
	22.00	62.96	59.00	60.98	66.92	60.08	59.00
	23.00	64.04	55.04	64.04	71.96	56.30	55.04
	24.00	66.92	57.02	55.94	62.06	51.08	51.08
	25.00	66.92	60.98	50.00	57.92	51.98	50.00
	26.00	68.00	64.04	46.94	57.02	66.02	46.94
	27.00	66.92	64.04	50.00	50.00	66.92	50.00
	28.00	64.94	62.96	51.98	57.92	51.62	51.62
	29.00	64.94	66.02	62.06	64.94	44.96	44.96
	30.00	62.06	64.94	64.04	66.02	44.06	44.06
	31.00	64.04	62.06	59.00	68.00	44.96	44.96
9.00	1.00	64.94	73.04	48.02	59.00	57.02	48.02
	2.00	69.98	60.08	48.92	48.02	53.96	48.02
	3.00	66.02	55.04	64.94	51.08	48.02	48.02
	4.00	64.94	57.92	53.06	64.04	55.94	53.06
	5.00	68.00	53.96	51.08	62.96	48.92	48.92
	6.00	62.96	46.04	48.92	51.98	51.98	46.04
	7.00	68.00	39.02	48.92	53.06	60.08	39.02
	8.00	68.00	44.06	55.94	59.00	62.06	44.06
	9.00	62.96	55.04	57.02	60.08	64.04	55.04
	10.00	68.00	69.08	55.94	66.02	64.94	55.94
	11.00	62.96	62.96	46.04	60.08	59.00	46.04
9.00	12.00	66.92	57.02	55.94	53.96	55.94	53.96
	13.00	69.08	53.06	46.04	44.06	55.94	44.06
	14.00	69.98	59.00	39.92	37.94	57.02	37.94
	15.00	51.08	48.02	41.00	44.06	57.92	41.00
	16.00	44.06	46.94	53.06	37.04	57.92	37.04
	17.00	42.98	55.04	57.02	55.94	57.92	42.98
	18.00	39.92	51.08	62.06	51.98	64.94	39.92
	19.00	53.96	46.94	53.06	55.04	62.96	46.94

	20.00	62.06	41.00	53.96	51.98	66.02	41.00
	21.00	64.04	33.08	46.04	51.98	71.06	33.08
	22.00	59.00	39.92	39.92	48.92	71.06	39.92
	23.00	60.98	42.98	39.02	53.06	68.72	39.02
	24.00	60.98	42.98	30.92	55.04	57.02	30.92
	25.00	62.96	44.96	37.04	50.00	47.66	37.04
	26.00	53.06	53.96	39.92	42.08	42.08	39.92
	27.00	42.98	51.08	53.06	55.04	39.02	39.02
	28.00	46.04	53.06	57.92	46.04	37.04	37.04
	29.00	42.08	48.92	48.92	46.94	51.08	42.08
	30.00	37.94	42.98	42.98	46.04	55.94	37.94
10.00	1.00	48.92	41.00	42.98	39.92	57.02	39.92
	2.00	53.96	42.08	46.04	53.06	46.94	42.08
	3.00	46.04	48.02	55.04	48.02	44.06	44.06
	4.00	35.06	55.94	46.04	48.92	35.60	35.06
	5.00	30.92	55.94	35.06	37.04	32.00	30.92
	6.00	42.08	55.94	39.92	30.92	30.92	30.92
	7.00	46.04	53.06	55.94	32.00	41.00	32.00
	8.00	50.00	51.98	51.98	33.08	50.00	33.08
	9.00	53.06	53.96	39.92	39.02	46.04	39.02
	10.00	46.04	53.06	37.94	35.96	46.04	35.96
	11.00	55.04	53.06	42.08	33.08	46.04	33.08
	12.00	50.00	55.04	46.04	28.04	46.76	28.04
	13.00	48.92	44.06	39.92	44.96	39.02	39.02
	14.00	39.02	37.94	35.06	41.00	37.94	35.06
	15.00	35.06	50.00	39.92	37.94	53.60	35.06
	16.00	35.96	57.02	41.00	46.94	41.72	35.96
	17.00	30.02	46.94	42.98	53.96	33.08	30.02
	18.00	39.92	35.96	48.02	53.96	35.96	35.96
10.00	19.00	46.04	37.94	48.92	39.92	39.92	37.94
	20.00	42.98	42.08	50.00	35.96	44.96	35.96
	21.00	44.96	44.96	46.94	28.94	51.08	28.94
	22.00	39.02	35.96	46.94	37.04	59.00	35.96
	23.00	30.02	41.00	44.96	28.94	48.02	28.94
	24.00	32.00	33.08	44.96	26.06	38.30	26.06
	25.00	37.04	26.96	46.94	30.92	35.06	26.96
	26.00	41.00	30.92	50.00	46.94	42.98	30.92
	27.00	30.02	30.02	51.08	42.08	41.00	30.02
	28.00	26.06	35.96	48.02	46.94	28.22	26.06
	29.00	44.96	30.92	39.02	50.00	24.98	24.98
	30.00	53.06	28.94	37.04	35.96	30.02	28.94
	31.00	51.08	39.92	37.04	35.06	44.96	35.06
11.00	1.00	32.00	33.98	46.04	28.04	34.70	28.04
	2.00	24.98	28.94	35.96	33.98	24.98	24.98
	3.00	50.00	32.00	35.06	42.08	33.98	32.00
	4.00	51.98	32.00	33.08	33.98	37.94	32.00
	5.00	51.98	24.08	42.08	35.96	28.94	24.08
	6.00	46.04	26.06	48.92	41.00	37.04	26.06
	7.00	33.08	21.02	48.92	35.96	47.30	21.02
	8.00	28.94	37.04	48.02	37.94	39.92	28.94
	9.00	28.04	30.92	48.02	30.92	28.04	28.04
	10.00	24.08	44.06	42.98	41.00	23.00	23.00
	11.00	19.94	37.04	44.06	44.96	37.94	19.94

	12.00	28.94	28.04	35.06	42.08	42.08	28.04
	13.00	44.96	28.94	35.06	53.06	42.98	28.94
	14.00	46.04	33.08	37.04	35.96	31.28	31.28
	15.00	35.96	30.02	33.08	32.00	24.08	24.08
	16.00	28.94	26.96	33.98	44.96	39.20	26.96
	17.00	37.94	35.06	48.02	41.00	26.06	26.06
	18.00	32.00	30.02	51.08	33.08	26.60	26.60
	19.00	26.96	24.08	35.06	30.92	31.64	24.08
	20.00	28.94	28.94	28.94	32.00	37.04	28.94
	21.00	33.08	35.96	46.04	23.00	39.02	23.00
	22.00	32.00	33.98	42.08	17.96	40.64	17.96
	23.00	33.98	33.08	44.96	17.06	39.02	17.06
	24.00	41.00	33.08	32.00	24.08	32.90	24.08
11.00	25.00	35.06	28.04	28.04	37.04	28.04	28.04
	26.00	26.96	21.02	26.96	46.94	39.02	21.02
	27.00	30.02	21.92	37.94	32.00	38.66	21.92
	28.00	24.08	28.04	30.92	35.96	31.46	24.08
	29.00	26.96	28.04	39.92	32.00	23.00	23.00
	30.00	30.02	26.06	26.06	17.96	26.06	17.96
12.00	1.00	33.98	26.06	21.92	17.06	26.96	17.06
	2.00	30.92	26.96	26.06	17.96	30.02	17.96
	3.00	32.00	30.02	30.02	28.94	30.02	28.94
	4.00	28.94	26.96	24.98	35.96	32.72	24.98
	5.00	28.94	33.08	26.96	30.02	32.00	26.96
	6.00	26.06	30.02	30.92	17.96	28.58	17.96
	7.00	30.02	26.96	28.04	12.92	23.00	12.92
	8.00	23.00	24.98	30.92	15.98	26.06	15.98
	9.00	21.92	23.00	28.04	24.08	32.90	21.92
	10.00	26.96	15.08	28.04	14.00	30.02	14.00
	11.00	32.00	8.96	21.02	28.04	30.02	8.96
	12.00	35.06	3.02	21.02	44.06	35.06	3.02
	13.00	24.08	5.00	28.94	41.00	39.20	5.00
	14.00	17.06	8.06	15.08	30.02	39.20	8.06
	15.00	12.02	6.08	10.04	21.92	33.98	6.08
	16.00	6.98	12.92	12.02	15.08	34.70	6.98
	17.00	24.98	12.02	10.94	30.02	31.64	10.94
	18.00	33.98	30.92	15.98	12.02	28.94	12.02
	19.00	35.96	30.02	6.08	10.04	19.94	6.08
	20.00	30.92	6.98	3.92	24.08	14.00	3.92
	21.00	28.04	5.00	3.02	19.04	14.00	3.02
	22.00	21.92	23.00	15.98	28.04	15.98	15.98
	23.00	15.08	26.06	21.92	30.92	26.06	15.08
	24.00	21.02	17.96	21.92	35.96	43.70	17.96
	25.00	19.94	17.96	26.06	46.04	30.92	17.96
	26.00	23.00	19.94	26.06	42.98	12.02	12.02
	27.00	23.00	6.08	21.02	30.92	12.02	6.08
	28.00	23.00	17.96	17.06	24.98	24.08	17.06
	29.00	8.96	17.96	15.08	19.94	28.94	8.96
	30.00	1.04	-2.02	5.00	30.92	28.04	-2.02
	31.00	12.02	-2.92	-4.00	30.92	41.00	-4.00

	Min of Dry-Bulb Temperature (F)		YEAR					
MONTH	DAY	HOUR	66.00	67.00	68.00	69.00	70.00	Grand Total
1.00	1.00		42.08	24.08	0.32	6.08	6.08	0.32

	2.00	33.98	32.72	-5.08	7.34	5.00	-5.08
	3.00	33.62	30.92	15.62	14.00	13.64	13.64
	4.00	26.96	33.26	13.28	10.04	11.30	10.04
	5.00	26.06	26.06	8.06	3.92	10.04	3.92
	6.00	38.66	21.02	8.06	10.04	22.28	8.06
	7.00	33.98	24.98	3.92	19.94	8.06	3.92
	8.00	10.58	32.00	-3.64	19.04	-0.40	-3.64
	9.00	10.04	24.08	-7.06	22.28	-2.92	-7.06
	10.00	24.98	24.08	6.62	14.72	1.58	1.58
	11.00	13.28	25.70	-4.00	12.92	15.08	-4.00
	12.00	6.98	24.08	-9.94	10.04	15.08	-9.94
	13.00	6.98	24.08	-7.06	21.92	17.96	-7.06
	14.00	24.08	33.08	24.98	24.98	8.96	8.96
	15.00	14.72	31.64	18.32	19.58	5.00	5.00
	16.00	5.00	23.00	6.98	14.00	6.98	5.00
	17.00	16.70	24.26	10.94	28.58	26.96	10.94
	18.00	24.62	8.24	21.92	35.96	12.20	8.24
	19.00	24.08	6.98	26.96	28.22	5.36	5.36
	20.00	24.08	15.98	30.02	23.00	-2.02	-2.02
	21.00	21.92	26.06	30.02	26.96	-0.04	-0.04
	22.00	14.00	37.04	24.08	30.02	-2.02	-2.02
	23.00	28.04	39.92	23.00	35.96	1.04	1.04
	24.00	15.98	41.00	12.02	41.36	8.96	8.96
	25.00	10.04	51.08	3.02	24.26	17.96	3.02
	26.00	5.00	42.08	6.08	12.02	24.98	5.00
	27.00	10.04	36.68	19.94	8.24	24.98	8.24
	28.00	1.04	24.08	33.08	3.92	30.02	1.04
	29.00	-0.04	17.96	35.06	23.00	38.30	-0.04
	30.00	12.02	16.34	35.96	32.72	17.24	12.02
	31.00	8.06	8.96	35.06	30.02	12.92	8.06
2.00	1.00	15.08	29.66	32.00	28.04	30.92	15.08
	2.00	19.94	24.62	37.94	30.92	41.00	19.94
2.00	3.00	16.34	14.00	30.02	25.34	10.22	10.22
	4.00	12.02	17.06	21.92	17.06	3.02	3.02
	5.00	10.58	29.30	22.64	15.98	9.68	9.68
	6.00	3.02	6.62	23.00	12.92	24.98	3.02
	7.00	-0.94	6.08	26.96	15.98	17.96	-0.94
	8.00	14.00	-2.92	19.94	15.08	24.98	-2.92
	9.00	19.04	8.96	21.92	23.00	32.00	8.96
	10.00	33.08	26.06	6.98	15.98	35.06	6.98
	11.00	40.64	19.94	3.02	10.94	28.22	3.02
	12.00	35.96	1.94	12.56	24.08	19.04	1.94
	13.00	35.96	-4.00	6.98	16.34	8.06	-4.00
	14.00	35.06	14.00	15.08	10.94	3.02	3.02
	15.00	28.58	39.02	21.02	14.00	16.70	14.00
	16.00	28.04	20.66	15.98	12.02	17.06	12.02
	17.00	21.20	19.04	11.66	15.98	12.02	11.66
	18.00	17.96	17.96	10.04	19.94	24.08	10.04
	19.00	5.00	19.94	12.92	24.98	17.96	5.00
	20.00	3.02	28.94	5.00	28.04	15.08	3.02
	21.00	12.92	20.66	1.94	26.96	14.00	1.94
	22.00	21.02	15.08	6.08	24.08	24.08	6.08
	23.00	26.96	20.66	17.42	30.56	22.64	17.42

	24.00	28.04	10.94	8.96	30.02	21.92	8.96
	25.00	30.02	8.96	10.04	28.04	6.98	6.98
	26.00	26.96	10.94	12.92	26.96	1.04	1.04
	27.00	15.98	14.00	17.06	26.06	17.06	14.00
	28.00	35.06	19.76	24.08	24.08	19.04	19.04
	29.00			32.00			32.00
3.00	1.00	37.94	12.02	24.98	24.08	15.98	12.02
	2.00	35.96	10.94	23.00	28.94	33.08	10.94
	3.00	28.94	37.04	10.04	28.94	32.00	10.04
	4.00	42.98	30.92	15.08	22.28	32.00	15.08
	5.00	37.22	30.92	30.92	17.06	33.08	17.06
	6.00	28.94	30.92	24.08	19.94	28.04	19.94
	7.00	24.98	24.62	14.00	24.26	24.98	14.00
	8.00	19.04	17.06	21.02	21.02	17.24	17.06
	9.00	15.98	32.00	39.92	24.08	15.08	15.08
	10.00	24.98	30.02	37.04	24.98	14.00	14.00
3.00	11.00	35.06	37.94	29.30	15.98	19.94	15.98
	12.00	37.04	35.06	26.96	14.00	23.00	14.00
	13.00	32.90	35.06	19.58	26.06	28.94	19.58
	14.00	26.06	39.56	17.96	30.74	24.62	17.96
	15.00	29.66	30.56	28.94	28.04	17.96	17.96
	16.00	21.02	17.96	37.04	26.06	17.96	17.96
	17.00	26.06	11.66	39.92	24.08	19.94	11.66
	18.00	35.06	3.74	39.02	35.96	30.02	3.74
	19.00	46.94	-2.02	42.08	37.94	32.00	-2.02
	20.00	39.02	19.04	39.02	33.08	28.94	19.04
	21.00	35.96	30.56	50.00	40.28	33.98	30.56
	22.00	42.08	28.94	42.08	35.42	30.92	28.94
	23.00	48.74	32.00	29.66	26.06	32.00	26.06
	24.00	33.62	30.02	26.96	35.06	33.98	26.96
	25.00	26.06	28.04	26.06	40.64	35.06	26.06
	26.00	26.06	37.04	39.92	33.98	40.64	26.06
	27.00	21.92	37.94	41.00	30.02	33.62	21.92
	28.00	19.94	41.00	42.98	24.98	28.94	19.94
	29.00	23.00	42.08	51.98	31.46	19.94	19.94
	30.00	32.00	33.98	42.98	23.00	6.08	6.08
	31.00	30.02	42.08	39.92	21.02	28.04	21.02
4.00	1.00	28.04	44.96	35.60	19.94	26.96	19.94
	2.00	35.06	57.02	32.00	33.98	35.06	32.00
	3.00	32.00	34.34	37.94	30.02	35.06	30.02
	4.00	35.78	28.04	48.02	33.98	33.98	28.04
	5.00	32.00	39.02	31.64	48.02	30.02	30.02
	6.00	33.98	48.92	28.04	39.92	30.92	28.04
	7.00	35.96	37.04	33.98	30.02	35.96	30.02
	8.00	35.06	35.96	46.04	41.00	33.08	33.08
	9.00	33.26	35.06	50.36	46.04	46.94	33.26
	10.00	30.92	35.24	41.00	51.62	30.56	30.56
	11.00	35.06	28.04	41.00	39.38	24.08	24.08
	12.00	30.02	26.96	33.98	33.98	26.96	26.96
	13.00	37.94	35.06	48.02	35.06	30.92	30.92
	14.00	32.00	46.04	51.98	42.98	42.98	32.00
	15.00	35.06	54.68	41.00	44.96	42.98	35.06
	16.00	39.02	51.98	37.04	55.04	37.04	37.04

4.00	17.00	37.04	42.98	35.96	57.02	50.00	35.96
	18.00	35.96	43.70	42.08	57.74	40.46	35.96
	19.00	45.68	41.00	51.98	39.02	33.08	33.08
	20.00	42.08	41.90	48.92	37.04	39.02	37.04
	21.00	44.96	39.02	53.96	35.96	42.08	35.96
	22.00	44.96	48.38	54.32	44.06	46.04	44.06
	23.00	41.00	40.28	46.04	41.72	46.04	40.28
	24.00	53.06	33.98	46.04	37.94	46.04	33.98
	25.00	51.62	33.08	42.08	37.94	42.08	33.08
	26.00	40.64	33.98	41.00	50.00	50.00	33.98
	27.00	37.94	35.06	43.70	48.92	51.08	35.06
	28.00	37.94	39.92	35.96	56.30	53.96	35.96
	29.00	37.94	37.04	37.94	46.04	57.02	37.04
	30.00	48.02	37.94	41.36	42.08	59.00	37.94
5.00	1.00	45.32	50.00	39.92	35.96	57.02	35.96
	2.00	39.02	53.24	42.08	42.98	53.24	39.02
	3.00	35.06	44.96	50.00	53.96	46.04	35.06
	4.00	38.66	37.94	46.40	55.94	46.04	37.94
	5.00	33.08	46.94	39.02	46.04	46.94	33.08
	6.00	44.60	37.04	37.04	39.02	37.94	37.04
	7.00	35.06	39.02	35.96	51.98	33.98	33.98
	8.00	43.34	39.02	39.92	55.04	42.08	39.02
	9.00	31.64	42.62	55.04	52.34	57.02	31.64
	10.00	30.02	39.92	55.40	44.96	62.06	30.02
	11.00	33.98	39.02	48.92	42.98	60.08	33.98
	12.00	46.94	41.72	53.06	41.00	60.08	41.00
	13.00	44.96	35.96	51.08	42.98	62.06	35.96
	14.00	42.98	42.08	48.92	42.08	55.04	42.08
	15.00	44.06	48.02	53.06	39.02	51.98	39.02
	16.00	51.08	42.98	57.02	51.08	51.08	42.98
	17.00	48.02	42.98	57.92	59.00	48.56	42.98
	18.00	55.94	48.02	55.04	64.04	46.94	46.94
	19.00	60.98	58.28	50.00	62.96	50.00	50.00
	20.00	57.02	45.32	46.94	60.98	56.12	45.32
	21.00	56.66	42.98	46.04	50.36	44.96	42.98
	22.00	55.40	39.92	44.96	46.94	55.94	39.92
	23.00	48.92	39.02	46.94	57.02	60.62	39.02
5.00	24.00	55.94	44.06	51.98	57.02	55.94	44.06
	25.00	60.98	46.04	44.06	53.24	55.94	44.06
	26.00	55.04	46.94	44.06	44.60	59.72	44.06
	27.00	55.04	48.02	48.02	35.06	48.92	35.06
	28.00	60.08	55.40	48.92	51.98	46.04	46.04
	29.00	48.74	46.76	52.34	73.04	46.04	46.04
	30.00	44.96	41.00	53.96	61.34	48.02	41.00
	31.00	41.00	42.98	53.96	53.06	51.98	41.00
6.00	1.00	42.08	44.96	53.96	57.02	60.08	42.08
	2.00	42.08	50.00	60.98	66.92	66.02	42.08
	3.00	44.06	55.04	57.56	51.98	56.66	44.06
	4.00	60.08	59.00	53.06	46.94	53.96	46.94
	5.00	62.06	59.00	51.98	51.08	59.00	51.08
	6.00	66.92	60.08	60.08	57.20	51.26	51.26
	7.00	67.28	60.08	64.04	55.04	44.96	44.96
	8.00	62.06	64.04	64.94	53.06	50.00	50.00

	9.00	62.06	66.02	69.98	55.04	62.06	55.04
	10.00	50.90	68.00	61.70	48.92	60.08	48.92
	11.00	48.02	64.94	60.98	60.98	62.06	48.02
	12.00	46.94	66.92	64.58	68.00	59.90	46.94
	13.00	57.02	66.38	58.28	68.72	48.02	48.02
	14.00	61.70	60.08	53.96	68.00	48.92	48.92
	15.00	55.94	65.66	55.04	66.38	55.94	55.04
	16.00	57.92	68.00	57.02	54.32	57.92	54.32
	17.00	55.94	66.92	54.32	48.92	64.04	48.92
	18.00	51.98	66.56	48.02	55.04	62.06	48.02
	19.00	57.02	57.74	60.08	60.98	59.90	57.02
	20.00	53.96	53.06	52.34	59.90	50.00	50.00
	21.00	65.30	55.04	44.96	57.02	48.02	44.96
	22.00	55.04	70.70	59.00	51.98	55.76	51.98
	23.00	55.94	66.92	61.70	57.92	51.08	51.08
	24.00	66.02	66.02	59.00	66.92	55.94	55.94
	25.00	66.02	61.34	68.00	64.76	58.64	58.64
	26.00	64.04	57.02	60.08	60.98	55.04	55.04
	27.00	68.00	53.06	58.64	68.00	51.62	51.62
	28.00	69.98	57.92	57.92	73.04	44.96	44.96
	29.00	69.98	55.94	57.92	62.96	48.02	48.02
6.00	30.00	66.92	60.98	69.98	59.00	66.02	59.00
7.00	1.00	57.92	64.04	71.06	59.36	62.06	57.92
	2.00	60.98	68.72	73.04	51.08	69.08	51.08
	3.00	68.00	64.94	64.04	60.08	64.94	60.08
	4.00	69.98	57.92	57.74	53.96	66.20	53.96
	5.00	66.02	57.92	51.98	69.98	62.06	51.98
	6.00	69.98	53.06	57.74	61.34	60.44	53.06
	7.00	66.02	57.02	50.00	55.94	53.96	50.00
	8.00	57.92	62.06	60.98	55.94	60.08	55.94
	9.00	55.04	70.34	69.98	55.04	64.94	55.04
	10.00	71.06	68.00	64.94	60.98	66.56	60.98
	11.00	68.72	69.08	69.98	62.96	62.96	62.96
	12.00	66.02	69.98	68.00	62.78	62.96	62.78
	13.00	73.04	64.94	66.92	60.08	55.04	55.04
	14.00	70.34	62.06	69.08	62.96	62.06	62.06
	15.00	62.06	60.08	71.06	62.06	66.02	60.08
	16.00	55.04	60.08	71.96	66.92	64.04	55.04
	17.00	60.08	57.92	71.96	71.96	57.02	57.02
	18.00	66.02	64.04	73.94	71.06	64.04	64.04
	19.00	66.02	64.04	68.00	64.58	59.00	59.00
	20.00	59.36	66.92	64.22	64.04	65.66	59.36
	21.00	48.92	67.10	55.94	66.02	57.02	48.92
	22.00	55.04	62.06	62.96	68.00	53.96	53.96
	23.00	68.00	64.94	69.98	63.68	53.96	53.96
	24.00	64.94	69.08	68.00	60.08	62.06	60.08
	25.00	69.08	68.00	65.30	64.94	66.92	64.94
	26.00	71.96	64.04	57.92	66.02	64.04	57.92
	27.00	66.02	62.06	62.96	68.00	62.96	62.06
	28.00	69.08	64.22	63.32	69.98	66.92	63.32
	29.00	63.32	62.96	55.94	69.98	68.00	55.94
	30.00	57.92	66.02	51.98	66.02	66.02	51.98
	31.00	55.94	64.04	66.02	64.94	71.96	55.94

8.00	1.00	55.94	62.06	62.96	66.92	68.72	55.94
	2.00	63.68	59.00	62.06	66.02	64.04	59.00
	3.00	57.02	68.00	64.04	64.04	60.98	57.02
	4.00	51.98	66.92	71.96	63.68	57.74	51.98
	5.00	60.98	64.40	66.02	62.06	53.06	53.06
8.00	6.00	60.98	59.00	68.00	60.98	57.92	57.92
	7.00	69.98	57.92	70.70	62.06	59.00	57.92
	8.00	64.94	66.92	66.02	67.64	55.94	55.94
	9.00	69.98	68.00	69.08	60.98	60.08	60.08
	10.00	69.98	62.96	63.68	61.70	60.98	60.98
	11.00	71.60	57.02	54.68	55.94	60.08	54.68
	12.00	64.76	53.96	50.00	55.04	60.08	50.00
	13.00	57.02	59.00	53.96	59.00	62.96	53.96
	14.00	57.92	57.02	66.02	62.96	60.98	57.02
	15.00	62.06	59.00	57.02	68.00	64.04	57.02
	16.00	66.92	60.08	55.04	70.70	66.02	55.04
	17.00	64.04	64.94	71.06	66.92	64.94	64.04
	18.00	57.02	66.92	63.68	67.64	60.08	57.02
	19.00	64.04	69.08	60.98	64.94	55.94	55.94
	20.00	60.98	61.34	69.08	56.66	69.08	56.66
	21.00	60.98	60.08	69.98	48.92	57.38	48.92
	22.00	71.06	60.98	64.04	48.02	50.00	48.02
	23.00	67.10	57.02	71.96	55.04	60.98	55.04
	24.00	60.08	55.94	71.96	60.08	55.94	55.94
	25.00	55.94	55.94	72.32	64.94	53.96	53.96
	26.00	62.42	62.06	58.28	55.04	55.94	55.04
	27.00	55.04	66.92	53.42	46.94	60.98	46.94
	28.00	60.98	61.70	46.94	51.98	60.08	46.94
	29.00	66.92	60.08	46.04	57.92	64.94	46.04
	30.00	66.02	60.08	48.02	64.94	62.96	48.02
	31.00	64.94	49.64	51.08	66.02	56.66	49.64
9.00	1.00	64.04	46.04	55.04	66.92	48.92	46.04
	2.00	60.08	50.00	57.92	67.64	46.04	46.04
	3.00	66.92	46.04	51.98	66.02	55.94	46.04
	4.00	66.92	57.02	55.04	64.94	69.62	55.04
	5.00	60.62	55.94	62.06	66.92	60.26	55.94
	6.00	55.94	55.04	64.04	68.00	55.76	55.04
	7.00	53.96	57.92	55.04	68.00	48.02	48.02
	8.00	53.06	55.04	51.98	62.96	57.02	51.98
	9.00	50.00	62.96	57.92	57.92	62.06	50.00
	10.00	53.06	46.76	60.98	48.74	63.68	46.76
	11.00	55.04	42.08	60.08	44.06	51.08	42.08
9.00	12.00	53.06	42.08	55.04	51.08	44.96	42.08
	13.00	59.00	46.04	53.06	53.96	53.06	46.04
	14.00	59.00	50.00	48.02	57.02	57.02	48.02
	15.00	46.76	51.98	53.96	64.04	57.92	46.76
	16.00	39.92	62.06	55.04	60.98	58.46	39.92
	17.00	44.06	60.08	55.94	53.96	50.00	44.06
	18.00	48.02	62.06	57.02	47.30	64.40	47.30
	19.00	51.98	57.02	51.98	42.98	51.98	42.98
	20.00	53.06	57.02	51.08	46.94	44.96	44.96
	21.00	51.98	62.96	55.04	44.06	60.08	44.06
	22.00	55.22	43.70	57.92	44.06	64.94	43.70

	23.00	50.00	42.98	60.08	44.96	69.08	42.98
	24.00	44.96	39.92	60.08	53.96	66.02	39.92
	25.00	47.30	41.00	64.04	51.98	69.98	41.00
	26.00	39.92	42.08	53.78	46.04	62.96	39.92
	27.00	44.06	55.94	46.94	48.92	48.92	44.06
	28.00	49.64	64.94	46.94	50.72	42.08	42.08
	29.00	51.08	58.64	44.06	44.06	41.00	41.00
	30.00	50.00	50.00	46.94	42.08	42.98	42.08
10.00	1.00	42.98	45.68	53.06	46.94	43.34	42.98
	2.00	39.92	39.92	57.02	57.92	42.08	39.92
	3.00	39.02	51.08	53.96	62.78	46.94	39.02
	4.00	51.08	55.94	42.44	45.32	40.28	40.28
	5.00	48.74	61.34	37.04	42.98	35.06	35.06
	6.00	42.98	44.06	33.98	44.06	48.92	33.98
	7.00	37.94	37.04	51.08	51.98	51.98	37.04
	8.00	44.06	48.92	44.96	54.32	51.98	44.06
	9.00	46.94	56.30	44.96	42.98	53.96	42.98
	10.00	48.02	45.68	44.96	42.98	55.04	42.98
	11.00	46.04	44.06	51.62	46.04	59.00	44.06
	12.00	39.92	44.96	50.00	53.06	57.92	39.92
	13.00	35.96	42.08	53.06	53.06	59.00	35.96
	14.00	51.98	46.04	48.02	45.68	59.00	45.68
	15.00	51.08	46.04	57.02	37.94	49.28	37.94
	16.00	48.02	55.04	53.96	35.06	34.34	34.34
	17.00	41.00	55.04	53.06	40.64	28.94	28.94
	18.00	37.04	47.30	60.08	39.02	39.02	37.04
10.00	19.00	42.98	39.02	51.62	42.08	39.02	39.02
	20.00	41.00	35.96	42.98	48.92	35.06	35.06
	21.00	35.96	46.04	45.32	44.96	48.92	35.96
	22.00	37.94	39.02	39.02	28.58	55.94	28.58
	23.00	48.02	35.06	43.70	26.06	53.96	26.06
	24.00	39.92	42.98	39.92	21.92	46.94	21.92
	25.00	35.96	42.98	44.96	33.98	44.96	33.98
	26.00	33.98	35.96	41.36	30.92	48.20	30.92
	27.00	30.92	33.98	37.94	38.30	35.24	30.92
	28.00	33.98	35.96	43.70	33.08	26.96	26.96
	29.00	36.68	32.90	34.70	26.06	32.00	26.06
	30.00	28.58	26.06	32.00	26.96	42.08	26.06
	31.00	28.04	37.04	28.94	30.92	46.04	28.04
11.00	1.00	48.02	44.96	28.94	47.66	46.04	28.94
	2.00	53.96	50.72	49.64	50.00	42.98	42.98
	3.00	33.62	44.96	41.90	53.06	39.92	33.62
	4.00	28.04	35.06	37.04	39.92	42.08	28.04
	5.00	30.92	32.00	44.06	37.58	35.06	30.92
	6.00	35.96	26.06	42.08	35.96	35.96	26.06
	7.00	30.02	26.06	42.08	39.92	35.96	26.06
	8.00	42.98	23.00	41.72	39.56	33.98	23.00
	9.00	48.92	26.06	39.02	39.02	41.00	26.06
	10.00	59.00	37.94	33.08	45.32	46.22	33.08
	11.00	44.06	38.66	35.96	42.98	53.96	35.96
	12.00	41.00	46.76	28.94	37.04	51.62	28.94
	13.00	29.30	33.62	28.94	33.98	44.06	28.94
	14.00	26.06	26.06	30.92	37.22	39.02	26.06

	15.00	29.66	16.70	35.06	22.64	36.32	16.70
	16.00	28.04	14.00	35.96	21.92	30.92	14.00
	17.00	42.08	23.00	35.96	24.98	30.92	23.00
	18.00	49.28	30.92	39.56	39.92	28.04	28.04
	19.00	26.06	31.64	32.00	34.34	37.94	26.06
	20.00	21.02	24.98	30.02	27.32	37.94	21.02
	21.00	21.02	21.92	28.94	20.30	35.06	20.30
	22.00	24.08	33.98	37.04	17.06	32.00	17.06
	23.00	26.06	33.98	28.94	30.02	16.70	16.70
	24.00	30.92	33.08	37.94	28.04	15.08	15.08
11.00	25.00	48.02	33.08	35.24	23.00	19.04	19.04
	26.00	37.94	33.08	33.08	32.72	23.36	23.36
	27.00	30.92	30.20	33.08	26.06	37.04	26.06
	28.00	43.34	24.08	33.08	24.08	39.92	24.08
	29.00	33.98	21.02	36.32	30.92	37.94	21.02
	30.00	32.00	19.04	27.32	28.94	32.00	19.04
12.00	1.00	33.98	14.36	24.08	23.36	28.04	14.36
	2.00	15.98	12.92	37.58	19.04	41.00	12.92
	3.00	9.68	32.00	37.04	23.36	33.08	9.68
	4.00	6.08	28.94	39.02	17.06	25.34	6.08
	5.00	20.66	28.04	29.66	21.02	21.02	20.66
	6.00	30.92	30.92	24.98	19.94	20.30	19.94
	7.00	39.56	35.06	26.06	17.06	12.02	12.02
	8.00	43.70	39.92	21.02	33.62	10.04	10.04
	9.00	44.06	32.72	9.68	31.28	30.02	9.68
	10.00	55.04	26.96	6.98	28.94	30.56	6.98
	11.00	31.64	30.02	1.04	37.94	28.94	1.04
	12.00	24.98	39.20	15.98	33.26	28.04	15.98
	13.00	21.02	39.92	31.28	26.96	26.96	21.02
	14.00	30.56	30.56	28.58	26.96	28.58	26.96
	15.00	30.02	28.04	12.92	24.26	21.02	12.92
	16.00	26.06	28.04	12.02	19.94	19.04	12.02
	17.00	26.96	32.00	23.00	20.66	28.94	20.66
	18.00	32.36	33.26	19.04	17.96	24.08	17.96
	19.00	19.94	35.96	24.98	26.96	24.08	19.94
	20.00	21.20	32.00	30.92	19.94	26.06	19.94
	21.00	26.96	28.94	28.94	19.04	24.08	19.04
	22.00	17.06	32.72	26.96	19.04	23.00	17.06
	23.00	17.06	24.26	24.62	10.94	26.06	10.94
	24.00	18.32	21.02	14.00	6.44	24.08	6.44
	25.00	21.02	19.94	5.72	-4.00	19.94	-4.00
	26.00	21.92	15.98	5.00	17.24	19.94	5.00
	27.00	21.92	10.04	14.00	19.94	12.02	10.04
	28.00	14.00	21.02	26.60	22.64	19.04	14.00
	29.00	26.78	13.10	23.00	19.94	15.08	13.10
	30.00	26.06	1.04	19.94	26.06	10.94	1.04
	31.00	24.08	8.06	21.20	19.94	11.66	8.06
	Min of Dry-Bulb Temperature (F)	YEAR					
MONTH	DAY HOUR	71.00	72.00	73.00	74.00	75.00	Grand Total
1.00	1.00	19.94	19.04	36.68	21.56	33.62	19.04
	2.00	10.04	29.66	26.96	17.06	23.00	10.04
	3.00	23.00	28.04	19.94	23.00	21.02	19.94
	4.00	24.98	30.92	30.56	14.00	33.08	14.00

	5.00	25.70	12.20	26.24	6.08	24.26	6.08
	6.00	14.72	6.08	10.04	23.00	19.94	6.08
	7.00	10.04	21.02	7.70	21.02	27.32	7.70
	8.00	8.06	21.02	5.72	10.94	24.98	5.72
	9.00	10.04	24.44	5.00	14.72	39.02	5.00
	10.00	19.04	37.04	12.92	23.00	35.06	12.92
	11.00	26.06	33.62	14.00	20.66	46.22	14.00
	12.00	10.58	33.08	12.02	9.68	33.08	9.68
	13.00	8.96	32.00	10.94	3.02	26.06	3.02
	14.00	18.68	19.04	17.96	1.04	15.62	1.04
	15.00	16.34	1.22	28.94	27.32	10.94	1.22
	16.00	8.06	-0.04	30.02	33.98	21.92	-0.04
	17.00	5.00	3.02	33.08	9.32	17.96	3.02
	18.00	3.02	24.08	30.02	8.06	21.02	3.02
	19.00	-2.02	31.46	42.98	21.02	31.28	-2.02
	20.00	3.92	26.06	22.28	15.98	4.64	3.92
	21.00	10.94	24.98	15.08	29.30	-0.04	-0.04
	22.00	28.04	28.94	32.00	33.98	21.92	21.92
	23.00	23.90	37.04	34.70	35.06	26.96	23.90
	24.00	21.92	35.96	28.58	30.92	28.94	21.92
	25.00	26.96	19.58	23.00	26.96	34.70	19.58
	26.00	15.26	14.00	28.94	26.06	33.98	14.00
	27.00	3.56	10.04	33.08	41.72	28.04	3.56
	28.00	1.94	17.96	33.26	35.96	28.04	1.94
	29.00	6.98	15.08	9.32	33.98	33.98	6.98
	30.00	16.34	19.22	5.00	35.60	26.96	5.00
	31.00	1.22	12.02	10.94	28.22	24.98	1.22
2.00	1.00	-2.02	17.06	12.92	23.00	25.70	-2.02
	2.00	-2.92	24.98	33.98	19.94	21.92	-2.92
2.00	3.00	-2.92	28.04	31.64	14.90	19.94	-2.92
	4.00	12.92	12.92	30.92	4.64	15.98	4.64
	5.00	21.02	6.08	28.94	1.94	24.08	1.94
	6.00	28.04	12.92	26.96	6.08	32.00	6.08
	7.00	21.02	8.96	28.94	16.70	19.04	8.96
	8.00	28.58	3.92	20.66	12.92	14.00	3.92
	9.00	13.46	5.00	12.02	8.96	13.46	5.00
	10.00	5.00	10.94	6.08	8.06	6.98	5.00
	11.00	8.06	8.96	1.94	15.98	19.94	1.94
	12.00	33.08	10.04	-0.04	14.00	21.02	-0.04
	13.00	22.64	30.02	6.08	30.92	19.94	6.08
	14.00	14.00	30.92	10.94	14.36	21.92	10.94
	15.00	15.98	26.06	28.04	10.04	24.98	10.04
	16.00	19.76	21.92	2.66	10.04	32.00	2.66
	17.00	15.08	19.04	-4.00	22.64	35.06	-4.00
	18.00	26.96	26.96	-0.94	19.04	37.04	-0.94
	19.00	32.00	21.20	15.08	28.04	34.70	15.08
	20.00	33.98	4.64	28.04	28.94	33.08	4.64
	21.00	33.62	1.04	30.56	21.02	24.98	1.04
	22.00	30.92	5.36	22.10	37.22	28.04	5.36
	23.00	30.20	1.04	14.00	20.30	41.00	1.04
	24.00	28.94	20.66	17.96	15.98	48.02	15.98
	25.00	28.94	28.94	15.98	17.60	35.06	15.98
	26.00	26.96	23.72	20.66	12.92	35.06	12.92

	27.00	37.94	17.06	15.98	12.92	30.74	12.92
	28.00	37.04	28.94	12.92	28.94	21.92	12.92
	29.00		33.08				33.08
3.00	1.00	30.74	39.20	24.98	32.36	27.32	24.98
	2.00	24.08	35.78	33.98	30.02	21.02	21.02
	3.00	26.60	12.74	39.92	33.98	21.02	12.74
	4.00	21.02	8.96	39.92	42.08	19.04	8.96
	5.00	22.28	20.30	39.92	37.22	21.02	20.30
	6.00	28.04	14.00	35.96	30.02	32.00	14.00
	7.00	28.22	21.02	39.02	44.96	33.08	21.02
	8.00	20.66	17.96	42.98	32.36	17.06	17.06
	9.00	19.04	12.02	35.06	30.92	12.92	12.02
	10.00	14.00	12.92	35.96	26.96	21.92	12.92
3.00	11.00	30.92	12.02	42.08	23.00	30.56	12.02
	12.00	28.04	32.00	44.96	19.04	35.96	19.04
	13.00	33.08	35.96	35.96	14:00	31.64	14.00
	14.00	35.96	27.68	33.08	19.94	28.04	19.94
	15.00	42.08	26.96	42.98	19.04	24.98	19.04
	16.00	35.42	28.94	44.06	35.06	21.92	21.92
	17.00	27.68	37.94	30.74	28.04	32.00	27.68
	18.00	24.08	30.38	24.98	26.96	33.08	24.08
	19.00	28.94	24.98	26.96	30.92	42.08	24.98
	20.00	31.64	21.02	24.98	24.98	37.94	21.02
	21.00	30.02	30.02	19.94	29.30	30.02	19.94
	22.00	28.04	35.60	28.22	24.98	39.02	24.98
	23.00	25.70	28.22	24.98	33.08	37.94	24.98
	24.00	21.02	23.36	24.98	21.38	37.04	21.02
	25.00	19.94	19.94	32.00	10.94	35.96	10.94
	26.00	19.04	21.92	41.00	21.02	22.64	19.04
	27.00	19.94	24.98	35.06	21.92	19.04	19.04
	28.00	24.08	21.02	30.02	28.22	19.04	19.04
	29.00	34.34	26.06	30.92	19.04	33.98	19.04
	30.00	30.02	35.06	39.92	25.34	31.64	25.34
	31.00	24.08	33.98	44.06	30.92	26.06	24.08
4.00	1.00	28.04	30.92	46.94	33.98	35.06	28.04
	2.00	37.04	32.00	45.32	37.04	33.08	32.00
	3.00	32.00	28.04	41.00	35.06	28.04	28.04
	4.00	28.94	30.02	37.94	60.98	23.00	23.00
	5.00	28.94	24.98	36.68	42.98	21.92	21.92
	6.00	30.02	26.96	33.08	33.26	26.96	26.96
	7.00	33.08	21.92	42.08	30.02	26.96	21.92
	8.00	26.96	19.94	32.72	30.92	28.04	19.94
	9.00	30.02	21.02	26.06	24.98	30.02	21.02
	10.00	34.70	28.04	32.72	23.00	28.04	23.00
	11.00	28.94	35.96	26.06	30.92	28.94	26.06
	12.00	33.08	37.04	26.96	37.94	30.92	26.96
	13.00	55.04	42.08	26.06	53.96	26.06	26.06
	14.00	32.36	37.04	24.98	51.98	30.92	24.98
	15.00	28.04	41.00	28.04	41.36	40.64	28.04
	16.00	35.96	44.06	41.00	37.04	39.92	35.96
4.00	17.00	32.00	42.98	57.02	35.06	42.98	32.00
	18.00	37.04	42.08	57.02	39.02	44.96	37.04
	19.00	42.08	48.02	55.94	34.34	51.44	34.34

	20.00	42.08	36.68	49.64	26.96	43.70	26.96
	21.00	42.98	33.08	44.06	37.04	35.06	33.08
	22.00	41.90	39.02	55.04	56.66	30.02	30.02
	23.00	37.94	37.94	46.04	41.00	37.04	37.04
	24.00	32.72	41.00	43.34	37.04	50.00	32.72
	25.00	32.00	33.98	39.02	30.92	47.30	30.92
	26.00	39.02	28.04	45.68	44.06	42.98	28.04
	27.00	39.02	33.98	42.98	33.98	39.02	33.98
	28.00	42.98	30.92	42.08	50.00	39.92	30.92
	29.00	42.08	39.02	39.02	62.96	46.04	39.02
	30.00	42.26	42.98	35.96	57.56	46.94	35.96
5.00	1.00	35.96	53.96	46.04	39.38	46.94	35.96
	2.00	42.98	59.36	59.00	33.98	46.94	33.98
	3.00	40.64	58.28	48.92	42.08	42.98	40.64
	4.00	39.92	48.56	39.02	37.04	50.00	37.04
	5.00	42.08	44.78	37.94	28.04	48.02	28.04
	6.00	46.94	35.96	41.00	39.02	44.06	35.96
	7.00	41.00	51.62	37.04	35.06	48.02	35.06
	8.00	46.94	48.02	50.00	35.96	42.98	35.96
	9.00	46.04	42.62	52.70	51.08	51.08	42.62
	10.00	46.04	39.92	46.94	44.42	48.02	39.92
	11.00	48.02	35.06	47.66	35.96	51.98	35.06
	12.00	59.36	44.96	44.96	48.02	57.02	44.96
	13.00	42.98	44.06	44.96	46.94	55.94	42.98
	14.00	39.02	57.02	39.92	44.06	53.06	39.02
	15.00	37.94	55.58	41.36	62.06	53.96	37.94
	16.00	51.08	53.24	35.96	53.96	59.90	35.96
	17.00	51.98	50.00	32.00	62.78	51.08	32.00
	18.00	46.94	51.98	32.72	57.92	60.98	32.72
	19.00	57.02	55.04	35.06	50.36	64.04	35.06
	20.00	59.00	55.94	50.00	39.02	60.08	39.02
	21.00	50.36	57.92	48.02	44.06	69.62	44.06
	22.00	45.68	57.92	44.96	59.00	64.94	44.96
	23.00	41.00	50.00	48.02	60.08	66.92	41.00
5.00	24.00	42.08	51.98	50.00	53.60	64.94	42.08
	25.00	60.98	51.62	50.00	42.98	57.92	42.98
	26.00	53.60	41.00	48.56	47.66	57.02	41.00
	27.00	50.00	42.98	46.04	46.04	64.94	42.98
	28.00	48.02	48.02	50.36	46.04	55.94	46.04
	29.00	44.06	51.08	56.66	53.96	53.06	44.06
	30.00	53.96	60.98	51.08	57.92	64.94	51.08
	31.00	53.06	60.98	53.06	60.08	69.08	53.06
6.00	1.00	46.04	50.90	50.00	57.02	60.98	46.04
	2.00	55.04	46.94	55.94	51.08	57.92	46.94
	3.00	62.06	50.00	55.04	48.02	57.92	48.02
	4.00	59.00	59.72	59.00	51.08	55.04	51.08
	5.00	62.96	59.00	59.00	57.02	57.92	57.02
	6.00	60.98	57.92	64.94	51.08	59.00	51.08
	7.00	60.98	54.32	64.76	53.96	53.96	53.96
	8.00	66.02	48.92	59.00	59.00	55.04	48.92
	9.00	57.92	62.06	64.04	57.92	53.96	53.96
	10.00	51.08	41.00	60.08	66.02	48.92	41.00
	11.00	48.02	33.98	64.04	55.94	51.98	33.98

	12.00	64.04	44.06	66.02	51.08	60.08	44.06
	13.00	64.04	60.98	62.96	44.96	62.96	44.96
	14.00	56.30	62.96	55.04	51.98	60.98	51.98
	15.00	53.06	71.06	53.06	60.08	64.94	53.06
	16.00	53.06	64.04	60.98	62.96	66.92	53.06
	17.00	53.06	60.98	51.08	55.76	60.08	51.08
	18.00	57.92	60.98	53.06	48.92	71.96	48.92
	19.00	57.02	62.96	57.02	51.98	71.06	51.98
	20.00	64.04	68.00	64.04	62.96	60.98	60.98
	21.00	66.02	62.96	64.04	60.98	55.94	55.94
	22.00	60.98	53.24	64.22	64.04	60.98	53.24
	23.00	57.02	51.08	62.06	57.92	64.94	51.08
	24.00	66.92	51.08	60.08	51.98	70.34	51.08
	25.00	62.06	53.06	59.00	53.96	66.02	53.06
	26.00	62.96	55.76	62.96	53.96	64.94	53.96
	27.00	59.00	51.98	64.04	53.96	62.06	51.98
	28.00	66.02	57.02	66.02	55.58	66.02	55.58
	29.00	60.98	62.06	62.06	55.04	66.02	55.04
6.00	30.00	69.08	60.62	62.06	53.06	64.04	53.06
7.00	1.00	68.90	60.08	57.92	59.00	55.04	55.04
	2.00	59.72	62.06	62.96	57.92	55.04	55.04
	3.00	51.08	59.00	68.72	69.98	65.66	51.08
	4.00	53.06	55.94	68.00	73.04	62.96	53.06
	5.00	57.92	51.98	64.22	66.02	57.92	51.98
	6.00	60.98	53.06	57.92	61.70	64.94	53.06
	7.00	60.08	51.98	57.92	55.94	64.04	51.98
	8.00	64.94	53.96	64.94	62.96	66.02	53.96
	9.00	67.64	51.08	68.00	64.94	66.02	51.08
	10.00	60.98	62.96	64.94	64.58	66.02	60.98
	11.00	59.72	66.02	57.92	55.04	66.92	55.04
	12.00	53.06	66.92	51.98	51.08	64.04	51.08
	13.00	60.08	68.90	55.94	51.08	69.08	51.08
	14.00	62.06	64.94	70.70	57.02	69.98	57.02
	15.00	55.04	69.62	62.96	64.04	69.98	55.04
	16.00	59.00	69.08	59.00	57.74	69.98	57.74
	17.00	59.36	69.08	57.02	46.94	71.06	46.94
	18.00	55.94	69.08	59.00	64.04	69.98	55.94
	19.00	62.06	69.98	59.00	64.40	71.96	59.00
	20.00	56.30	69.98	69.08	55.94	69.98	55.94
	21.00	50.00	69.98	64.94	50.00	71.06	50.00
	22.00	60.08	71.96	64.04	53.06	66.02	53.06
	23.00	62.96	77.00	64.04	64.58	62.96	62.96
	24.00	64.94	73.04	60.08	60.08	69.08	60.08
	25.00	66.92	65.66	60.98	62.06	65.66	60.98
	26.00	64.04	59.00	66.02	62.96	57.92	57.92
	27.00	60.44	60.98	73.04	68.00	53.06	53.06
	28.00	53.96	59.00	68.00	69.08	66.74	53.96
	29.00	68.00	53.06	64.04	64.94	62.06	53.06
	30.00	64.04	57.92	59.00	62.06	59.00	57.92
	31.00	68.90	64.04	64.04	57.02	64.94	57.02
8.00	1.00	64.94	62.96	69.98	55.04	69.98	55.04
	2.00	68.00	64.04	69.08	60.08	73.04	60.08
	3.00	68.36	67.28	66.02	66.20	73.04	66.02

	4.00	59.36	55.94	60.98	62.78	74.66	55.94
	5.00	55.04	46.94	59.00	57.02	71.06	46.94
8.00	6.00	51.98	53.96	59.00	53.96	59.72	51.98
	7.00	57.02	66.20	60.98	59.00	57.92	57.02
	8.00	62.06	62.96	69.98	55.94	57.02	55.94
	9.00	64.94	59.72	71.06	60.08	55.04	55.04
	10.00	68.00	51.98	69.26	60.08	60.98	51.98
	11.00	68.36	48.02	68.00	53.06	68.00	48.02
	12.00	55.94	62.06	64.94	51.08	64.94	51.08
	13.00	51.08	64.04	62.06	62.06	64.04	51.08
	14.00	57.02	62.06	60.98	61.70	64.22	57.02
	15.00	57.02	59.00	66.02	53.96	59.00	53.96
	16.00	59.00	55.04	64.94	55.04	64.04	55.04
	17.00	53.06	60.08	64.04	63.32	64.04	53.06
	18.00	55.04	62.06	62.96	60.98	63.68	55.04
	19.00	62.06	64.94	62.06	55.94	55.04	55.04
	20.00	66.02	55.94	62.06	57.92	57.92	55.94
	21.00	68.00	53.96	57.92	60.98	55.04	53.96
	22.00	64.04	60.08	55.04	57.02	60.08	55.04
	23.00	52.70	64.04	46.94	66.92	53.06	46.94
	24.00	46.04	71.06	55.04	62.06	62.06	46.04
	25.00	46.04	66.92	53.96	53.96	69.98	46.04
	26.00	64.94	66.92	64.94	59.00	69.62	59.00
	27.00	59.00	68.00	69.98	68.00	60.98	59.00
	28.00	62.24	64.04	73.04	64.58	53.96	53.96
	29.00	60.98	59.00	73.04	64.04	59.00	59.00
	30.00	59.00	59.00	68.00	59.90	62.60	59.00
	31.00	56.30	55.04	64.04	57.02	57.92	55.04
9.00	1.00	51.08	60.98	62.06	65.30	57.02	51.08
	2.00	60.08	60.08	66.92	60.98	60.08	60.08
	3.00	64.04	60.62	66.92	56.30	53.96	53.96
	4.00	64.04	55.04	66.92	51.08	48.92	48.92
	5.00	64.94	46.94	66.02	44.96	53.06	44.96
	6.00	66.92	46.04	62.60	53.96	60.62	46.04
	7.00	69.08	51.08	55.04	55.04	51.98	51.08
	8.00	69.08	55.94	53.06	57.02	62.06	53.06
	9.00	66.92	52.70	49.64	59.00	48.38	48.38
	10.00	66.02	44.96	42.98	60.08	39.92	39.92
	11.00	66.92	44.96	53.06	57.92	50.00	44.96
9.00	12.00	68.00	62.06	50.00	69.08	52.34	50.00
	13.00	63.68	60.98	44.06	67.46	43.34	43.34
	14.00	62.06	56.66	59.00	49.46	39.92	39.92
	15.00	66.02	48.92	53.24	46.04	37.94	37.94
	16.00	60.08	48.92	48.92	52.34	51.62	48.92
	17.00	57.92	60.08	44.96	48.92	53.06	44.96
	18.00	57.92	62.96	48.38	55.94	59.00	48.38
	19.00	57.92	55.04	42.08	53.06	59.00	42.08
	20.00	62.96	48.92	48.02	62.60	60.08	48.02
	21.00	48.38	46.94	39.92	49.46	59.00	39.92
	22.00	42.98	46.22	48.02	42.98	51.98	42.98
	23.00	51.98	39.02	61.70	35.96	55.04	35.96
	24.00	42.98	51.08	55.94	30.02	55.04	30.02
	25.00	35.96	57.56	56.30	44.06	53.96	35.96

	26.00	51.08	64.04	53.96	44.06	59.72	44.06
	27.00	53.06	56.30	57.02	46.04	57.56	46.04
	28.00	57.02	48.02	60.08	57.92	48.92	48.02
	29.00	62.96	55.04	55.94	56.30	44.96	44.96
	30.00	57.20	43.70	46.04	46.04	50.00	43.70
10.00	1.00	51.08	35.96	42.98	42.98	57.92	35.96
	2.00	62.06	35.06	58.64	37.22	41.90	35.06
	3.00	62.06	44.06	62.96	34.70	35.06	34.70
	4.00	57.02	46.94	59.00	28.94	42.08	28.94
	5.00	56.66	46.94	49.28	44.06	44.96	44.06
	6.00	49.28	57.56	48.02	46.94	55.94	46.94
	7.00	42.26	44.60	44.06	43.34	44.06	42.26
	8.00	37.94	37.94	51.08	35.06	39.02	35.06
	9.00	45.68	37.04	53.06	33.98	53.60	33.98
	10.00	47.30	33.08	53.42	42.08	51.98	33.08
	11.00	44.06	32.00	46.04	41.00	53.06	32.00
	12.00	39.02	50.00	42.08	50.00	48.02	39.02
	13.00	37.94	35.06	46.04	48.92	53.06	35.06
	14.00	55.04	35.06	51.26	53.96	60.08	35.06
	15.00	46.94	33.08	48.02	48.20	60.98	33.08
	16.00	44.06	35.78	41.72	46.04	47.30	35.78
	17.00	46.94	34.70	37.94	44.06	44.06	34.70
	18.00	39.02	26.96	39.02	28.76	49.28	26.96
10.00	19.00	37.94	26.78	35.96	23.00	50.00	23.00
	20.00	49.64	19.94	46.04	26.96	46.40	19.94
	21.00	48.92	24.08	40.64	26.06	42.98	24.08
	22.00	44.06	35.96	33.08	28.04	57.02	28.04
	23.00	55.94	46.94	37.04	37.94	51.98	37.04
	24.00	51.98	44.60	37.04	35.96	57.92	35.96
	25.00	53.96	35.06	39.92	37.94	60.08	35.06
	26.00	54.32	28.94	41.00	42.08	44.78	28.94
	27.00	53.06	30.02	37.58	41.72	42.08	30.02
	28.00	56.66	48.92	37.04	32.00	50.00	32.00
	29.00	46.94	44.06	41.00	44.96	49.46	41.00
	30.00	42.98	32.72	39.92	51.08	31.64	31.64
	31.00	53.06	30.02	35.96	53.06	26.06	26.06
11.00	1.00	59.00	35.06	43.70	51.98	35.06	35.06
	2.00	60.08	42.98	42.98	57.02	51.08	42.98
	3.00	42.26	41.00	39.20	55.04	55.04	39.20
	4.00	35.06	37.94	33.08	53.06	57.02	33.08
	5.00	32.00	40.28	30.92	51.98	49.28	30.92
	6.00	39.02	37.94	28.04	46.04	39.92	28.04
	7.00	27.68	35.06	30.02	42.62	48.92	27.68
	8.00	24.98	44.24	26.06	42.08	60.98	24.98
	9.00	17.96	38.66	26.06	37.04	51.98	17.96
	10.00	28.94	37.04	21.92	33.98	51.98	21.92
	11.00	30.92	41.00	27.32	35.96	39.74	27.32
	12.00	32.00	39.02	30.02	44.96	37.04	30.02
	13.00	31.46	39.02	41.72	38.66	39.56	31.46
	14.00	24.98	33.98	48.02	37.04	33.08	24.98
	15.00	38.66	24.08	44.06	30.02	32.00	24.08
	16.00	39.56	24.62	30.56	32.36	35.06	24.62
	17.00	33.08	24.08	26.96	30.92	30.92	24.08

	18.00	33.08	23.00	28.04	33.98	37.94	23.00
	19.00	42.98	21.92	34.34	30.92	46.94	21.92
	20.00	33.98	27.68	26.06	44.96	39.92	26.06
	21.00	32.72	23.90	33.08	30.92	40.28	23.90
	22.00	24.98	19.04	43.70	25.34	35.60	19.04
	23.00	21.02	14.00	32.00	21.02	30.02	14.00
	24.00	21.02	24.98	37.04	36.68	26.96	21.02
11.00	25.00	29.30	21.92	39.20	27.68	26.06	21.92
	26.00	30.92	36.68	37.04	21.92	28.04	21.92
	27.00	30.92	35.06	41.90	21.02	36.68	21.02
	28.00	33.98	31.64	46.40	28.94	35.06	28.94
	29.00	33.08	22.28	34.34	26.60	32.00	22.28
	30.00	28.58	21.02	30.92	26.06	41.00	21.02
12.00	1.00	19.58	28.04	26.96	26.96	29.66	19.58
	2.00	15.44	26.06	23.00	37.04	24.08	15.44
	3.00	12.02	31.28	26.96	29.66	24.26	12.02
	4.00	19.94	26.96	39.02	23.90	23.00	19.94
	5.00	10.94	33.08	53.06	21.92	28.04	10.94
	6.00	28.22	30.56	35.60	21.92	32.00	21.92
	7.00	37.04	19.94	28.76	26.06	23.00	19.94
	8.00	37.04	19.94	24.98	42.62	21.92	19.94
	9.00	35.96	35.06	32.00	27.32	32.00	27.32
	10.00	41.00	35.42	31.64	26.06	35.60	26.06
	11.00	33.98	25.70	26.96	26.06	33.98	25.70
	12.00	28.94	23.00	22.28	38.30	33.98	22.28
	13.00	32.72	31.28	21.02	37.94	33.98	21.02
	14.00	26.06	24.98	26.06	34.70	41.36	24.98
	15.00	34.70	26.06	18.32	32.00	33.98	18.32
	16.00	39.56	16.34	15.26	35.06	25.70	15.26
	17.00	32.36	10.04	10.04	32.72	24.08	10.04
	18.00	17.06	12.74	9.32	28.76	16.70	9.32
	19.00	17.06	28.94	8.06	26.06	12.92	8.06
	20.00	30.02	33.98	23.36	30.02	17.06	17.06
	21.00	33.98	33.98	15.98	32.00	19.94	15.98
	22.00	19.04	33.98	15.08	31.64	21.02	15.08
	23.00	14.00	30.92	22.64	28.04	17.78	14.00
	24.00	32.72	30.92	12.92	35.06	10.04	10.04
	25.00	28.04	37.94	17.24	31.28	12.02	12.02
	26.00	37.40	33.62	37.04	28.04	27.32	27.32
	27.00	39.02	32.00	39.92	28.04	29.66	28.04
	28.00	34.34	28.76	31.64	29.66	21.92	21.92
	29.00	30.02	19.94	30.92	26.96	17.06	17.06
	30.00	30.92	28.94	26.96	33.62	25.70	25.70
	31.00	19.58	46.04	27.68	24.98	34.70	19.58
	Min of Dry-Bulb Temperature (F)	YEAR					
MONTH	DAY HOUR	76.00	77.00	78.00	79.00	80.00	Grand Total
1.00	1.00	21.74	8.96	21.02	42.08	21.92	8.96
	2.00	12.92	19.04	23.00	26.96	24.08	12.92
	3.00	28.94	12.92	15.08	6.08	23.00	6.08
	4.00	19.22	19.94	12.92	3.92	17.06	3.92
	5.00	11.30	5.00	24.08	10.94	21.92	5.00
	6.00	6.98	10.04	30.92	15.98	14.00	6.98
	7.00	22.64	15.98	35.96	24.08	24.98	15.98

	8.00	6.08	10.94	37.04	19.04	21.02	6.08
	9.00	1.94	14.00	10.04	8.06	21.02	1.94
	10.00	3.92	12.92	8.06	10.04	12.92	3.92
	11.00	12.92	8.06	17.06	3.02	28.04	3.02
	12.00	17.96	5.00	14.00	1.94	19.94	1.94
	13.00	15.98	-0.94	23.00	19.04	14.00	-0.94
	14.00	26.24	12.02	17.96	21.02	33.08	12.02
	15.00	19.94	19.04	12.92	12.02	30.02	12.02
	16.00	19.94	-0.94	12.02	15.08	26.06	-0.94
	17.00	5.00	-9.04	21.02	12.02	33.08	-9.04
	18.00	-2.02	-5.98	23.00	5.00	37.94	-5.98
	19.00	-4.00	3.02	19.94	-0.94	33.98	-4.00
	20.00	20.66	17.06	21.02	12.02	26.06	12.02
	21.00	23.72	10.04	14.00	28.04	26.06	10.04
	22.00	1.94	10.04	15.98	26.96	21.92	1.94
	23.00	-5.98	10.04	10.94	26.06	17.96	-5.98
	24.00	10.94	10.04	3.92	26.96	14.00	3.92
	25.00	12.92	23.00	32.00	26.06	14.00	12.92
	26.00	34.34	19.04	15.98	30.02	17.96	15.98
	27.00	30.20	12.92	12.92	32.00	23.00	12.92
	28.00	21.02	1.94	12.02	30.92	21.92	1.94
	29.00	23.00	-7.06	10.94	30.02	15.08	-7.06
	30.00	19.04	5.00	14.00	26.96	12.02	5.00
	31.00	10.94	1.04	14.00	19.94	10.04	1.04
2.00	1.00	28.58	12.92	12.02	12.92	8.06	8.06
	2.00	3.92	12.02	12.92	14.00	8.96	3.92
2.00	3.00	6.98	14.00	8.06	12.02	10.04	6.98
	4.00	19.04	24.98	1.04	10.04	15.98	1.04
	5.00	19.94	6.98	-2.02	6.98	15.08	-2.02
	6.00	15.98	3.02	12.92	5.00	10.04	3.02
	7.00	12.02	6.08	12.92	8.06	19.04	6.08
	8.00	20.66	6.98	17.96	8.96	19.94	6.98
	9.00	19.04	5.00	10.04	-0.94	15.08	-0.94
	10.00	15.08	24.98	8.96	-5.98	17.96	-5.98
	11.00	31.64	24.98	10.04	-9.04	14.00	-9.04
	12.00	26.96	35.96	23.00	-11.92	19.04	-11.92
	13.00	39.56	32.00	24.98	-4.00	17.06	-4.00
	14.00	24.62	30.02	17.96	-5.98	19.94	-5.98
	15.00	24.08	15.98	6.98	3.92	19.94	3.92
	16.00	37.04	10.94	8.96	-0.04	15.98	-0.04
	17.00	35.96	8.06	26.96	-9.04	10.04	-9.04
	18.00	35.96	3.92	19.04	-16.06	6.08	-16.06
	19.00	40.28	24.08	10.94	6.98	12.02	6.98
	20.00	31.28	23.00	-0.94	1.94	21.92	-0.94
	21.00	26.96	10.94	10.94	21.02	37.04	10.94
	22.00	28.40	3.02	6.98	28.94	33.98	3.02
	23.00	17.96	35.06	15.98	30.02	35.96	15.98
	24.00	21.20	32.00	15.08	33.98	33.98	15.08
	25.00	41.00	35.06	24.08	35.06	28.94	24.08
	26.00	44.96	33.98	21.92	33.08	12.92	12.92
	27.00	41.00	39.92	15.08	26.06	14.00	14.00
	28.00	32.36	28.04	6.08	26.06	12.92	6.08
	29.00	30.92				3.92	3.92

3.00	1.00	41.00	24.98	12.92	28.94	1.94	1.94
	2.00	35.60	17.96	14.00	35.96	3.92	3.92
	3.00	33.98	26.06	14.00	35.06	8.06	8.06
	4.00	37.94	37.04	12.02	35.06	21.92	12.02
	5.00	44.96	33.08	6.08	51.98	33.98	6.08
	6.00	30.92	28.94	6.08	35.96	26.96	6.08
	7.00	31.64	23.00	14.00	28.04	33.98	14.00
	8.00	23.36	26.96	14.00	26.96	44.06	14.00
	9.00	21.02	28.04	17.06	28.04	30.02	17.06
	10.00	21.92	42.98	23.00	41.00	26.06	21.92
3.00	11.00	26.24	37.94	24.98	17.96	19.94	17.96
	12.00	19.94	41.00	35.06	17.06	17.06	17.06
	13.00	30.92	46.04	32.00	19.94	17.06	17.06
	14.00	26.96	44.06	35.06	28.94	28.94	26.96
	15.00	34.70	39.92	33.98	12.92	26.96	12.92
	16.00	26.24	39.02	28.94	15.08	17.06	15.08
	17.00	18.32	28.94	24.08	30.02	37.94	18.32
	18.00	12.92	28.04	23.00	33.08	30.92	12.92
	19.00	34.34	23.00	30.92	24.08	28.04	23.00
	20.00	44.96	19.94	26.96	28.94	39.02	19.94
	21.00	42.08	26.96	37.94	30.92	35.06	26.96
	22.00	24.98	30.92	39.02	33.98	32.00	24.98
	23.00	21.92	26.96	42.98	37.94	30.92	21.92
	24.00	37.04	19.04	26.96	51.98	30.02	19.04
	25.00	46.04	17.06	24.08	35.96	35.06	17.06
	26.00	37.94	21.92	30.92	28.04	33.98	21.92
	27.00	51.98	23.00	37.94	24.98	30.02	23.00
	28.00	39.38	42.98	37.04	21.02	33.98	21.02
	29.00	30.02	48.02	33.98	35.96	39.92	30.02
	30.00	44.96	51.98	32.00	48.92	44.96	32.00
	31.00	44.06	41.00	32.00	57.02	33.98	32.00
4.00	1.00	41.00	30.92	46.04	44.06	28.04	28.04
	2.00	35.06	37.94	30.02	39.92	42.08	30.02
	3.00	37.04	39.02	23.00	35.06	35.96	23.00
	4.00	33.98	35.06	30.92	28.04	44.06	28.04
	5.00	32.00	37.94	41.00	37.04	37.94	32.00
	6.00	37.94	28.94	33.08	30.02	39.02	28.94
	7.00	37.94	24.08	41.00	26.06	42.98	24.08
	8.00	33.98	24.08	30.92	24.08	48.92	24.08
	9.00	30.02	19.94	28.94	32.00	50.00	19.94
	10.00	30.02	26.06	30.92	30.92	41.00	26.06
	11.00	25.70	39.92	48.02	28.94	42.08	25.70
	12.00	21.92	55.94	42.08	35.06	42.08	21.92
	13.00	30.92	48.92	44.06	39.02	44.06	30.92
	14.00	37.94	42.08	39.02	37.04	39.02	37.04
	15.00	46.04	33.08	33.98	39.02	42.98	33.08
	16.00	57.02	35.96	30.92	39.02	28.04	28.04
4.00	17.00	55.94	35.06	32.00	37.94	26.96	26.96
	18.00	62.06	35.06	32.00	37.04	33.98	32.00
	19.00	66.92	44.06	44.06	32.00	35.06	32.00
	20.00	62.06	51.08	41.00	30.02	44.06	30.02
	21.00	59.00	51.98	35.96	33.08	42.08	33.08
	22.00	59.00	59.00	35.06	50.00	42.98	35.06

	23.00	49.10	53.06	28.04	48.02	33.98	28.04
	24.00	39.02	42.98	35.96	46.04	44.06	35.96
	25.00	46.04	42.98	33.98	57.02	50.00	33.98
	26.00	37.94	41.00	42.08	55.94	41.00	37.94
	27.00	37.04	41.00	42.98	46.94	46.94	37.04
	28.00	41.00	35.96	42.98	42.08	48.02	35.96
	29.00	44.06	28.94	37.94	42.08	46.04	28.94
	30.00	41.00	33.08	35.06	35.06	50.00	33.08
5.00	1.00	48.02	39.02	30.02	39.92	51.98	30.02
	2.00	51.08	55.04	37.94	33.08	53.06	33.08
	3.00	42.44	44.96	37.94	41.00	48.02	37.94
	4.00	37.04	37.94	32.00	46.04	53.96	32.00
	5.00	37.04	46.94	39.02	39.02	55.04	37.04
	6.00	60.98	57.02	41.00	41.00	53.96	41.00
	7.00	44.60	44.06	46.94	46.04	44.06	44.06
	8.00	41.00	32.00	39.92	55.94	41.00	32.00
	9.00	35.96	32.00	53.96	57.92	39.92	32.00
	10.00	44.96	39.02	50.00	62.96	37.04	37.04
	11.00	55.94	39.92	44.96	60.98	53.06	39.92
	12.00	42.08	35.96	53.96	59.00	53.96	35.96
	13.00	35.96	51.08	55.94	57.92	60.98	35.96
	14.00	55.04	44.06	53.96	53.06	50.00	44.06
	15.00	64.94	33.08	51.08	48.92	44.96	33.08
	16.00	66.02	39.92	50.00	46.04	37.94	37.94
	17.00	57.92	51.08	50.00	39.92	44.06	39.92
	18.00	39.92	57.92	51.08	44.96	55.94	39.92
	19.00	39.92	60.98	48.02	55.94	60.98	39.92
	20.00	42.62	53.96	55.04	55.94	51.98	42.62
	21.00	53.06	57.92	55.04	51.98	55.04	51.98
	22.00	44.42	59.00	42.08	48.02	48.02	42.08
	23.00	37.04	57.92	50.00	48.92	55.04	37.04
5.00	24.00	41.00	60.98	55.94	53.96	62.06	41.00
	25.00	46.94	62.96	55.04	53.06	57.02	46.94
	26.00	47.66	53.96	55.94	46.04	44.06	44.06
	27.00	46.04	44.96	59.00	44.96	42.08	42.08
	28.00	46.04	53.96	62.96	48.92	46.94	46.04
	29.00	53.06	46.94	62.96	48.02	51.98	46.94
	30.00	60.08	50.00	60.08	50.00	60.08	50.00
	31.00	62.06	48.92	64.94	48.92	62.96	48.92
6.00	1.00	61.34	59.00	62.06	55.94	55.94	55.94
	2.00	53.78	57.92	59.00	60.98	64.94	53.78
	3.00	48.02	46.94	55.04	59.00	60.98	46.94
	4.00	51.98	42.08	48.02	57.02	57.92	42.08
	5.00	48.02	57.02	48.92	55.04	51.98	48.02
	6.00	51.08	48.92	44.06	59.00	46.94	44.06
	7.00	55.04	46.04	53.06	60.98	62.06	46.04
	8.00	59.00	42.08	62.96	68.00	46.04	42.08
	9.00	57.92	50.00	57.92	68.00	41.00	41.00
	10.00	62.96	50.00	51.98	68.00	44.06	44.06
	11.00	68.00	50.00	51.98	46.94	39.02	39.02
	12.00	60.08	51.08	60.98	41.00	41.00	41.00
	13.00	55.94	57.02	48.02	41.00	44.96	41.00
	14.00	62.06	60.08	44.06	42.98	51.98	42.98

	15.00	68.00	60.08	39.92	51.08	62.96	39.92
	16.00	71.24	51.98	42.98	62.96	51.98	42.98
	17.00	66.02	60.98	57.92	62.06	42.98	42.98
	18.00	62.06	62.96	60.08	55.94	46.94	46.94
	19.00	71.96	62.96	59.00	51.98	55.04	51.98
	20.00	66.02	53.06	53.06	51.08	55.04	51.08
	21.00	66.02	55.94	60.08	55.94	53.96	53.96
	22.00	69.98	50.00	62.06	55.94	53.96	50.00
	23.00	71.24	46.04	51.98	53.06	55.94	46.04
	24.00	68.00	53.06	48.92	48.92	60.08	48.92
	25.00	71.06	62.96	48.92	42.08	66.92	42.08
	26.00	68.00	60.08	64.04	44.06	62.96	44.06
	27.00	60.98	53.96	69.08	53.06	66.02	53.06
	28.00	62.06	59.00	68.00	53.96	57.92	53.96
	29.00	64.94	66.92	59.00	50.00	64.04	50.00
6.00	30.00	64.04	60.98	59.00	62.06	62.96	59.00
7.00	1.00	62.96	69.98	48.02	57.02	60.08	48.02
	2.00	60.08	55.94	48.02	57.02	64.04	48.02
	3.00	55.94	46.94	53.96	57.92	60.98	46.94
	4.00	62.06	62.06	51.08	50.00	60.98	50.00
	5.00	59.00	64.04	48.92	46.94	66.02	46.94
	6.00	60.08	64.04	55.04	44.96	57.92	44.96
	7.00	64.58	64.04	59.00	44.06	48.92	44.06
	8.00	64.04	66.92	62.96	51.08	60.08	51.08
	9.00	62.78	64.94	69.08	55.94	66.02	55.94
	10.00	55.04	60.98	64.04	62.96	69.08	55.04
	11.00	66.02	62.96	53.06	60.98	60.98	53.06
	12.00	59.00	64.94	46.04	66.02	60.08	46.04
	13.00	57.02	69.98	51.98	62.06	51.98	51.98
	14.00	60.98	64.94	66.92	66.92	55.04	55.04
	15.00	59.00	59.00	66.02	66.92	62.06	59.00
	16.00	64.94	66.02	64.04	66.02	73.94	64.04
	17.00	61.34	66.02	62.96	64.94	69.08	61.34
	18.00	53.06	66.92	55.04	64.04	66.92	53.06
	19.00	60.08	64.94	57.92	57.02	64.94	57.02
	20.00	62.96	68.00	66.92	62.06	71.96	62.06
	21.00	69.62	69.08	68.00	64.94	69.98	64.94
	22.00	62.96	57.92	69.98	64.94	69.08	57.92
	23.00	66.02	50.00	71.06	66.92	66.02	50.00
	24.00	66.74	57.92	64.94	66.92	59.00	57.92
	25.00	57.92	64.04	64.04	71.06	55.94	55.94
	26.00	48.92	55.94	60.08	73.04	62.06	48.92
	27.00	62.06	48.02	66.92	64.94	64.04	48.02
	28.00	64.94	48.02	60.08	60.98	69.08	48.02
	29.00	66.02	57.02	53.06	66.02	69.98	53.06
	30.00	68.90	64.04	57.02	66.02	62.96	57.02
	31.00	65.66	60.08	55.04	69.98	60.08	55.04
8.00	1.00	57.74	62.96	60.08	73.04	68.00	57.74
	2.00	50.00	59.00	64.04	71.96	69.98	50.00
	3.00	51.98	59.00	68.00	64.94	68.00	51.98
	4.00	53.06	60.98	64.94	66.02	71.06	53.06
	5.00	57.92	66.02	62.06	64.04	69.08	57.92
8.00	6.00	65.30	71.96	68.00	62.06	69.98	62.06

	7.00	64.04	69.08	69.08	50.00	62.96	50.00
	8.00	66.92	69.98	66.92	66.92	73.04	66.92
	9.00	66.92	64.04	62.96	64.04	69.98	62.96
	10.00	62.96	64.94	66.02	68.00	62.96	62.96
	11.00	57.02	69.98	62.96	60.98	69.98	57.02
	12.00	62.96	66.02	64.94	55.94	66.02	55.94
	13.00	69.08	62.96	64.94	53.96	60.98	53.96
	14.00	66.92	66.92	59.00	60.98	62.06	59.00
	15.00	62.60	57.02	62.96	55.94	64.94	55.94
	16.00	59.00	59.00	69.98	48.92	60.08	48.92
	17.00	57.02	60.08	69.98	42.98	51.98	42.98
	18.00	57.92	51.98	60.98	57.02	62.06	51.98
	19.00	57.02	46.04	57.02	62.06	64.04	46.04
	20.00	57.02	51.08	60.98	55.04	60.98	51.08
	21.00	60.98	44.06	50.00	62.06	62.06	44.06
	22.00	66.92	59.00	50.00	55.94	60.98	50.00
	23.00	64.04	53.96	50.00	60.08	64.04	50.00
	24.00	60.08	51.98	57.92	71.96	60.98	51.98
	25.00	57.92	46.94	60.08	68.00	62.06	46.94
	26.00	68.00	46.94	59.00	60.08	62.96	46.94
	27.00	69.98	59.00	55.04	69.98	64.94	55.04
	28.00	71.06	64.94	66.02	64.94	68.00	64.94
	29.00	57.74	66.92	68.00	71.06	68.00	57.74
	30.00	51.08	66.02	64.94	71.06	69.98	51.08
	31.00	44.96	64.94	62.06	62.96	71.96	44.96
9.00	1.00	51.08	69.08	57.02	59.00	66.92	51.08
	2.00	51.62	66.92	50.00	69.08	69.08	50.00
	3.00	46.04	60.08	53.96	68.00	62.06	46.04
	4.00	55.04	51.98	55.04	62.96	57.02	51.98
	5.00	54.68	62.96	50.00	66.92	64.94	50.00
	6.00	50.00	62.96	55.04	71.06	60.08	50.00
	7.00	46.04	53.96	60.98	64.04	55.94	46.04
	8.00	60.08	55.94	51.98	51.98	51.98	51.98
	9.00	60.08	55.04	48.02	42.98	53.96	42.98
	10.00	55.04	62.06	44.06	46.04	53.96	44.06
	11.00	48.92	46.94	59.00	51.98	48.02	46.94
9.00	12.00	46.94	39.02	55.04	46.04	59.00	39.02
	13.00	55.04	59.00	50.00	53.96	62.96	50.00
	14.00	57.92	51.98	46.94	60.08	68.00	46.94
	15.00	62.06	46.04	53.96	53.96	50.00	46.04
	16.00	62.06	55.94	53.96	46.04	44.96	44.96
	17.00	64.76	60.08	48.02	48.02	62.06	48.02
	18.00	60.08	62.06	62.06	51.08	51.08	51.08
	19.00	60.98	62.96	57.02	42.08	44.96	42.08
	20.00	57.02	55.94	59.00	35.96	53.96	35.96
	21.00	48.74	53.06	57.02	53.06	68.00	48.74
	22.00	46.04	53.96	53.96	55.94	71.06	46.04
	23.00	42.08	51.98	42.98	46.04	55.04	42.08
	24.00	46.40	50.00	42.98	41.00	48.92	41.00
	25.00	39.02	48.92	46.04	44.06	57.02	39.02
	26.00	48.92	53.06	35.96	51.98	48.02	35.96
	27.00	57.02	55.04	41.00	46.94	39.92	39.92
	28.00	42.98	48.92	46.04	55.04	41.00	41.00

	29.00	37.94	44.96	35.96	62.96	46.04	35.96
	30.00	44.96	44.96	44.06	62.06	51.98	44.06
10.00	1.00	51.98	55.94	57.92	59.00	48.02	48.02
	2.00	55.04	48.02	44.96	60.08	53.96	44.96
	3.00	54.68	42.98	41.00	57.92	51.08	41.00
	4.00	48.02	42.08	51.98	55.04	42.98	42.08
	5.00	48.92	39.02	46.04	48.02	37.94	37.94
	6.00	57.92	41.00	53.96	48.02	35.06	35.06
	7.00	58.64	35.06	44.06	46.04	44.06	35.06
	8.00	53.60	39.92	39.02	39.92	39.92	39.02
	9.00	44.60	46.04	35.06	39.92	41.00	35.06
	10.00	39.92	42.08	37.04	35.96	33.98	33.98
	11.00	35.96	35.96	44.06	37.94	53.06	35.96
	12.00	33.08	39.02	55.04	42.98	46.04	33.08
	13.00	42.08	37.94	55.04	41.00	39.92	37.94
	14.00	42.08	39.92	42.98	39.92	39.92	39.92
	15.00	43.34	37.04	39.02	39.92	42.08	37.04
	16.00	41.00	33.98	37.04	35.96	44.06	33.98
	17.00	37.94	33.08	33.98	41.00	55.04	33.08
	18.00	31.28	33.08	28.94	50.00	57.02	28.94
10.00	19.00	28.04	42.08	46.04	46.04	50.00	28.04
	20.00	42.08	46.04	39.92	57.02	42.08	39.92
	21.00	39.56	37.04	35.06	60.08	42.08	35.06
	22.00	37.94	35.96	42.98	57.92	33.98	33.98
	23.00	35.06	33.98	41.00	48.92	33.98	33.98
	24.00	39.02	35.06	33.98	39.02	32.00	32.00
	25.00	43.70	37.94	37.94	39.02	41.00	37.94
	26.00	30.92	48.02	51.98	35.96	39.02	30.92
	27.00	24.08	55.94	37.04	30.02	39.02	24.08
	28.00	21.92	42.98	30.92	37.04	39.02	21.92
	29.00	33.08	37.04	32.00	42.98	35.96	32.00
	30.00	35.96	33.98	28.94	33.98	33.08	28.94
	31.00	39.92	30.02	30.92	30.02	30.02	30.02
11.00	1.00	30.92	37.94	35.96	42.08	39.92	30.92
	2.00	28.04	48.92	26.06	48.92	32.00	26.06
	3.00	44.60	55.94	33.08	35.96	28.04	28.04
	4.00	37.94	60.98	35.96	30.02	46.04	30.02
	5.00	33.08	55.94	35.06	28.94	35.06	28.94
	6.00	34.34	51.98	37.94	37.04	30.02	30.02
	7.00	37.04	46.04	39.92	41.00	41.00	37.04
	8.00	25.34	46.04	32.00	33.08	30.92	25.34
	9.00	24.08	50.00	26.06	42.08	28.94	24.08
	10.00	33.98	44.06	32.00	48.02	32.00	32.00
	11.00	31.28	33.98	39.92	42.08	30.02	30.02
	12.00	24.08	30.02	39.02	35.96	30.02	24.08
	13.00	28.94	26.06	35.06	39.02	28.04	26.06
	14.00	30.92	24.98	44.06	35.96	41.00	24.98
	15.00	28.04	30.92	37.94	30.02	33.98	28.04
	16.00	26.96	44.06	33.08	28.04	24.08	24.08
	17.00	26.96	39.02	30.02	30.02	17.06	17.06
	18.00	35.96	35.96	42.98	42.08	28.94	28.94
	19.00	39.02	35.96	35.96	33.98	26.06	26.06
	20.00	36.32	30.92	26.96	44.96	26.06	26.06

	21.00	30.92	39.92	30.02	39.02	23.00	23.00
	22.00	30.92	35.06	28.04	48.02	30.92	28.04
	23.00	33.08	35.96	30.02	44.96	26.06	26.06
	24.00	30.92	39.92	39.02	55.94	39.02	30.92
11.00	25.00	26.96	28.94	26.06	51.98	33.98	26.06
	26.00	33.98	21.92	19.04	46.94	26.96	19.04
	27.00	48.92	21.92	19.04	41.00	26.96	19.04
	28.00	41.72	26.06	26.96	35.96	35.06	26.06
	29.00	18.32	24.08	24.08	26.96	33.98	18.32
	30.00	8.96	30.92	30.02	26.06	33.08	8.96
12.00	1.00	8.06	37.94	21.02	26.06	37.94	8.06
	2.00	8.42	35.96	24.98	21.92	39.92	8.42
	3.00	3.02	30.92	23.00	19.94	19.94	3.02
	4.00	8.24	28.04	39.02	28.04	17.06	8.24
	5.00	17.96	26.96	32.00	28.94	17.06	17.06
	6.00	12.92	23.00	26.96	37.04	19.04	12.92
	7.00	23.00	17.96	26.96	37.04	32.00	17.96
	8.00	8.96	12.92	41.00	28.04	44.96	8.96
	9.00	9.68	12.92	24.08	24.08	35.06	9.68
	10.00	24.44	8.96	15.98	33.98	33.98	8.96
	11.00	24.08	5.00	12.02	41.00	17.06	5.00
	12.00	27.32	6.98	19.04	39.02	21.92	6.98
	13.00	3.56	24.08	28.04	30.92	23.00	3.56
	14.00	3.02	35.06	24.98	28.04	15.08	3.02
	15.00	26.06	37.04	21.92	21.02	12.02	12.02
	16.00	26.96	30.02	30.92	30.92	21.92	21.92
	17.00	28.94	30.02	26.06	12.92	8.96	8.96
	18.00	20.66	30.92	17.96	17.06	8.96	8.96
	19.00	14.00	33.08	6.98	15.98	6.98	6.98
	20.00	30.74	33.08	15.98	17.96	-0.04	-0.04
	21.00	12.02	33.08	30.92	17.96	6.98	6.98
	22.00	12.56	28.04	26.06	33.08	1.94	1.94
	23.00	19.94	26.96	19.04	35.96	19.94	19.04
	24.00	17.60	26.06	19.04	39.92	12.92	12.92
	25.00	17.06	24.08	24.98	42.08	-7.06	-7.06
	26.00	19.76	12.02	19.04	33.08	-0.04	-0.04
	27.00	12.92	10.04	17.96	30.92	8.96	8.96
	28.00	15.08	12.02	15.08	33.08	23.00	12.02
	29.00	13.64	12.92	6.98	35.06	32.00	6.98
	30.00	1.04	21.92	12.02	30.02	10.94	1.04
	31.00	8.96	26.06	30.02	28.04	10.04	8.96

	Min of Dry-Bulb Temperature (F)	YEAR					
MONTH	DAY HOUR	81.00	82.00	83.00	84.00	85.00	Grand Total
1.00	1.00	15.08	30.02	24.08	12.92	37.94	12.92
	2.00	8.96	19.94	28.94	23.00	30.02	8.96
	3.00	6.08	19.94	26.06	28.04	24.08	6.08
	4.00	-5.98	33.98	17.96	33.98	21.02	-5.98
	5.00	10.94	26.06	24.98	35.06	19.04	10.94
	6.00	10.94	21.92	28.04	35.06	15.08	10.94
	7.00	8.96	24.98	32.00	15.08	30.92	8.96
	8.00	1.94	17.06	28.04	8.96	10.04	1.94
	9.00	-4.00	8.06	19.04	19.94	6.98	-4.00
	10.00	1.94	-2.02	30.92	21.02	8.06	-2.02

	11.00	-2.02	-2.92	35.06	8.96	14.00	-2.92
	12.00	-9.94	-2.02	19.04	-0.04	10.94	-9.94
	13.00	-11.92	5.00	15.08	8.06	19.04	-11.92
	14.00	10.94	15.98	19.04	24.08	19.94	10.94
	15.00	21.02	6.08	26.96	6.98	10.04	6.08
	16.00	24.98	6.08	19.94	-0.94	3.92	-0.94
	17.00	8.06	-9.04	12.02	17.06	15.08	-9.04
	18.00	6.98	-7.06	8.96	15.98	19.04	-7.06
	19.00	26.96	1.04	5.00	6.98	14.00	1.04
	20.00	19.04	15.08	6.98	1.04	-5.08	-5.08
	21.00	8.96	14.00	1.04	-9.94	-14.08	-14.08
	22.00	12.02	-0.04	8.06	-9.94	3.02	-9.94
	23.00	30.92	10.94	30.92	6.98	19.04	6.98
	24.00	26.96	8.96	33.08	26.06	21.02	8.96
	25.00	24.98	6.98	33.98	33.98	24.08	6.98
	26.00	37.04	-0.04	21.92	32.00	15.08	-0.04
	27.00	35.06	6.98	24.08	28.94	10.94	6.98
	28.00	24.98	17.06	24.08	21.02	23.00	17.06
	29.00	17.06	19.94	17.06	23.00	17.06	17.06
	30.00	10.94	15.08	26.96	26.96	14.00	10.94
	31.00	10.04	33.98	30.02	15.08	15.98	10.04
2.00	1.00	12.02	23.00	30.02	8.96	28.04	8.96
	2.00	23.00	15.08	30.92	3.92	17.06	3.92
2.00	3.00	8.96	32.00	37.04	28.04	3.92	3.92
	4.00	8.96	21.92	19.94	33.08	-5.98	-5.98
	5.00	3.02	15.98	14.00	30.02	6.08	3.02
	6.00	15.08	17.06	14.00	24.08	19.04	14.00
	7.00	24.98	10.94	21.92	17.06	12.02	10.94
	8.00	21.92	24.08	23.00	15.08	6.98	6.98
	9.00	12.92	26.06	10.04	21.92	14.00	10.04
	10.00	12.92	14.00	1.04	28.04	17.06	1.04
	11.00	26.06	10.04	10.94	39.92	15.08	10.04
	12.00	10.94	14.00	12.02	39.02	35.06	10.94
	13.00	5.00	19.94	-0.04	35.96	26.96	-0.04
	14.00	17.06	17.96	8.96	46.94	21.92	8.96
	15.00	24.08	28.94	15.98	42.08	17.06	15.98
	16.00	33.08	35.06	28.94	39.02	17.96	17.96
	17.00	44.06	28.94	35.06	42.08	24.98	24.98
	18.00	46.04	26.06	30.92	42.08	26.06	26.06
	19.00	50.00	28.94	24.98	37.94	28.94	24.98
	20.00	51.98	32.00	26.96	35.96	19.94	19.94
	21.00	46.94	32.00	28.94	32.00	19.94	19.94
	22.00	48.02	30.02	35.06	26.06	41.00	26.06
	23.00	46.04	30.92	33.08	32.00	48.02	30.92
	24.00	39.92	21.02	30.02	42.98	50.00	21.02
	25.00	32.00	8.96	26.06	30.02	37.94	8.96
	26.00	30.02	6.08	19.94	24.98	37.04	6.08
	27.00	30.02	12.92	15.08	21.92	21.92	12.92
	28.00	28.04	12.02	24.98	28.94	15.98	12.02
	29.00				21.02		21.02
3.00	1.00	37.04	15.98	33.08	15.08	30.02	15.08
	2.00	28.94	26.06	37.94	19.04	32.00	19.04
	3.00	23.00	10.94	37.94	19.94	26.06	10.94

	4.00	19.94	3.92	35.06	15.98	21.02	3.92
	5.00	30.02	30.02	37.04	28.04	28.94	28.04
	6.00	24.98	21.02	35.96	30.02	15.98	15.98
	7.00	24.98	26.06	37.94	15.08	15.08	15.08
	8.00	30.92	12.92	35.96	10.04	35.06	10.04
	9.00	33.98	12.02	35.96	8.96	33.08	8.96
	10.00	33.08	10.04	33.08	1.04	28.94	1.04
3.00	11.00	30.02	35.96	33.98	12.92	32.00	12.92
	12.00	28.04	35.06	28.94	6.98	37.04	6.98
	13.00	33.98	32.00	28.04	21.02	35.06	21.02
	14.00	21.02	37.94	28.04	26.96	33.98	21.02
	15.00	24.98	33.08	37.04	17.06	28.04	17.06
	16.00	21.02	33.98	32.00	37.04	24.08	21.02
	17.00	12.92	33.98	33.98	24.08	24.98	12.92
	18.00	8.06	33.98	37.94	26.06	17.96	8.06
	19.00	15.98	37.04	48.02	35.06	12.92	12.92
	20.00	17.06	32.00	37.94	33.98	32.00	17.06
	21.00	21.02	39.92	35.96	35.06	21.92	21.02
	22.00	30.02	35.06	24.98	33.98	19.94	19.94
	23.00	30.02	30.02	21.02	32.00	33.08	21.02
	24.00	32.00	30.92	19.04	26.06	35.06	19.04
	25.00	33.98	35.06	14.00	28.94	28.04	14.00
	26.00	28.04	30.02	15.08	28.94	26.06	15.08
	27.00	35.06	19.94	32.00	24.08	28.94	19.94
	28.00	30.02	17.06	39.02	33.98	55.04	17.06
	29.00	42.98	21.92	26.06	30.92	53.96	21.92
	30.00	55.94	30.92	21.02	32.00	39.02	21.02
	31.00	50.00	51.08	24.08	30.92	33.98	24.08
4.00	1.00	50.00	42.08	24.98	24.08	35.06	24.08
	2.00	46.04	30.02	26.06	26.96	30.92	26.06
	3.00	35.96	39.02	35.96	33.08	30.02	30.02
	4.00	60.08	28.04	39.02	39.02	35.06	28.04
	5.00	44.96	23.00	41.00	48.02	44.96	23.00
	6.00	37.94	17.96	33.98	42.08	44.06	17.96
	7.00	32.00	14.00	48.02	35.96	33.98	14.00
	8.00	46.04	21.02	46.04	35.96	28.94	21.02
	9.00	48.02	26.96	39.02	30.92	24.98	24.98
	10.00	37.04	26.96	39.92	30.02	19.94	19.94
	11.00	51.98	28.94	39.02	33.08	35.96	28.94
	12.00	44.96	32.00	39.02	37.04	32.00	32.00
	13.00	39.92	42.98	32.00	48.02	44.96	32.00
	14.00	39.92	37.04	37.04	42.98	42.98	37.04
	15.00	33.08	32.00	44.96	46.04	51.98	32.00
	16.00	28.04	46.04	33.08	46.04	46.94	28.04
4.00	17.00	46.94	60.08	30.92	44.06	32.00	30.92
	18.00	46.04	42.98	32.00	37.94	35.96	32.00
	19.00	35.96	35.06	28.04	46.94	60.08	28.04
	20.00	32.00	50.00	28.04	44.96	57.02	28.04
	21.00	28.04	37.94	33.98	41.00	55.94	28.04
	22.00	28.94	35.06	30.02	32.00	55.94	28.94
	23.00	44.06	30.92	33.98	39.02	53.06	30.92
	24.00	44.06	46.94	39.92	42.98	46.94	39.92
	25.00	37.94	42.98	33.08	44.06	46.94	33.08

	26.00	39.92	55.04	35.96	37.94	48.02	35.96
	27.00	46.94	44.06	37.94	50.00	44.96	37.94
	28.00	46.04	39.02	50.00	48.02	42.98	39.02
	29.00	53.96	37.04	59.00	48.02	42.08	37.04
	30.00	46.94	39.02	57.92	53.06	41.00	39.02
5.00	1.00	39.92	42.98	60.98	50.00	51.08	39.92
	2.00	46.04	44.96	64.04	41.00	44.96	41.00
	3.00	37.04	44.96	60.98	42.08	39.92	37.04
	4.00	42.08	42.98	48.02	50.00	35.06	35.06
	5.00	51.98	39.92	39.02	48.02	50.00	39.02
	6.00	42.98	44.96	39.02	42.98	59.00	39.02
	7.00	37.04	55.94	46.04	44.96	50.00	37.04
	8.00	37.04	53.06	37.94	51.98	39.92	37.04
	9.00	42.08	51.98	37.94	44.06	33.08	33.08
	10.00	48.02	42.98	33.98	46.04	53.96	33.98
	11.00	62.06	39.92	37.04	46.94	57.92	37.04
	12.00	48.02	48.92	35.96	55.94	62.96	35.96
	13.00	42.08	55.94	37.04	44.06	62.96	37.04
	14.00	46.04	48.02	48.02	44.06	57.02	44.06
	15.00	57.92	44.96	51.08	39.92	50.00	39.92
	16.00	50.00	46.94	37.94	41.00	55.04	37.94
	17.00	42.98	60.08	30.92	37.94	55.94	30.92
	18.00	41.00	55.94	32.00	41.00	44.96	32.00
	19.00	39.92	60.08	51.98	50.00	39.92	39.92
	20.00	41.00	59.00	55.04	53.96	50.00	41.00
	21.00	42.98	55.94	53.06	53.06	55.94	42.98
	22.00	51.08	50.00	51.08	60.08	46.94	46.94
	23.00	46.04	50.00	57.02	59.00	46.94	46.04
5.00	24.00	44.06	50.00	50.00	51.98	46.94	44.06
	25.00	59.00	53.96	41.00	53.06	48.92	41.00
	26.00	60.08	48.02	53.96	57.02	53.96	48.02
	27.00	62.96	57.02	44.96	53.06	59.00	44.96
	28.00	62.96	57.92	37.04	57.02	57.02	37.04
	29.00	62.96	59.00	51.98	57.92	50.00	50.00
	30.00	64.04	59.00	62.06	48.92	50.00	48.92
	31.00	53.06	64.94	55.04	46.94	60.08	46.94
6.00	1.00	44.96	62.96	46.94	42.98	60.08	42.98
	2.00	57.02	53.06	44.96	53.96	48.92	44.96
	3.00	59.00	48.02	48.02	48.92	57.02	48.02
	4.00	62.96	55.94	55.94	46.94	50.00	46.94
	5.00	59.00	57.02	51.08	53.96	55.04	51.08
	6.00	66.92	55.94	60.98	62.96	51.98	51.98
	7.00	59.00	55.04	55.94	64.94	44.96	44.96
	8.00	48.92	53.06	51.98	66.02	57.92	48.92
	9.00	64.04	51.08	39.02	71.96	57.92	39.02
	10.00	60.08	57.02	48.02	69.98	66.02	48.02
	11.00	59.00	53.06	55.04	68.00	57.92	53.06
	12.00	57.92	50.00	53.96	55.94	55.94	50.00
	13.00	59.00	48.92	60.08	68.00	50.00	48.92
	14.00	62.06	50.00	62.06	64.04	46.04	46.04
	15.00	62.96	50.00	64.94	53.06	42.98	42.98
	16.00	73.94	64.04	64.04	44.96	57.02	44.96
	17.00	60.98	62.96	62.96	62.06	60.08	60.08

	18.00	51.98	57.02	62.96	62.06	64.04	51.98
	19.00	62.96	60.08	66.02	68.00	57.02	57.02
	20.00	64.94	53.96	64.04	59.00	51.98	51.98
	21.00	60.08	55.04	62.06	51.98	48.92	48.92
	22.00	66.02	51.08	55.04	51.98	53.96	51.08
	23.00	60.08	55.04	55.94	57.02	66.02	55.04
	24.00	53.96	51.98	66.92	66.02	62.06	51.98
	25.00	66.02	50.00	55.04	60.08	51.08	50.00
	26.00	55.94	59.00	44.96	53.96	51.98	44.96
	27.00	51.08	62.06	60.98	51.98	51.98	51.08
	28.00	51.08	64.94	60.08	62.96	51.98	51.08
	29.00	53.96	66.02	59.00	62.96	57.02	53.96
6.00	30.00	64.04	59.00	55.04	64.04	53.96	53.96
7.00	1.00	64.04	53.06	62.96	66.92	57.02	53.06
	2.00	66.02	46.04	71.06	66.02	57.02	46.04
	3.00	66.92	53.06	68.00	66.02	62.06	53.06
	4.00	68.00	53.96	71.96	64.04	55.94	53.96
	5.00	66.02	50.00	66.02	69.08	62.06	50.00
	6.00	64.04	57.92	57.92	66.92	64.04	57.92
	7.00	66.02	60.08	50.00	60.98	62.96	50.00
	8.00	69.08	69.98	51.98	51.98	55.04	51.98
	9.00	73.94	64.04	57.02	50.00	64.04	50.00
	10.00	66.92	57.02	48.02	57.02	64.04	48.02
	11.00	60.98	64.94	46.94	69.98	57.02	46.94
	12.00	64.94	66.02	57.92	68.00	55.94	55.94
	13.00	71.96	59.00	66.92	62.06	57.92	57.92
	14.00	64.94	62.96	57.92	64.04	66.92	57.92
	15.00	62.96	64.04	60.98	68.00	68.00	60.98
	16.00	55.04	66.02	73.94	73.04	64.94	55.04
	17.00	60.08	69.98	66.02	60.98	53.96	53.96
	18.00	62.06	71.06	69.08	64.04	57.02	57.02
	19.00	62.96	69.98	66.92	60.08	59.00	59.00
	20.00	71.06	66.02	62.96	57.92	71.06	57.92
	21.00	68.00	55.94	64.04	64.94	62.06	55.94
	22.00	57.92	53.96	59.00	62.96	66.02	53.96
	23.00	50.00	60.08	51.98	68.00	55.94	50.00
	24.00	55.04	55.94	64.04	71.06	48.92	48.92
	25.00	64.04	55.04	62.96	60.08	64.94	55.04
	26.00	69.08	66.92	57.02	53.96	69.98	53.96
	27.00	62.06	60.98	55.04	62.06	62.06	55.04
	28.00	59.00	64.94	62.06	60.98	55.04	55.04
	29.00	55.94	60.98	71.96	59.00	60.98	55.94
	30.00	53.06	59.00	68.00	62.96	64.94	53.06
	31.00	53.06	66.02	66.92	60.98	62.96	53.06
8.00	1.00	57.92	60.98	64.94	66.02	60.08	57.92
	2.00	62.96	59.00	64.94	69.98	53.06	53.06
	3.00	62.06	62.96	59.00	69.98	51.98	51.98
	4.00	64.94	60.98	66.92	71.06	57.92	57.92
	5.00	64.94	66.02	66.92	68.00	59.00	59.00
8.00	6.00	60.08	60.08	66.92	66.02	60.98	60.08
	7.00	57.02	62.96	64.94	71.06	66.02	57.02
	8.00	66.02	66.92	64.94	64.94	66.02	64.94
	9.00	66.02	68.00	64.94	69.98	62.96	62.96

	10.00	64.04	66.02	55.04	71.06	62.96	55.04
	11.00	66.02	55.94	64.94	71.06	66.02	55.94
	12.00	64.94	53.06	55.94	68.00	55.94	53.06
	13.00	60.98	50.00	55.04	69.98	57.02	50.00
	14.00	64.94	51.08	48.02	69.08	73.04	48.02
	15.00	68.00	53.06	51.98	68.00	73.04	51.98
	16.00	59.00	57.02	53.96	62.96	60.98	53.96
	17.00	53.06	62.06	60.08	64.04	55.04	53.06
	18.00	44.96	53.96	69.08	55.04	57.02	44.96
	19.00	53.06	51.98	69.08	60.98	62.96	51.98
	20.00	53.96	62.96	71.06	55.04	60.98	53.96
	21.00	51.98	48.92	59.00	48.02	57.02	48.02
	22.00	60.08	42.08	55.94	53.96	53.96	42.08
	23.00	50.00	55.94	60.98	64.94	48.02	48.02
	24.00	59.00	60.08	57.02	60.98	53.06	53.06
	25.00	60.08	57.92	60.08	55.94	62.06	55.94
	26.00	53.06	51.98	62.06	55.04	68.00	51.98
	27.00	57.92	59.00	64.94	55.94	66.02	55.94
	28.00	66.02	46.94	66.92	64.04	57.92	46.94
	29.00	66.92	39.02	64.94	69.08	62.96	39.02
	30.00	66.92	51.08	60.08	68.00	62.96	51.08
	31.00	66.02	55.94	62.06	62.06	55.94	55.94
9.00	1.00	64.04	66.92	60.98	55.04	55.04	55.04
	2.00	62.96	66.02	55.04	57.02	62.06	55.04
	3.00	64.94	55.94	57.02	68.00	55.04	55.04
	4.00	62.06	50.00	60.98	55.04	69.98	50.00
	5.00	62.06	46.04	62.96	50.00	71.96	46.04
	6.00	64.94	48.92	71.06	44.96	73.04	44.96
	7.00	64.94	55.94	64.94	41.00	69.98	41.00
	8.00	60.98	57.02	55.04	50.00	69.08	50.00
	9.00	51.08	57.92	51.98	55.04	66.92	51.08
	10.00	44.06	51.98	59.00	62.96	60.98	44.06
	11.00	60.98	55.04	66.92	64.04	46.94	46.94
9.00	12.00	60.98	57.02	59.00	57.92	39.02	39.02
	13.00	51.98	57.02	53.06	55.04	37.94	37.94
	14.00	64.94	57.92	48.02	64.04	39.92	39.92
	15.00	60.98	60.98	41.00	46.94	39.02	39.02
	16.00	53.96	57.92	46.94	42.08	42.08	42.08
	17.00	57.02	48.92	57.92	41.00	46.04	41.00
	18.00	53.96	44.96	48.92	44.96	51.08	44.96
	19.00	53.06	42.98	60.08	46.94	53.96	42.98
	20.00	48.92	46.94	64.04	55.04	55.94	46.94
	21.00	41.00	53.96	53.96	53.96	57.02	41.00
	22.00	51.08	55.94	44.96	48.02	60.98	44.96
	23.00	46.94	51.98	42.08	59.00	64.04	42.08
	24.00	48.02	50.00	39.02	69.08	50.00	39.02
	25.00	46.94	51.08	37.94	66.92	44.96	37.94
	26.00	53.06	48.92	44.06	50.00	48.02	44.06
	27.00	57.92	53.96	44.96	42.98	55.04	42.98
	28.00	48.92	48.02	50.00	44.06	51.98	44.06
	29.00	39.92	53.96	42.08	48.02	42.98	39.92
	30.00	42.98	53.96	48.92	42.08	48.92	42.08
10.00	1.00	44.06	50.00	57.02	50.00	51.98	44.06

	2.00	44.96	48.02	60.08	44.96	51.98	44.96
	3.00	42.98	39.92	51.98	42.98	50.00	39.92
	4.00	41.00	51.98	53.96	46.94	53.96	41.00
	5.00	50.00	44.96	59.00	44.06	51.08	44.06
	6.00	53.06	51.08	51.08	35.96	46.04	35.96
	7.00	46.94	55.04	44.06	37.04	37.94	37.04
	8.00	44.06	62.96	44.06	55.04	39.92	39.92
	9.00	42.08	55.04	46.94	59.00	51.98	42.08
	10.00	33.98	44.06	42.08	57.92	50.00	33.98
	11.00	37.04	37.04	42.08	53.96	39.92	37.04
	12.00	33.98	48.92	55.94	48.02	30.92	30.92
	13.00	33.98	50.00	60.08	48.02	44.96	33.98
	14.00	33.98	46.04	46.94	44.96	55.04	33.98
	15.00	39.92	46.04	42.98	42.98	57.02	39.92
	16.00	42.98	39.92	35.06	44.96	42.08	35.06
	17.00	37.94	35.96	44.06	50.00	33.08	33.08
	18.00	42.08	26.96	46.94	59.00	37.94	26.96
10.00	19.00	39.02	35.06	42.08	55.04	55.04	35.06
	20.00	32.00	46.94	37.04	53.06	42.98	32.00
	21.00	39.02	44.06	32.00	53.06	39.92	32.00
	22.00	48.92	32.00	28.94	57.02	42.98	28.94
	23.00	39.92	26.96	42.08	53.06	46.04	26.96
	24.00	33.98	30.92	48.92	48.92	51.08	30.92
	25.00	33.08	32.00	39.92	41.00	44.96	32.00
	26.00	46.94	39.92	39.92	53.06	39.92	39.92
	27.00	55.94	33.98	39.02	60.98	39.92	33.98
	28.00	46.04	28.94	33.98	62.06	33.08	28.94
	29.00	35.96	37.94	37.04	51.08	26.06	26.06
	30.00	39.02	48.02	26.96	39.02	30.02	26.96
	31.00	37.04	51.98	28.04	44.96	42.98	28.04
11.00	1.00	46.94	57.92	30.02	48.92	42.08	30.02
	2.00	39.02	53.06	39.92	33.08	39.02	33.08
	3.00	39.92	59.00	39.92	26.96	46.04	26.96
	4.00	33.08	50.00	33.98	33.08	46.04	33.08
	5.00	35.96	32.00	33.98	51.98	48.02	32.00
	6.00	37.94	28.94	33.98	39.02	44.06	28.94
	7.00	33.08	28.94	37.04	30.02	44.96	28.94
	8.00	32.00	35.06	30.92	23.00	37.04	23.00
	9.00	33.98	35.96	35.06	39.02	35.96	33.98
	10.00	28.94	33.08	39.92	46.04	53.06	28.94
	11.00	39.02	37.04	39.92	46.94	41.00	37.04
	12.00	28.94	50.00	32.00	32.00	39.02	28.94
	13.00	21.92	35.96	28.04	30.92	46.94	21.92
	14.00	33.08	28.94	26.06	30.92	44.06	26.06
	15.00	42.08	28.94	37.04	26.96	30.92	26.96
	16.00	42.08	21.92	37.94	35.06	30.02	21.92
	17.00	42.08	28.94	35.96	33.08	39.92	28.94
	18.00	42.98	30.92	32.00	33.08	33.08	30.92
	19.00	44.06	37.04	39.02	21.92	51.98	21.92
	20.00	42.08	39.92	42.08	19.94	50.00	19.94
	21.00	33.98	46.04	44.96	24.08	30.02	24.08
	22.00	33.08	51.98	46.04	24.98	28.94	24.98
	23.00	32.00	51.98	35.06	23.00	33.08	23.00

	24.00	24.98	28.94	44.96	28.94	33.08	24.98
11.00	25.00	24.08	24.98	32.00	28.94	30.02	24.08
	26.00	24.08	32.00	33.08	26.96	30.92	24.08
	27.00	35.06	19.94	35.96	30.02	33.98	19.94
	28.00	37.94	15.98	35.06	53.06	33.08	15.98
	29.00	32.00	33.08	37.04	33.08	33.08	32.00
	30.00	24.98	37.94	35.06	28.04	35.96	24.98
12.00	1.00	21.92	41.00	30.02	39.92	35.96	21.92
	2.00	37.94	46.94	26.06	33.98	24.98	24.98
	3.00	33.08	48.92	28.04	33.08	21.02	21.02
	4.00	28.94	55.04	28.04	26.96	19.94	19.94
	5.00	30.02	51.98	35.06	26.96	19.04	19.04
	6.00	24.98	50.00	39.92	28.04	26.96	24.98
	7.00	28.94	35.96	30.02	19.04	24.98	19.04
	8.00	32.00	30.92	26.96	21.92	32.00	21.92
	9.00	24.08	10.94	28.94	23.00	33.08	10.94
	10.00	21.92	6.98	35.06	37.04	35.06	6.98
	11.00	21.92	21.02	28.04	37.04	41.00	21.02
	12.00	28.04	15.98	30.92	35.96	32.00	15.98
	13.00	19.94	10.04	39.92	39.92	30.02	10.04
	14.00	17.96	19.94	35.96	35.96	17.06	17.06
	15.00	28.94	26.96	35.96	37.94	12.02	12.02
	16.00	28.04	39.02	33.08	39.02	26.96	26.96
	17.00	24.98	17.06	23.00	44.06	19.94	17.06
	18.00	14.00	8.96	17.96	33.08	8.96	8.96
	19.00	8.06	21.92	12.92	30.02	6.98	6.98
	20.00	10.04	28.94	6.98	30.92	1.04	1.04
	21.00	8.06	30.02	1.04	28.04	14.00	1.04
	22.00	24.08	26.96	24.08	35.06	8.96	8.96
	23.00	33.98	26.96	15.98	26.96	24.98	15.98
	24.00	33.98	33.98	-0.04	30.92	32.00	-0.04
	25.00	26.06	33.98	-4.00	21.02	10.94	-4.00
	26.00	21.02	33.98	-0.94	21.02	3.92	-0.94
	27.00	28.04	26.96	8.96	24.98	10.94	8.96
	28.00	30.02	37.94	15.08	33.08	19.94	15.08
	29.00	28.94	32.00	17.06	48.02	14.00	14.00
	30.00	21.92	24.98	8.96	28.94	15.08	8.96
	31.00	19.04	21.92	8.96	21.02	17.06	8.96

Min of Dry-Bulb Temperature (F) YEAR

MONTH	DAY HOUR	86.00	87.00	88.00	89.00	90.00	Grand Total
1.00	1.00	26.06	19.94	26.06	23.00	28.04	19.94
	2.00	24.98	26.06	12.92	32.00	26.96	12.92
	3.00	33.08	24.08	8.06	24.08	24.08	8.06
	4.00	24.98	17.06	17.06	5.00	30.02	5.00
	5.00	24.98	15.98	3.92	5.00	28.04	3.92
	6.00	17.96	12.92	1.94	19.04	28.04	1.94
	7.00	12.02	30.02	3.02	23.00	21.92	3.02
	8.00	8.96	26.06	10.04	35.96	24.98	8.96
	9.00	15.08	30.02	15.08	24.08	26.96	15.08
	10.00	30.92	28.94	5.00	19.04	35.96	5.00
	11.00	23.00	30.02	-5.08	24.98	28.04	-5.08
	12.00	24.98	28.94	10.94	28.04	24.08	10.94
	13.00	12.02	28.04	12.02	23.00	19.04	12.02

	14.00	8.06	19.94	-0.94	15.08	21.02	-0.94
	15.00	-0.04	39.02	-4.00	32.00	28.94	-4.00
	16.00	15.98	19.04	6.08	26.96	30.02	6.08
	17.00	24.98	14.00	24.08	26.06	37.04	14.00
	18.00	35.06	21.02	35.06	24.98	39.02	21.02
	19.00	48.02	26.06	30.92	30.02	23.00	23.00
	20.00	35.06	23.00	32.00	23.00	24.08	23.00
	21.00	32.00	17.96	30.02	8.06	32.00	8.06
	22.00	28.94	15.98	19.04	10.94	33.08	10.94
	23.00	21.02	8.06	15.08	21.92	30.92	8.06
	24.00	15.08	1.04	24.08	23.00	37.94	1.04
	25.00	24.08	-2.02	30.02	30.02	39.92	-2.02
	26.00	32.00	8.06	12.02	30.92	30.92	8.06
	27.00	12.92	-5.08	6.08	33.08	21.92	-5.08
	28.00	6.08	-2.92	-0.04	26.06	35.06	-2.92
	29.00	3.02	14.00	1.94	35.96	28.94	1.94
	30.00	10.94	26.06	24.08	39.92	26.06	10.94
	31.00	14.00	24.08	30.02	32.00	23.00	14.00
2.00	1.00	6.98	23.00	44.96	39.92	26.06	6.98
	2.00	32.00	28.04	26.06	35.96	37.04	26.06
2.00	3.00	28.04	26.96	17.96	17.96	28.04	17.96
	4.00	32.00	26.06	17.06	14.00	19.94	14.00
	5.00	32.00	17.96	8.96	15.98	19.94	8.96
	6.00	21.92	23.00	3.92	23.00	28.94	3.92
	7.00	14.00	23.00	1.04	21.02	33.98	1.04
	8.00	17.96	24.08	19.04	17.96	26.96	17.96
	9.00	26.06	10.94	12.92	10.94	39.92	10.94
	10.00	24.08	10.04	17.96	12.92	28.94	10.04
	11.00	17.06	24.08	17.96	21.02	24.08	17.06
	12.00	12.02	19.94	19.94	24.08	24.98	12.02
	13.00	6.98	10.04	14.00	15.98	24.08	6.98
	14.00	10.04	6.98	17.96	37.04	32.00	6.98
	15.00	17.96	-5.08	26.06	35.06	30.92	-5.08
	16.00	15.08	-0.04	24.08	17.96	39.02	-0.04
	17.00	24.08	3.02	23.00	10.94	17.06	3.02
	18.00	33.98	15.98	30.02	12.02	10.94	10.94
	19.00	35.06	15.98	24.08	23.00	26.06	15.98
	20.00	35.06	19.04	35.96	26.96	19.04	19.04
	21.00	24.08	12.02	15.08	37.94	15.08	12.02
	22.00	17.96	15.08	12.92	30.02	33.98	12.92
	23.00	26.96	30.02	33.98	17.06	30.92	17.06
	24.00	23.00	24.98	24.08	10.04	24.08	10.04
	25.00	15.08	19.94	17.96	6.08	3.92	3.92
	26.00	12.02	15.08	14.00	21.92	1.94	1.94
	27.00	15.08	15.98	24.98	24.08	14.00	14.00
	28.00	15.98	26.06	24.08	19.04	19.94	15.98
	29.00			23.00			23.00
3.00	1.00	17.96	37.94	19.94	24.08	17.96	17.96
	2.00	17.96	32.00	15.08	19.04	26.06	15.08
	3.00	21.92	26.96	30.92	24.08	26.06	21.92
	4.00	30.02	19.94	21.92	33.98	15.08	15.08
	5.00	32.00	19.04	19.04	28.04	19.94	19.04
	6.00	28.04	17.96	17.96	19.04	14.00	14.00

	7.00	10.04	32.00	28.94	12.02	3.92	3.92
	8.00	6.98	41.00	26.06	8.96	12.02	6.98
	9.00	23.00	19.94	37.94	17.06	24.08	17.06
	10.00	35.96	8.96	30.02	21.02	35.96	8.96
3.00	11.00	33.98	8.06	26.96	24.98	44.96	8.06
	12.00	28.04	23.00	28.04	19.04	53.06	19.04
	13.00	35.96	26.06	35.96	12.02	55.04	12.02
	14.00	39.92	19.94	28.04	30.92	53.96	19.94
	15.00	42.08	23.00	23.00	44.06	53.06	23.00
	16.00	37.94	21.02	24.08	35.06	62.06	21.02
	17.00	35.06	26.96	28.04	37.04	51.08	26.96
	18.00	28.94	28.94	24.98	26.96	39.02	24.98
	19.00	46.04	26.06	26.96	24.08	33.98	24.08
	20.00	12.92	28.04	19.04	19.94	30.02	12.92
	21.00	10.04	30.92	14.00	26.96	28.94	10.04
	22.00	14.00	37.94	12.02	21.02	33.08	12.02
	23.00	28.94	35.06	26.06	21.92	28.94	21.92
	24.00	32.00	32.00	46.94	33.08	26.96	26.96
	25.00	28.94	39.92	51.08	33.98	26.06	26.06
	26.00	48.02	46.94	48.92	42.08	24.98	24.98
	27.00	39.02	37.04	35.06	37.94	19.04	19.04
	28.00	37.04	48.02	33.98	53.06	19.04	19.04
	29.00	48.02	41.00	37.94	51.08	26.06	26.06
	30.00	51.08	48.92	48.92	42.08	33.98	33.98
	31.00	46.04	28.94	37.04	35.96	35.06	28.94
4.00	1.00	46.94	24.08	46.04	33.08	41.00	24.08
	2.00	44.96	30.02	46.94	30.02	42.98	30.02
	3.00	37.04	33.08	50.00	41.00	33.98	33.08
	4.00	46.94	39.02	55.94	42.08	33.98	33.98
	5.00	37.94	39.92	48.02	46.94	35.06	35.06
	6.00	37.04	42.08	44.96	37.94	37.94	37.04
	7.00	42.08	42.98	42.08	32.00	30.92	30.92
	8.00	44.96	42.08	35.06	32.00	28.94	28.94
	9.00	37.94	39.92	35.06	35.96	30.02	30.02
	10.00	33.98	33.98	33.98	28.94	48.02	28.94
	11.00	30.92	37.94	30.92	23.00	33.08	23.00
	12.00	32.00	39.92	39.92	26.06	30.02	26.06
	13.00	28.04	44.96	30.02	33.98	23.00	23.00
	14.00	32.00	39.02	33.08	26.96	33.08	26.96
	15.00	39.92	50.00	33.08	44.06	44.96	33.08
	16.00	42.98	46.04	30.92	39.92	35.96	30.92
4.00	17.00	41.00	44.96	35.06	33.98	33.98	33.98
	18.00	35.96	51.08	35.06	42.98	30.02	30.02
	19.00	41.00	51.98	28.04	37.94	28.94	28.04
	20.00	46.94	51.08	32.00	35.06	46.04	32.00
	21.00	44.06	57.92	37.04	39.92	48.92	37.04
	22.00	30.02	51.08	33.08	30.92	44.06	30.02
	23.00	28.94	48.92	32.00	30.02	46.04	28.94
	24.00	33.98	42.98	42.08	30.92	48.92	30.92
	25.00	44.06	39.02	39.02	42.08	51.08	39.02
	26.00	46.94	35.06	32.00	44.96	59.00	32.00
	27.00	48.92	39.92	42.98	39.92	57.92	39.92
	28.00	48.02	35.06	39.92	35.96	60.98	35.06

	29.00	55.04	39.92	39.02	48.92	53.96	39.02
	30.00	51.08	41.00	39.92	46.94	51.08	39.92
5.00	1.00	46.94	35.06	41.00	53.06	50.00	35.06
	2.00	39.92	41.00	42.98	46.94	46.94	39.92
	3.00	33.98	42.98	44.06	41.00	39.02	33.98
	4.00	35.06	44.06	39.92	37.94	46.94	35.06
	5.00	50.00	44.06	51.98	51.08	44.96	44.06
	6.00	62.06	44.06	53.06	50.00	42.98	42.98
	7.00	59.00	46.94	51.98	37.94	42.08	37.94
	8.00	48.92	35.06	46.94	37.04	46.94	35.06
	9.00	44.96	37.94	48.02	39.02	55.04	37.94
	10.00	41.00	55.94	50.00	44.96	53.06	41.00
	11.00	44.06	53.06	44.96	44.06	42.08	42.08
	12.00	42.08	48.92	35.96	44.06	33.98	33.98
	13.00	44.96	39.02	50.00	42.08	48.92	39.02
	14.00	46.94	42.98	44.96	48.02	48.92	42.98
	15.00	53.06	48.92	46.04	48.92	53.96	46.04
	16.00	59.00	39.92	53.06	53.06	57.92	39.92
	17.00	60.98	51.08	57.02	53.96	55.04	51.08
	18.00	59.00	55.94	57.02	51.98	51.98	51.98
	19.00	64.94	48.92	57.02	55.94	48.02	48.02
	20.00	62.96	44.96	55.94	57.92	51.08	44.96
	21.00	59.00	51.08	57.92	57.92	46.94	46.94
	22.00	55.04	57.02	59.00	46.94	39.92	39.92
	23.00	53.06	62.06	55.04	51.08	42.98	42.98
5.00	24.00	46.94	53.96	55.04	53.06	42.98	42.98
	25.00	57.92	50.00	46.04	44.96	41.00	41.00
	26.00	51.98	57.02	44.06	60.08	51.08	44.06
	27.00	53.06	53.96	44.96	55.04	48.02	44.96
	28.00	60.98	59.00	55.04	44.96	48.02	44.96
	29.00	55.94	60.98	55.04	42.08	51.08	42.08
	30.00	60.08	62.96	57.92	55.94	48.02	48.02
	31.00	64.94	66.02	62.06	66.02	39.02	39.02
6.00	1.00	62.06	66.02	53.96	66.02	46.04	46.04
	2.00	44.06	64.04	44.06	64.04	59.00	44.06
	3.00	35.96	62.96	48.02	55.04	66.02	35.96
	4.00	51.08	60.98	46.04	57.92	48.02	46.04
	5.00	66.02	53.96	50.00	51.08	44.06	44.06
	6.00	66.92	55.04	57.92	55.04	46.94	46.94
	7.00	64.94	51.98	55.04	53.96	59.00	51.98
	8.00	66.92	64.94	48.02	57.92	51.08	48.02
	9.00	55.04	55.04	46.04	60.08	62.96	46.04
	10.00	46.94	50.00	37.94	60.98	60.08	37.94
	11.00	64.94	42.98	37.94	53.96	51.08	37.94
	12.00	57.92	60.98	48.02	46.04	42.98	42.98
	13.00	55.94	60.98	57.02	60.08	51.08	51.08
	14.00	53.96	55.04	57.92	57.02	59.00	53.96
	15.00	60.98	68.00	62.96	57.92	62.06	57.92
	16.00	69.08	55.94	66.92	60.08	62.96	55.94
	17.00	53.06	57.02	60.08	57.92	66.02	53.06
	18.00	44.96	51.98	53.96	51.08	66.02	44.96
	19.00	46.94	60.08	59.00	55.94	60.98	46.94
	20.00	60.08	64.94	71.60	60.98	60.08	60.08

	21.00	51.08	68.00	68.00	66.92	60.08	51.08
	22.00	51.98	68.00	62.96	66.92	57.92	51.98
	23.00	64.04	62.96	57.92	66.92	64.04	57.92
	24.00	57.02	57.02	48.02	64.94	60.98	48.02
	25.00	51.08	60.98	57.92	64.94	57.92	51.08
	26.00	46.04	62.06	57.92	60.08	53.96	46.04
	27.00	57.02	59.00	51.08	62.96	66.02	51.08
	28.00	68.00	53.96	48.02	64.04	59.00	48.02
	29.00	60.08	57.02	53.06	55.04	66.02	53.06
6.00	30.00	53.96	69.98	48.92	46.94	66.02	46.94
7.00	1.00	46.94	66.02	46.04	51.98	62.06	46.04
	2.00	59.00	64.04	51.08	59.00	60.08	51.08
	3.00	53.06	68.00	48.92	60.98	55.94	48.92
	4.00	46.04	66.02	60.08	66.92	64.94	46.04
	5.00	62.96	57.92	64.94	64.04	68.00	57.92
	6.00	64.04	66.02	64.94	66.02	57.92	57.92
	7.00	71.06	62.96	66.92	66.92	48.92	48.92
	8.00	69.08	68.00	66.02	59.00	57.92	57.92
	9.00	66.92	68.00	71.96	53.96	71.06	53.96
	10.00	60.08	68.00	69.08	68.00	66.92	60.08
	11.00	55.04	69.08	71.96	66.02	59.00	55.04
	12.00	60.08	69.98	69.08	59.00	55.94	55.94
	13.00	68.00	69.98	64.04	57.02	57.02	57.02
	14.00	62.06	62.96	68.00	59.00	62.06	59.00
	15.00	57.92	55.94	66.02	51.08	69.98	51.08
	16.00	59.00	57.02	64.04	59.00	66.92	57.02
	17.00	62.96	51.08	69.08	60.08	62.06	51.08
	18.00	68.00	59.00	66.02	57.92	64.04	57.92
	19.00	69.08	66.92	73.04	60.98	66.92	60.98
	20.00	69.98	68.00	68.00	64.94	68.00	64.94
	21.00	60.98	68.00	68.00	64.04	68.00	60.98
	22.00	55.94	66.92	66.92	66.92	64.04	55.94
	23.00	62.96	64.04	62.96	68.00	66.92	62.96
	24.00	64.04	69.98	66.02	64.04	64.94	64.04
	25.00	69.08	69.98	60.98	66.92	59.00	59.00
	26.00	69.98	68.00	62.96	69.98	59.00	59.00
	27.00	69.08	64.04	65.12	68.00	60.98	60.98
	28.00	68.00	57.02	68.00	60.08	64.04	57.02
	29.00	66.02	51.98	66.02	53.06	62.96	51.98
	30.00	66.02	60.98	66.92	57.02	64.94	57.02
	31.00	62.06	64.04	68.00	60.08	62.06	60.08
8.00	1.00	62.96	59.00	68.00	59.00	59.00	59.00
	2.00	60.98	64.94	64.94	60.08	53.06	53.06
	3.00	62.96	69.98	71.06	64.94	59.00	59.00
	4.00	57.92	64.04	71.96	71.96	62.96	57.92
	5.00	57.92	64.94	71.96	69.08	62.96	57.92
8.00	6.00	64.04	64.04	71.06	66.02	66.92	64.04
	7.00	66.92	62.96	66.02	53.96	64.04	53.96
	8.00	66.92	66.92	60.98	46.94	59.00	46.94
	9.00	64.94	64.04	62.96	46.94	60.08	46.94
	10.00	57.92	64.94	69.98	51.08	62.96	51.08
	11.00	64.94	55.94	71.06	57.92	66.02	55.94
	12.00	53.06	53.06	73.04	60.08	62.06	53.06

	13.00	51.08	57.02	69.08	64.94	62.06	51.08
	14.00	55.94	57.02	77.00	62.96	62.96	55.94
	15.00	64.04	60.08	75.02	60.98	57.02	57.02
	16.00	68.00	64.04	66.02	66.92	59.00	59.00
	17.00	68.00	69.98	60.08	60.08	62.96	60.08
	18.00	66.92	66.02	59.00	53.06	66.92	53.06
	19.00	66.92	59.00	53.06	60.98	57.02	53.06
	20.00	66.02	60.08	55.04	64.04	53.96	53.96
	21.00	60.08	51.08	55.94	66.92	55.94	51.08
	22.00	59.00	66.02	44.06	60.08	60.98	44.06
	23.00	55.04	55.94	53.96	64.04	62.06	53.96
	24.00	57.92	48.92	60.08	55.94	64.04	48.92
	25.00	53.06	42.98	55.94	48.92	66.92	42.98
	26.00	55.04	48.02	62.96	46.94	62.96	46.94
	27.00	62.06	57.02	55.94	50.00	64.94	50.00
	28.00	46.94	59.00	71.96	64.04	64.94	46.94
	29.00	41.00	55.94	62.06	68.00	62.96	41.00
	30.00	42.08	48.02	55.04	66.02	53.96	42.08
	31.00	44.96	55.94	51.08	59.00	53.06	44.96
9.00	1.00	50.00	51.08	50.00	59.00	55.04	50.00
	2.00	57.02	46.94	51.08	51.08	64.04	46.94
	3.00	57.92	48.92	53.96	46.04	57.02	46.04
	4.00	62.96	42.98	60.08	48.92	53.06	42.98
	5.00	64.04	51.08	48.92	46.94	62.06	46.94
	6.00	55.04	60.08	42.98	53.96	66.92	42.98
	7.00	48.92	64.04	42.98	55.94	64.04	42.98
	8.00	44.96	64.94	44.96	59.00	50.00	44.96
	9.00	42.98	66.02	51.98	64.94	53.06	42.98
	10.00	46.94	59.00	55.94	66.92	60.08	46.94
	11.00	64.94	53.06	51.08	62.06	57.92	51.08
9.00	12.00	62.06	64.04	46.04	57.02	64.04	46.04
	13.00	48.02	64.04	59.00	55.94	64.04	48.02
	14.00	46.94	55.04	48.02	62.06	60.08	46.94
	15.00	42.98	48.92	48.02	57.92	60.08	42.98
	16.00	44.06	53.06	37.94	57.92	50.00	37.94
	17.00	37.04	64.94	52.34	57.92	44.06	37.04
	18.00	39.92	53.96	60.08	55.94	37.04	37.04
	19.00	55.04	53.96	62.96	57.02	41.00	41.00
	20.00	51.08	53.96	69.98	62.06	48.92	48.92
	21.00	53.96	57.92	57.92	64.04	41.00	41.00
	22.00	51.98	48.92	55.94	68.00	51.08	48.92
	23.00	62.06	46.94	58.10	41.00	48.02	41.00
	24.00	64.04	50.00	51.98	39.02	46.04	39.02
	25.00	55.94	42.08	51.08	35.96	42.98	35.96
	26.00	60.98	41.00	48.02	48.02	51.98	41.00
	27.00	57.92	46.04	44.06	37.94	48.92	37.94
	28.00	55.04	53.06	44.06	33.08	48.92	33.08
	29.00	60.98	53.96	37.04	42.08	51.98	37.04
	30.00	64.04	53.06	53.06	44.96	53.06	44.96
10.00	1.00	64.94	42.08	55.04	44.96	46.94	42.08
	2.00	57.02	39.02	59.00	60.08	46.94	39.02
	3.00	53.06	39.92	51.98	44.06	39.92	39.92
	4.00	62.06	37.04	46.94	41.00	51.08	37.04

	5.00	48.02	37.04	44.96	39.92	50.00	37.04
	6.00	39.92	42.08	37.94	50.00	55.94	37.94
	7.00	37.04	44.96	35.06	48.02	53.06	35.06
	8.00	37.94	37.04	32.00	37.94	60.08	32.00
	9.00	42.08	37.04	33.08	32.00	59.00	32.00
	10.00	32.00	44.06	44.06	30.92	66.02	30.92
	11.00	28.94	39.92	39.02	41.00	62.06	28.94
	12.00	46.04	30.02	33.98	37.94	53.96	30.02
	13.00	57.02	30.92	33.08	44.96	64.94	30.92
	14.00	44.96	30.02	33.08	44.96	53.96	30.02
	15.00	37.94	32.00	39.92	53.96	48.02	32.00
	16.00	44.96	41.00	46.94	57.02	41.00	41.00
	17.00	44.06	42.98	51.08	46.94	42.98	42.98
	18.00	37.94	42.08	48.92	42.08	46.04	37.94
10.00	19.00	30.02	35.96	33.98	41.00	42.08	30.02
	20.00	32.00	46.94	30.02	37.94	37.04	30.02
	21.00	33.98	41.00	37.04	33.98	37.94	33.98
	22.00	42.98	35.96	33.98	39.92	46.94	33.98
	23.00	48.92	44.06	35.96	33.08	53.96	33.08
	24.00	39.92	37.94	41.00	35.06	42.98	35.06
	25.00	30.02	37.04	33.98	42.08	37.94	30.02
	26.00	46.94	28.94	30.92	39.02	33.98	28.94
	27.00	48.02	33.98	26.96	42.08	28.94	26.96
	28.00	48.02	35.06	37.04	46.04	39.02	35.06
	29.00	39.92	33.08	33.98	44.06	30.92	30.92
	30.00	35.96	28.94	28.04	50.00	26.96	26.96
	31.00	28.04	37.04	21.92	53.96	41.00	21.92
11.00	1.00	37.04	32.00	35.06	44.06	42.98	32.00
	2.00	33.08	41.00	39.02	35.06	44.96	33.08
	3.00	24.98	46.04	35.06	30.92	51.08	24.98
	4.00	33.98	42.98	33.98	26.96	46.94	26.96
	5.00	30.92	33.08	53.06	35.06	48.02	30.92
	6.00	35.96	30.92	42.98	48.02	39.02	30.92
	7.00	30.92	30.02	35.96	37.94	35.96	30.02
	8.00	46.94	33.08	39.02	48.92	26.96	26.96
	9.00	44.96	39.02	35.96	44.06	24.98	24.98
	10.00	30.02	24.98	37.94	37.94	37.94	24.98
	11.00	30.02	24.98	37.94	35.06	33.08	24.98
	12.00	32.00	26.06	32.00	35.06	30.92	26.06
	13.00	19.04	33.08	39.02	28.94	26.06	19.04
	14.00	15.98	30.92	35.96	39.92	30.02	15.98
	15.00	23.00	30.02	35.96	57.92	33.98	23.00
	16.00	35.06	35.06	41.00	33.98	42.98	33.98
	17.00	41.00	48.02	37.04	28.94	32.00	28.94
	18.00	32.00	42.08	33.08	24.98	26.06	24.98
	19.00	17.06	39.92	30.92	21.92	21.92	17.06
	20.00	15.98	24.98	37.94	32.00	28.94	15.98
	21.00	30.92	14.00	33.98	19.94	37.04	14.00
	22.00	28.94	15.08	30.92	17.96	35.96	15.08
	23.00	28.04	19.94	24.98	19.94	39.02	19.94
	24.00	39.92	35.06	28.94	19.04	30.92	19.04
11.00	25.00	32.00	39.92	30.02	19.94	33.08	19.94
	26.00	33.98	32.00	28.94	37.04	33.98	28.94

	27.00	30.02	30.92	51.08	32.00	39.02	30.02
	28.00	23.00	33.98	33.98	35.96	51.08	23.00
	29.00	28.04	39.02	32.00	17.06	35.06	17.06
	30.00	21.02	35.96	30.02	19.94	28.04	19.94
12.00	1.00	15.08	35.96	32.00	14.00	28.94	14.00
	2.00	30.02	28.94	26.96	12.92	33.98	12.92
	3.00	37.94	28.04	30.92	14.00	30.92	14.00
	4.00	30.92	30.92	24.08	10.04	30.02	10.04
	5.00	28.94	26.06	28.94	15.98	24.98	15.98
	6.00	21.92	28.94	26.96	26.06	26.06	21.92
	7.00	30.92	26.96	35.06	15.98	32.00	15.98
	8.00	33.08	26.06	28.94	14.00	26.96	14.00
	9.00	32.00	30.92	23.00	8.06	33.08	8.06
	10.00	28.04	33.98	17.96	14.00	30.02	14.00
	11.00	24.98	33.08	5.00	28.94	24.08	5.00
	12.00	28.04	35.06	-5.08	26.06	26.96	-5.08
	13.00	12.02	30.92	5.00	12.92	35.06	5.00
	14.00	8.06	30.92	12.02	8.06	21.92	8.06
	15.00	24.98	33.08	19.04	15.08	23.00	15.08
	16.00	30.92	30.02	12.92	14.00	33.98	12.92
	17.00	33.08	26.06	12.92	8.06	33.08	8.06
	18.00	35.06	21.92	12.92	1.94	37.04	1.94
	19.00	33.08	24.08	19.94	3.02	35.06	3.02
	20.00	32.00	33.08	35.96	10.94	24.98	10.94
	21.00	26.06	32.00	35.06	6.08	39.02	6.08
	22.00	19.04	28.04	26.06	-0.94	51.98	-0.94
	23.00	26.06	30.92	26.96	1.04	42.08	1.04
	24.00	24.08	26.96	30.92	-7.06	21.02	-7.06
	25.00	37.94	42.08	32.00	8.96	14.00	8.96
	26.00	33.98	26.96	24.98	6.08	17.96	6.08
	27.00	30.92	21.92	26.06	-0.04	14.00	-0.04
	28.00	30.92	24.08	28.94	14.00	19.04	14.00
	29.00	28.94	10.94	24.08	15.98	33.08	10.94
	30.00	26.96	5.00	15.98	23.00	35.96	5.00
	31.00	24.08	3.02	21.92	28.94	19.94	3.02

	Min of Dry-Bulb Temperature (F)	YEAR					
MONTH	DAY HOUR	1991.00	1992.00	1993.00	1994.00	1995.00	Grand Total
1.00	1.00	19.04	12.92	21.92	19.94	33.98	12.92
	2.00	24.98	21.92	23.00	24.98	19.94	19.94
	3.00	24.08	33.98	21.92	21.02	17.06	17.06
	4.00	19.94	39.02	35.06	19.04	12.92	12.92
	5.00	17.96	35.06	35.96	14.00	8.96	8.96
	6.00	32.00	33.08	32.00	10.94	12.02	10.94
	7.00	17.06	33.08	28.94	17.96	30.02	17.06
	8.00	8.96	24.08	32.00	6.98	24.08	6.98
	9.00	23.00	26.96	24.98	6.08	21.02	6.08
	10.00	21.92	30.02	21.02	8.06	15.08	8.06
	11.00	17.06	26.06	24.08	8.06	24.98	8.06
	12.00	24.08	28.04	30.92	21.92	35.06	21.92
	13.00	15.08	39.02	35.06	30.02	39.02	15.08
	14.00	10.04	26.06	30.92	14.00	50.00	10.04
	15.00	21.92	15.08	30.02	-0.04	60.98	-0.04
	16.00	37.94	8.06	28.94	-4.00	42.98	-4.00

	17.00	33.08	6.98	28.94	8.06	37.94	6.98
	18.00	28.94	6.98	19.04	-4.00	37.04	-4.00
	19.00	30.02	3.02	10.94	-13.00	39.92	-13.00
	20.00	33.98	8.96	17.96	-9.04	37.94	-9.04
	21.00	6.98	17.96	19.94	-20.02	30.92	-20.02
	22.00	3.02	19.04	37.04	12.02	24.98	3.02
	23.00	6.08	32.00	32.00	6.98	21.02	6.08
	24.00	17.96	19.04	30.92	30.02	26.96	17.96
	25.00	8.96	15.98	24.98	30.02	30.02	8.96
	26.00	6.98	14.00	17.96	8.96	26.96	6.98
	27.00	19.94	12.02	24.98	3.92	23.00	3.92
	28.00	26.06	21.02	23.00	24.98	12.92	12.92
	29.00	21.02	21.02	17.96	30.02	6.98	6.98
	30.00	35.06	21.02	17.96	12.92	12.92	12.92
	31.00	19.94	28.94	24.98	1.94	19.94	1.94
2.00	1.00	17.06	15.98	6.08	8.96	32.00	6.08
	2.00	24.98	15.98	1.04	-0.94	15.08	-0.94
2.00	3.00	35.96	23.00	15.98	3.02	8.96	3.02
	4.00	37.94	17.96	24.08	10.94	23.00	10.94
	5.00	33.08	19.04	24.98	21.92	1.94	1.94
	6.00	41.00	12.92	5.00	19.94	1.04	1.04
	7.00	37.94	24.08	1.04	14.00	8.06	1.04
	8.00	33.98	23.00	17.06	10.94	1.94	1.94
	9.00	30.02	12.92	10.04	5.00	8.06	5.00
	10.00	28.94	5.00	28.04	1.94	21.92	1.94
	11.00	17.06	17.06	30.92	10.04	21.92	10.04
	12.00	12.02	5.00	24.08	17.96	3.92	3.92
	13.00	23.00	6.08	26.96	24.98	6.08	6.08
	14.00	30.92	24.98	19.94	10.04	14.00	10.04
	15.00	12.92	26.96	17.06	3.92	12.92	3.92
	16.00	8.06	33.98	28.94	17.96	32.00	8.06
	17.00	17.96	30.02	21.02	14.00	21.92	14.00
	18.00	23.00	35.96	10.04	21.02	21.92	10.04
	19.00	33.98	39.92	1.04	24.98	26.96	1.04
	20.00	32.00	30.02	-0.04	39.92	30.02	-0.04
	21.00	28.04	28.04	8.96	39.02	28.94	8.96
	22.00	33.08	26.96	28.04	28.04	21.02	21.02
	23.00	15.98	33.98	19.04	24.98	33.08	15.98
	24.00	17.96	33.08	12.92	24.98	24.08	12.92
	25.00	30.02	32.00	10.04	21.02	19.04	10.04
	26.00	28.04	30.02	10.94	12.02	17.06	10.94
	27.00	19.94	30.92	6.98	6.08	24.08	6.08
	28.00	26.06	28.94	6.98	8.06	33.08	6.98
	29.00		12.92				12.92
3.00	1.00	30.02	15.08	12.92	10.04	28.94	10.04
	2.00	51.08	33.98	24.08	17.06	23.00	17.06
	3.00	46.94	28.94	30.02	24.08	17.06	17.06
	4.00	33.98	28.04	32.00	21.02	26.96	21.02
	5.00	32.00	35.96	28.04	28.04	28.94	28.04
	6.00	30.92	39.02	26.96	19.04	39.02	19.04
	7.00	26.06	37.94	24.98	30.02	42.08	24.98
	8.00	21.02	44.96	33.98	30.02	21.92	21.02
	9.00	19.94	44.06	32.00	26.06	15.98	15.98

	10.00	24.08	48.92	24.08	30.92	12.02	12.02
3.00	11.00	19.04	15.98	23.00	26.06	19.94	15.98
	12.00	19.04	15.98	19.04	15.98	33.08	15.98
	13.00	21.02	15.98	19.04	32.00	35.06	15.98
	14.00	30.92	15.98	12.02	35.06	35.06	12.02
	15.00	32.00	15.08	6.98	35.06	37.94	6.98
	16.00	28.04	10.04	21.02	17.96	44.06	10.04
	17.00	26.96	21.92	17.06	15.98	37.04	15.98
	18.00	33.98	23.00	3.92	19.04	33.08	3.92
	19.00	35.96	28.04	-2.02	24.08	30.02	-2.02
	20.00	37.04	19.94	21.92	30.92	37.04	19.94
	21.00	32.00	19.94	30.02	24.98	41.00	19.94
	22.00	35.96	17.06	28.94	35.96	37.94	17.06
	23.00	35.96	21.92	23.00	39.92	37.04	21.92
	24.00	37.94	17.06	33.98	37.94	28.94	17.06
	25.00	39.02	24.08	33.98	30.92	26.96	24.08
	26.00	33.08	37.94	28.04	30.92	28.04	28.04
	27.00	42.98	33.08	30.92	35.96	30.02	30.02
	28.00	48.92	28.94	46.04	37.04	33.08	28.94
	29.00	37.04	28.04	46.04	33.08	28.94	28.04
	30.00	28.04	33.98	42.98	32.00	42.08	28.04
	31.00	21.92	33.98	35.06	28.04	35.06	21.92
4.00	1.00	32.00	30.92	41.00	32.00	30.92	30.92
	2.00	33.98	28.04	39.02	39.02	28.04	28.04
	3.00	30.02	26.06	35.06	37.04	24.98	24.98
	4.00	28.94	28.94	33.98	30.92	21.92	21.92
	5.00	48.02	28.94	30.92	33.08	17.06	17.06
	6.00	46.94	30.92	35.96	48.02	24.08	24.08
	7.00	53.06	35.96	35.06	33.98	32.00	32.00
	8.00	55.94	39.02	35.96	28.94	28.94	28.94
	9.00	60.08	33.98	48.02	37.04	35.96	33.98
	10.00	42.08	39.92	42.08	44.96	26.96	26.96
	11.00	35.96	46.94	37.04	37.04	30.92	30.92
	12.00	32.00	32.00	35.06	39.92	46.94	32.00
	13.00	37.04	26.06	35.96	44.06	39.92	26.06
	14.00	37.04	30.92	30.92	44.06	37.94	30.92
	15.00	41.00	32.00	51.08	48.92	33.98	32.00
	16.00	44.06	41.00	55.04	48.02	32.00	32.00
4.00	17.00	48.02	42.08	39.92	42.08	30.92	30.92
	18.00	41.00	41.00	37.94	41.00	39.02	37.94
	19.00	37.94	42.08	41.00	53.06	51.98	37.94
	20.00	39.92	44.96	57.92	39.92	46.94	39.92
	21.00	35.96	57.02	41.00	33.08	51.08	33.08
	22.00	35.06	57.92	35.06	32.00	44.96	32.00
	23.00	42.98	50.00	35.06	32.00	39.92	32.00
	24.00	44.06	51.08	39.92	44.06	42.98	39.92
	25.00	44.06	42.98	53.96	60.08	35.06	35.06
	26.00	42.98	41.00	37.94	48.92	42.98	37.94
	27.00	51.98	42.08	33.98	57.92	51.98	33.98
	28.00	53.06	41.00	35.96	46.04	44.96	35.96
	29.00	51.98	37.04	48.02	53.06	46.04	37.04
	30.00	53.96	48.02	51.98	50.00	41.00	41.00
5.00	1.00	50.00	48.92	51.08	44.96	44.06	44.06

	2.00	46.04	59.00	46.94	41.00	46.04	41.00
	3.00	42.08	48.92	53.06	35.06	44.06	35.06
	4.00	41.00	44.96	55.04	48.02	42.08	41.00
	5.00	39.02	42.08	60.98	42.98	50.00	39.02
	6.00	53.06	39.92	57.92	48.92	44.96	39.92
	7.00	48.02	37.94	48.92	46.94	44.06	37.94
	8.00	44.96	48.02	46.94	48.92	39.02	39.02
	9.00	46.04	55.04	53.96	44.96	39.02	39.02
	10.00	53.06	48.02	53.96	44.06	51.08	44.06
	11.00	44.96	51.98	60.08	37.94	51.08	37.94
	12.00	57.92	50.00	60.98	46.94	53.96	46.94
	13.00	60.98	55.04	48.92	41.00	51.98	41.00
	14.00	64.94	53.06	39.02	35.06	51.98	35.06
	15.00	60.98	55.04	53.96	44.96	53.06	44.96
	16.00	53.96	53.96	53.06	46.04	46.04	46.04
	17.00	60.08	55.04	44.06	44.06	57.92	44.06
	18.00	46.04	57.02	48.02	44.96	50.00	44.96
	19.00	46.04	42.98	50.00	46.04	50.00	42.98
	20.00	44.06	42.08	44.06	46.04	44.06	42.08
	21.00	46.94	44.96	37.94	42.98	51.98	37.94
	22.00	57.92	48.02	44.96	51.98	48.02	44.96
	23.00	59.00	53.96	39.02	55.94	44.96	39.02
5.00	24.00	62.06	44.06	57.02	53.06	64.04	44.06
	25.00	68.00	42.08	60.98	59.00	55.94	42.08
	26.00	68.00	44.96	53.06	51.08	55.04	44.96
	27.00	66.92	46.94	53.06	39.02	50.00	39.02
	28.00	62.06	39.02	53.96	37.04	55.94	37.04
	29.00	57.92	41.00	50.00	46.04	57.92	41.00
	30.00	66.92	48.92	44.06	57.02	55.04	44.06
	31.00	69.98	57.02	51.98	60.98	48.92	48.92
6.00	1.00	62.06	57.02	48.92	53.96	53.96	48.92
	2.00	53.96	53.96	42.98	44.06	66.92	42.98
	3.00	53.06	50.00	51.98	46.94	62.96	46.94
	4.00	55.04	53.96	53.06	44.96	57.92	44.96
	5.00	46.94	62.06	51.08	51.08	51.08	46.94
	6.00	48.02	62.06	53.96	59.00	57.02	48.02
	7.00	46.94	62.06	50.00	64.94	64.04	46.94
	8.00	50.00	69.08	57.92	53.96	57.02	50.00
	9.00	57.02	57.92	66.02	42.08	55.04	42.08
	10.00	55.94	48.92	69.98	50.00	62.96	48.92
	11.00	64.94	50.00	64.94	57.02	62.06	50.00
	12.00	57.02	50.00	53.06	57.92	55.94	50.00
	13.00	50.00	55.94	55.04	62.96	46.94	46.94
	14.00	46.04	59.00	57.92	62.96	51.08	46.04
	15.00	55.04	57.02	60.98	69.08	48.02	48.02
	16.00	71.96	51.08	57.02	69.98	50.00	50.00
	17.00	69.98	57.02	53.96	71.06	57.02	53.96
	18.00	64.94	60.08	62.06	68.00	60.08	60.08
	19.00	62.96	64.04	71.06	68.00	68.00	62.96
	20.00	62.06	55.94	68.00	59.00	71.06	55.94
	21.00	59.00	51.98	66.02	66.02	66.92	51.98
	22.00	62.06	48.02	62.96	62.96	60.08	48.02
	23.00	57.92	42.08	55.04	57.02	60.08	42.08

	24.00	53.06	57.92	48.02	64.94	62.06	48.02
	25.00	55.94	57.02	53.06	66.02	64.94	53.06
	26.00	57.02	53.06	64.04	57.92	66.02	53.06
	27.00	60.98	59.00	60.08	66.02	64.04	59.00
	28.00	64.04	53.96	62.96	64.94	55.94	53.96
	29.00	73.04	55.04	64.94	64.04	57.02	55.04
6.00	30.00	66.92	68.00	60.08	62.96	64.94	60.08
7.00	1.00	55.94	66.02	60.08	60.98	69.08	55.94
	2.00	62.06	55.94	62.06	59.00	60.98	55.94
	3.00	64.94	60.08	62.06	64.94	50.00	50.00
	4.00	64.04	60.98	66.92	59.00	55.04	55.04
	5.00	62.96	55.94	64.94	66.02	69.98	55.94
	6.00	64.94	60.98	73.04	66.92	66.92	60.98
	7.00	66.92	53.96	73.94	62.06	66.92	53.96
	8.00	69.98	55.94	73.94	71.06	60.08	55.94
	9.00	62.96	66.92	71.96	69.98	57.02	57.02
	10.00	53.96	64.94	71.96	64.04	59.00	53.96
	11.00	55.04	69.08	69.98	57.92	57.92	55.04
	12.00	53.96	62.96	71.06	55.04	60.08	53.96
	13.00	66.92	66.02	66.02	64.04	62.06	62.06
	14.00	64.04	64.94	66.02	62.96	73.04	62.96
	15.00	53.96	68.00	66.02	66.02	80.06	53.96
	16.00	57.92	66.92	57.02	64.94	73.04	57.02
	17.00	64.94	68.00	60.08	59.00	69.98	59.00
	18.00	66.02	68.00	53.06	68.00	69.98	53.06
	19.00	69.08	66.02	68.00	68.00	62.06	62.06
	20.00	66.92	62.06	68.00	66.92	62.06	62.06
	21.00	73.04	62.96	60.08	71.96	68.00	60.08
	22.00	69.08	55.94	55.04	68.00	64.94	55.04
	23.00	71.06	64.04	57.02	66.02	71.06	57.02
	24.00	62.06	60.98	55.94	66.02	66.02	55.94
	25.00	66.02	60.08	60.08	64.04	68.00	60.08
	26.00	64.04	64.94	69.08	64.94	73.04	64.04
	27.00	62.06	68.00	68.00	60.98	71.06	60.98
	28.00	55.04	57.92	68.00	60.08	68.00	55.04
	29.00	62.06	53.96	68.00	60.08	73.04	53.96
	30.00	57.02	64.94	64.04	66.92	66.92	57.02
	31.00	66.92	66.92	64.94	60.98	59.00	59.00
8.00	1.00	60.08	59.00	60.98	64.04	64.04	59.00
	2.00	66.02	55.94	66.92	64.04	69.98	55.94
	3.00	68.00	62.96	64.04	64.94	71.96	62.96
	4.00	68.00	57.92	62.96	66.02	71.96	57.92
	5.00	62.96	53.96	55.94	51.08	71.06	51.08
8.00	6.00	53.06	51.08	53.96	44.96	66.02	44.96
	7.00	55.04	55.94	59.00	48.92	62.06	48.92
	8.00	59.00	59.00	53.06	53.96	51.98	51.98
	9.00	68.00	66.02	60.08	59.00	53.96	53.96
	10.00	62.96	62.96	62.96	59.00	59.00	59.00
	11.00	60.08	66.02	64.94	57.02	68.00	57.02
	12.00	57.92	57.92	62.96	60.98	66.92	57.92
	13.00	60.08	57.92	62.96	71.06	64.04	57.92
	14.00	62.06	60.98	62.06	60.08	64.94	60.08
	15.00	64.04	60.98	62.06	53.96	75.02	53.96

	16.00	60.98	60.98	69.08	50.00	73.04	50.00
	17.00	64.94	62.96	68.00	64.04	66.92	62.96
	18.00	69.08	64.94	68.00	64.94	64.04	64.04
	19.00	66.92	57.92	64.94	62.06	64.04	57.92
	20.00	62.96	51.98	66.92	64.04	55.94	51.98
	21.00	64.04	46.94	55.94	66.92	62.06	46.94
	22.00	60.08	51.08	50.00	57.92	60.98	50.00
	23.00	66.92	53.06	55.04	48.02	51.08	48.02
	24.00	64.04	60.08	68.00	48.02	62.06	48.02
	25.00	64.94	64.94	69.98	55.04	53.96	53.96
	26.00	57.02	66.92	64.04	60.08	51.98	51.98
	27.00	59.00	66.92	64.04	62.06	64.04	59.00
	28.00	66.02	64.94	69.98	57.92	66.02	57.92
	29.00	64.94	57.02	59.00	55.04	62.96	55.04
	30.00	66.92	51.98	64.94	53.06	57.92	51.98
	31.00	59.00	59.00	69.08	57.92	57.02	57.02
9.00	1.00	50.00	51.08	66.02	53.96	64.04	50.00
	2.00	46.04	48.92	66.02	48.02	57.92	46.04
	3.00	51.98	66.02	73.04	44.06	51.08	44.06
	4.00	62.06	62.96	62.96	48.92	55.04	48.92
	5.00	59.00	60.98	60.98	44.06	60.08	44.06
	6.00	53.06	62.06	57.02	44.96	57.02	44.96
	7.00	53.96	62.06	59.00	53.96	64.94	53.96
	8.00	55.94	64.04	57.02	50.00	59.00	50.00
	9.00	57.92	66.02	60.98	55.04	57.92	55.04
	10.00	64.04	62.06	55.04	48.02	50.00	48.02
	11.00	57.02	53.96	48.02	42.98	37.04	37.04
9.00	12.00	48.92	46.04	42.98	44.06	46.94	42.98
	13.00	48.02	42.98	62.96	55.94	60.98	42.98
	14.00	62.06	48.02	60.98	62.96	57.02	48.02
	15.00	64.94	51.98	60.08	59.00	48.92	48.92
	16.00	69.08	57.92	53.96	66.02	50.00	50.00
	17.00	68.00	60.98	53.96	62.96	57.02	53.96
	18.00	59.00	62.06	55.94	51.08	48.02	48.02
	19.00	51.08	50.00	42.98	46.04	39.92	39.92
	20.00	44.06	44.06	33.08	44.06	57.92	33.08
	21.00	39.92	57.92	48.02	48.02	64.04	39.92
	22.00	37.04	60.08	51.08	53.06	51.98	37.04
	23.00	53.06	42.98	48.92	53.96	42.98	42.98
	24.00	48.92	35.06	46.94	57.92	35.96	35.06
	25.00	53.06	37.94	42.98	59.00	53.06	37.94
	26.00	48.92	53.06	53.96	62.96	51.98	48.92
	27.00	39.02	59.00	53.96	57.92	46.04	39.02
	28.00	35.96	51.08	50.00	50.00	46.94	35.96
	29.00	35.06	44.06	44.06	48.02	46.04	35.06
	30.00	33.08	39.02	35.96	46.94	42.98	33.08
10.00	1.00	53.06	33.08	30.92	48.02	44.06	30.92
	2.00	59.00	37.94	46.94	42.98	51.08	37.94
	3.00	60.08	53.06	46.94	33.98	48.02	33.98
	4.00	55.04	44.96	46.04	44.96	62.96	44.96
	5.00	64.04	37.04	39.02	37.04	62.06	37.04
	6.00	44.06	30.92	35.06	33.98	62.06	30.92
	7.00	39.02	35.06	48.92	41.00	60.08	35.06

	8.00	37.94	39.02	50.00	44.06	46.04	37.94
	9.00	44.06	57.92	44.96	51.08	39.92	39.92
	10.00	48.02	51.08	33.08	37.04	44.96	33.08
	11.00	42.98	51.08	28.94	32.00	51.08	28.94
	12.00	37.04	48.02	44.06	33.08	46.04	33.08
	13.00	35.96	46.94	32.00	37.04	50.00	32.00
	14.00	30.02	35.06	32.00	42.98	55.94	30.02
	15.00	46.94	48.02	44.96	42.08	46.94	42.08
	16.00	39.02	51.98	39.92	33.98	42.98	33.98
	17.00	37.94	33.98	55.94	33.98	35.96	33.98
	18.00	44.06	32.00	46.94	42.08	41.00	32.00
10.00	19.00	39.02	33.08	37.04	46.04	44.96	33.08
	20.00	33.08	30.92	48.02	53.06	51.08	30.92
	21.00	30.02	39.92	50.00	44.06	41.00	30.02
	22.00	35.96	37.94	44.06	50.00	35.06	35.06
	23.00	42.98	32.00	37.94	48.92	39.02	32.00
	24.00	51.08	41.00	33.98	37.94	48.02	33.98
	25.00	53.06	37.04	44.06	42.08	44.06	37.04
	26.00	53.96	32.00	48.92	35.06	42.98	32.00
	27.00	60.98	37.94	44.96	35.96	44.96	35.96
	28.00	41.00	30.92	39.92	33.08	48.92	30.92
	29.00	30.92	41.00	35.96	39.92	42.08	30.92
	30.00	26.96	42.08	39.92	41.00	37.94	26.96
	31.00	37.04	39.02	33.08	50.00	42.08	33.08
11.00	1.00	46.94	33.98	33.08	44.96	46.04	33.08
	2.00	41.00	33.98	33.08	42.98	55.94	33.08
	3.00	33.08	42.98	35.06	37.04	42.98	33.08
	4.00	24.98	39.92	35.96	55.94	30.92	24.98
	5.00	19.04	35.96	48.02	55.94	28.94	19.04
	6.00	24.08	37.04	37.04	53.96	24.08	24.08
	7.00	32.00	28.94	30.02	39.02	32.00	28.94
	8.00	28.04	21.02	24.08	39.02	30.02	21.02
	9.00	19.94	19.04	28.04	46.94	26.06	19.04
	10.00	30.92	33.98	26.96	37.04	26.96	26.96
	11.00	33.08	44.96	28.94	35.06	37.04	28.94
	12.00	33.98	46.94	35.06	28.94	24.08	24.08
	13.00	35.96	37.94	33.98	44.96	23.00	23.00
	14.00	37.04	30.92	48.02	48.92	32.00	30.92
	15.00	35.06	26.06	53.06	46.04	30.02	26.06
	16.00	35.96	24.08	35.96	42.98	26.96	24.08
	17.00	26.06	33.98	33.98	37.04	21.92	21.92
	18.00	24.08	32.00	35.06	48.92	26.96	24.08
	19.00	37.94	26.06	32.00	41.00	33.98	26.06
	20.00	44.06	24.98	30.02	35.96	33.08	24.98
	21.00	51.08	41.00	26.96	44.96	32.00	26.96
	22.00	51.08	53.96	33.98	33.98	28.04	28.04
	23.00	46.94	50.00	32.00	21.92	26.06	21.92
	24.00	33.98	44.06	37.94	19.94	21.92	19.94
11.00	25.00	28.04	44.96	24.98	35.06	15.98	15.98
	26.00	26.96	50.00	19.04	26.06	23.00	19.04
	27.00	23.00	41.00	35.96	21.02	30.92	21.02
	28.00	33.08	33.08	37.04	39.92	28.94	28.94
	29.00	44.96	32.00	30.92	39.92	21.02	21.02

	30.00	48.02	33.98	26.96	33.98	10.04	10.04
12.00	1.00	44.96	35.96	21.92	32.00	28.94	21.92
	2.00	35.06	30.92	28.94	30.02	28.04	28.04
	3.00	35.06	32.00	37.04	30.92	26.96	26.96
	4.00	19.94	24.98	37.04	41.00	30.02	19.94
	5.00	17.06	24.98	37.04	50.00	23.00	17.06
	6.00	24.08	19.94	33.98	48.02	30.02	19.94
	7.00	26.06	28.04	37.94	30.02	26.06	26.06
	8.00	41.00	21.02	30.92	23.00	19.04	19.04
	9.00	37.94	15.98	26.06	21.02	24.98	15.98
	10.00	33.98	19.04	37.04	35.06	6.08	6.08
	11.00	28.04	33.98	19.04	24.08	8.06	8.06
	12.00	32.00	33.08	15.98	17.06	8.96	8.96
	13.00	46.04	30.02	23.00	19.04	8.96	8.96
	14.00	33.08	21.92	26.06	32.00	19.04	19.04
	15.00	28.04	19.94	35.96	28.04	33.08	19.94
	16.00	17.06	30.92	28.94	26.06	32.00	17.06
	17.00	12.02	37.04	21.02	35.96	26.96	12.02
	18.00	12.92	28.04	26.06	33.98	24.98	12.92
	19.00	10.94	28.04	33.08	33.98	19.04	10.94
	20.00	15.98	28.94	35.06	30.02	12.92	12.92
	21.00	28.94	21.92	33.08	26.96	12.92	12.92
	22.00	28.94	30.02	24.08	28.04	24.08	24.08
	23.00	33.08	30.92	15.08	28.04	24.08	15.08
	24.00	24.08	10.94	8.96	37.94	21.92	8.96
	25.00	21.02	12.02	19.04	35.96	21.02	12.02
	26.00	15.08	15.98	5.00	28.94	15.98	5.00
	27.00	26.06	8.96	-0.94	24.08	10.94	-0.94
	28.00	17.96	19.94	8.06	28.04	21.02	8.06
	29.00	33.08	35.96	1.94	17.06	19.04	1.94
	30.00	21.92	39.92	15.08	14.00	12.92	12.92
	31.00	14.00	42.98	10.94	17.96	21.02	10.94

	Min of Dry-Bulb Temperature (F)	YEAR					
MONTH	DAY HOUR	1996.00	1997.00	1998.00	1999.00	2000.00	Grand Total
1.00	1.00	30.00	10.00	6.00	11.00	21.00	6.00
	2.00	25.00	20.00	19.00	0.00	31.00	0.00
	3.00	19.00	34.00	40.00	18.00	51.00	18.00
	4.00	5.00	40.00	44.00	16.00	47.00	5.00
	5.00	4.00	45.00	41.00	9.00	26.00	4.00
	6.00	-2.00	34.00	45.00	5.00	18.00	-2.00
	7.00	4.00	24.00	50.00	19.00	32.00	4.00
	8.00	11.00	21.00	51.00	10.00	19.00	10.00
	9.00	4.00	19.00	54.00	24.00	31.00	4.00
	10.00	15.00	29.00		10.00	37.00	10.00
	11.00	5.00	16.00		13.00	38.00	5.00
	12.00	14.00	10.00		13.00	35.00	10.00
	13.00	19.00	13.00	32.00	21.00	17.00	13.00
	14.00	24.00	17.00	16.00	11.00	7.00	7.00
	15.00	16.00	11.00	20.00	23.00	11.00	11.00
	16.00	1.00	28.00	31.00	14.00	23.00	1.00
	17.00	30.00	5.00	28.00	31.00	2.00	2.00
	18.00	35.00	2.00	29.00	34.00	-1.00	-1.00
	19.00	29.00	-2.00	29.00	39.00	5.00	-2.00

	20.00	17.00	9.00	27.00	38.00	21.00	9.00
	21.00	17.00	21.00	23.00	28.00	4.00	4.00
	22.00	16.00	26.00	21.00	36.00	1.00	1.00
	23.00	28.00	26.00	25.00	41.00	7.00	7.00
	24.00	33.00	15.00	32.00	40.00	23.00	15.00
	25.00	21.00	31.00	27.00	31.00	17.00	17.00
	26.00	19.00	21.00	19.00	28.00	19.00	19.00
	27.00	35.00	15.00	24.00	21.00	5.00	5.00
	28.00	24.00	26.00	28.00	34.00	4.00	4.00
	29.00	20.00	14.00	19.00	22.00	8.00	8.00
	30.00	22.00	10.00	34.00	20.00	5.00	5.00
	31.00	15.00	24.00	30.00	9.00	24.00	9.00
2.00	1.00	1.00	32.00	18.00	14.00	22.00	1.00
	2.00	16.00	27.00	29.00	36.00	15.00	15.00
2.00	3.00	7.00	34.00	32.00	38.00	9.00	7.00
	4.00	1.00	25.00	32.00	32.00	20.00	1.00
	5.00	-3.00	34.00	33.00	26.00	17.00	-3.00
	6.00	4.00	30.00	18.00	26.00	21.00	4.00
	7.00	11.00	25.00	21.00	31.00	25.00	11.00
	8.00	27.00	27.00	22.00	30.00	8.00	8.00
	9.00	37.00	13.00	23.00	19.00	17.00	13.00
	10.00	33.00	11.00	26.00	33.00	25.00	11.00
	11.00	35.00	21.00	34.00	28.00	29.00	21.00
	12.00	13.00	27.00	41.00	44.00	13.00	13.00
	13.00	3.00	12.00	31.00	23.00	10.00	3.00
	14.00	18.00	22.00	19.00	15.00	29.00	15.00
	15.00	20.00	31.00	9.00	11.00	25.00	9.00
	16.00	12.00	18.00	19.00	27.00	24.00	12.00
	17.00	11.00	16.00	32.00	39.00	20.00	11.00
	18.00	18.00	28.00	36.00	35.00	21.00	18.00
	19.00	11.00	43.00	38.00	29.00	27.00	11.00
	20.00	34.00	32.00	39.00	25.00	25.00	25.00
	21.00	47.00	39.00	36.00	20.00	23.00	20.00
	22.00	42.00	38.00	36.00	8.00	21.00	8.00
	23.00	39.00	24.00	31.00	3.00	37.00	3.00
	24.00	45.00	28.00	32.00	18.00	38.00	18.00
	25.00	40.00	12.00	31.00	19.00	39.00	12.00
	26.00	37.00	21.00	33.00	25.00	37.00	21.00
	27.00	27.00	43.00	26.00	23.00	41.00	23.00
	28.00	38.00	34.00	40.00	35.00	37.00	34.00
	29.00	20.00				30.00	20.00
3.00	1.00	16.00	35.00	41.00	34.00	30.00	16.00
	2.00	26.00	43.00	31.00	29.00	31.00	26.00
	3.00	20.00	31.00	34.00	32.00	29.00	20.00
	4.00	12.00	30.00	31.00	27.00	28.00	12.00
	5.00	26.00	33.00	31.00	22.00	37.00	22.00
	6.00	32.00	32.00	27.00	32.00	36.00	27.00
	7.00	17.00	24.00	37.00	13.00	28.00	13.00
	8.00	11.00	27.00	37.00	10.00	48.00	10.00
	9.00	4.00	18.00	39.00	12.00	48.00	4.00
	10.00	1.00	28.00	28.00	22.00	36.00	1.00
3.00	11.00	5.00	35.00	16.00	18.00	36.00	5.00
	12.00	15.00	25.00	14.00	20.00	30.00	14.00

	13.00	23.00	19.00	19.00	22.00	26.00	19.00
	14.00	34.00	27.00	29.00	24.00	30.00	24.00
	15.00	41.00	30.00	27.00	32.00	35.00	27.00
	16.00	27.00	18.00	23.00	26.00	50.00	18.00
	17.00	23.00	16.00	22.00	37.00	26.00	16.00
	18.00	34.00	35.00	34.00	41.00	14.00	14.00
	19.00	34.00	26.00	37.00	33.00	24.00	24.00
	20.00	36.00	33.00	38.00	29.00	34.00	29.00
	21.00	33.00	27.00	31.00	32.00	36.00	27.00
	22.00	25.00	31.00	28.00	32.00	38.00	25.00
	23.00	27.00	20.00	27.00	31.00	35.00	20.00
	24.00	28.00	20.00	25.00	35.00	35.00	20.00
	25.00	38.00	28.00	23.00	31.00	49.00	23.00
	26.00	36.00	39.00	38.00	23.00	47.00	23.00
	27.00	19.00	30.00	48.00	26.00	33.00	19.00
	28.00	24.00	41.00	62.00	37.00	37.00	24.00
	29.00	29.00	49.00	62.00	40.00	38.00	29.00
	30.00	38.00	49.00	50.00	41.00	38.00	38.00
	31.00	33.00	27.00	59.00	37.00	27.00	27.00
4.00	1.00	37.00	28.00	59.00	48.00	30.00	28.00
	2.00	31.00	34.00	52.00	52.00	49.00	31.00
	3.00	29.00	30.00	42.00	49.00	54.00	29.00
	4.00	31.00	50.00	38.00	48.00	52.00	31.00
	5.00	30.00	43.00	35.00	29.00	33.00	29.00
	6.00	25.00	48.00	36.00	34.00	29.00	25.00
	7.00	32.00	56.00	32.00	47.00	43.00	32.00
	8.00	29.00	32.00	45.00	48.00	47.00	29.00
	9.00	28.00	21.00	41.00	39.00	25.00	21.00
	10.00	29.00	22.00	33.00	35.00	34.00	22.00
	11.00	35.00	26.00	30.00	31.00	33.00	26.00
	12.00	47.00	36.00	32.00	36.00	33.00	32.00
	13.00	44.00	45.00	34.00	34.00	26.00	26.00
	14.00	39.00	35.00	45.00	36.00	34.00	34.00
	15.00	30.00	27.00	51.00	36.00	45.00	27.00
	16.00	40.00	31.00	48.00	41.00	55.00	31.00
4.00	17.00	35.00	40.00	62.00	42.00	42.00	35.00
	18.00	34.00	34.00	35.00	41.00	36.00	34.00
	19.00	49.00	34.00	45.00	36.00	41.00	34.00
	20.00	58.00	36.00	42.00	35.00	50.00	35.00
	21.00	57.00	28.00	34.00	33.00	47.00	28.00
	22.00	46.00	35.00	43.00	45.00	41.00	35.00
	23.00	61.00	41.00	47.00	47.00	39.00	39.00
	24.00	37.00	41.00	39.00	33.00	40.00	33.00
	25.00	44.00	33.00	45.00	26.00	40.00	26.00
	26.00	55.00	35.00	39.00	41.00	38.00	35.00
	27.00	38.00	36.00	30.00	36.00	40.00	30.00
	28.00	38.00	46.00	34.00	40.00	43.00	34.00
	29.00	45.00	40.00	34.00	38.00	37.00	34.00
	30.00	51.00	41.00	51.00	40.00	47.00	40.00
5.00	1.00	40.00	54.00	54.00	40.00	36.00	36.00
	2.00	46.00	41.00	54.00	43.00	50.00	41.00
	3.00	49.00	50.00	54.00	49.00	36.00	36.00
	4.00	50.00	44.00	56.00	50.00	51.00	44.00

	5.00	50.00	36.00	57.00	55.00	60.00	36.00
	6.00	43.00	48.00	54.00	57.00	56.00	43.00
	7.00	35.00	36.00	50.00	58.00	60.00	35.00
	8.00	44.00	35.00	58.00	59.00	61.00	35.00
	9.00	51.00	46.00	56.00	49.00	63.00	46.00
	10.00	50.00	47.00	54.00	46.00	53.00	46.00
	11.00	52.00	40.00	52.00	41.00	52.00	40.00
	12.00	38.00	54.00	49.00	44.00	53.00	38.00
	13.00	35.00	50.00	41.00	51.00	59.00	35.00
	14.00	29.00	43.00	44.00	46.00	50.00	29.00
	15.00	39.00	51.00	53.00	44.00	38.00	38.00
	16.00	46.00	41.00	56.00	42.00	36.00	36.00
	17.00	51.00	38.00	62.00	47.00	46.00	38.00
	18.00	55.00	37.00	54.00	52.00	58.00	37.00
	19.00	66.00	54.00	57.00	60.00	47.00	47.00
	20.00	74.00	52.00	57.00	50.00	44.00	44.00
	21.00	63.00	44.00	57.00	39.00	48.00	39.00
	22.00	49.00	45.00	49.00	50.00	52.00	45.00
	23.00	47.00	44.00	36.00	56.00	52.00	36.00
5.00	24.00	56.00	46.00	40.00	56.00	58.00	40.00
	25.00	38.00	56.00	54.00	47.00	52.00	38.00
	26.00	43.00	48.00	58.00	55.00	55.00	43.00
	27.00	49.00	38.00	52.00	50.00	45.00	38.00
	28.00	50.00	42.00	52.00	41.00	41.00	41.00
	29.00	50.00	46.00	62.00	51.00	54.00	46.00
	30.00	38.00	54.00	60.00	51.00	44.00	38.00
	31.00	38.00	56.00	63.00		43.00	38.00
6.00	1.00	46.00	59.00	56.00		57.00	46.00
	2.00	54.00	52.00	46.00	77.00	58.00	46.00
	3.00	52.00	46.00	50.00	63.00	54.00	46.00
	4.00	58.00	46.00	44.00	50.00	47.00	44.00
	5.00	54.00	50.00	45.00	49.00	50.00	45.00
	6.00	50.00	52.00	48.00	55.00	50.00	48.00
	7.00	64.00	53.00	43.00	67.00	49.00	43.00
	8.00	67.00	44.00	47.00	64.00	51.00	44.00
	9.00	66.00	47.00	47.00	60.00	61.00	47.00
	10.00	68.00	50.00	62.00	62.00	63.00	50.00
	11.00	67.00	57.00	55.00	52.00	66.00	52.00
	12.00	63.00	60.00	60.00	49.00	68.00	49.00
	13.00	65.00	62.00	63.00	67.00	58.00	58.00
	14.00	63.00	58.00	61.00	63.00	55.00	55.00
	15.00	63.00	44.00	56.00	55.00	58.00	44.00
	16.00	57.00	56.00	63.00	45.00	65.00	45.00
	17.00	66.00	58.00	61.00	54.00	68.00	54.00
	18.00	64.00	58.00		51.00	60.00	51.00
	19.00	64.00	65.00	76.00	46.00	53.00	46.00
	20.00	61.00	57.00	64.00	55.00	50.00	50.00
	21.00	68.00	68.00	63.00	57.00	64.00	57.00
	22.00	60.00	66.00	67.00	53.00	66.00	53.00
	23.00	60.00	56.00	69.00	57.00	60.00	56.00
	24.00	54.00	58.00	67.00	56.00	58.00	54.00
	25.00	68.00	64.00	64.00	62.00	70.00	62.00
	26.00	49.00	68.00	75.00	66.00	69.00	49.00

	27.00	48.00	62.00	71.00	66.00	66.00	48.00
	28.00	62.00	52.00	61.00	74.00	56.00	52.00
	29.00	63.00	58.00	66.00	72.00	57.00	57.00
6.00	30.00	62.00	58.00	62.00	58.00	55.00	55.00
7.00	1.00	66.00	65.00	61.00	67.00	53.00	53.00
	2.00	59.00	65.00	55.00	75.00	57.00	55.00
	3.00	62.00	67.00	56.00	70.00	61.00	56.00
	4.00	57.00	66.00	57.00	73.00	67.00	57.00
	5.00	52.00	52.00	62.00	77.00	65.00	52.00
	6.00	54.00	50.00	52.00	76.00	49.00	49.00
	7.00	60.00	56.00	61.00	68.00	48.00	48.00
	8.00	65.00	54.00	61.00	59.00	47.00	47.00
	9.00	67.00	65.00	61.00	61.00	52.00	52.00
	10.00	59.00	58.00	60.00	68.00	67.00	58.00
	11.00	50.00	49.00	51.00	49.00	57.00	49.00
	12.00	54.00	54.00	52.00	50.00	49.00	49.00
	13.00	64.00	59.00	56.00	58.00	55.00	55.00
	14.00	63.00	61.00	64.00	58.00	62.00	58.00
	15.00	69.00	66.00	65.00	55.00	63.00	55.00
	16.00	62.00	67.00	70.00	64.00	62.00	62.00
	17.00	63.00	63.00	67.00	68.00	59.00	59.00
	18.00	65.00	69.00	68.00	70.00	61.00	61.00
	19.00	69.00	60.00	60.00	65.00	54.00	54.00
	20.00	57.00	48.00	70.00	61.00	52.00	48.00
	21.00	55.00	60.00	63.00	63.00	51.00	51.00
	22.00	57.00	64.00	71.00	68.00	57.00	57.00
	23.00	61.00	61.00	68.00	64.00	50.00	50.00
	24.00	61.00	58.00	62.00	67.00	56.00	56.00
	25.00	64.00	58.00	54.00	63.00	57.00	54.00
	26.00	65.00	56.00	55.00	63.00	58.00	55.00
	27.00	58.00	69.00	58.00	62.00	64.00	58.00
	28.00	52.00	64.00	66.00	63.00	66.00	52.00
	29.00	59.00	64.00	65.00	63.00	65.00	59.00
	30.00	62.00	47.00	59.00	63.00	67.00	47.00
	31.00	65.00	51.00	61.00	65.00	68.00	51.00
8.00	1.00	65.00	57.00	50.00	70.00	68.00	50.00
	2.00	57.00	66.00	52.00	56.00	65.00	52.00
	3.00	61.00	66.00	56.00	54.00	68.00	54.00
	4.00	60.00	60.00	58.00	56.00	63.00	56.00
	5.00	61.00	56.00	66.00	63.00	51.00	51.00
8.00	6.00	63.00	49.00	63.00	54.00	55.00	49.00
	7.00	64.00	50.00	60.00	56.00	68.00	50.00
	8.00	66.00	51.00	62.00	68.00	71.00	51.00
	9.00	67.00	56.00	66.00	57.00	69.00	56.00
	10.00	57.00	62.00	71.00	51.00	61.00	51.00
	11.00	49.00	63.00	67.00	60.00	63.00	49.00
	12.00	58.00	63.00	62.00	61.00	63.00	58.00
	13.00	59.00	68.00	54.00	69.00	59.00	54.00
	14.00	56.00	64.00	62.00	67.00	59.00	56.00
	15.00	65.00	53.00	66.00	62.00	59.00	53.00
	16.00	62.00	68.00	66.00	53.00	69.00	53.00
	17.00	61.00	66.00	68.00	57.00	57.00	57.00
	18.00	57.00	59.00	64.00	63.00	53.00	53.00

	19.00	56.00	47.00	51.00	57.00	55.00	47.00
	20.00	63.00	54.00	46.00	60.00	47.00	46.00
	21.00	67.00	55.00	52.00	56.00	43.00	43.00
	22.00	64.00	54.00	60.00	58.00	50.00	50.00
	23.00	62.00	56.00	69.00	51.00	61.00	51.00
	24.00	66.00	52.00	68.00	59.00	65.00	52.00
	25.00	55.00	58.00	68.00	62.00	53.00	53.00
	26.00	56.00	58.00	66.00	65.00	53.00	53.00
	27.00	60.00	60.00	61.00	65.00	61.00	60.00
	28.00	60.00	63.00	61.00	63.00	64.00	60.00
	29.00	59.00	61.00	61.00	67.00	63.00	59.00
	30.00	53.00	57.00	63.00	49.00	64.00	49.00
	31.00	53.00	55.00	57.00	47.00	64.00	47.00
9.00	1.00	53.00	65.00	52.00	55.00	69.00	52.00
	2.00	54.00	61.00	59.00	56.00	70.00	54.00
	3.00	57.00	55.00	51.00	58.00	68.00	51.00
	4.00	62.00	41.00	56.00	65.00	64.00	41.00
	5.00	65.00	44.00	56.00	67.00	44.00	44.00
	6.00	64.00	53.00	54.00	69.00	42.00	42.00
	7.00	70.00	52.00	61.00	70.00	45.00	45.00
	8.00	71.00	61.00	52.00	64.00	49.00	49.00
	9.00	63.00	59.00	48.00	62.00	58.00	48.00
	10.00	66.00	58.00	52.00	65.00	63.00	52.00
	11.00	61.00	62.00	46.00	50.00	63.00	46.00
9.00	12.00	59.00	60.00	55.00	49.00	66.00	49.00
	13.00	60.00	55.00	61.00	55.00	61.00	55.00
	14.00	48.00	55.00	63.00	62.00	46.00	46.00
	15.00	49.00	53.00	68.00	58.00	55.00	49.00
	16.00	53.00	55.00	68.00	55.00	50.00	50.00
	17.00	56.00	55.00	63.00	54.00	43.00	43.00
	18.00	54.00	60.00	48.00	45.00	51.00	45.00
	19.00	51.00	51.00	58.00	45.00	57.00	45.00
	20.00	44.00	55.00	59.00	52.00	57.00	44.00
	21.00	47.00	46.00	64.00	50.00	63.00	46.00
	22.00	58.00	35.00	61.00	45.00	46.00	35.00
	23.00	51.00	54.00	44.00	39.00	48.00	39.00
	24.00	38.00	39.00	36.00	45.00	55.00	36.00
	25.00	47.00	39.00	50.00	51.00	42.00	39.00
	26.00	41.00	54.00	60.00	47.00	45.00	41.00
	27.00	57.00	36.00	65.00	55.00	38.00	36.00
	28.00	63.00	49.00	60.00	64.00	45.00	45.00
	29.00	49.00	54.00	41.00	65.00	29.00	29.00
	30.00	47.00	55.00	50.00	55.00	37.00	37.00
10.00	1.00	46.00	45.00	52.00	38.00	43.00	38.00
	2.00	54.00	32.00	38.00	43.00	48.00	32.00
	3.00	44.00	47.00	39.00	54.00	51.00	39.00
	4.00	30.00	53.00	43.00	47.00	48.00	30.00
	5.00	32.00	60.00	50.00	43.00	51.00	32.00
	6.00	37.00	55.00	40.00	33.00	54.00	33.00
	7.00	40.00	52.00	53.00	30.00	42.00	30.00
	8.00	46.00	68.00	58.00	30.00	33.00	30.00
	9.00	47.00	56.00	52.00	52.00	26.00	26.00
	10.00	46.00	63.00	54.00	57.00	30.00	30.00

	11.00	38.00	42.00	53.00	57.00	41.00	38.00
	12.00	26.00	37.00	53.00	34.00	37.00	26.00
	13.00	45.00	46.00	51.00	46.00	35.00	35.00
	14.00	49.00	55.00	50.00	41.00	43.00	41.00
	15.00	35.00	46.00	48.00	31.00	50.00	31.00
	16.00	38.00	32.00	34.00	39.00	56.00	32.00
	17.00	49.00	31.00	38.00	47.00	49.00	31.00
	18.00	53.00	39.00	48.00	46.00	51.00	39.00
10.00	19.00	46.00	35.00	54.00	30.00	42.00	30.00
	20.00	41.00	32.00	44.00	45.00	36.00	32.00
	21.00	41.00	33.00	43.00	34.00	44.00	33.00
	22.00	43.00	36.00	36.00	37.00	43.00	36.00
	23.00	47.00	27.00	37.00	41.00	35.00	27.00
	24.00	44.00	38.00	44.00	39.00	42.00	38.00
	25.00	39.00	41.00	41.00	38.00	48.00	38.00
	26.00	41.00	28.00	46.00	36.00	50.00	28.00
	27.00	47.00	40.00	51.00	37.00	46.00	37.00
	28.00	53.00	38.00	46.00	29.00	40.00	29.00
	29.00	37.00	29.00	44.00	36.00	33.00	29.00
	30.00	43.00	31.00	38.00	43.00	33.00	31.00
	31.00	43.00	35.00	36.00	49.00	35.00	35.00
11.00	1.00	36.00	49.00	34.00	44.00	29.00	29.00
	2.00	31.00	46.00	41.00	52.00	35.00	31.00
	3.00	27.00	34.00	37.00	38.00	37.00	27.00
	4.00	34.00	40.00	23.00	35.00	42.00	23.00
	5.00	38.00	27.00	32.00	34.00	40.00	27.00
	6.00	46.00	33.00	34.00	46.00	30.00	30.00
	7.00	54.00	40.00	30.00	36.00	30.00	30.00
	8.00	52.00	43.00	39.00	32.00	35.00	32.00
	9.00	40.00	41.00	33.00	30.00	49.00	30.00
	10.00	33.00	39.00	33.00	57.00	47.00	33.00
	11.00	28.00	34.00	48.00	38.00	43.00	28.00
	12.00	26.00	26.00	36.00	28.00	39.00	26.00
	13.00	22.00	21.00	36.00	43.00	36.00	21.00
	14.00	26.00	27.00	36.00	40.00	41.00	26.00
	15.00	17.00	27.00	45.00	35.00	30.00	17.00
	16.00	17.00	27.00	35.00	26.00	30.00	17.00
	17.00	26.00	26.00	42.00	26.00	36.00	26.00
	18.00	31.00	19.00	31.00	22.00	30.00	19.00
	19.00	38.00	19.00	28.00	39.00	27.00	19.00
	20.00	31.00	31.00	43.00	46.00	20.00	20.00
	21.00	31.00	27.00	34.00	44.00	26.00	26.00
	22.00	32.00	37.00	31.00	50.00	22.00	22.00
	23.00	28.00	35.00	33.00	54.00	18.00	18.00
	24.00	35.00	29.00	43.00	53.00	9.00	9.00
11.00	25.00	36.00	20.00	31.00	41.00	21.00	20.00
	26.00	31.00	30.00	40.00	43.00	35.00	30.00
	27.00	22.00	36.00	37.00	45.00	42.00	22.00
	28.00	14.00	30.00	32.00	37.00	40.00	14.00
	29.00	19.00	39.00	42.00	31.00	34.00	19.00
	30.00	25.00	36.00	50.00	27.00	33.00	25.00
12.00	1.00	37.00	30.00	47.00	17.00	29.00	17.00
	2.00	35.00	29.00	38.00	16.00	21.00	16.00

	3.00	29.00	24.00	50.00	29.00	13.00	13.00
	4.00	36.00	35.00	50.00	40.00	10.00	10.00
	5.00	31.00	32.00	48.00	44.00	23.00	23.00
	6.00	32.00	26.00	48.00	49.00	20.00	20.00
	7.00	33.00	25.00	46.00	34.00	21.00	21.00
	8.00	29.00	30.00	40.00	26.00	21.00	21.00
	9.00	30.00	20.00	33.00	27.00	21.00	20.00
	10.00	28.00	30.00	23.00	34.00	17.00	17.00
	11.00	29.00	30.00	34.00	34.00	32.00	29.00
	12.00	36.00	31.00	23.00	26.00	26.00	23.00
	13.00	36.00	27.00	26.00	26.00	10.00	10.00
	14.00	32.00	27.00	26.00	33.00	24.00	24.00
	15.00	34.00	14.00	21.00	34.00	25.00	14.00
	16.00	37.00	31.00	29.00	36.00	28.00	28.00
	17.00	39.00	25.00	34.00	29.00	37.00	25.00
	18.00	40.00	26.00	26.00	29.00	20.00	20.00
	19.00	29.00	28.00	27.00	27.00	16.00	16.00
	20.00	12.00	31.00	38.00	27.00	18.00	12.00
	21.00	9.00	25.00	42.00	31.00	10.00	9.00
	22.00	19.00	15.00	23.00	28.00	17.00	15.00
	23.00	29.00	28.00	9.00	22.00	3.00	3.00
	24.00	40.00	33.00	20.00	11.00	9.00	9.00
	25.00	25.00	34.00	16.00	13.00	10.00	10.00
	26.00	22.00	37.00	15.00	21.00	5.00	5.00
	27.00	30.00	31.00	17.00	25.00	16.00	16.00
	28.00	30.00	27.00	30.00	7.00	12.00	7.00
	29.00	39.00	23.00	25.00	21.00	4.00	4.00
	30.00	32.00	28.00	11.00	25.00	18.00	11.00
	31.00	23.00	12.00	7.00	31.00	20.00	7.00
	Min of Dry-Bulb Temperature (F)	YEAR					
MONTH	DAY HOUR	2001.00	2002.00	2003.00	2004.00	2005.00	Grand Total
1.00	1.00	19.00	12.00	35.00	32.00	38.00	12.00
	2.00	7.00	15.00	27.00	33.00	28.00	7.00
	3.00	14.00	16.00	24.00	41.00	38.00	14.00
	4.00	18.00	23.00	27.00	36.00	39.00	18.00
	5.00	18.00	29.00	27.00	33.00	30.00	18.00
	6.00	26.00	28.00	26.00	21.00	28.00	21.00
	7.00	24.00	26.00	15.00	12.00	29.00	12.00
	8.00	29.00	16.00	22.00	17.00	27.00	16.00
	9.00	19.00	24.00	36.00	4.00	27.00	4.00
	10.00	19.00	37.00	25.00	-5.00	30.00	-5.00
	11.00	25.00	32.00	18.00	-1.00	28.00	-1.00
	12.00	24.00	33.00	19.00	23.00	31.00	19.00
	13.00	17.00	31.00	18.00	19.00	35.00	17.00
	14.00	19.00	26.00	11.00	1.00	30.00	1.00
	15.00	33.00	34.00	11.00	1.00	15.00	1.00
	16.00	34.00	31.00	12.00	-3.00	14.00	-3.00
	17.00	33.00	32.00	11.00	11.00	13.00	11.00
	18.00	26.00	25.00	0.00	19.00	2.00	0.00
	19.00	32.00	16.00	6.00	16.00	0.00	0.00
	20.00	29.00	19.00	18.00	15.00	14.00	14.00
	21.00	16.00	24.00	8.00	11.00	0.00	0.00
	22.00	8.00	33.00	7.00	15.00	-6.00	-6.00

	23.00	7.00	33.00	2.00	6.00	5.00	2.00
	24.00	15.00	37.00	4.00	7.00	-1.00	-1.00
	25.00	22.00	30.00	13.00	1.00	13.00	1.00
	26.00	14.00	34.00	20.00	10.00	20.00	10.00
	27.00	25.00	28.00	2.00	14.00	0.00	0.00
	28.00	22.00	31.00	-4.00	17.00	-3.00	-4.00
	29.00	11.00	37.00	18.00	15.00	0.00	0.00
	30.00	31.00	40.00	10.00	6.00	20.00	6.00
	31.00	34.00	33.00	22.00	9.00	10.00	9.00
2.00	1.00	35.00	37.00	33.00	16.00	9.00	9.00
	2.00	30.00	24.00	33.00	15.00	8.00	8.00
2.00	3.00	19.00	19.00	32.00	23.00	22.00	19.00
	4.00	14.00	22.00	35.00	29.00	27.00	14.00
	5.00	29.00	12.00	22.00	16.00	22.00	12.00
	6.00	31.00	26.00	11.00	25.00	21.00	11.00
	7.00	33.00	31.00	24.00	29.00	29.00	24.00
	8.00	21.00	34.00	10.00	11.00	37.00	10.00
	9.00	35.00	34.00	16.00	14.00	37.00	14.00
	10.00	27.00	36.00	24.00	32.00	27.00	24.00
	11.00	17.00	22.00	6.00	26.00	20.00	6.00
	12.00	11.00	16.00	14.00	13.00	26.00	11.00
	13.00	30.00	24.00	11.00	30.00	23.00	11.00
	14.00	31.00	11.00	10.00	25.00	27.00	10.00
	15.00	33.00	30.00	12.00	11.00	39.00	11.00
	16.00	28.00	37.00	4.00	1.00	35.00	1.00
	17.00	21.00	29.00	10.00	10.00	20.00	10.00
	18.00	13.00	21.00	20.00	11.00	19.00	11.00
	19.00	17.00	21.00	26.00	22.00	9.00	9.00
	20.00	33.00	41.00	34.00	25.00	21.00	21.00
	21.00	19.00	45.00	20.00	34.00	27.00	19.00
	22.00	8.00	37.00	37.00	30.00	31.00	8.00
	23.00	16.00	29.00	27.00	22.00	26.00	16.00
	24.00	19.00	20.00	20.00	28.00	18.00	18.00
	25.00	29.00	34.00	17.00	15.00	14.00	14.00
	26.00	34.00	37.00	11.00	11.00	13.00	11.00
	27.00	25.00	29.00	17.00	20.00	12.00	12.00
	28.00	20.00	21.00	26.00	18.00	24.00	18.00
	29.00				23.00		23.00
3.00	1.00	19.00	21.00	29.00	30.00	23.00	19.00
	2.00	25.00	25.00	32.00	44.00	22.00	22.00
	3.00	34.00	41.00	3.00	40.00	16.00	3.00
	4.00	28.00	20.00	7.00	39.00	13.00	7.00
	5.00	22.00	11.00	32.00	45.00	10.00	10.00
	6.00	18.00	25.00	22.00	46.00	20.00	18.00
	7.00	27.00	30.00	0.00	35.00	31.00	0.00
	8.00	23.00	35.00	20.00	34.00	16.00	16.00
	9.00	30.00	50.00	25.00	31.00	10.00	10.00
	10.00	28.00	29.00	13.00	31.00	11.00	11.00
3.00	11.00	21.00	21.00	10.00	22.00	21.00	10.00
	12.00	20.00	31.00	28.00	27.00	22.00	20.00
	13.00	32.00	39.00	31.00	24.00	23.00	23.00
	14.00	35.00	41.00	14.00	20.00	20.00	14.00
	15.00	30.00	50.00	26.00	38.00	20.00	20.00

	16.00	28.00	35.00	35.00	27.00	26.00	26.00
	17.00	35.00	24.00	42.00	25.00	20.00	20.00
	18.00	29.00	31.00	37.00	25.00	26.00	25.00
	19.00	27.00	35.00	32.00	29.00	24.00	24.00
	20.00	26.00	36.00	32.00	21.00	37.00	21.00
	21.00	36.00	35.00	41.00	31.00	33.00	31.00
	22.00	33.00	16.00	47.00	17.00	25.00	16.00
	23.00	33.00	21.00	36.00	12.00	30.00	12.00
	24.00	35.00	30.00	33.00	32.00	28.00	28.00
	25.00	22.00	31.00	45.00	41.00	33.00	22.00
	26.00	21.00	34.00	41.00	44.00	25.00	21.00
	27.00	16.00	37.00	37.00	54.00	37.00	16.00
	28.00	23.00	30.00	44.00	43.00	34.00	23.00
	29.00	31.00	33.00	51.00	35.00	36.00	31.00
	30.00	35.00	48.00	30.00	30.00	29.00	29.00
	31.00	34.00	45.00	23.00	39.00	40.00	23.00
4.00	1.00	33.00	43.00	23.00	43.00	40.00	23.00
	2.00	34.00	30.00	34.00	41.00	40.00	30.00
	3.00	27.00	40.00	42.00	41.00	33.00	27.00
	4.00	27.00	30.00	39.00	32.00	34.00	27.00
	5.00	27.00	23.00	34.00	22.00	35.00	22.00
	6.00	42.00	26.00	26.00	26.00	45.00	26.00
	7.00	47.00	19.00	27.00	40.00	59.00	19.00
	8.00	37.00	40.00	28.00	33.00	43.00	28.00
	9.00	40.00	56.00	33.00	32.00	35.00	32.00
	10.00	43.00	42.00	36.00	31.00	37.00	31.00
	11.00	48.00	39.00	37.00	33.00	44.00	33.00
	12.00	47.00	39.00	41.00	40.00	29.00	29.00
	13.00	52.00	54.00	34.00	40.00	29.00	29.00
	14.00	39.00	50.00	31.00	40.00	34.00	31.00
	15.00	36.00	61.00	48.00	35.00	39.00	35.00
	16.00	44.00	62.00	61.00	28.00	34.00	28.00
4.00	17.00	35.00	62.00	37.00	46.00	36.00	35.00
	18.00	33.00	69.00	34.00	53.00	44.00	33.00
	19.00	26.00	62.00	41.00	54.00	48.00	26.00
	20.00	33.00	52.00	40.00	47.00	59.00	33.00
	21.00	47.00	40.00	45.00	49.00	43.00	40.00
	22.00	52.00	40.00	49.00	53.00	35.00	35.00
	23.00	56.00	33.00	37.00	51.00	43.00	33.00
	24.00	61.00	30.00	34.00	49.00	37.00	30.00
	25.00	39.00	43.00	35.00	39.00	35.00	35.00
	26.00	34.00	34.00	52.00	44.00	40.00	34.00
	27.00	36.00	29.00	48.00	45.00	53.00	29.00
	28.00	41.00	46.00	39.00	33.00	44.00	33.00
	29.00	30.00	39.00	53.00	48.00	33.00	30.00
	30.00	37.00	37.00	41.00	53.00	49.00	37.00
5.00	1.00	50.00	33.00	55.00	56.00	45.00	33.00
	2.00	55.00	47.00	54.00	65.00	37.00	37.00
	3.00	57.00	43.00	47.00	45.00	31.00	31.00
	4.00	58.00	33.00	39.00	38.00	34.00	33.00
	5.00	54.00	41.00	43.00	39.00	35.00	35.00
	6.00	43.00	47.00	43.00	37.00	42.00	37.00
	7.00	38.00	59.00	52.00	55.00	36.00	36.00

	8.00	38.00	51.00	56.00	45.00	45.00	38.00
	9.00	54.00	45.00	51.00	46.00	46.00	45.00
	10.00	48.00	52.00	45.00	57.00	54.00	45.00
	11.00	50.00	42.00	59.00	60.00	57.00	42.00
	12.00	58.00	49.00	50.00	62.00	50.00	49.00
	13.00	45.00	53.00	47.00	63.00	32.00	32.00
	14.00	35.00	45.00	48.00	64.00	54.00	35.00
	15.00	36.00	40.00	41.00	63.00	61.00	36.00
	16.00	43.00	40.00	52.00	55.00	47.00	40.00
	17.00	49.00	56.00	46.00	51.00	40.00	40.00
	18.00	52.00	39.00	45.00	64.00	44.00	39.00
	19.00	58.00	32.00	40.00	60.00	39.00	32.00
	20.00	50.00	34.00	47.00	50.00	51.00	34.00
	21.00	50.00	30.00	50.00	64.00	40.00	30.00
	22.00	56.00	32.00	48.00	64.00	49.00	32.00
	23.00	53.00	39.00	50.00	70.00	47.00	39.00
5.00	24.00	56.00	47.00	52.00	69.00	50.00	47.00
	25.00	56.00	45.00	53.00	56.00	48.00	45.00
	26.00	57.00	53.00	54.00	61.00	52.00	52.00
	27.00	55.00	56.00	51.00	57.00	50.00	50.00
	28.00	53.00	62.00	51.00	61.00	48.00	48.00
	29.00	49.00	60.00	50.00	47.00	49.00	47.00
	30.00	44.00	63.00	50.00	39.00	45.00	39.00
	31.00	43.00	65.00	57.00	51.00	46.00	43.00
6.00	1.00	40.00	55.00	47.00	55.00	55.00	40.00
	2.00	53.00	58.00	40.00	53.00	54.00	40.00
	3.00	57.00	46.00	46.00	55.00	56.00	46.00
	4.00	53.00	52.00	51.00	46.00	60.00	46.00
	5.00	46.00	62.00	55.00	53.00	59.00	46.00
	6.00	58.00	60.00	54.00	51.00	64.00	51.00
	7.00	51.00	54.00	54.00	51.00	62.00	51.00
	8.00	46.00	51.00	57.00	57.00	70.00	46.00
	9.00	47.00	57.00	58.00	65.00	68.00	47.00
	10.00	48.00	59.00	52.00	61.00	71.00	48.00
	11.00	60.00	65.00	68.00	53.00	72.00	53.00
	12.00	60.00	69.00	66.00	44.00	73.00	44.00
	13.00	62.00	61.00	67.00	55.00	67.00	55.00
	14.00	67.00	58.00	68.00	61.00	75.00	58.00
	15.00	66.00	56.00	56.00	66.00	73.00	56.00
	16.00	68.00	56.00	47.00	65.00	61.00	47.00
	17.00	64.00	51.00	49.00	71.00	52.00	49.00
	18.00	58.00	48.00	57.00	69.00	58.00	48.00
	19.00	61.00	53.00	57.00	65.00	51.00	51.00
	20.00	66.00	57.00	59.00	46.00	54.00	46.00
	21.00	66.00	59.00	57.00	46.00	56.00	46.00
	22.00	66.00	61.00	56.00	65.00	60.00	56.00
	23.00	61.00	69.00	55.00	58.00	48.00	48.00
	24.00	57.00	69.00	56.00	57.00	57.00	56.00
	25.00	53.00	66.00	57.00	61.00	63.00	53.00
	26.00	58.00	68.00	65.00	59.00	69.00	58.00
	27.00	62.00	68.00	66.00	46.00	71.00	46.00
	28.00	62.00	67.00	56.00	52.00	72.00	52.00
	29.00	65.00	54.00	61.00	54.00	73.00	54.00

6.00	30.00	66.00	61.00	68.00	57.00	69.00	57.00
7.00	1.00	65.00	63.00	56.00	58.00	69.00	56.00
	2.00	50.00	67.00	61.00	60.00	67.00	50.00
	3.00	47.00	71.00	61.00	54.00	53.00	47.00
	4.00	65.00	71.00	64.00	63.00	61.00	61.00
	5.00	63.00	62.00	71.00	71.00	70.00	62.00
	6.00	47.00	55.00	69.00	61.00	69.00	47.00
	7.00	49.00	53.00	69.00	59.00	68.00	49.00
	8.00	64.00	57.00	70.00	68.00	64.00	57.00
	9.00	61.00	68.00	63.00	63.00	62.00	61.00
	10.00	60.00	67.00	57.00	53.00	61.00	53.00
	11.00	60.00	49.00	62.00	59.00	58.00	49.00
	12.00	56.00	47.00	60.00	65.00	68.00	47.00
	13.00	51.00	53.00	56.00	64.00	68.00	51.00
	14.00	54.00	64.00	59.00	64.00	69.00	54.00
	15.00	53.00	63.00	60.00	61.00	71.00	53.00
	16.00	57.00	65.00	71.00	61.00	73.00	57.00
	17.00	65.00	57.00	59.00	59.00	76.00	57.00
	18.00	64.00	71.00	62.00	65.00	75.00	62.00
	19.00	63.00	69.00	55.00	62.00	73.00	55.00
	20.00	58.00	67.00	55.00	60.00	66.00	55.00
	21.00	54.00	63.00	67.00	60.00	61.00	54.00
	22.00	56.00	70.00	63.00	65.00	65.00	56.00
	23.00	62.00	70.00	67.00	69.00	69.00	62.00
	24.00	72.00	63.00	66.00	62.00	57.00	57.00
	25.00	74.00	65.00	58.00	58.00	68.00	58.00
	26.00	67.00	61.00	59.00	60.00	64.00	59.00
	27.00	49.00	65.00	67.00	62.00	70.00	49.00
	28.00	52.00	70.00	67.00	62.00	57.00	52.00
	29.00	61.00	75.00	54.00	61.00	58.00	54.00
	30.00	64.00	76.00	58.00	63.00	60.00	58.00
	31.00	58.00	62.00	56.00	70.00	66.00	56.00
8.00	1.00	59.00	67.00	64.00	69.00	69.00	59.00
	2.00	62.00	67.00	68.00	65.00	70.00	62.00
	3.00	72.00	67.00	71.00	66.00	66.00	66.00
	4.00	69.00	66.00	71.00	64.00	68.00	64.00
	5.00	65.00	68.00	68.00	61.00	73.00	61.00
8.00	6.00	66.00	63.00	64.00	47.00	59.00	47.00
	7.00	70.00	51.00	64.00	54.00	65.00	51.00
	8.00	70.00	52.00	66.00	51.00	70.00	51.00
	9.00	66.00	52.00	70.00	54.00	67.00	52.00
	10.00	76.00	53.00	69.00	60.00	66.00	53.00
	11.00	64.00	62.00	68.00	64.00	70.00	62.00
	12.00	68.00	64.00	67.00	66.00	71.00	64.00
	13.00	68.00	67.00	67.00	63.00	73.00	63.00
	14.00	61.00	67.00	65.00	63.00	70.00	61.00
	15.00	58.00	71.00	63.00	62.00	68.00	58.00
	16.00	63.00	68.00	66.00	59.00	68.00	59.00
	17.00	69.00	68.00	65.00	53.00	65.00	53.00
	18.00	58.00	67.00	57.00	61.00	57.00	57.00
	19.00	62.00	60.00	58.00	66.00	69.00	58.00
	20.00	67.00	66.00	60.00	64.00	69.00	60.00
	21.00	59.00	55.00	63.00	62.00	75.00	55.00

	22.00	56.00	65.00	68.00	48.00	62.00	48.00
	23.00	60.00	69.00	57.00	52.00	55.00	52.00
	24.00	62.00	66.00	50.00	64.00	54.00	50.00
	25.00	54.00	61.00	56.00	65.00	51.00	51.00
	26.00	57.00	56.00	64.00	58.00	59.00	56.00
	27.00	68.00	58.00	68.00	68.00	61.00	58.00
	28.00	59.00	64.00	55.00	67.00	68.00	55.00
	29.00	60.00	56.00	58.00	68.00	65.00	56.00
	30.00	58.00	58.00	66.00	69.00	74.00	58.00
	31.00	70.00	56.00	48.00	65.00	68.00	48.00
9.00	1.00	63.00	56.00	62.00	53.00	65.00	53.00
	2.00	43.00	59.00	60.00	52.00	56.00	43.00
	3.00	50.00	55.00	60.00	55.00	58.00	50.00
	4.00	63.00	69.00	66.00	58.00	53.00	53.00
	5.00	57.00	60.00	60.00	62.00	53.00	53.00
	6.00	46.00	47.00	47.00	55.00	56.00	46.00
	7.00	50.00	52.00	51.00	61.00	56.00	50.00
	8.00	59.00	54.00	55.00	66.00	55.00	54.00
	9.00	62.00	54.00	59.00	65.00	60.00	54.00
	10.00	68.00	60.00	49.00	63.00	52.00	49.00
	11.00	52.00	59.00	53.00	53.00	48.00	48.00
9.00	12.00	47.00	49.00	57.00	55.00	50.00	47.00
	13.00	52.00	44.00	62.00	56.00	62.00	44.00
	14.00	51.00	57.00	69.00	58.00	61.00	51.00
	15.00	38.00	69.00	69.00	57.00	69.00	38.00
	16.00	39.00	67.00	65.00	63.00	72.00	39.00
	17.00	43.00	53.00	49.00	62.00	67.00	43.00
	18.00	50.00	49.00	55.00	56.00	57.00	49.00
	19.00	54.00	54.00	62.00	44.00	58.00	44.00
	20.00	63.00	64.00	60.00	40.00	65.00	40.00
	21.00	62.00	68.00	48.00	47.00	55.00	47.00
	22.00	58.00	69.00	56.00	46.00	52.00	46.00
	23.00	50.00	57.00	62.00	53.00	68.00	50.00
	24.00	57.00	42.00	46.00	56.00	46.00	42.00
	25.00	54.00	48.00	56.00	56.00	61.00	48.00
	26.00	41.00	53.00	50.00	57.00	64.00	41.00
	27.00	48.00	54.00	64.00	48.00	56.00	48.00
	28.00	45.00	58.00	53.00	62.00	41.00	41.00
	29.00	49.00	42.00	50.00	58.00	56.00	42.00
	30.00	38.00	49.00	42.00	56.00	39.00	38.00
10.00	1.00	42.00	53.00	46.00	43.00	43.00	42.00
	2.00	45.00	61.00	38.00	53.00	48.00	38.00
	3.00	50.00	65.00	31.00	43.00	53.00	31.00
	4.00	51.00	61.00	44.00	38.00	53.00	38.00
	5.00	51.00	62.00	38.00	38.00	56.00	38.00
	6.00	48.00	46.00	34.00	33.00	54.00	33.00
	7.00	38.00	57.00	33.00	40.00	67.00	33.00
	8.00	33.00	42.00	41.00	48.00	50.00	33.00
	9.00	28.00	43.00	46.00	56.00	48.00	28.00
	10.00	39.00	56.00	56.00	45.00	50.00	39.00
	11.00	45.00	53.00	50.00	46.00	57.00	45.00
	12.00	52.00	55.00	42.00	43.00	50.00	42.00
	13.00	55.00	55.00	44.00	36.00	50.00	36.00

	14.00	58.00	40.00	44.00	48.00	55.00	40.00
	15.00	47.00	34.00	51.00	50.00	53.00	34.00
	16.00	41.00	46.00	44.00	44.00	49.00	41.00
	17.00	43.00	46.00	36.00	39.00	50.00	36.00
	18.00	34.00	37.00	38.00	42.00	43.00	34.00
10.00	19.00	32.00	42.00	43.00	44.00	41.00	32.00
	20.00	45.00	38.00	32.00	44.00	42.00	32.00
	21.00	40.00	34.00	52.00	44.00	42.00	34.00
	22.00	52.00	30.00	39.00	43.00	43.00	30.00
	23.00	49.00	39.00	32.00	30.00	42.00	30.00
	24.00	55.00	27.00	30.00	38.00	33.00	27.00
	25.00	57.00	35.00	30.00	45.00	36.00	30.00
	26.00	42.00	40.00	51.00	49.00	35.00	35.00
	27.00	38.00	44.00	47.00	38.00	37.00	37.00
	28.00	32.00	37.00	33.00	38.00	30.00	30.00
	29.00	24.00	27.00	45.00	43.00	30.00	24.00
	30.00	43.00	32.00	37.00	51.00	36.00	32.00
	31.00	38.00	26.00	41.00	57.00	33.00	26.00
11.00	1.00	45.00	32.00	48.00	48.00	36.00	32.00
	2.00	56.00	30.00	48.00	45.00	42.00	30.00
	3.00	56.00	32.00	51.00	42.00	32.00	32.00
	4.00	44.00	30.00	51.00	30.00	43.00	30.00
	5.00	37.00	30.00	53.00	40.00	48.00	30.00
	6.00	39.00	39.00	47.00	35.00	50.00	35.00
	7.00	32.00	30.00	41.00	40.00	48.00	30.00
	8.00	35.00	28.00	30.00	37.00	44.00	28.00
	9.00	39.00	36.00	20.00	28.00	40.00	20.00
	10.00	32.00	54.00	21.00	21.00	40.00	21.00
	11.00	36.00	60.00	29.00	38.00	36.00	29.00
	12.00	25.00	46.00	43.00	35.00	26.00	25.00
	13.00	24.00	42.00	36.00	28.00	44.00	24.00
	14.00	29.00	30.00	30.00	20.00	45.00	20.00
	15.00	49.00	42.00	33.00	28.00	41.00	28.00
	16.00	49.00	38.00	31.00	30.00	46.00	30.00
	17.00	34.00	36.00	42.00	29.00	31.00	29.00
	18.00	32.00	32.00	39.00	43.00	26.00	26.00
	19.00	33.00	29.00	51.00	48.00	24.00	24.00
	20.00	36.00	34.00	42.00	44.00	27.00	27.00
	21.00	28.00	36.00	30.00	46.00	30.00	28.00
	22.00	28.00	40.00	36.00	41.00	33.00	28.00
	23.00	33.00	30.00	40.00	32.00	21.00	21.00
	24.00	47.00	33.00	39.00	48.00	26.00	26.00
11.00	25.00	52.00	31.00	27.00	34.00	15.00	15.00
	26.00	41.00	32.00	29.00	27.00	17.00	17.00
	27.00	34.00	26.00	32.00	31.00	31.00	26.00
	28.00	49.00	18.00	44.00	43.00	43.00	18.00
	29.00	49.00	25.00	35.00	34.00	60.00	25.00
	30.00	51.00	36.00	33.00	33.00	40.00	33.00
12.00	1.00	50.00	25.00	32.00	40.00	33.00	25.00
	2.00	37.00	24.00	20.00	35.00	28.00	20.00
	3.00	28.00	11.00	16.00	25.00	23.00	11.00
	4.00	33.00	5.00	14.00	23.00	24.00	5.00
	5.00	53.00	18.00	24.00	38.00	24.00	18.00

6.00	48.00	22.00	20.00	28.00	22.00	20.00
7.00	46.00	14.00	16.00	35.00	18.00	14.00
8.00	30.00	25.00	17.00	42.00	10.00	10.00
9.00	32.00	7.00	23.00	32.00	21.00	7.00
10.00	22.00	10.00	33.00	39.00	22.00	10.00
11.00	34.00	16.00	39.00	40.00	16.00	16.00
12.00	24.00	32.00	31.00	34.00	22.00	22.00
13.00	41.00	34.00	23.00	33.00	5.00	5.00
14.00	48.00	35.00	21.00	23.00	-3.00	-3.00
15.00	35.00	36.00	21.00	16.00	9.00	9.00
16.00	26.00	23.00	22.00	20.00	29.00	20.00
17.00	35.00	20.00	31.00	28.00	23.00	20.00
18.00	38.00	10.00	25.00	19.00	16.00	10.00
19.00	37.00	27.00	26.00	18.00	23.00	18.00
20.00	34.00	40.00	25.00	-1.00	13.00	-1.00
21.00	31.00	33.00	22.00	3.00	15.00	3.00
22.00	27.00	33.00	29.00	22.00	22.00	22.00
23.00	26.00	31.00	38.00	39.00	30.00	26.00
24.00	31.00	30.00	41.00	23.00	31.00	23.00
25.00	23.00	28.00	31.00	13.00	33.00	13.00
26.00	15.00	26.00	28.00	13.00	34.00	13.00
27.00	18.00	28.00	32.00	14.00	31.00	14.00
28.00	22.00	15.00	22.00	6.00	27.00	6.00
29.00	22.00	30.00	27.00	24.00	40.00	22.00
30.00	17.00	24.00	37.00	33.00	31.00	17.00
31.00	15.00	36.00	30.00	38.00	27.00	15.00

Response to NRC Request for Additional Information Set No. 25
(RAI Set No. 25 Question #1)
Bell Bend Nuclear Power Plant
Berwick, Pennsylvania

Attachment 3 – RIZZO 2009 calculation package "Frazil Ice Analysis for BBNPP ESWEMS Pond-Response to RAI#25"

1. PURPOSE

According to USACE (1991), frazil ice often occurs in open water at night under clear conditions and cold ambient air temperatures (-6°C). The process begins when the water temperature is at or just below the freezing point (pure water is 0°C). If the atmosphere rapidly cools, the water at the air/water interface can begin to freeze under a process called *nucleation,* forming small ice crystals. Turbulence will mix the ice crystals through the entire flow depth, where frazil ice can accumulate on underwater objects.

The purpose of this Frazil Ice Analysis is to determine whether frazil ice presents a risk to the water intake for the Essential Service Water System (ESWS) at the Bell Bend Nuclear Power Plant (BBNPP) site. Under the unlikely scenario that frazil ice forms in the ESWS pond, this analysis will focus on the potential for mixing of frazil ice crystals formed at the surface to sufficient depths to cause a concern for the ESWEMS water intake system. The ESWEMS water intake system is approximately 9 m deep.

2. REFERENCES

1. USACE (March 1991). *Frazil Ice Blockage of Intake Trash Racks*. Daly, S.F. US Army Corps of Engineers, Washington D.C., Cold Regions Technical Digest No. 91-1, March 1991.
2. Black & Veatch Corporation (June 16, 2008). Drawing 161642-1EMS-S1002. Bell Bend Nuclear Power Plant.
3. US Army Corps of Engineers (2008). *Coastal Engineering Manual*, EM 1110-2-1100. US Army Corps of Engineers, Washington D.C.
4. Rizzo (July 2008). *Wave Runup Analysis for BBNPP ESWEMS Pond.* Proj. No. 07-3891. Paul C. Rizzo Associates, Inc., Monroeville, PA.

3. ASSUMPTIONS

1. Wind is the primary force for convective mixing in the ESWEMS pond.
2. Under still conditions, the buoyancy of the frazil ice is sufficient to bring the ice to the surface.

4. METHODOLOGY

To calculate the mixing depth as a result of sustained wind speeds, the maximum fetch limited wave characteristics are calculated. Sustained wind speeds were taken from **Reference 4** and are listed below in Table 4-1. U_t is the maximum overland wind speed and U_w is the overwater wind speed adjusted for the averaging interval. The conversion from U_t to U_w is detailed in **Reference 4**.

TABLE 4-1: Wind Speed

Event	U_t (mph)	U_w (m/s)
Fastest Recorded:	57	26.4
2 yr Freq.:	50	23.4
10 yr Freq.:	60	27.9
25 yr Freq.:	70	32.1
50 yr Freq.:	71	32.5
100 yr Freq.:	83	37.9
1000 yr Freq.:	118	53.0

Using the duration averaged overwater wind speeds, U_w, in Table 4.1, the wave height and periods are calculated using equations 3.1 and 3.2, found in **Reference 3**. In equation 3.1 H_{mo} is the calculated wave height [m], g is the gravitational acceleration [9.81 m^2/s], X is the fetch distance [m], and u_* is the friction velocity [m/s]. In equation 3.2, T_p is the calculated wave period [s].

$$H_{mo} = 4.13\times10^{-2}\left(\frac{gX}{u_*^2}\right)^{1/2}\left(\frac{u_*^2}{g}\right) \tag{3.1}$$

$$T_p = \left[0.751\left(\frac{gX}{u_*^2}\right)^{1/3}\right]\left(\frac{u_*}{g}\right) \tag{3.2}$$

Note: *Equation 3.2 is from* ***Reference 3****, The United States Army Corps of Engineers' Coastal Engineering Manual. Equation 3.2, as shown, includes a dimensionless, empirically derived coefficient of 0.751. The Coastal Engineering Manual referenced here is the 2008 edition. A calculation brief performed by Paul C. Rizzo Associates, Wave Runup Analysis for BBNPP ESWEMS Pond. Proj. No. 07-389, referenced herein as* ***Reference 4****, used the same equation from an earlier version of the Coastal Engineering Manual that contained a different coefficient equal to 0.651. In a telephone call with the USACE, San Francisco office, the coefficient in the 2008 Coastal Engineering Manual, 0.751, was specified as the correct coefficient. The coefficient from the earlier version of the Coastal Engineering Manual, 0.651, was determined to be a typo and was subsequently fixed. Any data referenced from* ***Reference 4*** *or conclusions drawn in this calculation brief are not impacted by this error.*

The friction velocity is calculated from equations 3.3 and 3.4 from **Reference 3**, where U_w listed in Table 4-1 is assumed to be equal to U_{10}. C_d is a dimensionless drag coefficient and U_{10} is the wind speed at 10 m elevation [m/s].

$$u_* = \sqrt{C_d U_{10}^2} \tag{3.3}$$

$$C_d = 0.001(1.1 + 0.035U_{10}) \tag{3.4}$$

Once the wave height (H_{mo}) and period (T_p) are known, the wavelength can be calculated using equation 3.5 from **Reference 3**. Equation 3.5 includes *d*, the depth of the pond [m].

$$L_0 = \frac{gT_p^2}{2\pi}\sqrt{\tanh\left(\frac{4\pi^2 d}{T_p^2 g}\right)} \tag{3.5}$$

The wave base, H_{wb}, is calculated in equation 3.6 and is then compared to the depth of the water intake. Equation 3.6 comes from **Reference 3**, page II-1-21, paragraph 1.

$$H_{wb} = \frac{L_0}{2} \tag{3.6}$$

5. INPUT

Aside from the wind speed data listed in Table 4.1, the parameters used in these calculations are listed below in Table 5.1. A conversion factor of 1 ft = 0.3048 m was used.

Table 5.1: List of Parameters

Parameter	Value	units	Symbol
pond depth:	6.3	m	d
max fetch:	688.8	ft	X
	209.9462	m	X
gravitational acceleration:	9.81	m/s^2	g

6. RESULTS

The calculated wave height (H_{mo}), wave period (T_p), wavelength (L_0), and wave base (H_{wb}) are listed in table 6.1. The wave base is the depth below the mean water surface where the fluid motion as a result of the waves is considered to be negligible. Intermediary values are included for comprehensiveness.

Table 6.1: Wave Results

Event	U_w (m/s)	C_d	U_* (m/s)	H_{mo} (m)	T_p (s)	Lo (m)	H_{wb} (m)
Fastest Recorded:	26.4	0.002024	1.19	0.23	1.03	1.66	0.8306
2 yr Freq.:	23.4	0.00192	1.03	0.20	0.98	1.50	0.7540
10 yr Freq.:	27.9	0.002077	1.27	0.24	1.06	1.74	0.8692
25 yr Freq.:	32.1	0.002224	1.51	0.29	1.12	1.95	0.9763
50 yr Freq.:	32.5	0.002238	1.54	0.29	1.12	1.97	0.9868
100 yr Freq.:	37.9	0.002427	1.87	0.36	1.20	2.25	1.1229
1000 yr Freq.:	53.0	0.002956	2.88	0.55	1.39	3.00	1.5000

7. CONCLUSION

According to **Reference 2** the water intake system for the ESWS is approximately 9 m under the surface of the water. Based upon the calculated wave base, H_{wb}, the maximum mixing depth as a result of the wind on the pond surface is limited to 1.50 m for the 1000 year frequency wind event. The sustained wind speeds are not sufficient to provide a deep enough mixing process to mix frazil ice to the depth of the ESWEMS water intake system. Therefore, in the unlikely event that frazil ice develops in the ESWS pond, it would not pose a threat to the operation of ESWEMS.

8. ELECTRONIC FILE LOCATIONS

The excel file holding all relevant calculations is named "BBNPP (07-3891) Frazil_Ice_Assessment.xlsx" and is located in the following location:

G:\GMS\BBMPP (07-3891)\Frazil Ice Assessment

Reference 1

USACE (March 1991). *Frazil Ice Blockage of Intake Trash Racks*. Daly, S.F. US Army Corps of Engineers, Washington D.C., Cold Regions Technical Digest No. 91-1, March 1991.

COLD REGIONS TECHNICAL DIGEST No. 91-1, March 1991

USA Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755-1290

Frazil Ice Blockage of Intake Trash Racks

Steven F. Daly

Introduction

Operating water intakes in lakes and rivers in northern regions is complicated by the presence of ice. One of the most difficult problems is the accumulation of frazil ice on the intake trash rack, which can completely block the trash rack and rapidly and unexpectedly shut down the intake facility. In extreme cases the blockage can cause the intake trash rack to collapse. Blockages of intake trash racks occur sporadically, most often at night, in cold weather and always underwater. As a result, opportunities for observation and measurement are limited. This has lent frazil blockage an air of mystery that it does not deserve.

Contributing to the air of mystery is the lack of any universal cure for the problem of frazil ice accumulation on intake trash racks. While at many intakes there are no obvious techniques for preventing blockage, some successful techniques have been instituted at specific locations. Unfortunately, given the many uses and designs for intakes, and the wide range of hydraulic conditions at intakes, it has proven to be quite difficult to generalize these successful techniques.

The author, a research hydraulic engineer, is a member of CRREL's Ice Engineering Research Branch.

Descriptions of frazil blockage can be found throughout the literature of cold regions engineering. People became aware of the problem as soon as they began to demand the uninterrupted use of rivers and lakes throughout the winter. The complete blockage of the water supply of the city of St. Petersburg, Russia, in 1914 by frazil ice is one early example. The writings of Murphy (1909),

Barnes (1928) and others provide very good overall descriptions of frazil ice blockage.

This digest presents an overview of frazil ice blockage of intake trash racks for intake operators and designers. It describes the frazil ice blockage process, techniques (both successful and less so) for coping with frazil blockage, and guidelines for operating under frazil ice conditions. It synthesizes information from the literature, laboratory experiments, and the experience of the author. Broader and more general information on designing intakes for cold regions is available elsewhere (Logan 1974, Ashton 1988) as is information on frazil ice (Williams 1959, Michel 1971, Osterkamp 1978, Martin 1981, Daly 1984, Ashton 1986).

The blockage process

Frazil ice accumulates on intake trash racks under conditions that make direct observation very difficult. As yet, there have been no quantitative measurements made while frazil ice was accumulating on an intake trash rack outside of a laboratory. Our understanding of the accumulation process comes from photos of river intake trash racks raised after becoming completely blocked, descriptions from intake operators, and experiments conducted at CRREL.

Rivers

The accumulation process starts when the water entering the intake becomes supercooled, that is, when the water is below its freezing temperature. The degree of supercooling may be very small (less than 0.0°C) and nearly impossible to detect without laboratory-grade equipment. Supercooling requires a large heat loss rate from the river that is always associated with low air temperatures (about -9°C or lower), open water and most often, clear nights. The association of frazil production and open water is so strong that it can be said quite confidently that trash racks will be blocked by frazil only before a stable ice cover has formed, after the ice cover has broken up, or where a stable ice cover cannot form.

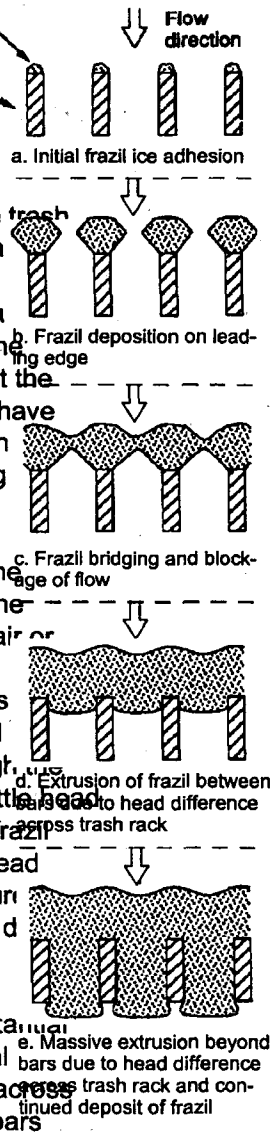
The water will supercool first at the surface, and in rivers the highly turbulent flow will mix the supercooled water quickly through the entire depth. Carried along with the supercooled water will be small crystals of ice—frazil ice—which, because of their small size, will have little effective buoyancy and will be easily carried to the bottom of the river. The first few crystals enter at the water's surface, and through a process known as secondary nucleation, the number of crystals quickly increases. The concentration of crystals in rivers has not been measured, but estimates are in the range of 1 million per cubic meter (approximately 30,000 per cubic foot). Because they are in supercooled water, the crystals will be growing in size and will stick to any object they contact—including

trash racks—as long as these objects are at a temperature below freezing. Given the effective heat transfer rates provided by flowing water, any object in the water that is not heated will quickly be at the temperature of the supercooled water and will accumulate frazil.

The frazil will collect first on the upstream face of the intake trash bars, regardless of the shape of the bars—pointed, rectangula rounded, streamlined, etc.—or the material—steel, aluminum, plastic, etc. The accumulation will grow into the flow by contin deposition, extending upstream and increasing in width until the space between adjacent bars is "bridged" (Fig. 1). At this point the trash rack will be effectively blocked. Almost all of the ice will have accumulated on the upstream side of the trash rack (Fig. 2). In laboratory experiments, and in some field reports, the bridging process is observed to occur first at the water line of the trash and then extend downward.

Calculations indicate that the quantity of ice deposited on the trash rack will far exceed the quantity of ice that is grown by the transfer of latent heat through the trash rack bars to the cold air or to the supercooled water flowing through the rack.

As the frazil accumulates on the trash rack, the head losses increase. That is, a greater and greater differential water level be required across the rack to drive the same flow rate through the trash rack. Because trash racks are designed to cause very little head loss under normal flow conditions, a considerable amount of frazil can accumulate before this head loss becomes noticeable. Head losses measured in laboratory experiments are shown in Figur Here the nondimensional head loss (the measured head loss d by the head loss of the rack without ice) is plotted against nondimensional time (time divided by the time at which total blockage occurs). The head loss is relatively small for a substa period of time but increases quite rapidly near the time of total blockage. As the head loss mounts, the differential pressure across the rack will tend to push the accumulated frazil through the bars and may even extrude the accumulated frazil completely through the trash rack (Fig. 1 and 4). Once the frazil has been extruded between the bars, it can adhere to a much larger area of the bars. As a result the accumulated frazil can withstand quite high differential pressures, equal to many feet of water.



a. Initial frazil ice adhesion

b. Frazil deposition on leading edge

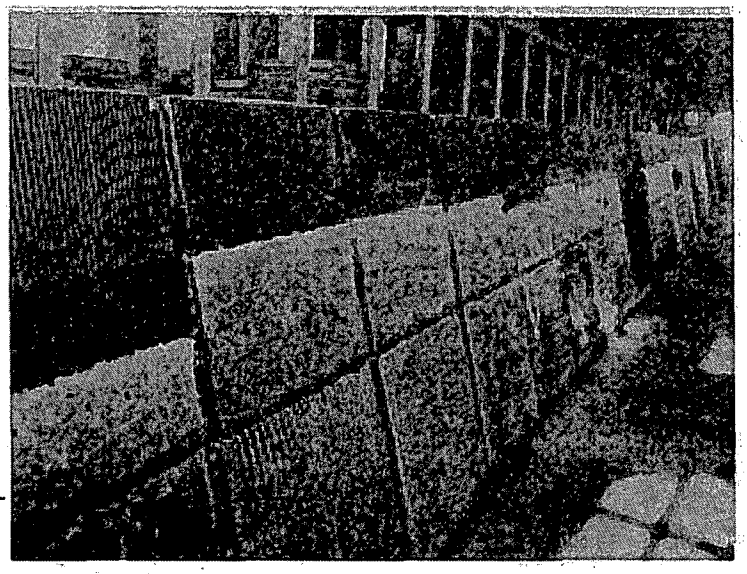
c. Frazil bridging and blockage of flow

d. Extrusion of frazil between bars due to head difference across trash rack

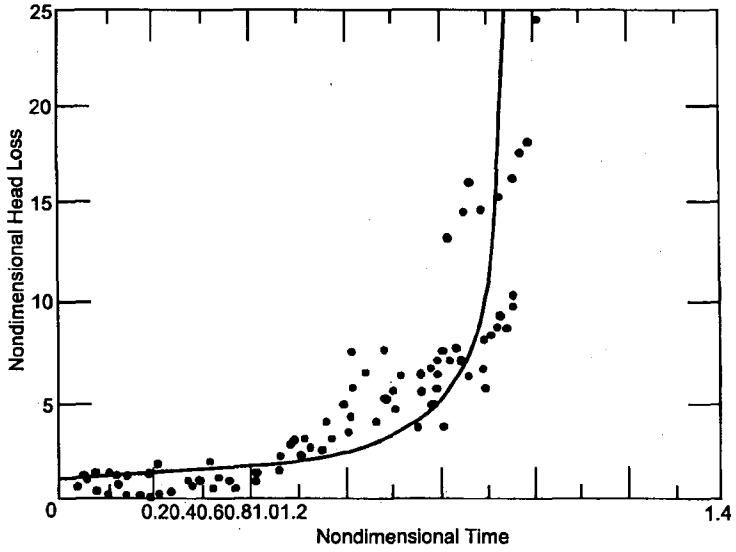
e. Massive extrusion beyond bars due to head difference across trash rack and continued deposit of frazil

f. Pattern of frazil ice accumulation on intake trash rack bars.

The process of blockage of intake trash racks in lakes has never been directly observed because of the racks' remote and often deep locations. As with river intakes, blockages of lake intake trash racks

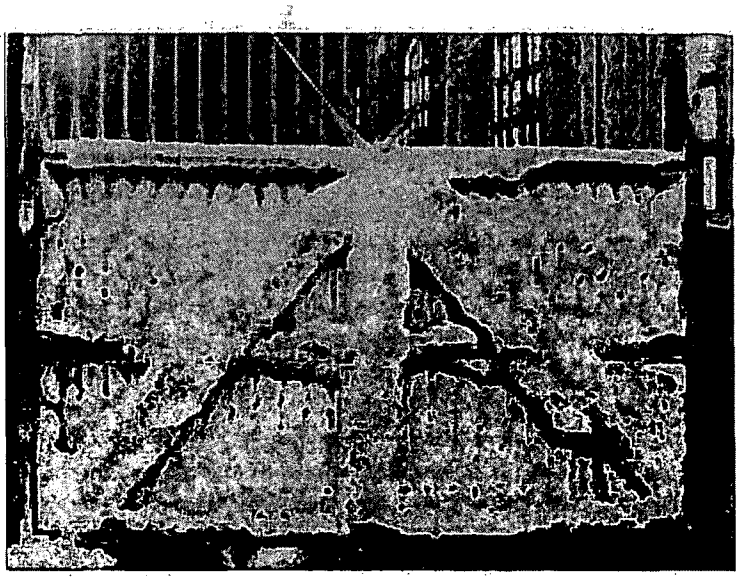


2. Accumulated frazil on trash racks raised from the water. (Photo courtesy of Pennsylvania Power & Light Company.)



3. Head loss through a trash rack during frazil ice accumulation in laboratory tests.

are associated with open water, low temperatures and clear nights. They are often also associated with strong winds, which increase the rate of heat loss at the water surface and may provide the turbulence that can mix the supercooled water to the depth of the intake. The intake flow can also entrain the supercooled water if it is high enough. The depth at which a lake intake will be safe from frazil blockage cannot be estimated simply, and it probably depends on



4. Back side of an intake trash rack raised from the water, showing massive extrusions of frazil ice through the rack bars. (Photo courtesy of Pennsylvania Power & Light Company.)

many factors, such as the fetch length, bottom topography, intake depth and intake flow rate. Blockages have been reported at intakes 20 m deep and much deeper.

The blockage of lake intake trash racks probably occurs in much the same way as river intakes. However, inspections of blocked lake intakes by divers suggest that the individual crystal size is larger at lake intakes than at river intakes. The reasons for this are not entirely clear, but it may result from a lower concentration of crystals in suspension because of the lower levels of turbulence in lakes. This means that the accumulated crystals may actually grow due to the release of latent heat allowed by the constant intake of supercooled water. This is in contrast to the river intakes, where the deposition of frazil crystals is by far the most significant source of ice.

Lake intakes are most often connected with a wet well from which water is pumped. As the intake trash rack becomes blocked, the wet well may be drawn down, and the differential pressure across the trash rack will increase. This differential pressure has been known to cause intakes to collapse. Close monitoring of the water level in the wet well may help in detecting blockage of the trash rack by frazil ice.

Many techniques have been tried to keep intake trash racks free from frazil ice. In the next few pages are listed some of the basic techniques that have been tried (not always successfully) or are frequently suggested.

Coping with frazil blockage

Suppressing frazil production

An intact, stable ice cover will always prevent the production of the frazil ice by "insulating" the water surface and preventing large heat loss rates responsible for supercooled water. If an ice cover can be successfully created and kept in place over a sufficient area of the river or lake in which the intake is located, frazil blockage probably can be completely avoided. There is no ready "rule of thumb" as to what is a sufficient area of the water surface that must be covered by ice. Supercooled water traveling beneath an ice cover will gradually be warmed to the freezing temperature by the latent heat released by the growing frazil crystals and the surface ice cover and by viscous dissipation in the flow. While Ashton (1988) suggested that a cover length equal to 10 minutes of travel time may be adequate to warm the water sufficiently, supercooled water has been measured several kilometers downstream from the head of an ice cover and with travel times as long as 1 to 3 hours on large rivers. The actual length required will vary widely, depending on the hydraulic conditions in the river. The techniques for creating and maintaining stable ice covers are described well elsewhere (U.S. Army Corps of Engineers 1982, Ashton 1986).

Using heat

The use of heat can be a very successful way to prevent frazil from adhering to intake trash racks. It is not effective or efficient to use heat to melt ice once it has accumulated on the trash rack. Rather, the heat should be used to prevent adhesion to the trash rack by warming the incoming water so that it is no longer supercooled or by warming the trash rack bars so that they are above the freezing temperature. The most attractive source of heat is the warm water that is often a byproduct at facilities that use intakes, such as the cooling water at power generation plants. The warm water is often dumped back into the river downstream of the intake and is essentially thrown away! By redirecting a portion of this waste heat to the intake, frazil blockage can be avoided. At small intakes, ground water may also be an adequate heat source. Enough warm water should be redirected to the intake to raise the entire intake flow temperature 0.1–0.2. If it is assumed that all the warm water will be drawn into the intake, the amount of water required is

$$Q_D = Q_T\left(\frac{T_R}{T_D}\right)$$

where Q_T =total intake flow rate
T_R =temperature rise above freezing required
T_D =temperature above freezing of the warm water to be delivered to the intake.

The warm water should be introduced immediately upstream of the intake trash rack, and it should be well mixed in the intake flow. Mixing the warm water with the intake flow can require the use of "spragers" or diffusers, but complicated designs for these devices are not usually warranted.

Another means of using heat to prevent frazil blockage is to heat the trash rack bars directly. If the bar temperatures can be kept above the freezing temperature, frazil will not adhere. The amount of heat supplied must be sufficient to offset the heat transfer to the flowing, supercooled water. Standard heat transfer relationships that relate the heat transfer to the bar shape and water velocity are available to guide designers (see, for example, Logan 1974); the degree of safety provided in the design is the temperature difference maintained between the trash rack bars and the supercooled water temperature. As a minimum the bars should be maintained at 0°C, but it is advisable that bar designs include the capability to maintain the bars at 1.0–1.5C during high frazil concentration events.

There is no simple means of supplying heat to the trash rack bars. Hollow bars, through which steam or warm water is pumped, have been used successfully. However, these systems seem to suffer from many operational problems. Incorporating resistance heaters in the trash rack bars has also been used successfully. In Sweden and other locations, energy is delivered to the trash rack bars by direct electrical connection.This often requires that the trash racks be redesigned, and safety is then a consideration.

Constructing heated enclosures over intakes is sometimes suggested, especially where large portions of the trash rack are exposed to air. However, heated enclosures by themselves cannot prevent frazil ice accumulation. The heat gain to the trash rack from the warm air developed within the enclosure will be balanced by the heat loss to the flowing water at a very small depth. The depth will depend largely on the bar size and the flow velocity but will probably be no more than several bar diameters below the surface. Below this depth, frazil will accumulate as described above. While heated enclosures will not prevent frazil accumulation, people working near the rack (raking, for instance) will appreciate the warmth.

Mechanical removal

Probably the most widespread method of dealing with frazil accumulation of intake trash racks is to use rakes to remove the ice. As seen earlier, before the development of large differential pressures across a trash rack, the accumulation of frazil ice will be largely on the upstream side of the racks. During this time it is relatively easy to remove by raking. Manual raking is undoubtedly

the single most widely used technique for dealing with frazil—"a strong back in a warm coat" can effectively clear large areas of racks covered with frazil ice. The cost of labor, the cold and wet working conditions, and the late night hours, however, combine to discourage this approach.

An alternative to manual raking is to use mechanical rakes. There are a number of manufacturers of mechanical rakes with a corresponding range of sophistication, from relatively simple, manually operated power rakes, to rakes using the best of robotics. Problems that can arise in operating mechanical rakes in very cold weather should not be ignored. The rake mechanisms inevitably move from completely submerged conditions to the cold air, leading to the formation of hard ice and resultant mechanical problems. Therefore, the usefulness of a mechanical rake for removing frazil in cold weather must be carefully evaluated.

The use of high-flow air bubblers and water jets is sometimes suggested as a means of removing frazil accumulations on intake trash racks. At present the use of high-flow air bubblers remains strictly experimental and should be approached as such. Water jets have been used successfully to remove frazil ice accumulations inside large conduits and may be effective for use with trash racks.

Back flushing

Back flushing is a technique to reverse the differential pressure across the trash rack. During back flushing, a higher pressure is created on the back side of the racks, and the flow through the rack is reversed. If the accumulation of frazil is largely on the upstream side of the rack (as in Fig. 1c), then it is likely that back flushing will be successful. This means that back flushing must be done as soon as possible during the accumulation process, before large differential pressures occur and the accumulated ice is extruded between the bars. If the accumulation has been extruded between the trash rack bars (as in Fig. 1d and 1c), then it is much less likely that the back flushing process will be successful.

Back flushing is accomplished by any means that the intake operators may have for increasing the pressure on the back side of the trash rack. Most often, back flushing is tried at intakes connected to wet wells, where water is allowed to flow from elevated tanks or stand pipes or is pumped into the wet well. Back flushing should be repeated frequently as long as frazil ice conditions persist.

Coatings and alternative trash rack materials

Almost all trash racks are made of metal—the vast majority of steel, a very few of aluminum. Steel in water quickly rusts, and the adhesion strength between ice and rusted steel is extremely high. Trash rack coatings will reduce the ice adhesion strength and can

extend the time to total blockage, but coatings by themselves will not prevent frazil blockage. Examples of coatings are two-part epoxies or heavy-duty marine-type paint. Coatings must be applied only after careful preparation of the racks, which at a minimum involves a thorough cleaning, usually by sand blasting. While coatings cannot prevent blockage, they will increase the ease of removal of frazil ice (such as by raking, for example).

Alternative trash rack materials—that is, nonmetals such as plastics, fiberglass, graphite or other material—must be carefully selected to provide the strength and durability required. Materials such as these will, like coatings, have a lower ice adhesion strength than steel, but "no material is known to which ice will not adhere" (Ashton 1986). As a result, using alternative materials for trash rack construction is not in itself a guarantee against ice blockage, but again, like coatings, they will allow frazil ice to be removed more easily.

Vibration

Vibration of trash racks has been shown to be effective in removing frazil ice accumulations in laboratory tests (Mussalli et al. 1987). In these tests a minimum vibration acceleration of 15 g was needed to shed accumulated frazil ice from the model trash racks. Under prototype conditions, enough energy must be supplied to remove ice but not to shake the trash rack apart. The natural flexibility of trash racks may make effective vibration difficult, and it also may make it difficult to vibrate an entire rack uniformly from one application point. Electric- or air-powered vibrators are used for many applications and are commercially available, but they will probably need to be modified for underwater use. At present the use of vibrators must be considered an experimental technique.

Blasting

Dynamite is sometimes used to remove accumulations of frazil from intake trash racks under extreme conditions. Blasting is effective, probably because of the vibrations set up in the trash rack combined with the pressure wave of the explosion. The first problem with blasting is to determine the correct size of the charge. It must be large enough to remove the ice but not so large as to damage the rack. Additional problems arise from environmental concerns, safety considerations and the complaints of nearby residents. Because of these problems the use of dynamite cannot be recommended.

Removal of trash racks

Removing the trash racks is an obvious solution and one that is sometimes used. The trash racks should be removed only after carefully weighing the problems caused by the frazil accumulation

against the damage that may be caused by not having the trash racks in place. This type of evaluation can only be done after many years of experience at a particular site and is not a step to be taken lightly.

Operating under frazil conditions

Maintaining adequate intake flow under frazil ice conditions can be very difficult. Given below are guidelines for intake operators who must maintain an uninterrupted supply of water and who face frazil ice conditions and frazil accumulation on the intake trash racks.

1. Monitor the water temperature, air temperature and surface ice cover extent to develop associations between these conditions and the formation of frazil ice. Almost all intake operators monitor these conditions as a routine matter and learn to anticipate the conditions under which frazil ice occurs. When the water temperature is close to freezing and no surface ice cover exists, forecasts of low air temperatures and clear nights should alert operators to the possibility of frazil ice.

2. Continuously monitor the degree of blockage on the intake trash rack. This can be done by measuring the differential pressure or water level across the trash rack or by visual inspection. At intakes that pump from a wet well, the water level difference between the wet well and the water level in the body of water in which the intake is located should be monitored. The degree of blockage will be indicated by the extent that the water level differential exceeds that found under normal operating conditions (caused by head losses in the intake structure and the intake piping systems). Continuous readouts of the instruments used to monitor these conditions should be available to the facility operators, and alarm conditions should be established. The chief benefit of this monitoring is to allow the operators to determine quickly and unambiguously the degree to which the trash racks are blocked, so that the appropriate measures can be taken.

3. Frazil ice accumulation can be minimized to some extent, although not eliminated altogether, through proper design of the intake trash racks. By having the maximum space between the trash rack bars and by using the thinnest bars possible with the minimum of supports consistent with strength and vibration considerations, the length of time until the intake is totally blocked can be extended. The ability of the rack to withstand the differential pressure under blocked conditions should also be carefully considered. A conservative approach is to design the rack to withstand the entire head of water possible on the upstream side of the rack. Some river intake trash racks are designed to this standard. This standard may not be practical for all intakes. The design should then reflect the maxi-

mum differential pressure the intake trash rack may experience given the monitoring program established as described above.

4. Develop plans for an orderly shutdown of the facility should the intake trash rack become blocked by frazil.

5. Take an active approach to dealing with frazil ice by using one of the techniques described in the previous section. If possible, actively manage the ice cover in the area of the intake to establish a stable ice cover as soon as possible in the winter season and to maintain it as long as possible. If there is a source of heat available, use it! Coat a section of your trash rack and then observe the results—is the ability to rake improved? If coatings are an improvement, consider coating the entire trash rack at your site.

6. Keep detailed logs of the water temperature, weather conditions and ice conditions throughout the winter to determine the specific conditions at which frazil ice blockage occurs. Determine simple alarm conditions based on these observations and make sure that the operating personnel are aware of them. Operating personnel have often developed keen insights into frazil problems from hard experience. Gather information from these people and make sure that it is not lost due to retirement or personnel changes.

Frazil ice blockage is a difficult and serious problem. By taking active measures, by compiling information about when frazil blockage occurs, and by anticipating its occurrence, the problems caused by frazil blockage can be minimized.

Acknowledgments

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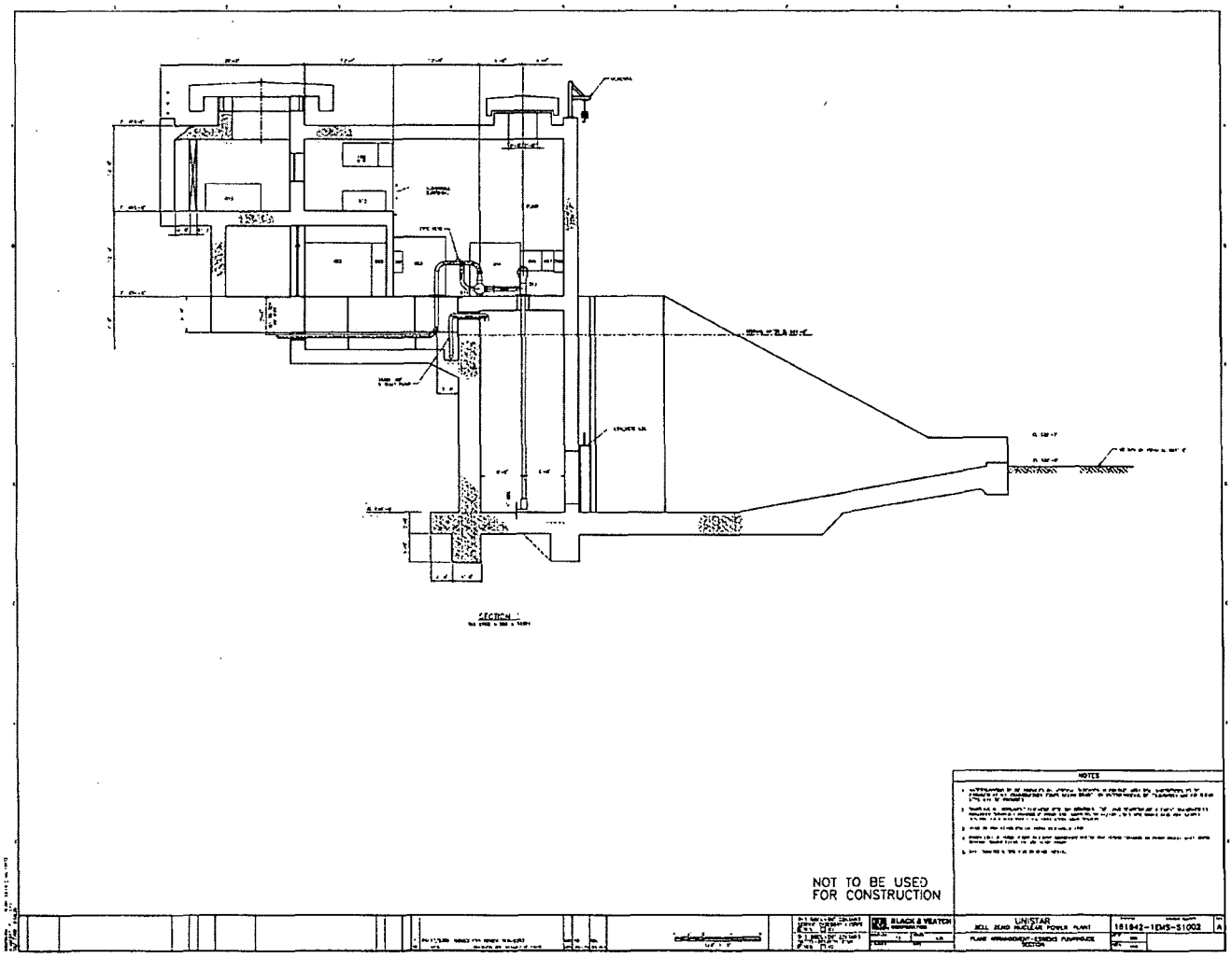
Paul C. Rizzo Associates, Inc.
CONSULTANTS

By GMS . Date 07/08/09. Subject Frazil Ice Analysis for BBNPP . ESWEMS Pond – Response to RAI # 25 . Sheet No. 19 of 66
Chkd. by FAM. Date 07-08-09.
Proj. No. 07-3891 .



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c. Linear wave theory.

(1) Introduction.

(a) The most elementary wave theory is the *small-amplitude* or *linear wave theory*. This theory, developed by Airy (1845), is easy to apply, and gives a reasonable approximation of wave characteristics for a wide range of wave parameters. A more complete theoretical description of waves may be obtained as the sum of many successive approximations, where each additional term in the series is a correction to preceding terms. For some situations, waves are better described by these higher-order theories, which are usually referred to as *finite-amplitude wave theories* (Mei 1991, Dean and Dalrymple 1991). Although there are limitations to its applicability, linear theory can still be useful provided the assumptions made in developing this simple theory are not grossly violated.

(b) The assumptions made in developing the linear wave theory are:

- The fluid is homogeneous and incompressible; therefore, the density ρ is a constant.
- Surface tension can be neglected.
- Coriolis effect due to the earth's rotation can be neglected.
- Pressure at the free surface is uniform and constant.
- The fluid is ideal or inviscid (lacks viscosity).
- The particular wave being considered does not interact with any other water motions. The flow is irrotational so that water particles do not rotate (only normal forces are important and shearing forces are negligible).
- The bed is a horizontal, fixed, impermeable boundary, which implies that the vertical velocity at the bed is zero.
- The wave amplitude is small and the waveform is invariant in time and space.
- Waves are plane or long-crested (two-dimensional).

(c) The first three assumptions are valid for virtually all coastal engineering problems. It is necessary to relax the fourth, fifth, and sixth assumptions for some specialized problems not considered in this manual. Relaxing the three final assumptions is essential in many problems, and is considered later in this chapter.

(d) The assumption of irrotationality stated as the sixth assumption above allows the use of a mathematical function termed the *velocity potential* Φ. The velocity potential is a scaler function whose gradient (i.e., the rate of change of Φ relative to the x-and z-coordinates in two dimensions where x = horizontal, z = vertical) at any point in fluid is the velocity vector. Thus,

$$u = \frac{\partial \Phi}{\partial x} \qquad \text{(II-1-1)}$$

is the fluid velocity in the x-direction, and

$$w = \frac{\partial \Phi}{\partial z} \qquad \text{(II-1-2)}$$

is the fluid velocity in the z-direction. Φ has the units of length squared divided by time. Consequently, if $\Phi(x, z, t)$ is known over the flow field, then fluid particle velocity components u and w can be found.

(e) The incompressible assumption (a) above implies that there is another mathematical function termed the *stream function* Ψ. Some wave theories are formulated in terms of the stream function Ψ, which is orthogonal to the potential function Φ. Lines of constant values of the potential function (equipotential lines) and lines of constant values of the stream function are mutually perpendicular or orthogonal. Consequently, if Φ is known, Ψ can be found, or vice versa, using the equations

$$\frac{\partial \Phi}{\partial x} = \frac{\partial \Psi}{\partial z} \tag{II-1-3}$$

$$\frac{\partial \Phi}{\partial z} = -\frac{\partial \Psi}{\partial x} \tag{II-1-4}$$

termed the *Cauchy-Riemann conditions* (Whitham 1974; Milne-Thompson 1976). Both Φ and Ψ satisfy the *Laplace equation* which governs the flow of an *ideal fluid* (inviscid and incompressible fluid). Thus, under the assumptions outlined above, the Laplace equation governs the flow beneath waves. The Laplace equation in two dimensions with x = horizontal, and z = vertical axes in terms of velocity potential Φ is given by

$$\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial z^2} = 0 \tag{II-1-5}$$

(f) In terms of the stream function, Ψ, Laplace's equation becomes

$$\frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial z^2} = 0 \tag{II-1-6}$$

(g) The linear theory formulation is usually developed in terms of the potential function, Φ.

In applying the seventh assumption to waves in water of varying depth (encountered when waves approach a beach), the local depth is usually used. This can be justified, but not without difficulty, for most practical cases in which the bottom slope is flatter than about 1 on 10. A progressive wave moving into shallow water will change its shape significantly. Effects due to the wave transformations are addressed in Parts II-3 and II-4.

(h) The most fundamental description of a simple sinusoidal oscillatory wave is by its length L (the horizontal distance between corresponding points on two successive waves), height H (the vertical distance to its crest from the preceding trough), period T (the time for two successive crests to pass a given point), and depth d (the distance from the bed to SWL).

(i) Figure II-1-1 shows a two-dimensional, simple progressive wave propagating in the positive x-direction, using the symbols presented above. The symbol η denotes the displacement of the water surface relative to the SWL and is a function of x and time t. At the wave crest, η is equal to the amplitude of the wave a, or one-half the wave height $H/2$.

(2) Wave celerity, length, and period.

(a) The speed at which a wave form propagates is termed the *phase velocity* or *wave celerity* C. Since the distance traveled by a wave during one wave period is equal to one wavelength, wave celerity can be related to the wave period and length by

$$C = \frac{L}{T} \tag{II-1-7}$$

(b) An expression relating wave celerity to wavelength and water depth is given by

$$C = \sqrt{\frac{gL}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)} \tag{II-1-8}$$

(c) Equation II-1-8 is termed the *dispersion relation* since it indicates that waves with different periods travel at different speeds. For a situation where more than one wave is present, the longer period wave will travel faster. From Equation II-1-7, it is seen that Equation II-1-8 can be written as

$$C = \frac{gT}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \tag{II-1-9}$$

(d) The values $2\pi/L$ and $2\pi/T$ are called the *wave number* k and the *wave angular frequency* ω, respectively. From Equation II-1-7 and II-1-9, an expression for wavelength as a function of depth and wave period may be obtained as

$$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) = \frac{gT}{\omega} \tanh(kd) \tag{II-1-10}$$

(e) Use of Equation II-1-10 involves some difficulty since the unknown L appears on both sides of the equation. Tabulated values of d/L and d/L_0 (SPM 1984) where L_0 is the deepwater wavelength may be used to simplify the solution of Equation II-1-10. Eckart (1952) gives an approximate expression for Equation II-1-10, which is correct to within about 10 percent. This expression is given by

$$L \approx \frac{gT^2}{2\pi} \sqrt{\tanh\left(\frac{4\pi^2}{T^2}\frac{d}{g}\right)} \tag{II-1-11}$$

(f) Equation II-1-11 explicitly gives L in terms of wave period T and is sufficiently accurate for many engineering calculations. The maximum error 10 percent occurs when $d/L \approx 1/2$. There are several other approximations for solving Equation II-1-10 (Hunt 1979; Venezian and Demirbilek 1979; Wu and Thornton 1986; Fenton and McKee 1990).

(g) Gravity waves may also be classified by the water depth in which they travel. The following classifications are made according to the magnitude of d/L and the resulting limiting values taken by the function $\tanh(2\pi d/L)$. Note that as the argument of the hyperbolic tangent $kd = 2\pi d/L$ gets large, the tanh (kd) approaches 1, and for small values of kd, tanh (kd) $\approx$ kd.

(h) Water waves are classified in Table II-1-1 based on the relative depth criterion d/L.

Table II-1-1
Classification of Water Waves

Classification	d/L	kd	tanh (kd)
Deep water	1/2 to ∞	π to ∞	≈1
Transitional	1/20 to 1/2	π/10 to π	tanh (kd)
Shallow water	0 to 1/20	0 to π/10	≈ kd

(i) In deep water, tanh (kd) approaches unity, Equations II-1-7 and II-1-8 reduce to

$$C_0 = \sqrt{\frac{gL_0}{2\pi}} = \frac{L_0}{T} \qquad \text{(II-1-12)}$$

and Equation II-1-9 becomes

$$C_0 = \frac{gT}{2\pi} \qquad \text{(II-1-13)}$$

(j) Although *deep water* actually occurs at an infinite depth, *tanh (kd)*, for most practical purposes, approaches unity at a much smaller d/L. For a relative depth of one-half (i.e., when the depth is one-half the wavelength), tanh $(2\pi d/L) = 0.9964$.

(k) When the relative depth d/L is greater than one-half, the wave characteristics are virtually independent of depth. Deepwater conditions are indicated by the subscript *0* as in L_o and C_o except that the period T remains constant and independent of depth for oscillatory waves, and therefore, the subscript for wave period is omitted (Ippen 1966). In the SI system (System International or metric system of units) where units of meters and seconds are used, the constant $g/2\pi$ is equal to 1.56 m/s^2, and

$$C_0 = \frac{gT}{2\pi} = \frac{9.8}{2\pi}T = 1.56T \ m/s \qquad \text{(II-1-14)}$$

and

$$L_0 = \frac{gT^2}{2\pi} = \frac{9.8}{2\pi}T^2 = 1.56T^2 \ m \qquad \text{(II-1-15)}$$

(l) If units of feet and seconds are specified, the constant $g/2\pi$ is equal to 5.12 ft/s^2, and

$$C_0 = \frac{gT}{2\pi} = 5.12T \ ft/s \qquad \text{(II-1-16)}$$

and

$$L_0 = \frac{gT^2}{2\pi} = 5.12T^2 \ ft \qquad \text{(II-1-17)}$$

(m) If Equations II-1-14 and II-1-15 are used to compute wave celerity when the relative depth is d/L = 0.25, the resulting error will be about 9 percent. It is evident that a relative depth of 0.5 is a satisfactory boundary separating deepwater waves from waves in water of *transitional depth*. If a wave is traveling in *transitional* depths, Equations II-1-8 and II-1-9 must be used without simplification. As a rule of thumb, Equation II-1-8 and II-1-9 must be used when the relative depth is between 0.5 and 0.04.

(n) When the relative water depth becomes shallow, i.e., $2\pi d/L < 1/4$ or $d/L < 1/25$, Equation II-1-8 can be simplified to

$$C = \sqrt{gd} \tag{II-1-18}$$

(o) Waves sufficiently long such that Equation II-1-18 may be applied are termed long waves. This relation is attributed to Lagrange. Thus, when a wave travels in shallow water, wave celerity depends only on water depth.

(p) In summary, as a wind wave passes from deep water to the beach its speed and length are first only a function of its period (or frequency); then as the depth becomes shallower relative to its length, the length and speed are dependent upon both depth and period; and finally the wave reaches a point where its length and speed are dependent only on depth (and not frequency).

(3) The sinusoidal wave profile. The equation describing the free surface as a function of time t and horizontal distance x for a simple sinusoidal wave can be shown to be

$$\eta = a \cos(kx - \omega t) = \frac{H}{2} \cos\left(\frac{2\pi x}{L} - \frac{2\pi t}{T}\right) = a \cos \theta \tag{II-1-19}$$

where η is the elevation of the water surface relative to the SWL, and $H/2$ is one-half the wave height equal to the wave amplitude a. This expression represents a periodic, sinusoidal, progressive wave traveling in the positive x-direction. For a wave moving in the negative x-direction, the minus sign before $2\pi t/T$ is replaced with a plus sign. When $\theta = (2\pi x/L - 2\pi t/T)$ equals 0, $\pi/2$, π, $3\pi/2$, the corresponding values of η are H/2, 0, -H/2, and 0, respectively (Figure II-1-1).

(4) Some useful functions.

(a) Dividing Equation II-1-9 by Equation II-1-13, and Equation II-1-10 by Equation II-1-15 yields,

$$\frac{C}{C_0} = \frac{L}{L_0} = \tanh\left(\frac{2\pi d}{L}\right) = \tanh kd \tag{II-1-20}$$

(b) If both sides of Equation II-1-20 are multiplied by d/L, it becomes

$$\frac{d}{L_0} = \frac{d}{L} \tanh\left(\frac{2\pi d}{L}\right) = \frac{d}{L} \tanh kd \tag{II-1-21}$$

(c) The terms d/L_o and d/L and other useful functions such as $kd = 2\pi d/L$ and $\tanh(kd)$ have been tabulated by Wiegel (1954) as a function of d/L_o (see also SPM 1984, Appendix C, Tables C-1 and C-2). These functions simplify the solution of wave problems described by the linear theory and are summarized in Figure II-1-5. An example problem illustrating the use of linear wave theory equations and the figures and tables mentioned follows.

EXAMPLE PROBLEM II-1-1

FIND:
The wave celerities C and lengths L corresponding to depths d = 200 meters (656 ft) and d = 3 m (9.8 ft).

GIVEN:
A wave with a period T = 10 seconds is propagated shoreward over a uniformly sloping shelf from a depth d = 200 m (656 ft) to a depth d = 3 m (9.8 ft).

SOLUTION:
Using Equation II-1-15,

$$L_0 = \frac{gT^2}{2\pi} = \frac{9.8\ T^2}{2\pi} = 1.56\ T^2\ m\ (5.12\ T^2\ ft)$$

$$L_0 = 1.56T^2 = 1.56(10)^2 = 156\ m\ (512\ ft)$$

For d = 200 m

$$\frac{d}{L_0} = \frac{200}{156} = 1.2821$$

Note that for values of

$$\frac{d}{L_0} > 1.0$$

$$\frac{d}{L_0} = \frac{d}{L}$$

therefore,

$$L = L_0 = 156\ m\ (512\ ft)\ (deepwater\ wave,\ since \frac{d}{L} > \frac{1}{2})$$

which is in agreement with Figure II-1-5.

By Equation II-1-7

$$C = \frac{L}{T} = \frac{156}{T}$$

$$C = \frac{156}{10} = 15.6\ m/s\ (51.2\ ft/s)$$

For d = 3 m

$$\frac{d}{L_0} = \frac{3}{156} = 0.0192$$

Example Problem II-1-1 (Continued)

EXAMPLE PROBLEM II-1-4

FIND:

The height of the wave H assuming that linear theory applies and the average frequency corresponds to the average wave amplitude.

GIVEN:

An average maximum pressure p = 124 kilonewtons per square meter is measured by a subsurface pressure gauge located in salt water 0.6 meter (1.97 ft) above the bed in depth d = 12 m (39 ft). The average frequency f = 0.06666 cycles per second (Hertz).

SOLUTION:

$$T = \frac{1}{f} = \frac{1}{(0.0666)} \approx 15\ s$$

$$L_0 = 1.56T^2 = 1.56(15)^2 = 351\ m\ (1152\ ft)$$

$$\frac{d}{L_0} = \frac{12}{351} \approx 0.0342$$

From Figure II-1-5, entering with d/L_o,

$$\frac{d}{L} = 0.07651$$

hence,

$$L = \frac{12}{(0.07651)} = 156.8\ m\ (515\ ft)$$

and

$$\cosh\left(\frac{2\pi d}{L}\right) = 1.1178$$

Therefore, from Equation II-1-43

$$K_s = \frac{\cosh\left[\frac{2\pi(z+d)}{L}\right]}{\cosh\left(\frac{2\pi d}{L}\right)} = \frac{\cosh\left[\frac{2\pi(-11.4+12)}{156.8}\right]}{1.1178} = 0.8949$$

Since $\eta = a = H/2$ when the pressure is maximum (under the wave crest), and N = 1.0 since linear theory is assumed valid,

$$\frac{H}{2} = \frac{N(p + \rho g z)}{\rho g K_s} = \frac{1.0\ [124 + (10.06)\ (-11.4)]}{(10.06)\ (0.8949)} = 1.04\ m\ (3.44\ ft)$$

Therefore,

$$H = 2(1.04) = 2.08\ m\ (6.3\ ft)$$

Note that the value of K in Figure II-1-5 or SPM (1984) could not be used since the pressure was not measured at the bottom.

Example Problem II-1-1 (Concluded)

By trial-and-error solution (Equation II-1-21) with d/L_o it is found that

$$\frac{d}{L} = 0.05641$$

hence

$$L = \frac{3}{0.05641} = 53.2\ m\ (174\ ft)\left(\text{transitional depth, since } \frac{1}{25} < \frac{d}{L} < \frac{1}{2}\right)$$

$$C = \frac{L}{T} = \frac{53.2}{10} = 5.32\ m/s\ (17.4\ ft/s)$$

An approximate value of L can also be found by using Equation II-1-11

$$L \approx \frac{gT^2}{2\pi}\sqrt{\tanh\left(\frac{4\pi^2}{T^2}\frac{d}{g}\right)}$$

which can be written in terms of L_o as

$$L \approx L_0\sqrt{\tanh\left(\frac{2\pi d}{L_0}\right)}$$

therefore

$$L \approx 156\sqrt{\tanh\left(\frac{2\pi(3)}{156}\right)}$$

$$L \approx 156\sqrt{\tanh(0.1208)}$$

$$L \approx 156\sqrt{0.1202} = 54.1\ m\ (177.5\ ft)$$

which compares with L = 53.3 m obtained using Equations II-1-8, II-1-9, or II-1-21. The error in this case is 1.5 percent. Note that Figure II-1-5 or Plate C-1 (SPM 1984) could also have been used to determine d/L.

(5) Local fluid velocities and accelerations.

(a) In wave force studies, the local fluid velocities and accelerations for various values of z and t during the passage of a wave must often be found. The horizontal component u and the vertical component w of the local fluid velocity are given by the following equations (with θ, x, and t as defined in Figure II-1-1):

$$u = \frac{H}{2}\frac{gT}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta \qquad \text{(II-1-22)}$$

$$w = \frac{H}{2}\frac{gT}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta \qquad \text{(II-1-23)}$$

(b) These equations express the local fluid velocity components any distance $(z + d)$ above the bottom. The velocities are periodic in both x and t. For a given value of the phase angle $\theta = (2\pi x/L - 2\pi t/T)$, the hyperbolic functions *cosh* and *sinh*, as functions of z result in an approximate exponential decay of the magnitude of velocity components with increasing distance below the free surface. The maximum positive horizontal velocity occurs when $\theta = 0, 2\pi$, etc., while the maximum horizontal velocity in the negative direction occurs when $\theta = \pi, 3\pi$, etc. On the other hand, the maximum positive vertical velocity occurs when $\theta = \pi/2, 5\pi/2$, etc., and the maximum vertical velocity in the negative direction occurs when $\theta = 3\pi/2, 7\pi/2$, etc. Fluid particle velocities under a wave train are shown in Figure II-1-2.

(c) The local fluid particle accelerations are obtained from Equations II-1-22 and II-1-23 by differentiating each equation with respect to t. Thus,

$$\alpha_x = \frac{g\pi H}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta = \frac{\partial u}{\partial t} \qquad \text{(II-1-24)}$$

$$\alpha_z = -\frac{g\pi H}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta = \frac{\partial w}{\partial t} \qquad \text{(II-1-25)}$$

(d) Positive and negative values of the horizontal and vertical fluid accelerations for various values of θ are shown in Figure II-1-2.

(e) Figure II-1-2, a sketch of the local fluid motion, indicates that the fluid under the crest moves in the direction of wave propagation and returns during passage of the trough. Linear theory does not predict any net mass transport; hence, the sketch shows only an oscillatory fluid motion. Figure II-1-3 depicts profiles of the surface elevation, particle velocities, and accelerations by the linear wave theory. The following problem illustrates the computations required to determine local fluid velocities and accelerations resulting from wave motions.

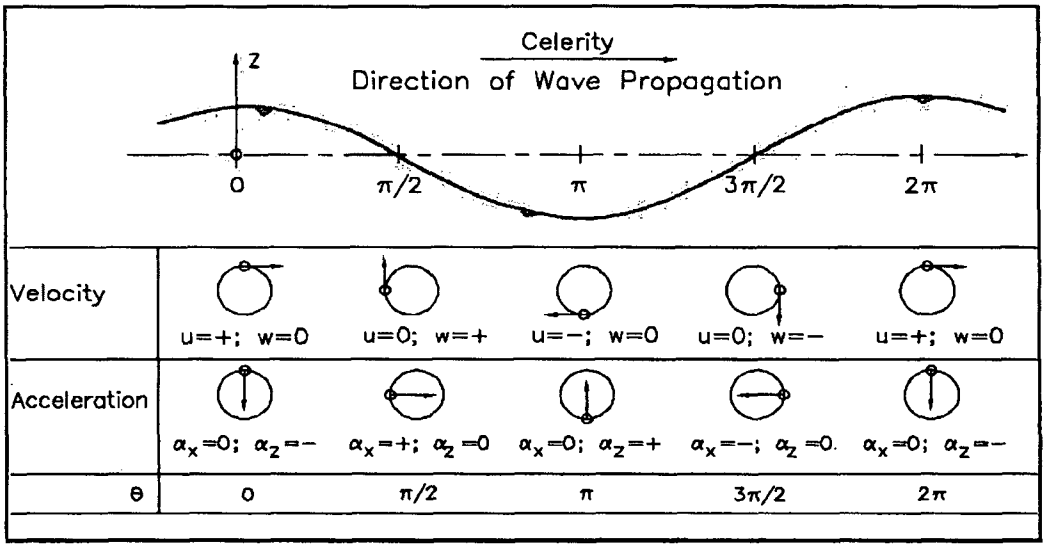

Figure II-1-2. Local fluid velocities and accelerations

(6) Water particle displacements.

(a) Another important aspect of linear wave theory deals with the displacement of individual water particles within the wave. Water particles generally move in elliptical paths in shallow or transitional depth water and in circular paths in deep water (Figure II-1-4). If the mean particle position is considered to be at the center of the ellipse or circle, then vertical particle displacement with respect to the mean position cannot exceed one-half the wave height. Thus, since the wave height is assumed to be small, the displacement of any fluid particle from its mean position must be small. Integration of Equations II-1-22 and II-1-23 gives the horizontal and vertical particle displacements from the mean position, respectively (Figure II-1-4).

(b) Fluid particle displacements are

$$\xi = -\frac{HgT^2}{4\pi L}\,\frac{\cosh\left(\dfrac{2\pi(z+d)}{L}\right)}{\cosh\left(\dfrac{2\pi d}{L}\right)}\,\sin\theta \qquad \text{(II-1-26)}$$

$$\zeta = +\frac{HgT^2}{4\pi L}\,\frac{\sinh\left(\dfrac{2\pi(z+d)}{L}\right)}{\cosh\left(\dfrac{2\pi d}{L}\right)}\,\cos\theta \qquad \text{(II-1-27)}$$

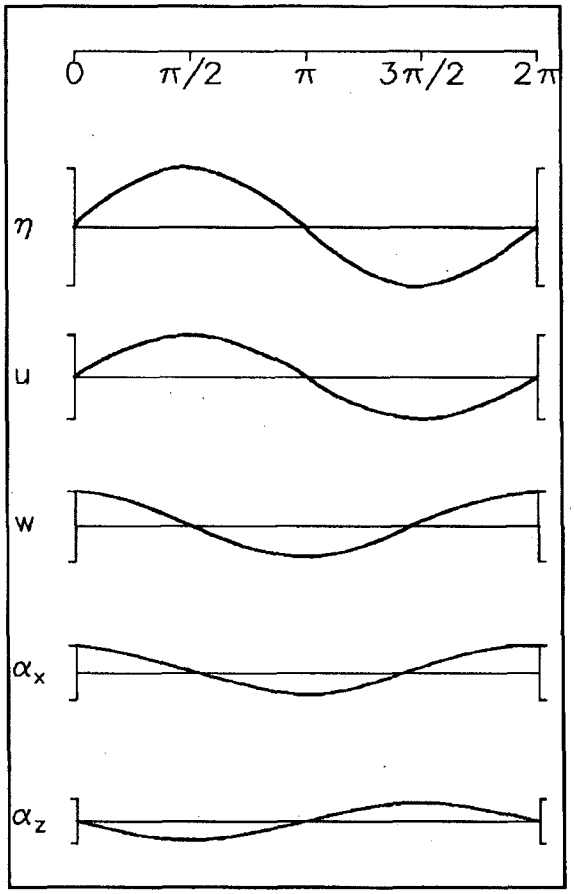

Figure II-1-3. Profiles of particle velocity and acceleration by Airy theory in relation to the surface elevation

where ξ is the horizontal displacement of the water particle from its mean position and ζ is the vertical displacement from its mean position (Figure II-1-4). The above equations can be simplified by using the relationship

$$\left(\frac{2\pi}{T}\right)^2 = \frac{2\pi g}{L} \tanh \frac{2\pi d}{L} \qquad \text{(II-1-28)}$$

EXAMPLE PROBLEM II-1-2

FIND:

The local horizontal and vertical velocities u and w, and accelerations α_x and α_z at an elevation $z = -5$ m (or $z = -16.4$ ft) below the SWL when $\theta = 2\pi x/L - 2\pi t/T = \pi/3$ (or 60°).

GIVEN:

A wave with a period $T = 8$ sec, in a water depth $d = 15$ m (49 ft), and a height $H = 5.5$ m (18.0 ft).

SOLUTION:

Calculate

$$L_0 = 1.56T^2 = 1.56(8)^2 = 99.8\ m\ (327\ ft)$$

$$\frac{d}{L_0} = \frac{15}{99.8} = 0.1503$$

By trial-and-error solution or using Figure II-1-5 for $d/L_0 = 0.1503$, we find

$$\frac{d}{L} = 0.1835$$

and

$$\cosh\frac{2\pi d}{L} = 1.742$$

hence

$$L = \frac{15}{0.1835} = 81.7\ m\ (268\ ft)$$

Evaluation of the constant terms in Equations II-1-22 to II-1-25 gives

$$\frac{HgT}{2L}\frac{1}{\cosh(2\pi d/L)} = \frac{5.5\ (9.8)(8)}{2\ (81.7)}\frac{1}{1.742} = 1.515$$

$$\frac{Hg\pi}{L}\frac{1}{\cosh(2\pi d/L)} = \frac{5.5\ (9.8)(3.1416)}{81.7}\frac{1}{1.742} = 1.190$$

Substitution into Equation II-1-22 gives

$$u = 1.515\ \cosh\left[\frac{2\pi(15 - 5)}{81.7}\right][\cos 60^0]$$

$$= 1.515\ [\cosh(0.7691)]\ (0.500)$$

Example Problem II-1-2 (Continued)

Example Problem II-1-2 (Concluded)

From the above known information, we find

$$\frac{2\pi d}{L} = 0.7691$$

and values of hyperbolic functions become

$$\cosh(0.7691) = 1.3106$$

and

$$\sinh(0.7691) = 0.8472$$

Therefore, fluid particle velocities are

$$u = 1.515(1.1306)(0.500) = 0.99\ m/s\ (3.26\ ft/s)$$

$$w = 1.515(0.8472)(0.866) = 1.11\ m/s\ (3.65\ ft/s)$$

and fluid particle accelerations are

$$\alpha_x = 1.190(1.3106)(0.866) = 1.35\ m/s^2\ (4.43\ ft/s^2)$$

$$\alpha_z = -1.190(0.8472)(0.500) = -0.50\ m/s^2\ (1.65\ ft/s^2)$$

(c) Thus,

$$\xi = -\frac{H}{2}\frac{\cosh\left(\frac{2\pi(z+d)}{L}\right)}{\sinh\left(\frac{2\pi d}{L}\right)}\sin\theta \qquad \text{(II-1-29)}$$

$$\zeta = +\frac{H}{2}\frac{\sinh\left(\frac{2\pi(z+d)}{L}\right)}{\sinh\left(\frac{2\pi d}{L}\right)}\cos\theta \qquad \text{(II-1-30)}$$

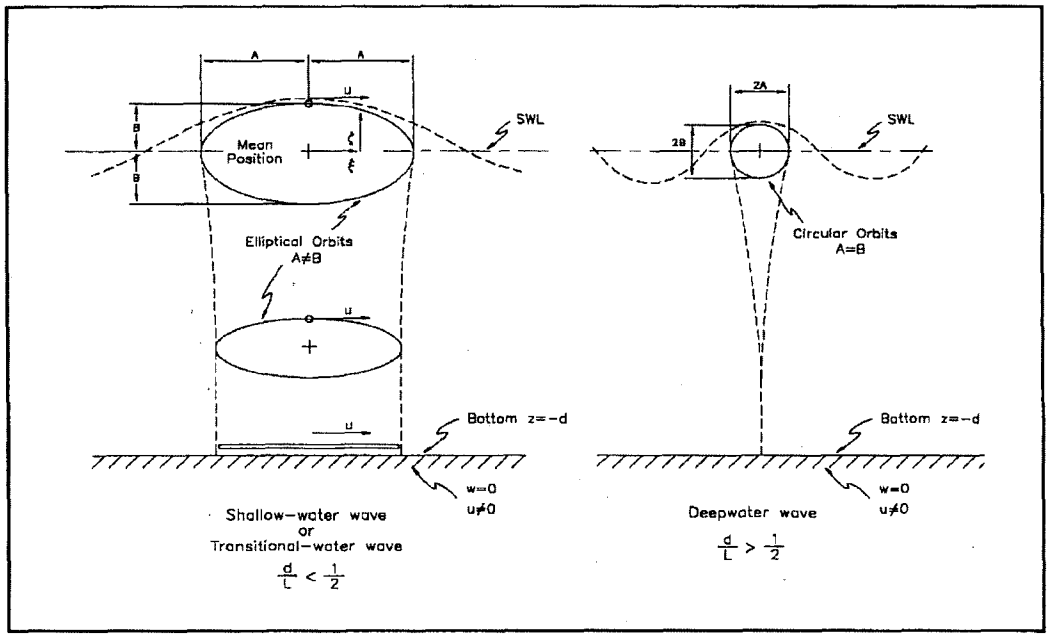

Figure II-1-4. Water particle displacements from mean position for shallow-water and deepwater waves

(d) Writing Equations II-1-29 and II-1-30 in the forms,

$$\sin^2\theta = \left[\frac{\xi}{a}\,\frac{\sinh\left(\dfrac{2\pi d}{L}\right)}{\cosh\left(\dfrac{2\pi(z+d)}{L}\right)}\right]^2 \qquad \text{(II-1-31)}$$

$$\cos^2\theta = \left[\frac{\zeta}{a}\,\frac{\sinh\left(\dfrac{2\pi d}{L}\right)}{\sinh\left(\dfrac{2\pi(z+d)}{L}\right)}\right]^2 \qquad \text{(II-1-32)}$$

and adding gives

$$\frac{\xi^2}{A^2} + \frac{\zeta^2}{B^2} = 1 \qquad \text{(II-1-33)}$$

in which A and B are

$$A = \frac{H}{2} \frac{\cosh\left(\frac{2\pi(z + d)}{L}\right)}{\sinh\left(\frac{2\pi d}{L}\right)} \tag{II-1-34}$$

$$B = \frac{H}{2} \frac{\sinh\left(\frac{2\pi(z + d)}{L}\right)}{\sinh\left(\frac{2\pi d}{L}\right)} \tag{II-1-35}$$

(e) Equation II-1-33 is the equation of an ellipse with a major- (horizontal) semi-axis equal to A and a minor (vertical) semi-axis equal to B. The lengths of A and B are measures of the horizontal and vertical displacements of the water particles (see Figure II-1-4). Thus, the water particles are predicted to move in closed orbits by linear wave theory; i.e., a fluid particle returns to its initial position after each wave cycle. Comparing laboratory measurements of particle orbits with this theory shows that particle orbits are not completely closed. This difference between linear theory and observations is due to the mass transport phenomenon, which is discussed later in this chapter. It shows that linear theory is inadequate to explain wave motion completely.

(f) Examination of Equations II-1-34 and II-1-35 shows that for deepwater conditions, A and B are equal and particle paths are circular (Figure II-1-4). These equations become

$$A = B = \frac{H}{2} e^{\left(\frac{2\pi z}{L}\right)} \quad \text{for } \frac{d}{L} > \frac{1}{2} \text{ (i.e., deepwater limit)} \tag{II-1-36}$$

(g) For shallow-water conditions (d/L < 1/25), the equations become

$$A = \frac{H}{2} \frac{L}{2\pi d} \tag{II-1-37}$$

and

$$B = \frac{H}{2}\left(1 + \frac{z}{d}\right) \tag{II-1-38}$$

EXAMPLE PROBLEM II-1-3

FIND:

(a) The maximum horizontal and vertical displacement of a water particle from its mean position when z = 0 and z = -d.

(b) The maximum water particle displacement at an elevation z = -7.5 m (-24.6 ft) when the wave is in infinitely deep water.

(c) For the deepwater conditions of (b) above, show that the particle displacements are small relative to the wave height when $z = -L_0/2$.

GIVEN:

A wave in a depth d = 12 m (39.4 ft), height H = 3 m (9.8 ft), and a period T = 10 sec. The corresponding deepwater wave height is H_o = 3.13 m (10.27 ft).

SOLUTION:

(a)

$$L_0 = 1.56T^2 = 1.56(10)^2 = 156\ m\ (512\ ft)$$

$$\frac{d}{L_0} = \frac{12}{156} = 0.0769$$

From hand calculators, we find

$$\sinh\left(\frac{2\pi d}{L}\right) = 0.8306$$

$$\tanh\left(\frac{2\pi d}{L}\right) = 0.6389$$

When z = 0, Equation II-1-34 reduces to

$$A = \frac{H}{2}\frac{1}{\tanh\left(\frac{2\pi d}{L}\right)}$$

and Equation II-1-35 reduces to

$$B = \frac{H}{2}$$

Thus

$$A = \frac{3}{2}\frac{1}{(0.6389)} = 2.35\ m\ (7.70\ ft)$$

$$B = \frac{H}{2} = \frac{3}{2} = 1.5\ m\ (4.92\ ft)$$

Example Problem II-1-3 (Continued)

Example Problem II-1-3 (Concluded)

When $z = -d$,

$$A = \frac{H}{2\sinh\left(\frac{2\pi d}{L}\right)} = \frac{3}{2(0.8306)} = 1.81\ m\ (5.92\ ft)$$

and $B = 0$.

(b) With $H_0 = 3.13$ m and $z = -7.5$ m (-24.6 ft), evaluate the exponent of e for use in Equation II-1-36, noting that $L = L_0$.

$$\frac{2\pi z}{L} = \frac{2\pi(-7.5)}{156} = -0.302$$

thus,

$$e^{-0.302} = 0.739$$

Therefore,

$$A = B = \frac{H_0}{2} e^{\left(\frac{2\pi z}{L}\right)} = \frac{3.13}{2}(0.739) = 1.16\ m\ (3.79\ ft)$$

The maximum displacement or diameter of the orbit circle would be 2(1.16) = 2.32 m (7.61 ft) when $z = -7.5$ m.

(c) At a depth corresponding to the half wavelength from the MWL, we have

$$z = -\frac{L_0}{2} = \frac{-156}{2} = -78.0\ m\ (255.9\ ft)$$

$$\frac{2\pi z}{L} = \frac{2\pi(-78)}{156} = -3.142$$

Therefore

$$e^{-3.142} = 0.043$$

and

$$A = B = \frac{H_0}{2} e^{\left(\frac{2\pi z}{L}\right)} = \frac{3.13}{2}(0.043) = 0.067\ m\ (0.221\ ft)$$

Thus, the maximum displacement of the particle is 0.067 m, which is small when compared with the deepwater height, $H_0 = 3.13$ m (10.45 ft).

(h) Thus, in deep water, the water particle orbits are circular as indicated by Equation II-1-36 (see Figure II-1-4). Equations II-1-37 and II-1-38 show that in transitional and shallow water, the orbits are elliptical. The more shallow the water, the flatter the ellipse. The amplitude of the water particle displacement decreases exponentially with depth and in deepwater regions becomes small relative to the wave height at a depth equal to one-half the wavelength below the free surface; i.e., when $z = L_0/2$.

(i) Water particle displacements and orbits based on linear theory are illustrated in Figure II-1-4. For shallow regions, horizontal particle displacement near the bottom can be large. In fact, this is apparent in offshore regions seaward of the breaker zone where wave action and turbulence lift bottom sediments into suspension. The vertical displacement of water particles varies from a minimum of zero at the bottom to a maximum equal to one-half the wave height at the surface.

(7) Subsurface pressure.

(a) Subsurface pressure under a wave is the sum of two contributing components, dynamic and static pressures, and is given by

$$p' = \frac{\rho g H \cosh\left[\frac{2\pi(z+d)}{L}\right]}{2\cosh\left(\frac{2\pi d}{L}\right)} \cos\theta - \rho g z + p_a \qquad \text{(II-1-39)}$$

where p' is the total or absolute pressure, p_a is the atmospheric pressure, and ρ is the mass density of water (for salt water, $\rho = 1{,}025$ kg/m^3 or 2.0 slugs/ft^3, for fresh water, $\rho = 1{,}000$ kg/m^3 or 1.94 slugs/ft^3). The first term of Equation II-1-39 represents a dynamic component due to acceleration, while the second term is the static component of pressure. For convenience, the pressure is usually taken as the gauge pressure defined as

$$p = p' - p_a = \frac{\rho g H \cosh\left[\frac{2\pi(z+d)}{L}\right]}{2\cosh\left(\frac{2\pi d}{L}\right)} \cos\theta - \rho g z \qquad \text{(II-1-40)}$$

(b) Equation II-1-40 can be written as

$$p = \rho g \eta \frac{\cosh\left[\frac{2\pi(z+d)}{L}\right]}{\cosh\left(\frac{2\pi d}{L}\right)} - \rho g z \qquad \text{(II-1-41)}$$

since

$$\eta = \frac{H}{2}\cos\left(\frac{2\pi x}{L} - \frac{2\pi t}{T}\right) = \frac{H}{2}\cos\theta \qquad \text{(II-1-42)}$$

(c) The ratio

$$K_z = \frac{\cosh\left[\frac{2\pi(z + d)}{L}\right]}{\cosh\left(\frac{2\pi d}{L}\right)} \tag{II-1-43}$$

is termed *the pressure response factor*. Hence, Equation II-1-41 can be written as

$$p = \rho g(\eta K_z - z) \tag{II-1-44}$$

(d) The pressure response factor K for the pressure at the bottom when $z = -d$,

$$K_z = K = \frac{1}{\cosh\left(\frac{2\pi d}{L}\right)} \tag{II-1-45}$$

is presented as function of d/L_0 in the tables (SPM 1984); see also Figure II-1-5. This figure is a convenient graphic means to determine intermediate and shallow-water values of the bottom pressure response factor K, the ratio C/C_0 ($=L/L_0 = k_0/k$), and a number of other variables commonly occurring in water wave calculations.

(e) It is often necessary to determine the height of surface waves based on subsurface measurements of pressure. For this purpose, it is convenient to rewrite Equation II-1-44 as

$$\eta = \frac{N(p + \rho g z)}{\rho g K_z} \tag{II-1-46}$$

where z is the depth below the SWL of the pressure gauge, and N a correction factor equal to unity if the linear theory applies.

(f) Chakrabarti (1987) presents measurements that correlate measured dynamic pressure in the water column (s in his notation is the elevation above the seabed) with linear wave theory. These laboratory measurements include a number of water depths, wave periods, and wave heights. The best agreement between the theory and these measurements occurs in deep water. Shallow-water pressure measurements for steep water waves deviate significantly from the linear wave theory predictions. The example problem hereafter illustrates the use of pertinent equations for finding wave heights from pressure measurements based on linear theory.

(8) Group velocity.

(a) It is desirable to know how fast wave energy is moving. One way to determine this is to look at the speed of wave groups that represents propagation of wave energy in space and time. The speed a group of

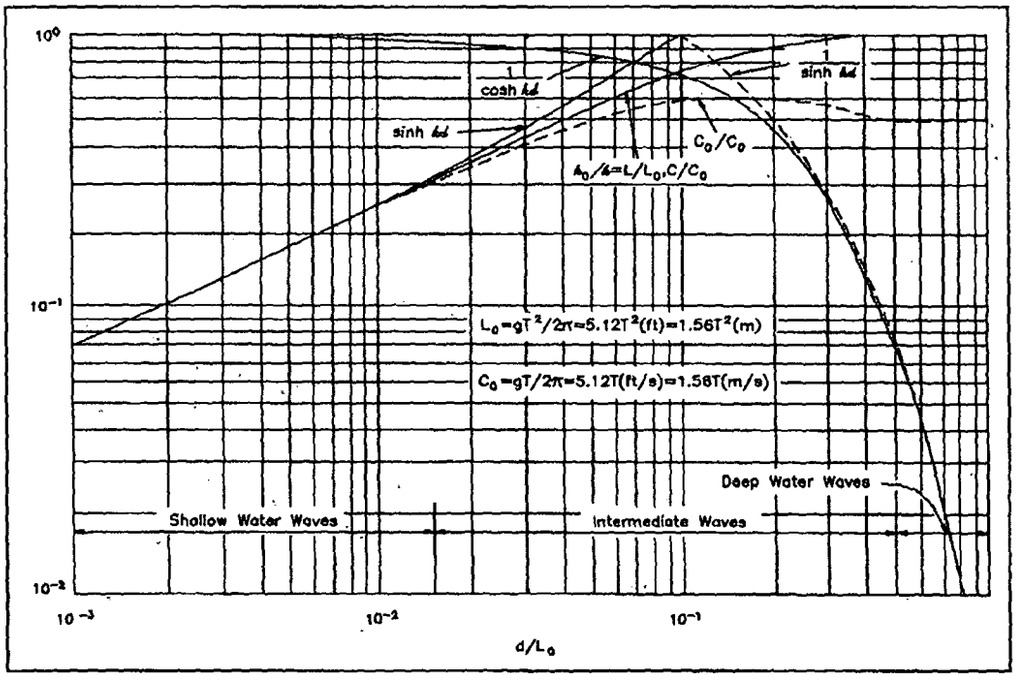

Figure II-1-5. Variation of wave parameters with d/L_0 (Dean and Dalrymple 1991)

waves or a wave train travels is generally not identical to the speed with which individual waves within the group travel. The group speed is termed the *group velocity* C_g; the individual wave speed is the *phase velocity* or *wave celerity* given by Equations II-1-8 or II-1-9. For waves propagating in deep or transitional water with gravity as the primary restoring force, the group velocity will be less than the phase velocity. For those waves, propagated primarily under the influence of surface tension (i.e., capillary waves), the group velocity may exceed the velocity of an individual wave.

(b) The concept of group velocity can be described by considering the interaction of two sinusoidal wave trains moving in the same direction with slightly different wavelengths and periods. The equation of the water surface is given by

$$\eta = \eta_1 + \eta_2 = \frac{H}{2}\cos\left(\frac{2\pi x}{L_1} - \frac{2\pi t}{T_1}\right) + \frac{H}{2}\cos\left(\frac{2\pi x}{L_2} - \frac{2\pi t}{T_2}\right) \qquad \text{(II-1-47)}$$

where η_1 and η_2 are the two components. They may be summed since superposition of solutions is permissible when the linear wave theory is used. For simplicity, the heights of both wave components have been assumed equal. Since the wavelengths of the two component waves, L_1 and L_2, have been assumed slightly different for some values of x at a given time, the two components will be in phase and the wave height observed will be 2H; for some other values of x, the two waves will be completely out of phase and

II-2-2. Wave Hindcasting and Forecasting

a. Introduction.

(1) The theory of wave generation has had a long and rich history. Beginning with some of the classic works of Kelvin (1887) and Helmholtz (1888) in the 1800's, many scientists, engineers, and mathematicians have addressed various forms of water wave motions and interactions with the wind. In the early 1900's, the work of Jeffreys (1924, 1925) hypothesized that waves created a "sheltering effect" and hence created a positive feedback mechanism for transfer of momentum into the wave field from the wind. However, it was not until World War II that organized wave predictions began in earnest. During the 1940's, large bodies of wave observations were collated and the bases for empirical wave predictions were formulated. Sverdrup and Munk (1947, 1951) presented the first documented relationships among various wave-generation parameters and resulting wave conditions. Bretschneider (1952) revised these relationships based on additional evidence; methods derived from these exemplary pioneer works are still in active use today.

(2) The basic tenet of the empirical prediction method is that interrelationships among dimensionless wave parameters will be governed by universal laws. Perhaps the most fundamental of these laws is the fetch-growth law. Given a constant wind speed and direction over a fixed fetch, it is expected that waves will reach a stationary fetch-limited state of development. In this situation, wave heights will remain constant (in a statistical sense) through time but will vary along the fetch. If dimensionless wave height is taken as

$$\hat{H} = \frac{gH}{u_*^2} \qquad \text{(II-2-22)}$$

where

H = characteristic wave height, originally taken as the significant wave height but more recently taken as the energy-based wave height H_{m0}

u_* = friction velocity

and dimensionless fetch is defined as

$$\hat{X} = \frac{gX}{u_*^2} \qquad \text{(II-2-23)}$$

where

X = straight line distance over which the wind blows

then idealized, fetch-limited wave heights are expected to follow a relationship of the form

$$\hat{H} = \lambda_1 \hat{X}^{m_1} \qquad \text{(II-2-24)}$$

where

λ_1 = dimensionless coefficient

m_1 = dimensionless exponent

(3) If dimensionless wave frequency (defined simply as one over the spectral peak wave period) defined as

$$\hat{f}_p = \frac{u_* f_p}{g} \qquad \text{(II-2-25)}$$

where

f_p = frequency of the spectral peak

then a stationary wave field also implies a fixed relationship between wave frequency and fetch of the form

$$\hat{f}_p = \lambda_2 \hat{X}^{m_2} \qquad \text{(II-2-26)}$$

where

λ_2 and m_2 are more empirical coefficients.

(4) Since u_* scales the effective rate of momentum transfer from the atmosphere into the waves, all empirical coefficients in these wave generation laws are expected to be universal values. Unfortunately, there is still some ambiguity in these values; however, in lieu of any demonstrated improvements over values from the *Shore Protection Manual* (1984), those values for fetch-limited wave growth will be adopted here.

(5) From basic conservation laws and the dispersion relationship, it is anticipated that any law governing the rate of growth of waves along a fetch will also form a unique constraint on the rate of growth of waves through time. If we define dimensionless time as

$$\hat{t} = \frac{g\,t}{u_*} \qquad \text{(II-2-27)}$$

where

t = time

additional relationships governing the duration-growth of waves will be

$$\hat{H} = \lambda_3 \hat{t}^{m_3} \qquad \text{(II-2-28)}$$

and

$$\hat{f}_p = \lambda_4 \hat{t}^{m_4} \qquad \text{(II-2-29)}$$

where

λ_4 and m_4 are more "universal" coefficients to be determined empirically.

(6) The form of Equations II-2-26 and II-2-27 imply that waves will continue to grow as long as fetch and time continue to increase. This concept was observed to be incorrect in the early compendiums of data

(Sverdrup and Munk 1947, Bretschneider 1952), which suggested that a "fully developed" wave height would evolve under the action of the wind. Available data indicated that this fully developed wave height could be represented as

$$H_\infty = \frac{\lambda_5 u^2}{g} \qquad \text{(II-2-30)}$$

where

H_∞ = fully developed wave height

λ_5 =dimensionless coefficient (approximately equal to 0.27)

u = wind speed

Wave heights defined by Equation II-2-30 are usually taken as representing an upper limit to wave growth for any wind speed.

(7) In the 1950's, researchers began to recognize that the wave generation process was best described as a spectral phenomenon (e.g. Pierson, Neumann, and James (1955)). Theoreticians then began to reexamine their ideas on the wave-generation process, with regard to how a turbulent wind field could interact with a random sea surface. Following along these lines, Phillips (1958) and Miles (1957) advanced two theories that formed the cornerstone of the understanding of wave generation physics for many years. Phillips' concept involved the resonant interactions of turbulent pressure fluctuations with waves propagating at the same speed. Miles' concept centered on the mean flux of momentum from a "matched layer" above the wave field into waves travelling at the same speed. Phillips' theory predicted linear wave growth and was believed to control the early stages of wave growth. Miles' theory predicted an exponential growth and was believed to control the major portion of wave growth observed in nature. Direct measurements of the Phillips' resonance mechanism indicated that the measured turbulent fluctuations were too small by about an order of magnitude to explain the observed early growth in waves; however, it was still adopted as a plausible concept. Subsequent field efforts by Snyder and Cox (1966) and Snyder et al. (1981) have supported at least the functional form of Miles' theory for the transfer of energy into the wave field from winds.

(8) From basic concepts of energy conservation and the fact that waves do attain limiting fully developed wave heights, it is obvious that wave generation physics cannot consist of only wind source terms. There must be some physical mechanism or mechanisms that leads to a balance of wave growth and dissipation for the case of fully developed conditions. Phillips (1958) postulated that one such mechanism in waves would be wave breaking. Based on dimensional considerations and the knowledge that wave breaking has a very strong local effect on waves, Phillips argued that energy densities within a spectrum would always have a universal limiting value given by

$$E(f) = \frac{\alpha\, g^2 f^{-5}}{(2\pi)^4} \qquad \text{(II-2-31)}$$

where E(f) is the spectral energy density in units of length squared per hertz and α was understood to be a universal (dimensionless) constant approximately equal to 0.0081. It should be noted here that energy densities in this equation are proportional to f^{-5} (as can be deduced from dimensional arguments) and that they are independent of wind speed. Phillips hypothesized that local wave breaking would be so strong that wind effects could not affect this universal level. In this context, a saturated region of spectral energy densities is assumed to exist in some region from near the spectral peak to frequencies sufficiently high that viscous

effects would begin to be significant. This region of saturated energy densities is termed the equilibrium range of the spectrum.

(9) Kitaigorodskii (1962) extended the similarity arguments of Phillips to distinct regions throughout the entire spectrum where different mechanisms might be of dominant importance. Pierson and Moskowitz (1964) followed the dimensional arguments of Phillips and supplemented these arguments, with relationships derived from measurements at sea. They extended the form of Phillips spectrum to the classical Pierson-Moskowitz spectrum

$$E(f) = \frac{\alpha\, g^2 f^{-5}}{(2\pi)^4} \exp\left[-0.74\left(\frac{f}{f_u}\right)^{-4}\right] \qquad \text{(II-2-32)}$$

where

f_u = limiting frequency for a fully developed wave spectrum (assumed to be a function only of wind speed)

(10) Based on these concepts of spectral wave growth due to wind inputs via Miles-Phillips mechanisms and a universal limiting form for spectral densities, first-generation (1G) wave models in the United States were born (Inoue 1967, Bunting 1970). It should be pointed out here that the first model of this type was actually developed in France (Gelci, Cazale, and Vassel 1957); however, that model did not incorporate the limiting Pierson-Moskowitz spectral form as did models in the United States. In these models, it was recognized that waves in nature are not only made up of an infinite (continuous) sum of infinitesimal wave components at different frequencies but that each frequency component is made up of an infinite (continuous) sum of wave components travelling in different directions. Thus, when waves travel outward from a storm, a single "wave train" moving in one direction does not emerge. Instead, directional wave spectra spread out in different directions and disperse due to differing group velocities associated with different frequencies. This behavior cannot be modeled properly in parametric (significant wave height) models and understanding of this behavior formed the basic motivation to model all wave components in a spectrum individually. The term discrete-spectral model has since been employed to describe models that include calculations of each separate (frequency-direction) wave component. The equation governing the energy balance in such models is sometimes termed the radiative transfer equation and can be written as

$$\frac{\partial E(f,\theta,x,y,t)}{\partial t} = -c_G\, \vec{\nabla} E(f,\theta,x,y,t) + \sum_{k=1}^{K} S(f,\theta,x,y,t)_k \qquad \text{(II-2-33)}$$

where

$E(f,\theta,x,y,t)$ = spectral energy density as a function of frequency (f), propagation direction (θ), two horizontal spatial coordinates (x and y) and time (t)

$S(f,\theta,x,y,t)_k$ = the kth source term, which exists in the same five dimensions as the energy density

The first term on the right side of this equation represents the effects of wave propagation on the wave field. The second term represents the effects of all processes that add energy to or remove energy from a particular frequency and direction component at a fixed point at a given time.

(11) In the late 1960's evidence of spectral behavior began to emerge which suggested that the equilibrium range in wave spectra did not have a universal value for α. Instead, it was observed that α varied

as a function of nondimensional fetch (Mitsuyasu 1968). This presented a problem to the "first-generation" interpretation of wave generation physics, since it implied that energies within the equilibrium range are not controlled by wave breaking. Fortunately, a theoretical foundation already existed to help explain this discrepancy. This foundation had been established in 1961 in an exceptional theoretical formulation by Klaus Hasselmann in Germany. In this formulation, Hasselmann, using relatively minimal assumptions, showed that waves in nature should interact with each other in such a way as to spread energy throughout a spectrum. This theory of wave-wave interactions predicted that energy near the spectral peak region should be spread to regions on either side of the spectral peak.

(12) Hasselmann et al. (1973) collected an extensive data set in the Joint North Sea Wave Project (JONSWAP). Careful analysis of these data confirmed the earlier findings of Mitsuyasu and revealed a clear relationship between Phillips' α and nondimensional fetch (Figure II-2-21). This finding and certain other spectral phenomena, such as the tendency of wave spectra to be more peaked than the Pierson-Moskowitz spectrum during active generation, could not be explained in terms of "first-generation" concepts; however, they could be explained in terms of a nonlinear interaction among wave components. This pointed out the necessity of incorporating wave-wave interactions into wave prediction models, and led to the development of second-generation (2G) wave models. The modified spectral shape which came out of the JONSWAP experiment has come to bear the name of that experiment; hence we now have the JONSWAP spectrum, which can be written as

$$E(f) = \frac{\alpha g^2}{(2\pi)^4 f^5} \exp\left[-1.25\left(\frac{f}{f_p}\right)^{-4}\right]\gamma^{\exp\left[-\frac{\left(\frac{f}{f_p}-1\right)^2}{2\sigma^2}\right]} \qquad \text{(II-2-34)}$$

where

α = equilibrium coefficient

σ = dimensionless spectral width parameter, with value σ_a for $f<f_p$ and value σ_b for $f \geq f_p$

γ = peakedness parameter

The average values of the σ and γ parameters in the JONSWAP data set were found to be $\gamma = 3.3$, $\sigma_a = 0.07$, and $\sigma_b = 0.09$. Figure II-2-22 compares this spectrum to the Pierson-Moskowitz spectrum.

(13) Early second-generation models (Barnett 1968, Resio 1981) followed an f^{-5} equilibrium-range formulation since prior research had been formulated with that spectral form. Toba (1978) was the first researcher to present data suggesting that the equilibrium range in spectra might be better fit by an f^{-4} dependence. Following his work, Forristall et al. (1978); Kahma (1981); and Donelan, Hamilton, and Hui (1982) all presented evidence from independent field measurements supporting the tendency of equilibrium ranges to follow an f^{-4} dependence. Kitaigorodskii (1983); Resio (1987,1988); and Resio and Perrie (1989) have all presented theoretical analyses showing how this behavior can be explained by the nature of nonlinear fluxes of energy through a spectrum. Subsequently, Resio and Perrie (1989) determined that, although certain spectral growth characteristics were somewhat different between the f^{-4} and f^{-5} formulations,

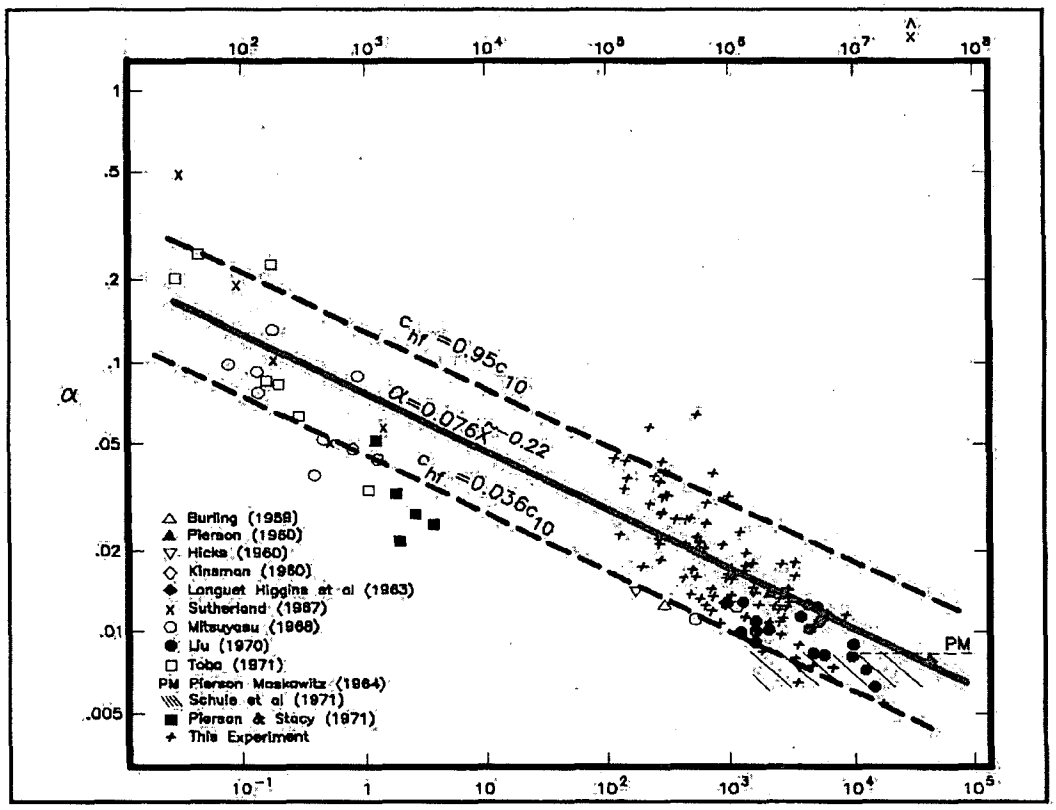

Figure II-2-21. Phillips' constant versus fetch scaled according to Kitaigorodskii. Small-fetch data are obtained from wind-wave tanks. Capillary-wave data were excluded where possible (Hasselmann et al. 1973)

the basic energy-growth equations were quite similar for the two formulations. The f^4 formulation is incorporated into CERC's WAVAD model, used in its hindcast studies.

(14) Since the early 1980's, a new class of wave model has come into existence (Hasselmann et al. 1985). This new class of wave model has been termed a third-generation wave model (3G). The distinction between second-generation and third-generation wave models is the method of solution used in these models. Second-generation wave models combine relatively broad-scale parameterizations of the nonlinear wave-wave interaction source term combined with constraints on the overall spectral shape to simulate wave growth. Third-generation models use a more detailed parameterization of the nonlinear wave-wave interaction source terms and relax most of the constraints on spectral shape in simulating wave growth. Various third-generation models are used around the world today; however, the third-generation model is probably the WAM model.

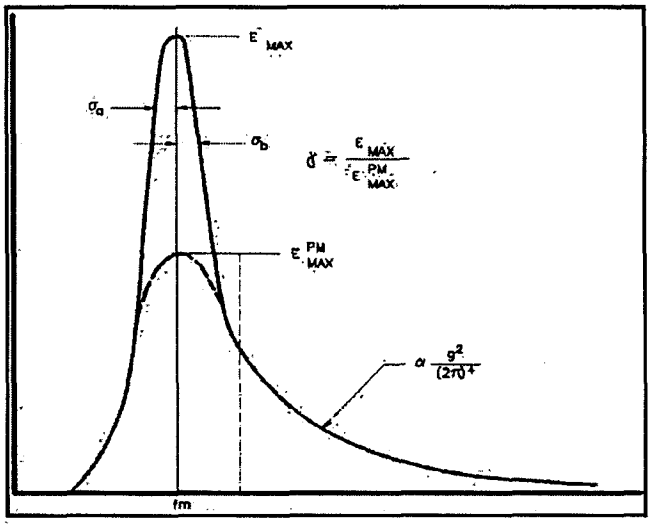

Figure II-2-22. Definition of JONSWAP parameters for spectral shape

(15) Part of the motivation to use third-generation models is related to the hope that future simulations of directional spectra can be made more accurate via the direct solution of the detailed source-term balance. This is expected to be particularly important in complex wave generation scenarios where second-generation models might not be able to handle the general source term balance. However, recent research by Van Vledder and Holthuisen (1993) has demonstrated rather convincingly that the "detailed balance" equations in the WAM (WAMDI Group 1988) model at this time still cannot accurately simulate waves in rapidly turning winds. Hence, there remains much work to be done in this area before the performance of third-generation models can be considered totally satisfactory.

(16) First-generation models that have been modified to allow the Phillips equilibrium coefficient to vary dynamically (Cardone 1992), second-generation models (Resio 1981, NORSWAM, Hubertz 1992), and third-generation models (Hasselmann et al. 1985) have all been shown to produce very good predictions and hindcasts of wave conditions for a wide range of meteorological situations. These models are recommended in developing wave conditions for design and planning situations having serious economic or safety implications, and should be properly verified with local wave data, wherever feasible. This is not meant to imply that wave models can supplant wave measurements, but rather that in most circumstances, these models should be used instead of parametric models.

b. Wave prediction in simple situations. In some situations it is desirable to estimate wave conditions for preliminary considerations in project designs or even for final design in cases where total project costs are minimal. In the past, nomograms have played an important role in providing such wave information. However, with today's proliferation of user-friendly computer software such as the ACES Program, reliance on nomograms is discouraged. ACES will assist a user in his or her calculations, will facilitate most applications, and will help avoid most potential pitfalls related to misuse of wave prediction schemes. In spite of this warning and advice to use ACES, conventional prediction methods will be discussed here in order to provide such information for appropriate applications.

(1) Assumptions in simplified wave predictions.

(a) Deep water. There are three situations in which simplified wave predictions can provide accurate estimates of wave conditions. The first of these occurs when a wind blows, with essentially constant direction, over a fetch for sufficient time to achieve steady-state, fetch-limited values. The second idealized situation occurs when a wind increases very quickly through time in an area removed from any close boundaries. In this situation, the wave growth can be termed duration-limited. It should be recognized that this condition is rarely met in nature; consequently, this prediction technique should only be used with great caution. Open-ocean winds rarely can be categorized in such a manner to permit a simple duration-growth scenario. The third situation that may be treated via simplified prediction methods is that of a fully developed wave height. Knowledge of the fully developed wave height can provide valuable upper limits for some design considerations; however, open-ocean waves rarely attain a limiting wave height for wind speeds above 50 knots or so. Equation II-2-30 provides an easy means to estimate this limiting wave height.

(b) Wave growth with fetch. In this section, SI units should be used in formulas and figures. Figure II-2-3 shows the time required to accomplish fetch-limited wave development for short fetches. The general equation for this can be derived by combining the JONSWAP growth law for peak frequency, an equation for the fully developed frequency, and the assumption that a local wave field propagates at a group velocity approximately equal to 0.85 times the group velocity of the spectral peak. This factor accounts for both frequency distribution of energy in a JONSWAP spectrum and angular spreading. This yields

$$t_{x,u} = 77.23 \frac{X^{0.67}}{u^{0.34} g^{0.33}} \qquad \text{(II-2-35)}$$

where

$t_{x,u}$ = time required for waves crossing a fetch of length x under a wind of velocity u to become fetch-limited

Equation II-2-35 can be used to determine whether or not waves in a particular situation can be categorized as fetch-limited.

The equations governing wave growth with fetch are

$$\frac{gH_{m_0}}{u_*^2} = 4.13 \times 10^{-2} * \left(\frac{gX}{u_*^2}\right)^{\frac{1}{2}}$$

and

$$\frac{gT_p}{u_*} = 0.751 \left(\frac{gX}{u_*^2}\right)^{\frac{1}{3}} \qquad \text{(II-2-36)}$$

$$C_D = \frac{u_*^2}{U_{10}^2}$$

$$C_D = 0.001(1.1 + 0.035\, U_{10})$$

where

X = straight line fetch distance over which the wind blows (units of m)

H_{m0} = energy-based significant wave height (m)

C_D = drag coefficient

U_{10} = wind speed at 10 m elevation (m/sec)

u_* = friction velocity (m/sec)

See Demirbilek, Bratos, and Thompson (1993) for more details.

Fully developed wave conditions in these equations are given by

$$\frac{gH_{m_0}}{u_*^2} = 2.115 \times 10^2$$

and (II-2-37)

$$\frac{gT_p}{u_*} = 2.398 \times 10^2$$

Equations governing wave growth with wind duration can be obtained by converting duration into an equivalent fetch given by

$$\frac{gX}{u_*^2} = 5.23 \times 10^{-3} \left(\frac{gt}{u_*}\right)^{\frac{3}{2}} \qquad \text{(II-2-38)}$$

where t in this equation is the wind duration. The fetch estimated from this equation can then be substituted into the fetch-growth equations to obtain duration-limited estimates of wave height and period. An example demonstrating these procedures is provided at the end of this chapter.

(c) Narrow fetches. Early wave prediction nomograms included modifications to predicted wave conditions based on a sort of aspect ratio for a fetch area, based on the ratio of fetch width to fetch length. Subsequent investigations (Resio and Vincent 1979) suggested that wave conditions in fetch areas were actually relatively insensitive to the width of a fetch; consequently, it is recommended here that fetch width not be used to estimate an effective fetch for use in nomograms or the ACES Program. Instead, it is recommended that the straightline fetch be used to define fetch length for applications.

(d) Shallow water. Many studies suggest that water depth acts to modify wave growth. Bottom friction and percolation (Putnam 1949, Putnam and Johnson 1949, Bretschneider and Reid 1953) have been postulated as significant processes that diminish wave heights in shallow water; however, recent studies in shallow water (Jensen 1993) indicate that fetch-limited wave growth in shallow water appears to follow growth laws that are quite close to deepwater wave growth for the same wind speeds, up to a point where an asymptotic depth-dependent wave height is attained. In light of this evidence, it seems prudent to disregard bottom friction effects on wave growth in shallow water. Also, evidence from Bouws et al. (1985) indicates that wave spectra in shallow water do not appear to have a noticeable dependence on variations in bottom

sediments. Consequently, it is recommended that deepwater wave growth formulae be used for all depths, with the constraint that no wave period can grow past a limiting value as shown by Vincent (1985). This limiting wave period is simply approximated by the relationship

$$T_p \approx 9.78\left(\frac{d}{g}\right)^{\frac{1}{2}} \qquad \text{(II-2-39)}$$

In cases with extreme amounts of material in the water column (for example sediment, vegetation, man-made structures, etc.), it is likely that the dissipation rate of wave energy will become very large. In such cases, Camfield's work (1977) may be used as a guideline for estimating frictional effects on wave growth and dissipation; however, it should be recognized that little experimental evidence exists to confirm the exact values of these dissipation rates.

(2) Prediction of deepwater waves from nomograms. Figures II-2-23 through II-2-26 are wave prediction nomograms under fetch-limited and duration-limited conditions. The curves in these nomograms are based on Equations II-2-30 and II-2-36 through II-2-38 presented previously in this section. The asymptotic upper limits in both cases provide information on the fully developed wave heights as a function of wind speed. The same information can be obtained more expediently via the ACES Program.

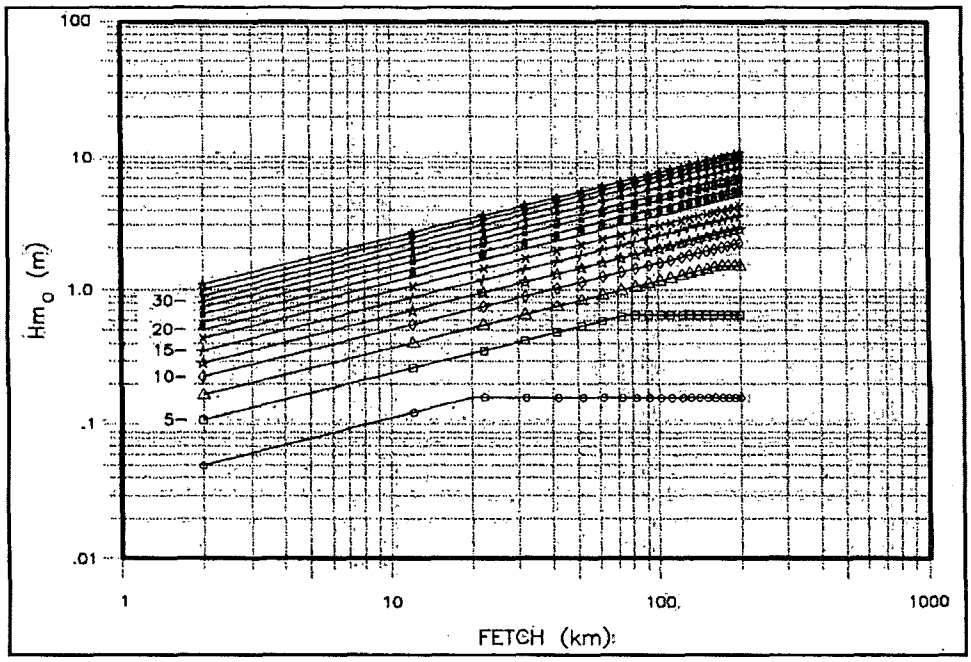

Figure II-2-23. Fetch-limited wave heights

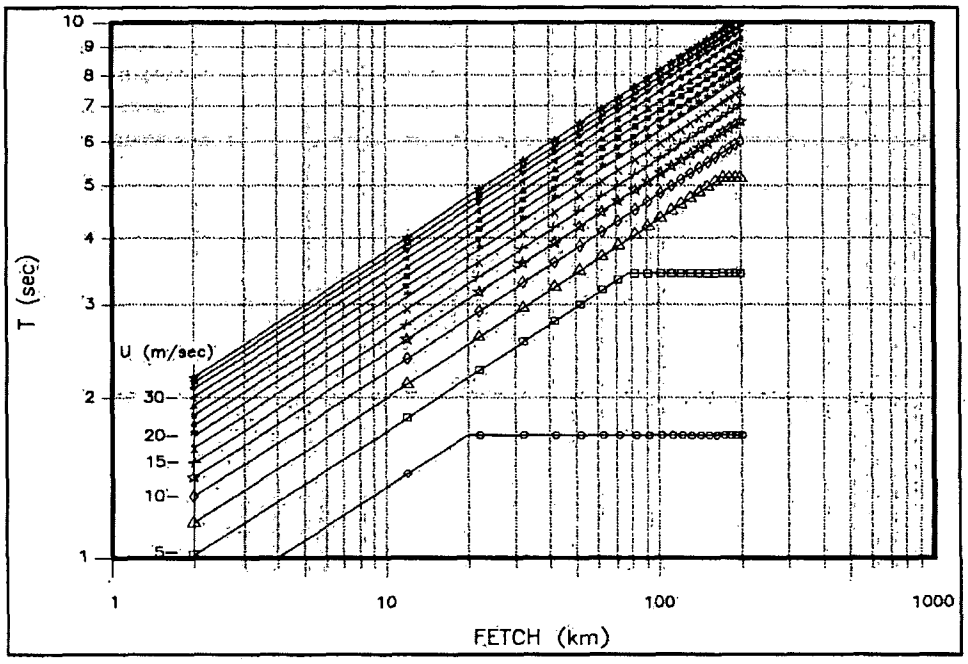

Figure II-2-24. Fetch-limited wave periods (wind speeds are plotted in increments of 2.5 m/s)

(3) Prediction of shallow-water waves. Rather than providing separate nomograms for shallow-water wave generation, the following procedure is recommended for estimating waves in shallow basins:

- Determine the straight-line fetch and over-water wind speed.
- Using the fetch and wind speed from (1), estimate the wave height and period from the deepwater nomograms.
- Compare the predicted peak wave period from (2) to the shallow-water limit given in Equation II-2-39. If that wave period is greater than the limiting value, then reduce the predicted wave period to this value. The wave height may be found by noting the dimensionless fetch associated with the limiting wave period and substituting this fetch for the actual fetch in the wave growth calculation.
- If the predicted wave period is less than the limiting value, then retain the deepwater values from (2).
- If wave height exceeds 0.6 times the depth, wave height should be limited to 0.6 times the depth.

c. *Parametric prediction of waves in hurricanes.*

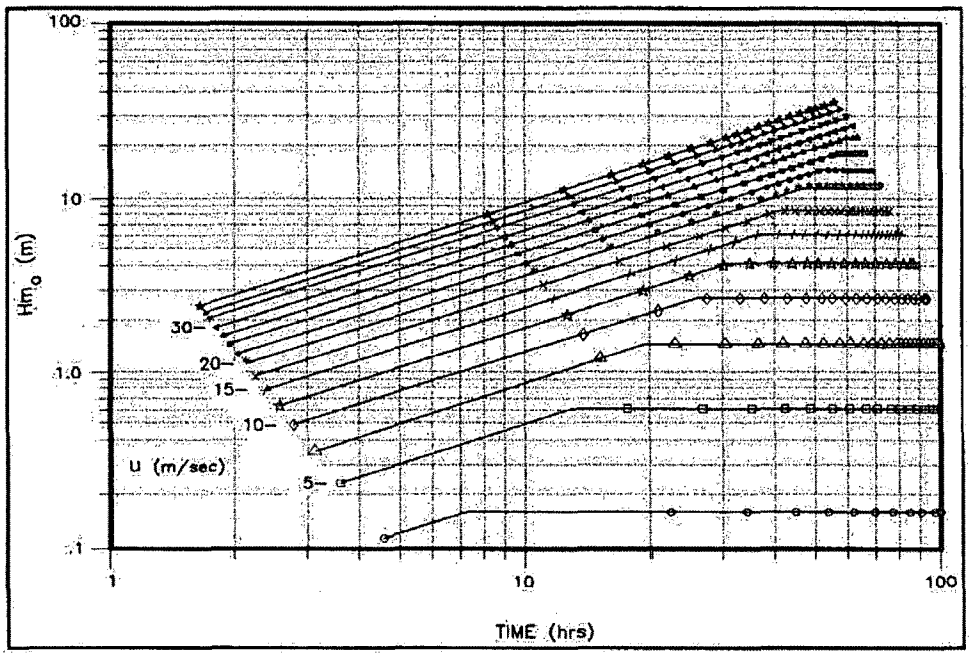

Figure II-2-25. Duration-limited wave heights (wind speeds are plotted in increments of 2.5 m/s)

(1) As shown Table II-2-2, waves from tropical storms, hurricanes, and typhoons represent a dominant threat to coastal and offshore structures and activities in many areas of the world. In this section, the generic term "hurricane" refers to all of these classes of storms. As pointed out previously in this chapter, the only distinction between tropical storms and hurricanes/typhoons is storm intensity (and somewhat the storm's degree of organization). The only distinction between hurricanes and typhoons is the point of origin of the storm.

(2) Spectral models have been shown to provide accurate estimates of hurricane wave conditions, when driven by good wind field information (Ward, Evans, and Pompa 1977; Corson et al. 1982; Cardone 1992; Hubertz 1992). Numerical spectral models can be run on most available PC's today, so there is little motivation not to use such models in any application with significant economic and/or safety implications. However, certain situations remain in which a parametric hurricane wave model may still play an important role in offshore and coastal applications. Therefore, some documentation of parametric models is still included in this manual.

(3) In general, parametric prediction methods tend to work well when applied to phenomena that have little or no dependence on previous states (i.e. systems with little or no memory). A good example of such a physical system is a hurricane wind field. It has been demonstrated (Ward et al. 1977) that hurricane wind fields can be well-represented by a small number of parameters, since winds in a hurricane tend always to remain very close to a dynamic balance with certain driving mechanisms. On the other hand, waves depend not only on the present wind field but also on earlier wind fields, bathymetric effects, pre-existing waves from other wind systems, and in general on the entire wave-generation process over the last to 12 to 24 hr.

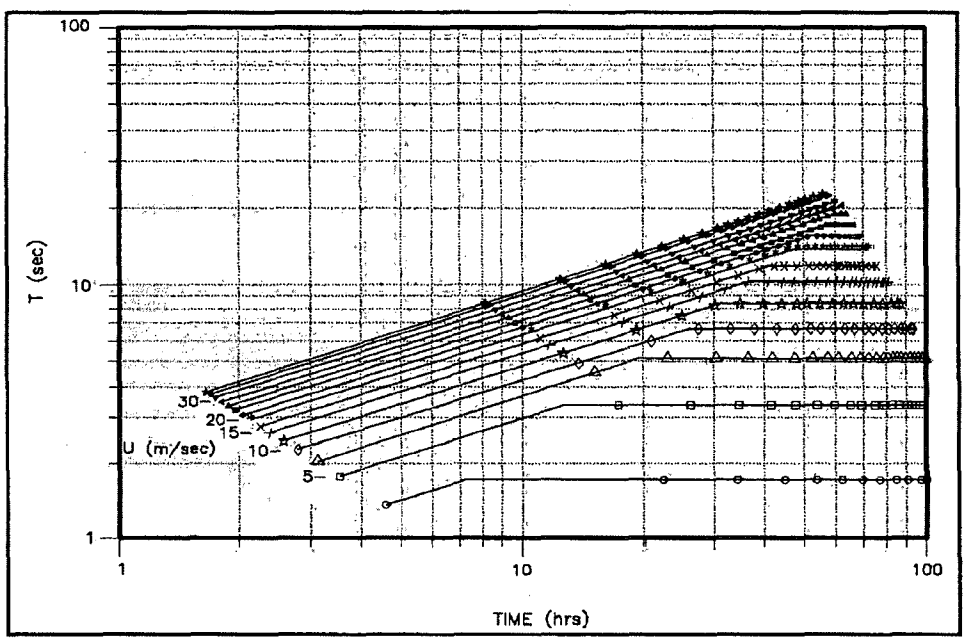

Figure II-2-28. Duration-limited wave periods.

Thus, parametric models do not work well for all hurricanes, but do provide accurate results when the following criteria are met for an interval of about 12 to 18 hr prior to the application of a parametric model:

- Hurricane intensity (maximum velocity) is relatively constant.
- Hurricane track is relatively straight.
- Hurricane forward speed is relatively constant.
- Hurricane is not affected by land or bathymetric effects.
- No strong secondary wind and/or wave systems affect conditions in the area of interest.

(4) In certain situations, where there is a lack of detail on the actual characteristics of a hurricane (such as in hurricane forecasts, older historical storms, hurricanes in some regions of the world where meteorological data are sparse), parametric models may provide accuracies equal to those of spectral models, provided that land effects and bathymetric effects are minimal. However, even when these criteria are met, situations where secondary wind and/or wave systems can seriously affect wave conditions in an area should be avoided. Examples of this occur when large-scale pressure gradients (monsoonal or extratropical) significantly affect the shape and/or wind distribution of a hurricane. Winds and waves in such a storm will not be distributed in a manner consistent with the assumptions made in this section.

(5) Young (1987) developed a parametric wave model based on results from simulations with a numerical spectral model. His results show that there is a strong dependence of wave height on the relative values of maximum wind speed and forward storm velocity (Figure II-2-27). These results can be used to estimate the maximum value of H_{m0} in a hurricane. The distribution of wave heights within a hurricane is also affected by the ratio of maximum wind speed to forward storm velocity; however, in an effort to simplify applications here, only one chart is presented (Figure II-2-28). This chart is characteristic of storms with strong winds (maximum wind speed greater than 40 m/sec) and slow-to-moderate forward velocities (V_f less than 12 m/sec).

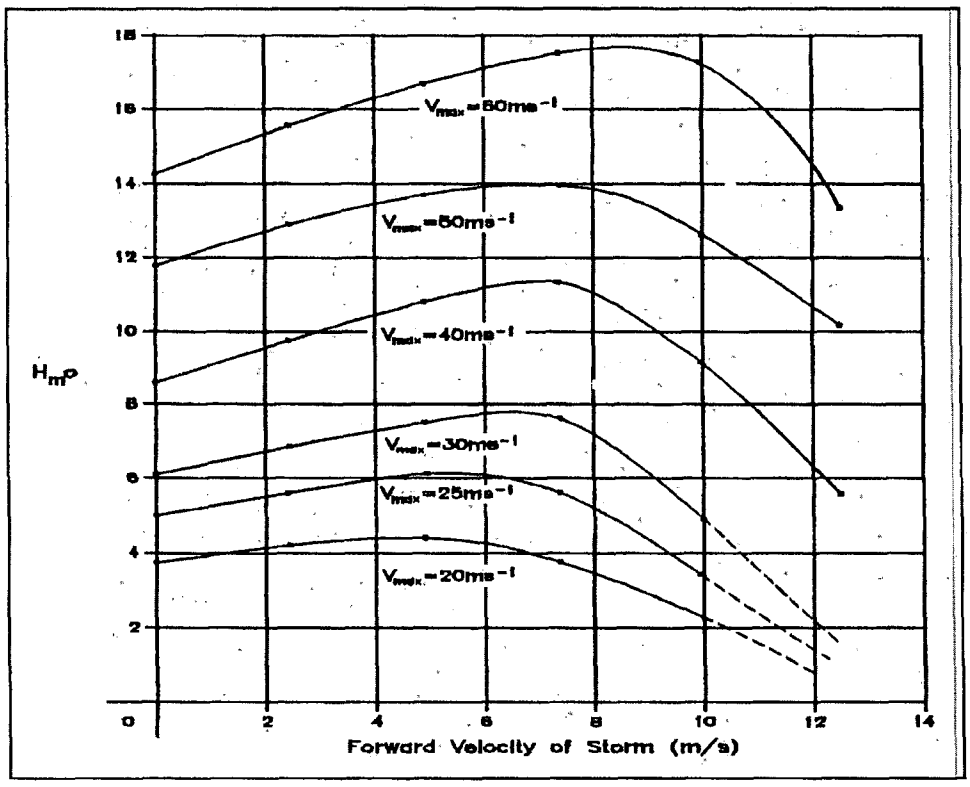

Figure II-2-27. Maximum value of H_{m0} in a hurricane as a function of V_{max} and forward velocity of storm (Young 1987)

II-2-3. Coastal Wave Climates in the United States.

a. Introduction.

(1) Coastal wave climates around U.S. coastlines are extremely varied. Past studies such as that by Thompson (1977) have relied primarily on measured wave conditions in coastal areas to specify nearshore wave climates. However, we now know that coastal wave heights can vary markedly as a function of distance

Reference 4

Rizzo (July 2008). *Wave Runup Analysis for BBNPP ESWEMS Pond.* Proj. No. 07-3891. Paul C. Rizzo Associates, Inc., Monroeville, PA.

F-12 12b

1. PURPOSE

The purpose of these wind setup and wave runup calculations is to determine the amount of freeboard necessary to prevent overtopping of the dike at the ESWEMS Pond at the Bell Bend Nuclear Power Plant (BBNPP) site. The following wind events were analyzed:

- Fastest Annual Recorded Wind Speed
- 2-year Wind Event
- 10-Year Wind Event
- 25-year Wind Event
- 50-year Wind Event
- 100-year Wind Event
- 1000-year Wind Event

In all cases, the wind event was analyzed on top of the water surface elevation resulting from the Probable Maximum Precipitation (PMP). According to ***Reference 4***, the PMP water surface elevation at the ESWEMS Pond is 672.13 feet (ft) msl. The pond has side slopes of 3H: 1V and a length of 700 ft at El. 674 ft msl, resulting in a maximum water surface length of 700 – 2*(674 – 672.13)*3 = 688.8 ft. Therefore, this distance was taken as the fetch for all wind events for both retention ponds. The corresponding depth for this water surface elevation is 20.63 ft since the bottom elevation is 651.5 ft msl.

2. METHODOLOGY

Note that wind setup equations require US units and wave runup equations require metric units.

2.1 Wind Setup

Wind setup is calculated by using Equation 15-1 of ***Reference 1:***

$$S = \frac{U^2 F}{1400D}$$

where U is average wind velocity in miles per hour, F is wind tide fetch in miles, and D is the (average) depth in feet. The wind tide fetch F is usually taken to be twice the distance of the effective fetch F_e, the distance over which wind can travel unobstructed across a body of water. The effective fetch distances were obtained as stated in ***Section 1*** and doubled to obtain wind tide fetch F.

Reference 2 gives the corresponding wind speeds for each wind event. ***Table 2-1*** shows the wind speed, effective fetch, wind tide fetch, average depth, and wind setup for each of the cases. A conversion factor of 5280^{-1} ft = 1 mile was used.

TABLE 2-1

CASE	U (MPH)	F_E (MI)	F (MI)	D (FT)	S (FT)
Fastest Annual Recorded Wind	57[1]	0.1305	0.2609	20.63	0.03
2 Year Frequency Wind Event	50	0.1305	0.2609	20.63	0.02
10 Year Frequency Wind Event	60	0.1305	0.2609	20.63	0.03
25 Year Frequency Wind Event	70	0.1305	0.2609	20.63	0.04
50 Year Frequency Wind Event	71	0.1305	0.2609	20.63	0.05
100 Year Frequency Wind Event	83	0.1305	0.2609	20.63	0.06
1,000 Year Frequency Wind Event	118	0.1305	0.2609	20.63	0.13

[1] Fastest annual recorded wind speed obtained from the SSES Unit 1 & 2 meteorological tower, based on available data from 2001 to 2007 (***Reference 5***).

2.2 Wave Runup

The calculation of wave runup involves finding the significant wave height and period based on fetch length and wind speed, then determining the wave runup based on the characteristics of the wave and embankment slope. USACE EM 1110-2-1100 (***Reference 3***) provides guidance for this process. Part II, Chapter 2 of EM 1101-2-1100, p.II-2-47, lays out the following procedure for calculation of shallow water wave heights and periods:

1. Determine the straight-line fetch and over water wind speed.
2. Using the fetch and wind speed from *(1)*, estimate the wave height and period from deepwater nomograms.
3. Compare the predicted wave period from *(2)* to the shallow-water limit given in Equation II-2-39.
   a. If the predicted wave is greater than the limiting value, reduce the predicted wave period to the limiting value. The wave height may be found by noting the dimensionless fetch associated with the limiting wave period and substituting this fetch for the actual fetch in the wave growth calculation.
   b. If the predicted wave period is less than the limiting value, retain the deepwater values from *(2)*.
4. If the wave height exceeds 0.6 times the depth, wave height should be limited to 0.6 times the depth.

Wave runup was then calculated using equations and suggested coefficients from Part VI, Chapter 5 of EM 1101-2-1100.

2.2.1 ***Determine the straight-line fetch and over water wind speed.***

2.2.1.1 Fetch *X*

Fetches were taken as the effective fetch distances from ***Section 2.1*** (half the distance of the fetch used in the wind setup calculation). Note that fetch is denoted as X in all proceeding wave runup calculations. Since the USACE equations require that the fetch is in meters, a conversion factor of 0.3048 was used to convert from feet to meters. The fetch for all cases is 688.8 ft (0.3048 m/ft) = 209.94 meters.

2.2.1.2 Wind Speed *U*

The same wind speed used for wind setup is used for wave runup (see Section 2.1). The wind speed was assumed to be measured at the standard 10 meter height. Additionally, all reported wind speeds were assumed to be the fastest-mile wind speeds; therefore, the duration time (t) was calculated as the time needed for the wind to travel one mile. The wind speed, in meters per second, is the given wind speed from ***Reference 2*** in mph multiplied by a conversion factor of 0.44704 to obtain meters per second.

Because the length of the fetch will dictate the averaging interval I_t for the waves, Figure II-2-3 is used to determine this time. A new averaging interval requires that the equations of Figure II-2-1 need to be consulted once again to find equivalent wind speed for the averaging interval duration (denoted as U_L).

Once the wind speed is normalized with respect to the type of observation and fetch length, the difference between wind speed over land and over water must be accounted for. As stated on p. II-2-13 of ***Reference 3***, "the ratio of overwater winds at a fixed level to overland wind speeds at a fixed level is not constant, but varies non-linearly as a function of wind speed." Figure II-2-7 illustrates this relationship for fetches greater than 16.1 km and yields a conversion factor R_L which can be used to find the overwater wind speed from the adjusted overland wind speed. For fetches less than 16.1 km, Figure II-2-20 suggests a specific conversion factor of 1.2. Fetches for all cases analyzed were less than 16.1 km, so a constant factor of $R_L = 1.2$ was used in all calculations.

This adjusted overwater wind speed $U_w = U_L * R_L$ is the wind speed that will be used for all following wave height and wave period calculations.

2.2.2 ***Using the fetch and wind speed, estimate the wave height and period from deepwater nomograms.***

While the above states nomograms are to be used, a more accurate estimation is to directly use the equations on which those nomograms are based. Equations II-2-36 are the governing equations for wave growth with relation to fetch length. The drag coefficient C_d is calculated first based on the wind speed.

$$C_d = 0.001(1.1 + 0.035U_{10})$$

Where U_{10} is the overwater wind speed (U_w) as calculated in ***Section 2.2.1.2***. From this, the friction velocity u_* is found.

$$u_* = \sqrt{C_d U_{10}^2}$$

Once the friction velocity is known, all the variables needed to calculate wave height H_{m0} and wave period T_p are known (X is the fetch distance for wave runup calculations).

$$H_{m0} = \left[4.13\times10^{-2} * \left(\frac{gX}{u_*^2}\right)^{\frac{1}{2}}\right]\left(\frac{u_*^2}{g}\right)$$

$$T_p = \left[0.651\left(\frac{gX}{u_*^2}\right)^{\frac{1}{3}}\right]\left(\frac{u_*}{g}\right)$$

2.2.3 ***Compare the predicted wave period to the shallow-water limit given in Equation II-2-39. If the predicted wave is greater than the limiting value, reduce the predicted wave period to the limiting value. The wave height may be found by noting the dimensionless fetch associated with the limiting wave period and substituting this fetch for the actual fetch in the wave growth calculation. If the predicted wave period is less than the limiting values, retain the deepwater values.***

Equation II-2-39 is given below.

$$T_p \approx 9.78\left(\frac{d}{g}\right)^{\frac{1}{2}}$$

The average depth d used to calculate the theoretical maximum shallow water wave period was 20.63 ft = 6.29 meters. The gravitational constant g is 9.81 m/s. The computed wave period from Section 2.2.2 never exceeded the limiting wave period. Therefore, no additional steps were necessary here.

2.2.4 ***If the wave height exceeds 0.6 times the depth, limit wave height to 0.6 times the depth.***

The wave height never exceeded 0.6(20.63 ft)(0.3048 m/ft) = 3.77 meters.

2.3 Wave Break Height

Part VI, Chapter 5 of EM 1101-2-1100 gives equations to calculate the height of wave runup on the structures. Equation VI-5-1 calculates the surf-similarity parameter.

$$\xi_0 = \frac{\tan\alpha}{\sqrt{s_0}}$$

The upstream slope of the embankments α is 3H:1V. S_0 is the wave steepness given by

$$s_0 = \frac{H_0}{L_0}$$

Where L_0 is the wavelength and can be calculated using the wave period from ***Section 2.2.2***.

$$L_0 = \frac{gT^2}{2\pi}$$

The wave runup is given by equation VI-5-3:

$$\frac{R_{ui\%}}{H_s} = (A\xi + C)\gamma_r\gamma_b\gamma_h\gamma_\beta$$

$R_{ui\%}$ is the runup level exceeded by i% of the incident waves and H_s is the significant wave height previously calculated in ***Section 2.2.2*** as H_{m0}. The coefficients A and C depend on the runup level chosen and are only provided in the manual for 33% and 2%, so 2% will be used as a conservative measure. Table VI-5-2 gives the values of $A = 1.6$ and $C = 0$ for $i = 2\%$ and $\xi \leq 2.5$. The following tables and equations give appropriate values for the γ coefficients. A value of 1.0 should be used if the coefficient can't be calculated or isn't applicable:

- Surface reduction factor, γ_r, can be found in Table VI-5-3. A value of 0.60 was used for the rip-rap slopes described in ***Reference 2***.
- Berm influence factor, γ_b, can be calculated using Equation VI-5-8. There are no berms on the structure, so a value of 1.0 was used.
- Shallow water influence (where waves deviate from Raleigh distribution), γ_h, is given in Equation VI-5-10.

  $$\gamma_h = \frac{H_{2\%}}{1.4H_s}$$

  This can't be calculated with available data, so a value of 1.0 was used.
- Angle of wave incidence reduction factor, γ_β, can be calculated using Equation VI-5-11. For short-crested waves with an angle of incidence β (in degrees):

  $$\gamma_\beta = 1 - 0.0022\beta$$

  In all cases β is 0 degrees since the fetch is perpendicular to the embankment. Therefore, this reduction factor is always equal to 1.

3. RESULTS

The freeboard requirement is the height above the still water surface that the wind setup combined with the wave runup will impact. The top of the retention pond embankment should be greater than this height above the PMP water surface elevation. ***Table 3-1*** shows the resulting wind setup, wave runup, and freeboard requirement values for each case. Note that $R_{u2\%}$ is the wave runup that 2% of the waves will exceed, which is the most conservative value that can be calculated using ***Reference 3***. All values are presented here in US units for summarization purposes.

TABLE 3-1

Case	Wind Setup S (FT)	Wave Runup $R_{U2\%}$ (FT)	Freeboard Requirement $S + R_{U2\%}$ (FT)
Fastest Annual Wind Event	0.03	0.56	0.59
2 Year Wind Event	0.02	0.50	0.52
10 Year Wind Event	0.03	0.59	0.62
25 Year Wind Event	0.04	0.68	0.73
50 Year Wind Event	0.05	0.69	0.74
100 Year Wind Event	0.06	0.81	0.87
1000 Year Wind Event	0.13	1.17	1.30

4. Input

Appendix A contains a detailed summary of all input, intermediate, and final values for the wave period, wave height, and wave runup.

5. Conclusions

As stated previously, the PMP water elevation is 672.13 ft msl. The strongest wind event analyzed will bring the wave action elevation to 672.13 + 1.30 = 673.43 ft msl. This is still under the overtopping elevation of 674.00 ft by a margin of 0.57 ft.

6. References

1. US Army Corps of Engineers (October 1997), *Hydraulic Requirements for Reservoirs*, EM 1110-2-1420.
2. Thom, H.C.S. (July 1968), "New Distributions of Extreme Winds in the United States," *Journal of the Structural Division*, American Society of Civil Engineers.
3. US Army Corps of Engineers (June 2006), *Coastal Engineering Manual*, EM 1110-2-1100.
4. Wallner, David (July 2008), *PMF for Bell Bend NPP Site Drainage System,* Paul C. Rizzo Associates, Inc, July 2008.
5. Gluckler, P (March 20, 2008). Areva. *FW: SSES 2006 and 2007 Met Data Uncompressed*, e-mail.

7. Electronic File Locations

All Microsoft Excel files that were used to perform this calculation are posted on the G-drive:

G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- Wind Setup
G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- Fastest Annual Recorded Wind
G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- 0002 Year Wind
G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- 0010 Year Wind

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By GMS . Date 07/08/09. Subject Frazil Ice Analysis for BBNPP . ESWEMS Pond – Response to RAI # 25 . Sheet No. 62 of 66
Chkd. by FAM . Date 07-08-09. Proj. No. 07-3891 .

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By DJW . Date 7/7/08 . Subject Wave Runup Analysis for BBNPP ESWEMS Pond . Sheet No. 7 of 61 .
Chkd. by FAM . Date 07-11-08 . Proj. No. 07-3891 .

G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- 0025 Year Wind
G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- 0050 Year Wind
G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- 0100 Year Wind
G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- 1000 Year Wind
G:\DJW\Berwick NPP (07-3891)\FSAR 2.4.8- Wave Runup (Water Resources)\BBNPP ESWEMS Pond- Wave Runup Results

Wave Height and Wave Period Results

	(1)[1]	(2)[1]	(3)[1]	(4)[1]	(5)[1]	(6)[1]	(7)[1]	(8)[1]	(9)[1]	(10)[1]	(11)[1]	(12)[1]	(13)[1]	(14)[1]	(15)[1]	(16)[1]
	Inputs						Intermediate Values						Calc. Values		Limiting Values	
Case	X (m)	d (m)	U (m/s)	t (s)	U_{max} (m/s)	L (min)	H (s)	UL (m/s)	R	U_L (m/s)	C_d	u (m/s)	H_{max} (m)	T_c (s)	H (m)	T (s)
Fastest Annual	209.9	6.3	25.5	63.2	20.6	7.0	420.0	22.0	1.2	26.40	0.00202	1.19	0.23	0.89	3.77	7.83
2 Year	209.9	6.3	22.4	72.0	18.3	7.0	420.0	19.5	1.2	23.44	0.00192	1.03	0.20	0.85	3.77	7.83
10 Year	209.9	6.3	26.8	60.0	21.6	6.0	360.0	23.3	1.2	27.90	0.00208	1.27	0.24	0.91	3.77	7.83
25 Year	209.9	6.3	31.3	51.4	24.8	6.0	360.0	26.7	1.2	32.10	0.00222	1.51	0.29	0.97	3.77	7.83
50 Year	209.9	6.3	31.7	50.7	25.1	6.0	360.0	27.1	1.2	32.51	0.00224	1.54	0.29	0.97	3.77	7.83
100 Year	209.9	6.3	37.1	43.4	29.0	5.0	300.0	31.6	1.2	37.90	0.00243	1.87	0.36	1.04	3.77	7.83
1000 Year	209.9	6.3	52.8	30.5	39.9	4.0	240.0	44.2	1.2	53.02	0.00296	2.88	0.55	1.20	3.77	7.83

[1]Refer to the Wave Height and Wave Period Calculations in the following pages to see how all parameters in each numbered column were calculated.

Wave Runup Results

	(1)[1]	(2)[1]	(3)[1]	(4)[1]	(5)[1]	(6)[1]	(7)[1]	(8)[1]	(9)[1]	(10)[1]	(11)[1]	(12)[1]	(13)[1]	(14)[1]
Case	α (rad)	H_b (m)	H_b (m)	a_b (m)	C	A	G	Y_r	Y_b	Y_h	Y_β	h_b (m)	R_{max} (m)	R_{max} (ft)
Fastest Annual	0.322	0.23	1.25	0.182	0.78	1.6	0	0.6	1.0	1.0	1.0	0.23	0.170	0.559
2 Year	0.322	0.20	1.13	0.173	0.80	1.6	0	0.6	1.0	1.0	1.0	0.20	0.151	0.495
10 Year	0.322	0.24	1.31	0.186	0.77	1.6	0	0.6	1.0	1.0	1.0	0.24	0.180	0.591
25 Year	0.322	0.29	1.47	0.197	0.75	1.6	0	0.6	1.0	1.0	1.0	0.29	0.208	0.684
50 Year	0.322	0.29	1.48	0.198	0.75	1.6	0	0.6	1.0	1.0	1.0	0.29	0.211	0.693
100 Year	0.322	0.36	1.69	0.211	0.73	1.6	0	0.6	1.0	1.0	1.0	0.36	0.248	0.814
1000 Year	0.322	0.55	2.25	0.244	0.67	1.6	0	0.6	1.0	1.0	1.0	0.55	0.357	1.170

[1]Refer to the Wave Runup Calculations in the following pages to see how all parameters in each numbered column were calculated.

Wave Height and Wave Period Calculations (Page 1 of 3)

(1) "X" is the fetch distance (F_e) from ***Reference 1***:

$$700ft - 2\cdot(674ft - 672.1304ft)\cdot 3 = 688.7824ft$$

$$688.782ft = 209.9408m$$

(2) "d" is the average depth (D) from ***Reference 1***:

$$672.1304ft - 651.5ft = 20.6304ft$$

$$20.63ft = 6.288m$$

(3) "U_t" is the overland wind speed from ***Reference 2*** (NOTE: the Fastest Annual Wind Speed was obtained from SSES Unit 1 & 2 meteorological tower data; see ***Reference 5***):

$$1mph = 0.44704\frac{m}{s}$$

(4) "t" is the overland wind speed duration:

All reported wind speeds were assumed to be the fastest mile wind speeds; therefore, the duration time (t) was calculated as the time needed for the wind to travel one mile (see Figure II-2-2 in ***Reference 3***).

(5) "U_{3600}" is the equivalent 1-hour overland wind speed from ***Reference 3***, Figure II-2-1:

$$U_{3600} := \frac{U_t}{1.277 + 0.296\tanh\left(0.9\cdot\log\left(\frac{45}{t}\right)\right)}$$

where "U_t" is the overland wind speed from (3) and "t" is the overland wind speed duration time from (4).

(6) "I_t" is the averaging interval from ***Reference 3***, Figure II-2-3 using the fetch distance "X" from (1) and the overland wind speed "U_t" from (3).

(7) I_t converted to seconds:

$$1min = 60s$$

(8) "U_L" is the overland wind speed adjusted for the duration of the averaging interval (I_t) from (7). It is calculated using ***Reference 3***, Figure II-2-3:

$$U_L := U_{3600}\left(1.277 + .296\tanh\left(0.9\cdot\log\left(\frac{45}{I_t}\right)\right)\right)$$

Wave Height and Wave Period Calculations (Page 2 of 3)

(9) "R_L" is the ratio of wind speed over water (U_W) to wind speed over land (U_L) from ***Reference 3***, Figure II-2-20 for a fetch length (X) ***less than*** 16.09 km.

(10) "U_W" is the overwater wind speed:

$$U_W := U_L \cdot R_L$$

where "U_L" is the adjusted overland wind speed from (8) and "R_L" is the ratio from (9).

(11) "C_d" is the drag coefficient from ***Reference 3***, Equations II-2-36:

$$C_d := 0.001\left(1.1 + 0.035 U_W\right)$$

where "U_W" is the overwater wind speed from (10).

(12) "u_*" is the friction velocity from ***Reference 3***, Equations II-2-36:

$$u_{star} := \sqrt{C_d \cdot U_W^{\,2}}$$

where "C_d" is the drag coefficient from (11) and "U_W" is the overwater wind speed from (10).

(13) "H_{m0}" is the energy-based significant wave height from ***Reference 3***, Equations II-2-36:

$$H_{m0} := 0.0413\left(\frac{g \cdot X}{u_{star}^{\,2}}\right)^{\frac{1}{2}} \cdot \frac{u_{star}^{\,2}}{g}$$

where "X" is the fetch distance from (1), "u_{star}" is the friction velocity from (12), and "g" is the acceleration due to gravity (9.81 m/s^2).

(14) "T_p" is the wave period from ***Reference 3***, Equations II-2-36:

$$T_p := 0.651\left(\frac{g \cdot X}{u_{star}}\right)^{\frac{1}{3}} \cdot \frac{u_{star}}{g}$$

where "X" is the fetch distance from (1), "u_{star}" is the friction velocity from (12), and "g" is the acceleration due to gravity (9.81 m/s^2).

Wave Height and Wave Period Calculations (Page 3 of 3)

(15) Limiting wave height (***Reference 3***):

$$H := 0.6 \cdot d$$

where "d" is the average depth from (2).

(16) Limiting wave period from ***Reference 3***, Equation II-2-39:

$$T := 9.78\left(\frac{d}{g}\right)^{\frac{1}{2}}$$

where "d" is the average depth from (2) and "g" is the acceleration due to gravity (9.81 m/s^2). NOTE: this relationship provides an ***approximation*** of the limiting wave period.