New York Power Pool

Tie-Line Ratings Task Force

Final Report

on

Tie-Line Ratings

1995

FINAL REPORT

NEW YORK POWER POOL TASK FORCE

ON

TIE-LINE RATINGS

APPROVED BY NYPP TRANSMISSION PLANNING ADVISORY SUBCOMMITTEE
NOVEMBER 1995

APPROVED NYPP SYSTEM OPERATIONS ADVISORY SUBCOMMITTEE
NOVEMBER 1995

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NYPP 1995 Tie-Line Rating Task Force

SECTION I

Introduction

INTRODUCTION

The 1995 Tie-Line Rating Report represents the third time the methodology for determining equipment rating has been investigated by the New York Power Pool (NYPP). The purpose of the original Task Force was to establish a clear and common methodology for determining equipment thermal ratings. This action would resolve the problem of non-uniformity regarding the determination of tie-line equipment ratings . The results could be used to establish ratings on equipment connecting different electric utilities with NYPP. The following gives an historical perspective of these efforts:

1969 Original Report

- Developed a uniform and acceptable method of determining thermal equipment ratings.
- Set key definitions.
- Established ambient weather conditions for the calculation of summer and winter ratings.
- Originated "Table of Rating Factors for transmission System Components".
- Equipment ratings were derived from ANSI Standards and loading guides.

1982 Report Revisions

- Changed assumed conductor life from 25 years to 40 years.
- Changed the long-time-emergency(LTE) period to 4 hours.
- Increased the wind speed from 2 feet/second to 3 feet/second (Overhead transmission lines only) based on a NEPOOL Weather Study.
- Decreased the maximum ambient temperature from 40ºC to 35ºC

This latest review was requested by the Transmission Planning Advisory Subcommittee and the System Operation Advisory Subcommittee. The charge was to review the intervening research, update the standards' list and assess their impact on equipment ratings. Upon completion of this task, recommend any changes to equipment ratings, if required. The first meeting was held in June of 1993 and membership of the Task Force was established. Below is the list of members who participated in this endeavor:

Frank Lembo	Consolidated Edison
Janos T. Hajagos	Long Island Lighting
Leon Hall	New York State Electric & Gas
Leonard Panzica	New York Power Authority
Robert Schultz	New York Power Authority
James F. Chastney(Secretary, **retired 11/1/94**)	New York Power Pool
Jerry Ancona	Niagara Mohawk Power Corporation
Charles J. Blattner(**retired 11/1/94**)	Niagara Mohawk Power Corporation
Larry Eng	Niagara Mohawk Power Corporation
William C. Merritt(**retired 7/1/94**)	Niagara Mohawk Power Corporation
Jack Y. Pousty	Orange & Rockland Utilities
Patrick M. Callahan(Chairperson)	Rochester Gas & Electric

At this time the chairperson would like to acknowledge the extra ordinary efforts of the Task

Force and thank the members for their commitment to excellence. The Executive Summary of this report documents the decisions made by this Task Force.

To assist the user of this report, the definitions of important terms, established and refined by the previous Task Forces, are presented below.

A. DEFINITIONS:

Tie Line

A tie line consists of all series components, including line conductors, bus taps and all equipment and apparatus which are in one electrical path between two buses.

Ampacity

Current carrying capacity in amperes.

Rating Factor

NYPP rating in percent of nameplate rating.

Normal(operating) Rating

Capacity in amperes which may be carried through consecutive twenty-four hour load cycles without exceeding agreed upon conductor or hottest spot equipment temperatures for this mode of operation.

Long Time Emergency(LTE) Rating

Capacity in amperes which may be carried through infrequent non-consecutive, appropriate four hour periods without exceeding agreed-upon maximum conductor or hottest spot equipment temperatures for this mode of operation.

Short Time Emergency(STE) Rating

Capacity in amperes which may be carried during very infrequent contingencies of fifteen minutes or less duration without exceeding agreed upon maximum conductor temperatures for this mode of operation.

Assumed Daily Load Factor

The load factor is the ratio of the average load in kilowatts during a 24-hour period to the peak or maximum hourly load occurring in that period. A ratio of 80% is representative for rating purposes, but for those circuits whose load factor is known to differ substantially from this ratio, the actual load factor should be used.

Assumed Hours of Operation at Rated Temperatures

It is assumed that only when the rated limiting temperatures are reached will annealing and loss of strength occur. In general, an environment more favorable than assumed, and operating and reliability considerations, result in a system whose line conductors are rarely operating near their thermal limit under normal operation. No more than 10 percent loss of life/strength is assumed over the life of the equipment. The estimated number of hours of operation at rated temperatures for each mode of operation over the 40 year assumed life of conductor.

Normal	7665 hours
Long Time Emergency Rating	300 hours
Short-Time Emergency Rating	12 1/2 hours

To estimate loss of strength of overhead conductors, annealing is assumed to occur only during operation at one of the three limiting(rated) temperatures that correspond to the normal, LTE, STE ratings for an assumed number of hours.

NYPP 1995 Tie-Line Rating Task Force

SECTION II

Executive Summary

EXECUTIVE SUMMARY

The Task Force recognized that the most critical parameters which impact equipment thermal ratings are ambient temperature and wind speed assumptions. Both of these variables were changed in the "Final Report New York Power Pool Task Force on Tie Line Ratings", June 1982 and resulted in higher equipment ratings. The Task Force reviewed available weather data and a survey of utilities in the Northeast[1]. This survey and R&D on real-time conductor ratings indicate the generally accepted appropriate effective maximum wind speed to be 3 feet/second. This conclusion is based upon the uncertainty of wind speed along a right-of-way. Below is a summary of the weather criteria for the 1995 report:

SEASON	**Ambient Temperatures[2]**		**Wind Speed Feet/Second**	
	Maximum	**Average**	**Conductor**	**Bus Section**
Summer	35°C	30°C	3ft/sec	2ft/sec
Winter	10°C	5°C	3ft/sec	2ft/sec
2) Interpolated values may be used for spring and fall.				

The values in the table above have not changed from the 1982 final report. The 1994 Task Force does believe that ambient temperature does not vary in magnitude over large geographic area and may offer the best opportunity for equipment rating increases. To this end, the Task Force has added thermal rating factors to sections of the report for ambient temperatures ranging from -40°C to +40°C whenever this information could be obtained or calculated. In the Overhead Conductor section of this report, there is also an example of the impact of solar radiation on conductor ratings. Along these same lines, a new section on Regional Weather data has been added with hourly weather observations of wind speed and ambient temperature. This information is further categorized into season and periods of the day.

The following table defines other critical assumptions which form the basis of this report:

Assumed life of equipment is 40 years
The Ratings are based on the assumption that line and terminal equipment are maintained in as "new condition".
A normal preload is used in establishing an STE rating.
The short-time-emergency(STE) time period is 15 minutes, totalling not more than 12-1/2 hours over the life of the equipment.
The long-time-emergency(LTE) period is 4 hours, totaling not more than 300 hours over the life of the equipment.

[1]"Overhead Transmission Line Ampacity Rating Survey", by Mohammad A. Pasha of United Illuminating Company, Northeast Transmission Group.

The equipment criteria described above also represents no change from the 1982 final report, which is a complement to the previous Task Forces. The 1995 report does include changes to STE ratings of disconnect switches and power transformers as well as additional information for adjusting equipment ratings based on real-time weather conditions. The following section summaries represent the highlights and revisions to the 1995 report.

SECTION SUMMARIES

New York State Regional Weather Data

- NEW SECTION.
- 1983 through 1992 hourly weather observations.
- Categorization of weather data(hourly) into summer & winter tables.
- Categorization of weather data(hourly) by wind speeds of 0-4 ft/sec., 4-6 ft/sec., 6-8 ft/sec. and > 8 ft/sec.
- Categorization of weather data(hourly) by daily time periods.
- Upstate N.Y. summer ambient temperature duration curves.
- Daily ambient temperature profiles for a 5-day upstate hot spell.
- Recommend research into wind speed along a right-of-way.

Overhead Conductors

- New IEEE Standard for calculation of bare overhead conductor. This standard includes a computer program listing and an executable program on a 3.5 computer disk.
- Expanded discussion of the impact of wind angle on conductor rating.
- Graphic of wind speeds from sheltered and unsheltered areas.
- A table of ambient temperature rating factors(%) from 40°C to -40°C, for selected conductor sizes.
- New table displaying the impact of solar radiation on selected conductors.

Air Disconnect Switches

- New method for the calculation of STE ratings.
- Table of ambient temperature rating factors(%) from 40°C to -40°C, for 30°C and 53°C rise disconnect switches.

High Voltage Power Circuit Breakers

- Expansion of Thermal Rating Factors to include eight breaker components for summer and winter NYPP ambient conditions.
- Rewrite an expansion of the STE section for power circuit breakers.

Power Transformers

- Section totally rewritten.
- Removal of Normal & LTE rating factors form summary table.
- Identification of software for the calculation of transformer loading capability based upon actual loading and ambient condition.
- Discussion of impact of LTC tap position on transformer ratings.
- Draft standard **IEEE PC57.91-199x** *IEEE Guide for Loading Mineral-Oil-Immersed Transformers*.

Current Transformers

- Addition of discussion on C.T. secondary circuitry.
- Inclusion of relay overload capabilities for selected GE and Westinghouse relays.
- Change in STE rating factor for free standing C.T.'s.
- Name change in references #2 and #3..

Line Traps

- The ANSI standard for Power Line Carrier Line Traps has been withdrawn.
- Inclusion of thermal rating factors for ambients less than 0°C.
- Discussion of NEPOOL rating calculation of line traps.

Substation Bus Conductor

- Inclusion of temperature limits for equipment connections.

Current Limiting Reactors

- NEW SECTION.
- Based upon a 1958 ANSI Standard for Dry type, Oil-Immersed and water-cooled reactors.

Series Capacitors

- NEW SECTION.

RATING FACTORS FOR TRANSMISSION SYSTEM COMPONENTS

TABLE 1

Season / Operating Conditions	Page #	Summer Normal	Summer LTE	Summer STE(1)	Winter Normal	Winter LTE	Winter STE(1)
Overhead Conductors - Maximum Temperatures							
ACSR (1350 Alloy, Steel Core)	28	95EC	115EC	125EC	95EC	115EC	125EC
SAC (1350 Alloy)		85EC	95EC	105EC	85EC	95EC	105EC
ACAR, AAAC (6201 Alloy)		95EC	110EC	120EC	95EC	110EC	120EC
Copper		75EC	100EC	125EC	75EC	100EC	125EC
Cable System - Finite Element Analysis	N/A	Determined by Owner's Engineer- Task Force recommends the acquisition of EPRI UTWORKSTATION					
Current Transformers - Bushing Types		Use Same Factors as Associated Equipment.					
Current Transformers - Free Standing Types	61	100%	128%	150%	122%	148%	150%
Air Disconnect Switches(SF_6, see NOTE #6)							
1. 30EC Temp. Rise	34	108%	153%	200%	141%	178%	200%
2. 53EC Temp. Rise		105%	127%	160%	125%	144%	174%
Circuit Breakers	41	104%	116%	133%	122%	134%	149%
Line Traps	81	101%	111%	141%	107%	118%	150%
Transformers (See Note 5)		See APPENDIX D			See APPENDIX D		
55EC Rise	50			150%			150%
65EC Rise				150%			150%
Current Limiting Reactors*(2)*	88	100%	100%	121%	118%	118%	142%
Series Capacitors	93	See Report Section VII					
Substation Rigid and Strain Bus: Max Conductor Temperature (See Note 5)							
Aluminum	85	85ºC	95ºC	105ºC	85ºC	95ºC	105ºC
ACSR		95ºC	115ºC	125ºC	95ºC	115ºC	125ºC
Copper		75ºC	100ºC	125ºC	75ºC	100ºC	125ºC
Equipment Connections		85ºC	95ºC	105ºC	85ºC	95ºC	105ºC

Conditions: Summer: June through September — Winter: December through February

Ambient Air Temp: Summer - 35EC Max. 30EC Average — Winter - 10EC Max. 5EC Average — Spring & Fall: Use interpolated values

Ambient Wind Speed: 3fps Overhead Conductors
2fps Terminal Equipment

(1) NESC Clearances must be maintained @ 'STE' temperatures

(2)55ºC rise dry type, self-cooled, 30ºC Summer, 5ºC Winter, 30 Minute STE

Notes to Table 1:

1. LTE: An infrequent emergency condition that should last no more than four hours.

2. STE: An infrequent emergency condition that should last nor more than 15 minutes.

3. If known conditions (i.e. still air) require more conservative criteria, the member company should rate their equipment accordingly.

4. If a manufacturer's rating recommendation for a specific piece of equipment is found to be in conflict with the above, the manufacturer's rating should be followed.

5. Temperature limitations of bus conductors connected to electrical power equipment should be coordinated with the thermal limits of the terminal equipment. If equipment thermal limits are unknown, apply the temperature limitations shown in Table 1.

6. SF_6 disconnect switches should be rated in the same manner as power circuit breakers.

(1) NESC Clearances must be maintained @ 'STE' temperatures

(2)55°C rise dry type, self-cooled, 30°C Summer, 5°C Winter, 30 Minute STE

NYPP 1995 Tie-Line Rating Task Force

SECTION III

N.Y.S. Regional Weather Data 1983-1992

NEW YORK STATE REGIONAL WEATHER DATA

The Task Force adopted a philosophy of presenting reference data which could be used by NYPP members in deciding what ambient weather conditions are the most appropriate for a particular time or location. To this end, hourly occurrences of temperature and coincident wind speed data was obtained from the Northeast Regional Climate Center at Cornell University[2]. This information was obtained from the airports at Albany, Binghamton, Bradford Pa., Buffalo, New York City(LaGuardia), Massena, Rochester and Syracuse. The data are then subdivided by wind speed, time of day, winter and summer. **A word of caution regarding the 0-4 feet/sec wind speeds. The actual values within this bandwidth, which includes the recommended wind speed for the NYPP rating calculation, is uncertain because of the starting inertia and bearing friction of individual anemometers.** The Task Force was unable to obtain this information from the locations presented herein.

Discussion

A. WIND SPEEDS

This parameter primarily impacts the rating of overhead conductors and buses. Changes in wind have a greater impact on the rating of a conductor than changes in ambient temperature. Since the 1982 report, research has demonstrated significant variability in wind speeds along a right-of-way caused by topography and structures, which adds to the uncertainty of a conductor rating. Research has also indicated that the minimum wind speed along a right-of-way is likely to be lower than indicated by airport data for the same hour. However, research to date has been concentrated in the Rochester Gas & Electric service area. The Task Force concluded that insufficient data was available to quantify a state-wide adjustment in the 3ft/sec wind speed that was adopted for conductor ratings in the 1982 report.

For record purposes, Appendix E in this report provides a summary and other excerpts from the NEPOOL report that was the basis for adoption of the 3ft/sec wind speed for NYPP in 1982. Its concluded that the coincidence of high temperature and wind speed less than 3ft/sec was .04% of the monitoring period.

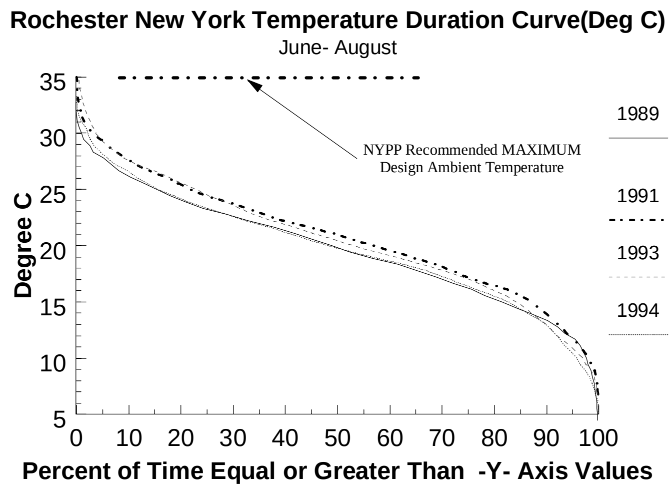
On going research has concluded that the greatest risk of violating conductor ratings occur at night, when the frequency of the 'no wind condition' increases. The cooler temperatures which may occur at night do not offset the loss of cooling effect by the low wind condition.

B. AMBIENT TEMPERATURES

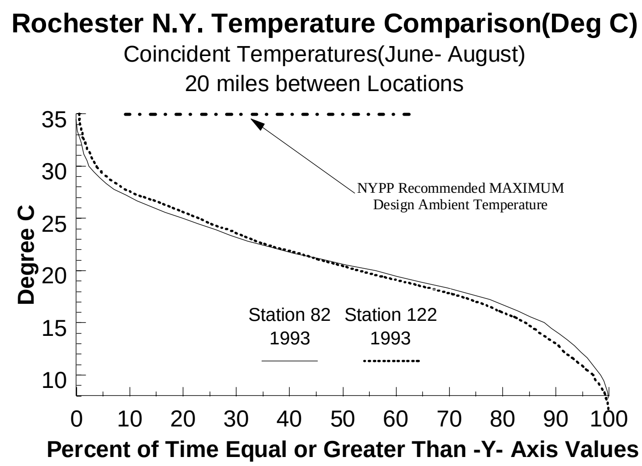
The Task Force has expanded this report to include rating adjustment factors for ambient temperatures other than those recommended for maximum summer or minimum winter temperatures. The following duration curve of summer ambient temperatures demonstrates an almost non-existent occurrence of 35°C in the selected years. Secondly, this family of curves shows that the temperature distribution is relatively constant for these years. Based upon this graph, there is potential to increase ratings, particular on equipment whose rating is not

[2] 1123 Bradfield Hall, Cornell University, Ithaca, N.Y. 14853-1901(607) 255-1751

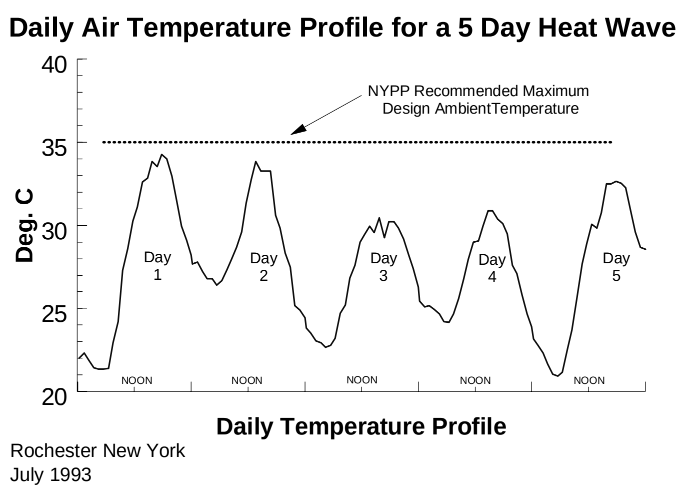
impacted by wind.



A second characteristic that makes ambiently adjusted ratings appealing is the relatively little variation in temperature across an area. This is shown below:



Another example of the conservatism of the recommended 35ºC ambient temperature for rating calculation is shown below, which will typically result in a record energy use.



The following tables are a summary of the weather data obtained for this report and the recommended summer and winter ambient temperatures occurrences.

WIND SPEED OCCURRENCES WITH TEMPERATURES AT OR ABOVE NYPP AMBIENTS FOR TIE-LINE RATINGS,10-YEAR PERIOD 1983-92

SUMMER(MAY-OCT) - TEMPERATURE 35C or above

	0-4fps				4-6fps				6-8fps				>8fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A		
Buffalo	0	0	0	0	0	0	0	0	0	1	1	0	0	4	1	0	7	0.016
Rochester	0	0	0	0	0	0	0	0	0	1	1	0	0	23	6	0	31	0.071
Syracuse	0	0	0	0	0	0	0	0	0	2	2	0	0	19	6	0	29	0.066
Binghamton	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	4	0.009
Albany	0	1	0	0	0	0	0	0	0	2	2	0	0	12	9	0	26	0.059
LaGuardia AP	0	0	0	0	0	0	0	0	0	3	3	0	2	69	36	0	113	0.258
Bradford, PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000
Massena	0	0	0	0	0	0	0	0	0	0	0	0	0	7	3	0	10	0.029

	0-4fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A		
Buffalo	0	0	0	0	0	0
Rochester	0	0	0	0	0	0
Syracuse	0	0	0	0	0	0
Binghamton	0	0	0	0	0	0
Albany	0	1	0	0	1	0.002
LaGuardia AP	0	0	0	0	0	0
Bradford, PA	0	0	0	0	0	0
Massena	0	0	0	0	0	0

WINTER(NOV-APR) - TEMPERATURE 10C or above

	0-4fps				4-6fps				6-8fps				>8fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A		
Buffalo	8	18	13	18	15	23	18	22	33	46	40	64	820	1281	1100	1787	5315	12.13
Rochester	21	18	17	62	42	29	28	80	36	43	60	112	747	1293	1096	1541	5224	11.92
Syracuse	16	8	12	85	42	35	49	124	66	75	100	179	742	1293	1059	1359	5254	11.99
Binghamton	10	10	6	17	8	10	17	19	22	32	29	47	684	1196	1042	1505	4655	10.62
Albany	34	40	48	171	8	10	15	24	57	63	81	109	718	1381	1125	1419	5302	12.1
LaGuardia AP	15	15	13	101	40	37	29	97	46	55	23	135	1553	2372	2107	3566	10266	23.42
Bradford, PA	11	10	19	73	4	10	12	30	18	24	29	82	658	1174	1056	1414	4626	10.55
Massena	38	24	42	169	5	3	4	2	7	9	11	21	492	663	823	818	3431	7.827

	0-4fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A		
Buffalo	8	18	13	18	57	0.130
Rochester	21	18	17	62	118	0.269
Syracuse	16	8	12	85	121	0.276
Binghamton	10	10	6	17	43	0.099
Albany	34	40	48	171	293	0.668
LaGuardia AP	15	15	13	101	144	0.329
Bradford, PA	11	10	19	73	113	0.258
Massena	38	24	42	169	273	0.623

Note: " %hrs" is percent of total hours in the 10-yr period or approx. 87760hrs.

C. RECOMMENDED RESEARCH

Better understanding of ambient conditions relevant to ratings would enable improved recommendations concerning NYPP rating calculations and airport data, particularly concerning overhead conductors. New research is recommended to develop information on the following topics:

- Wind speed and direction in transmission corridors in open and sheltered locations.
- Relationship between airport weather data and conditions in transmission corridors.
- Wind speed averaging period for rating calculations.

ALBANY NEW YORK

SUMMER: May - October

Hours of Occurrences

87,671 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	8	26	48	92	144	105	40	5	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	12	26	32	67	37	16	1
4PM - 7PM	0	0	0	0	0	0	0	1	15	59	93	124	121	49	6	0
8PM - 7AM	0	0	0	0	0	0	1	191	581	1142	1855	1697	655	47	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	10	13	37	59	65	38	2	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	5	13	31	44	44	15	0
4PM - 7PM	0	0	0	0	0	0	0	0	1	3	17	41	55	31	5	0
8PM - 7AM	0	0	0	0	0	0	1	26	73	144	308	330	133	10	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	15	38	101	185	196	93	2	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	19	38	102	144	119	45	2
4PM - 7PM	0	0	0	0	0	0	0	0	9	27	67	122	152	110	27	0
8PM - 7AM	0	0	0	0	0	0	0	29	143	320	585	727	378	37	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	97	521	1052	1716	1791	786	75	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	16	249	730	1351	1818	1802	570	12
4PM - 7PM	0	0	0	0	0	0	0	0	40	363	770	1316	1804	1567	356	9
8PM - 7AM	0	0	0	0	0	0	0	51	554	1527	3128	4107	2947	351	4	

BINGHAMTON NEW YORK

SUMMER: May - October

Hours of Occurrences

87,672 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	3	20	24	32	37	8	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	1	6	12	15	27	15	0	0
4PM - 7PM	0	0	0	0	0	0	0	0	1	6	12	28	39	16	2	0
8PM - 7AM	0	0	0	0	0	0	1	6	44	122	239	293	102	11	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	1	8	17	34	69	46	13	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	7	12	27	41	34	3	0
4PM - 7PM	0	0	0	0	0	0	0	0	2	15	23	43	46	24	2	0
8PM - 7AM	0	0	0	0	0	0	2	10	39	123	235	252	90	11	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	18	33	78	158	145	25	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	1	25	33	55	106	63	7	0
4PM - 7PM	0	0	0	0	0	0	0	0	10	29	59	100	144	86	6	0
8PM - 7AM	0	0	0	0	0	0	1	22	116	285	568	802	272	18	1	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	13	260	757	1351	2062	1666	465	17	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	110	428	1021	1542	2116	1410	240	3
4PM - 7PM	0	0	0	0	0	0	0	4	155	552	1049	1704	2058	1021	125	1
8PM - 7AM	0	0	0	0	0	0	0	176	1407	2995	5012	6107	2546	158	3	0

BUFFALO NEW YORK

SUMMER: May - October

Hours of Occurrences

87,667 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	1	3	5	18	35	36	6	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	1	1	3	6	11	11	1	0
4PM - 7PM	0	0	0	0	0	0	0	0	0	9	14	11	7	8	0	0
8PM - 7AM	0	0	0	0	0	0	0	5	41	133	227	205	71	1	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	4	27	51	82	80	34	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	8	22	33	29	19	2	0
4PM - 7PM	0	0	0	0	0	0	0	0	5	20	17	29	40	23	1	0
8PM - 7AM	0	0	0	0	0	0	0	8	85	181	379	363	108	5	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	10	42	71	124	135	54	2	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	8	38	50	82	72	8	1
4PM - 7PM	0	0	0	0	0	0	0	0	10	19	49	61	87	58	7	0
8PM - 7AM	0	0	0	0	0	0	0	20	163	401	765	819	347	18	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	4	153	649	1092	1713	2046	848	35	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	70	363	873	1405	2133	1794	312	4
4PM - 7PM	0	0	0	0	0	0	0	0	76	479	961	1492	2174	1541	161	1
8PM - 7AM	0	0	0	0	0	0	0	59	952	2494	4163	5388	4116	557	2	0

LaGUARDIA AIRPORT

SUMMER: May - October

Hours of Occurrences

87,671 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	0	0	9	23	27	26	2	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	0	5	8	11	15	4	0
4PM - 7PM	0	0	0	0	0	0	0	0	0	0	7	10	17	5	3	0
8PM - 7AM	0	0	0	0	0	0	0	0	0	21	143	205	282	49	2	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	0	5	24	52	73	70	8	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	0	6	23	46	51	24	0
4PM - 7PM	0	0	0	0	0	0	0	0	0	0	2	17	32	21	7	0
8PM - 7AM	0	0	0	0	0	0	0	0	0	33	159	274	382	60	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	0	4	24	59	119	82	17	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	0	8	21	48	59	26	3
4PM - 7PM	0	0	0	0	0	0	0	0	0	0	4	20	27	28	10	0
8PM - 7AM	0	0	0	0	0	0	0	0	0	35	187	393	454	85	2	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	8	244	860	1638	2220	1516	248	2
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	75	551	1324	1920	2144	919	69
4PM - 7PM	0	0	0	0	0	0	0	0	0	108	660	1517	2196	2057	576	36
8PM - 7AM	0	0	0	0	0	0	0	0	83	1141	3439	5656	6729	2094	189	0

MASSENA NEW YORK

Summer: May - October

Hours of Occurrences

87,651 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	1	14	36	81	140	224	172	45	2	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	2	7	32	71	82	85	11	0
4PM - 7PM	0	0	0	0	0	0	0	10	59	107	181	229	280	147	9	0
8PM - 7AM	0	0	0	0	0	0	45	327	965	1791	2549	2390	685	11	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	0	3	8	11	8	3	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	0	1	4	4	5	4	0
4PM - 7PM	0	0	0	0	0	0	0	0	2	5	5	11	10	5	0	0
8PM - 7AM	0	0	0	0	0	0	0	4	16	25	46	46	17	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	2	11	10	34	49	40	14	1	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	14	14	23	21	19	6	0
4PM - 7PM	0	0	0	0	0	0	0	2	5	16	36	41	44	24	6	0
8PM - 7AM	0	0	0	0	0	0	1	37	78	154	251	206	77	2	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	13	242	696	1220	1687	1790	758	44	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	97	465	961	1488	1950	1576	410	7
4PM - 7PM	0	0	0	0	0	0	0	2	133	446	982	1333	1778	1210	239	3
8PM - 7AM	0	0	0	0	0	0	10	126	920	2058	3376	3591	2008	254	0	0

ROCHESTER NEW YORK

SUMMER: May - October

Hours of Occurrences

87,669 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	1	6	26	52	44	45	10	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	1	2	18	18	45	27	4	0
4PM - 7PM	0	0	0	0	0	0	0	0	7	18	36	41	52	24	2	0
8PM - 7AM	0	0	0	0	0	0	0	20	235	471	828	614	292	12	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	1	9	21	82	77	94	29	2	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	7	32	50	67	56	10	0
4PM - 7PM	0	0	0	0	0	0	0	0	10	23	55	59	90	49	6	0
8PM - 7AM	0	0	0	0	0	0	2	29	173	333	698	725	282	17	1	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	1	21	44	98	163	186	60	5	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	1	15	40	69	117	95	9	1
4PM - 7PM	0	0	0	0	0	0	0	0	6	30	80	117	179	108	11	0
8PM - 7AM	0	0	0	0	0	0	0	31	229	497	949	1082	515	39	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	3	138	606	1060	1667	1956	778	75	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	54	369	855	1293	1911	1704	467	23
4PM - 7PM	0	0	0	0	0	0	0	0	89	468	897	1382	1896	1375	244	6
8PM - 7AM	0	0	0	0	0	0	0	57	836	2208	3268	4533	2789	315	2	0

SYRACUSE NEW YORK

SUMMER: May - October

Hours of Occurrences

87,672 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	1	8	18	37	52	50	14	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	3	16	8	20	10	1	0
4PM - 7PM	0	0	0	0	0	0	0	0	10	29	51	34	52	15	0	0
8PM - 7AM	0	0	0	0	0	0	1	54	286	498	909	962	437	18	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	1	16	71	123	195	240	98	11	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	17	52	76	84	88	23	0
4PM - 7PM	0	0	0	0	0	0	0	0	16	39	90	115	135	99	32	0
8PM - 7AM	0	0	0	0	0	0	0	41	298	564	1111	1358	693	84	3	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	0	37	72	173	300	339	135	8	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	4	20	77	123	197	192	40	2
4PM - 7PM	0	0	0	0	0	0	0	0	13	53	119	201	330	196	45	1
8PM - 7AM	0	0	0	0	0	0	0	58	275	595	1065	1301	648	74	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature (Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	5	103	479	917	1419	1597	776	65	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	26	306	780	1228	1813	1681	454	19
4PM - 7PM	0	0	0	0	0	0	0	0	71	380	826	1207	1718	1238	239	6
8PM - 7AM	0	0	0	0	0	0	0	71	546	1787	2830	3265	1952	313	3	0

BRADFORD PENNSYLVANIA

SUMMER: May - October

Hours of Occurrences

87,657 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	2	7	35	40	57	91	45	5	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	8	12	34	36	14	0	0
4PM - 7PM	0	0	0	0	0	0	0	1	21	35	49	94	91	25	2	0
8PM - 7AM	0	0	0	0	0	0	22	248	812	1403	1823	1315	214	4	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	2	8	17	33	56	42	8	1	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	0	1	5	16	44	11	0	0
4PM - 7PM	0	0	0	0	0	0	0	0	7	23	28	53	64	22	0	0
8PM - 7AM	0	0	0	0	0	0	5	44	172	234	397	401	64	4	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	2	10	45	67	145	103	6	0	0
12 Noon - 3PM	0	0	0	0	0	0	0	0	2	12	21	65	94	45	1	0
4PM - 7PM	0	0	0	0	0	0	0	0	10	44	78	132	169	50	3	0
8PM - 7AM	0	0	0	0	0	0	4	76	227	405	653	747	165	1	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	1	36	359	766	1332	2070	1648	315	6	0
12 Noon - 3PM	0	0	0	0	0	0	0	1	167	530	962	1614	2334	1241	88	0
4PM - 7PM	0	0	0	0	0	0	0	16	210	565	928	1584	2101	902	50	0
8PM - 7AM	0	0	0	0	0	0	7	241	1299	2214	3471	4214	1161	31	0	

ALBANY NEW YORK

WINTER: November - April

Hours of Occurrences

87,671 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	2	11	33	52	111	124	152	57	21	12	1	0	0	0
12 Noon - 3PM	0	0	0	0	0	4	31	62	78	40	22	11	6	1	0	0
4PM - 7PM	0	0	0	0	5	22	58	130	177	83	26	14	8	0	0	0
8PM - 7AM	0	0	5	58	211	454	663	1073	1001	326	141	27	3	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	3	3	14	20	37	38	31	6	2	0	0	0	0
12 Noon - 3PM	0	0	0	0	0	3	14	21	20	15	8	1	1	0	0	0
4PM - 7PM	0	0	0	0	2	5	15	35	45	23	9	4	1	1	0	0
8PM - 7AM	0	0	1	12	30	57	116	170	165	69	19	4	1	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	4	13	39	65	87	145	72	41	9	5	1	1	0
12 Noon - 3PM	0	0	0	0	1	12	29	57	91	95	41	13	5	2	2	0
4PM - 7PM	0	0	0	0	3	17	59	101	154	82	48	19	9	5	0	0
8PM - 7AM	0	0	0	13	64	157	293	408	486	204	83	23	2	0	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	10	123	361	659	1158	1808	1203	480	190	41	6	1	0
12 Noon - 3PM	0	0	0	0	19	186	550	1081	1810	1539	781	393	153	44	10	0
4PM - 7PM	0	0	0	0	27	230	590	1050	1818	1252	620	335	128	35	7	0
8PM - 7AM	0	0	0	25	339	976	1942	3324	4859	2532	1073	293	48	5	0	0

BINGHAMTON NEW YORK

WINTER: November - April

Hours of Occurrences

87,672 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	3	11	15	29	28	7	7	3	0	0	0	0
12 Noon - 3PM	0	0	0	0	0	2	6	13	21	6	6	4	0	0	0	0
4PM - 7PM	0	0	0	0	0	6	15	25	19	9	4	0	2	0	0	0
8PM - 7AM	0	0	0	0	9	34	81	102	85	39	9	8	0	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	5	6	20	27	28	10	3	3	1	1	0	0
12 Noon - 3PM	0	0	0	0	0	2	7	20	22	16	5	3	2	0	0	0
4PM - 7PM	0	0	0	0	0	7	17	38	27	19	10	4	3	0	0	0
8PM - 7AM	0	0	0	3	10	54	44	93	109	38	14	4	1	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	3	6	28	43	54	55	18	13	9	0	0	0	0
12 Noon - 3PM	0	0	0	0	1	6	15	38	49	28	21	5	6	0	0	0
4PM - 7PM	0	0	0	0	2	20	45	70	95	51	15	8	4	2	0	0
8PM - 7AM	0	0	0	5	23	104	228	310	287	145	29	15	3	0	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	2	13	149	460	962	1687	1868	993	483	154	39	8	0	0
12 Noon - 3PM	0	0	0	0	29	254	786	1484	1991	1228	697	317	139	42	1	0
4PM - 7PM	0	0	0	0	52	309	758	1540	1849	1145	625	281	102	34	0	0
8PM - 7AM	0	0	0	54	531	1542	2983	5329	5224	2721	1151	309	46	0	0	0

BUFFALO NEW YORK

WINTER: November - April

Hours of Occurrences

87,667 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	5	4	11	36	44	7	3	2	3	0	0	0
12 Noon - 3PM	0	0	0	0	0	0	15	16	31	15	12	1	5	0	0	0
4PM - 7PM	0	0	0	0	2	2	12	18	24	11	6	4	3	0	0	0
8PM - 7AM	0	0	0	1	13	20	84	129	114	65	12	4	2	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	1	3	10	28	43	61	18	8	6	0	1	0	0
12 Noon - 3PM	0	0	0	0	0	3	10	18	41	24	15	5	3	0	0	0
4PM - 7PM	0	0	0	0	1	4	8	20	41	20	12	3	3	0	0	0
8PM - 7AM	0	0	0	2	17	48	112	149	166	65	18	3	1	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	2	4	17	39	75	77	39	20	7	5	1	0	0
12 Noon - 3PM	0	0	0	0	0	3	31	40	61	44	31	6	6	2	1	0
4PM - 7PM	0	0	0	0	2	9	33	53	70	61	24	9	7	0	0	0
8PM - 7AM	0	0	0	7	26	135	191	347	378	172	44	18	2	0	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	2	77	368	850	1405	2027	1123	512	219	78	10	1	0
12 Noon - 3PM	0	0	0	0	20	205	694	1248	2097	1268	698	385	161	30	7	0
4PM - 7PM	0	0	0	0	25	234	777	1306	2154	1185	660	306	114	23	6	0
8PM - 7AM	0	0	0	25	216	1120	2645	4686	5988	2943	1199	522	61	5	0	0

LaGUARDIA AIRPORT

WINTER: November - April

Hours of Occurrences

87,671 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	0	10	29	26	9	4	1	1	0	0
12 Noon - 3PM	0	0	0	0	0	0	1	6	11	17	8	6	1	0	0	0
4PM - 7PM	0	0	0	0	0	0	0	1	10	19	4	4	5	0	0	0
8PM - 7AM	0	0	0	0	0	1	8	38	121	138	81	15	5	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	0	1	8	30	35	23	12	4	1	0	0
12 Noon - 3PM	0	0	0	0	0	0	2	5	17	28	16	15	6	0	0	0
4PM - 7PM	0	0	0	0	0	0	1	3	10	16	15	7	7	0	0	0
8PM - 7AM	0	0	0	0	0	1	7	29	106	123	82	10	5	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	0	1	3	17	47	48	25	15	5	1	0	0
12 Noon - 3PM	0	0	0	0	0	0	3	6	31	27	27	23	4	1	0	0
4PM - 7PM	0	0	0	0	0	0	0	5	17	32	13	7	3	0	0	0
8PM - 7AM	0	0	0	0	0	4	14	43	212	210	118	17	0	0	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	6	83	381	936	2044	1893	1156	322	64	8	3	0
12 Noon - 3PM	0	0	0	0	3	16	181	659	1681	2079	1513	588	223	38	10	0
4PM - 7PM	0	0	0	0	0	22	171	715	1750	2248	1434	552	149	29	3	0
8PM - 7AM	0	0	0	0	19	210	1111	2997	6624	5838	2799	681	77	11	0	0

MASSENA NEW YORK

WINTER: November - April

Hours of Occurrences

87,661 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	6	29	71	103	127	136	176	173	65	25	12	1	0	0	0
12 Noon - 3PM	0	0	0	2	7	17	51	64	102	32	17	4	3	0	0	0
4PM - 7PM	0	0	0	22	56	68	126	183	197	77	27	8	7	0	0	0
8PM - 7AM	0	24	213	465	578	695	899	1181	985	268	131	33	5	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	2	0	0	8	5	4	3	5	3	2	0	0	0	0
12 Noon - 3PM	0	0	0	0	0	2	9	1	6	3	1	1	0	1	0	0
4PM - 7PM	0	0	0	0	4	3	6	11	8	8	2	2	0	0	0	0
8PM - 7AM	0	0	2	7	7	21	20	31	28	8	2	0	0	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	1	10	10	24	17	31	45	7	5	1	1	0	0	0
12 Noon - 3PM	0	0	0	0	1	5	9	24	31	19	5	2	1	1	0	0
4PM - 7PM	0	0	0	1	11	17	31	42	77	22	8	2	1	0	0	0
8PM - 7AM	0	0	4	32	47	70	109	110	174	48	12	8	1	0	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	13	108	353	581	908	1235	1567	887	306	138	41	7	0	0
12 Noon - 3PM	0	0	0	32	238	587	875	1271	1738	1127	529	284	113	33	4	0
4PM - 7PM	0	0	0	30	264	562	808	1208	1651	878	455	263	82	22	1	0
8PM - 7AM	0	1	41	315	829	1548	2444	3379	4422	1739	622	181	14	1	0	0

ROCHESTER NEW YORK

WINTER: November - April

Hours of Occurrences

87,669 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	2	7	18	22	84	66	24	11	9	1	0	0	0
12 Noon - 3PM	0	0	0	0	0	2	22	43	52	21	13	3	2	0	0	0
4PM - 7PM	0	0	0	0	1	2	24	66	70	40	12	4	1	0	0	0
8PM - 7AM	0	0	0	9	33	106	264	420	378	160	51	11	0	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	9	12	39	76	102	52	24	8	9	1	0	0
12 Noon - 3PM	0	0	0	0	0	2	12	36	58	45	15	10	2	1	0	0
4PM - 7PM	0	0	0	0	1	5	29	64	71	44	21	7	0	0	0	0
8PM - 7AM	0	0	0	0	31	100	239	377	381	171	62	17	1	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	0	3	26	57	98	135	57	21	8	4	3	0	0
12 Noon - 3PM	0	0	0	0	0	2	20	53	100	64	26	10	4	3	0	0
4PM - 7PM	0	0	0	0	3	21	55	111	158	71	41	12	5	2	0	0
8PM - 7AM	0	0	0	1	44	122	318	606	591	250	90	22	0	0	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	3	71	351	820	1280	1909	1081	458	213	64	12	0	0
12 Noon - 3PM	0	0	0	0	12	223	850	1183	1925	1343	710	355	159	62	7	0
4PM - 7PM	0	0	0	0	13	257	698	1205	1887	1154	627	302	128	36	3	0
8PM - 7AM	0	0	0	10	218	1054	2326	3971	5244	2535	1090	416	31	4	0	0

SYRACUSE NEW YORK

WINTER: November - April

Hours of Occurrences

87,672 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	7	34	34	53	49	56	22	9	6	1	0	0	0
12 Noon - 3PM	0	0	0	0	0	15	21	30	34	22	4	3	1	0	0	0
4PM - 7PM	0	0	0	0	4	13	23	29	47	26	10	2	0	0	0	0
8PM - 7AM	0	0	3	40	100	128	227	369	368	191	62	20	3	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	9	15	24	43	70	110	59	29	10	3	0	0	0
12 Noon - 3PM	0	0	0	0	2	12	13	30	57	47	20	6	5	4	0	0
4PM - 7PM	0	0	0	0	10	18	28	59	104	58	36	9	3	1	0	0
8PM - 7AM	0	0	1	32	90	131	267	406	509	219	90	32	2	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	2	8	30	55	93	119	157	110	46	15	4	1	0	0
12 Noon - 3PM	0	0	0	0	7	15	23	68	95	95	46	23	5	1	0	0
4PM - 7PM	0	0	0	0	7	23	62	112	204	111	64	23	10	3	0	0
8PM - 7AM	0	0	4	39	100	185	378	615	728	343	139	34	4	2	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	19	80	301	727	1190	1912	998	454	205	67	16	0	0
12 Noon - 3PM	0	0	0	0	19	202	634	1146	1935	1319	666	377	180	60	10	0
4PM - 7PM	0	0	0	0	34	262	652	1247	1819	1080	570	302	138	44	5	0
8PM - 7AM	0	0	1	45	280	960	2232	3714	5001	2293	982	354	29	4	0	0

BRADFORD PENNSYLVANIA

WINTER: November - April

Hours of Occurrences

87,657 **TOTAL** hours analyzed during the period 1983 through 1992

Wind Speed = 0 to 4 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	9	21	49	50	54	41	18	8	3	0	0	0	0
12 Noon - 3PM	0	0	0	0	0	9	17	21	18	13	7	3	0	0	0	0
4PM - 7PM	0	0	0	0	4	20	34	52	63	33	8	5	5	1	0	0
8PM - 7AM	0	0	6	48	125	271	370	453	293	185	60	12	1	0	0	0

Wind Speed = 4 to 6 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	2	4	5	19	22	25	27	12	3	1	0	0	0	0
12 Noon - 3PM	0	0	0	0	0	1	11	9	18	9	7	1	2	0	0	0
4PM - 7PM	0	0	0	0	0	2	17	30	34	14	10	2	0	0	0	0
8PM - 7AM	0	0	1	15	35	75	119	156	142	55	26	3	1	0	0	0

Wind Speed = 6 to 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	0	3	9	28	46	84	57	33	15	1	2	0	0	0
12 Noon - 3PM	0	0	0	0	0	7	16	30	41	23	12	10	1	1	0	0
4PM - 7PM	0	0	0	0	4	18	30	66	61	42	16	7	5	1	0	0
8PM - 7AM	0	0	2	14	51	128	233	327	282	146	55	23	4	0	0	0

Wind Speed = GREATER THAN 8 feet/second

Time Period	Temperature(Deg. C)															
	-40 to -35	-35 to -31	-30 to -26	-25 to -21	-20 to -16	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39
8-11AM	0	0	13	32	152	513	1015	1777	1589	849	427	169	53	9	0	0
12 Noon - 3PM	0	0	0	23	45	324	793	1697	1788	1120	659	317	147	51	0	0
4PM - 7PM	0	0	0	24	79	374	804	1746	1562	1020	598	297	127	36	0	0
8PM - 7AM	0	0	31	118	488	1582	2792	5335	4149	2126	1117	269	28	0	0	0

NYPP 1995 Tie-Line Rating Task Force

SECTION IV

Overhead Conductor Ratings

OVERHEAD CONDUCTOR RATINGS

The conductor ratings parameters given in this report are the recommended factors to be used in determining the thermal ratings of overhead conductors. "The prime consideration in thermal rating determination is that the conductor not sustain more loss of strength due to annealing over its useful life than some agreed upon percentage, usually approximately ten percent." This statement from the Overhead Conductor Section of the 1970 report states the criteria that were used to develop allowable conductor temperatures. The limits were retained in the 1983 revision.

Allowable conductor temperatures for each operating condition were determined on the basis of the loss-of-strength criteria and the assumed number of hours of operation at each condition. The procedure was as follows: (1) the number of hours of operation at each operating condition was selected; (2) a tentative choice was made of the conductor operating temperature for each operating condition; (3) the time durations and temperatures from (1) and (2) were applied to laboratory data, giving loss of strength at a fixed temperature as a function of time to find the cumulative loss of strength which was then tested against the criterion. If the cumulative loss was too far over or under the 10 percent criterion, new conductor temperatures were chosen and the process repeated.

The 1995 Task Force reviewed the existing recommended conductor operating temperatures as they relate to loss of strength, annealing and clearances, and reviewed industry experience in a meeting with Glenn Davidson of Stone & Webster. It was determined that conductors in service suffer little strength loss since they seldom operate near rated temperatures and that the governing factor for a change in conductor rating would be clearance to ground or other wires. Given the uncertainty of actual field clearances, no reason was found to change the conductor temperatures indicated in the 1970 report, so they remain the same for each conductor type. It must be noted here that for lines built under the 1977 and more recent editions of the National Electrical Safety Code(NESC), clearances must be maintained at the highest(STE) conductor temperatures recommended in this report. For lines built under NESC editions prior to 1977, the owning utility may determine that in certain cases temperatures lower than recommended may be required to maintain clearances.

Overhead conductor ratings are determined by calculations based on the conductor temperatures and other parameters with the most important ones being A-C resistance, ambient wind speed and temperature. No industry standard ratings exist for overhead conductors, but rating calculation methods for steady-state conditions (normal and LTE) and a transient thermal rating are contained in the IEEE Standard 738-1993 (Reference #2). NYPP ratings should be calculated in accordance with this standard. This newly updated standard contains a computer program listing, a floppy disk containing the program and methodology of the calculation is explained. <u>The Task Force recommends obtaining and using this standard for overhead rating calculations.</u> The method is applicable to all of the conductor types found in NYPP systems, using the proper values of A-C resistance and other parameters. It can also be used to calculate conductor ratings for ambient conditions other than those recommended herein.

The rating calculation requires that values be chosen for a number of parameters as input to the calculation. Conductor emissivity, latitude and wind angle are examples. Each utility must select input values appropriate for their lines. If identical parameters are not assumed by two parties making the calculation for the same line, the ratings calculated will be different. In order for NYPP members to have a common set of conductor ratings, the parameters suggested in Appendix A should be used.

Ampacity for special conductor types can be calculated by the IEEE method, but the manufacturer should be consulted regarding temperature limits. For steel-supported aluminum conductor (SSAC), there is a single maximum operating temperature to select based on performance of the core wire coating and conductor accessories. Normal, LTE and STE ratings will be the same. For self-damping conductor (SDC) and compacted strand conductor, the IEEE ampacity calculation can be used with the temperature limits for ACSR.

A number of points to consider with respect to practical application are as follows:

- Thermal Ratings: The NYPP ratings provide thermal limits only, and do not recognize the increased sag and reduced ground clearance that occurs with higher conductor temperatures. **Some line ratings may be limited by clearance limits rather than thermal limits.**

- Physical Conditions: The NYPP ratings assume conductors and accessories to be in a condition so that conductor temperatures are not increased by broken strands, faulty connectors and splices and similar conditions.

- High Conductor Temperatures: Conditions are recognized that can cause conductor temperature to exceed the selected limits during any given period of operation. All such conditions require the coincidence of high ambient temperatures and high power transfer, with the following modifying or additional events:

  A. Ambient temperature exceeding assumed ambient.

  B. Wind speed less than 3 ft./sec.

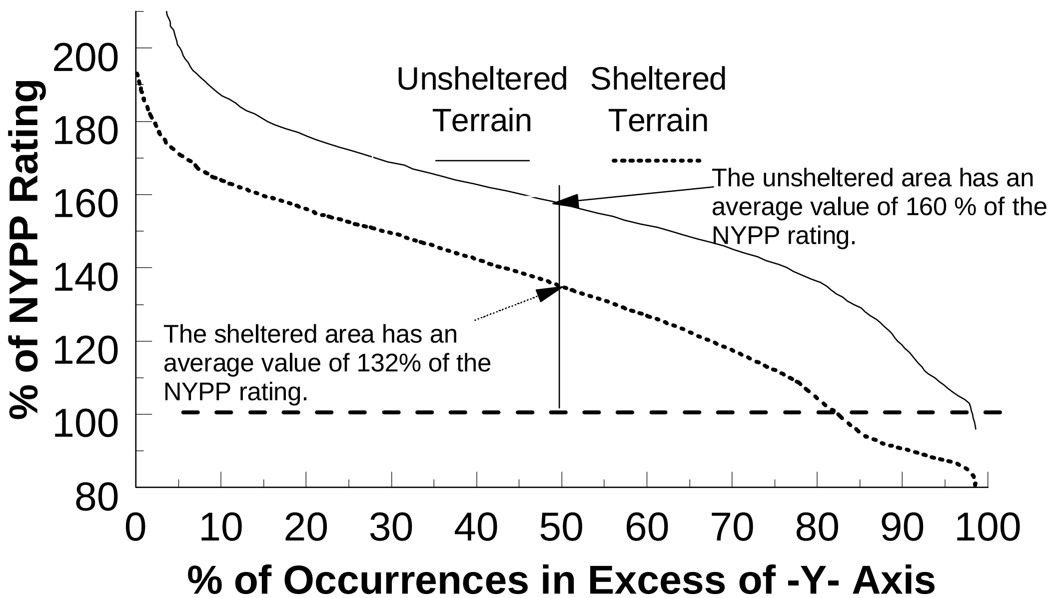
  C. Wind direction parallel to conductors which reduces heat loss by convection (conventional industry practice is to assume wind perpendicular to conductors in rating calculations). The IEEE Standard 738-1993 incorporates formulae which allows the user to define a wind angle other than perpendicular. It can be demonstrated that a change in wind angle from perpendicular to 20^{o} will reduce the rating by 10%. Consideration of using wind angle for ratings would include review of wind direction data for low wind/high temperature conditions. Application of wind angle to rating calculations is left an option to be decided by each utility.

D. Emergency power flow that exceeds the STE rating due to system conditions at the time.

E. A "sheltered area" of very low wind speed may exist somewhere in a line. The graph below presents coincident wind speed data(feet/second) obtained from a sheltered and unsheltered location in the Rochester Gas & Electric franchise area. Similar data could be collected and curves developed by other utilities. These curves could be used to develop a "wind sheltering factor" to account for lower effective wind speeds along a transmission line.

Impact of Topography on Overhead Conductor Rating

Comparison of coincident ratings(% of NYPP) based on
on wind speeds obtained from a valley location and open flat location



May through September 1988, hourly values
90 Degree wind angle

The curve in the figure above for "unsheltered terrain" is typical of wind speeds usually obtained from airport weather stations. Since temperature difference were small between the locations, most of the difference in ratings was due to reduced wind speed at the sheltered location. The rating was below the NYPP rating for approximately 18% of this period. If this was considered excessive by the utility, the rating could be adjusted to reduce the over-rating time.

Favorable conditions are also possible that are taken into account in rating calculations, including:

A. Ambient temperatures that are different than those chosen for the calculation of the NYPP summer or winter rating, The table below contains factors to adjust the ratings for different ambient air temperatures:

SAMPLE RATING FACTORS
(LTE)

Ambient Temperature °C	Ambient Temperature Adjustment Factors (%)		
	Conductor Types		
	4/0 Cu 7 strand "AA" Class	795 All Aluminum 37 strand	1431kcm ACSR 45/7
40	95	95	96
35	100	100	100
30	104	104	103
25	107	108	106
20	111	112	109
15	115	116	112
10	118	120	114
5	121	123	117
0	125	127	119
-5	127	130	122
-10	131	134	125
-15	134	137	127
-20	136	140	129
-25	139	143	132
-30	142	146	134
-35	145	148	136
-40	147	151	138

B. Wind exceeding 3 ft./sec.

C. Cloud cover or darkness that reduces or eliminates solar heating. The following table shows an approximate 5% increase in rating when sun is not present. It also demonstrates lesser increases as the conductor gets smaller:

IMPACT OF SOLAR RADIATION ON CONDUCTOR RATING

Conductor Type	Summer LTE Rating with SUN	Summer LTE Rating without SUN	% Increase with no SUN
2493 kcm ACSR 66/6	2686 amperes	2877 amperes	7.1%
1431kcm ACSR 45/7	1787 amperes	1888 amperes	5.6%
795 kcm ACSR 26/7	1258 amperes	1322 amperes	5.0%
336kcm ACSR 26/7	724 amperes	755 amperes	4.2%

D. Rain.

E. Cooling due to vertical air current caused by heating of the wires or the earth.

F. Pre-disturbance power flow below the normal rating.

The frequency and duration of excess temperature occurrences is assumed to be low enough that the lifetime 10 percent loss of strength criterion will not be exceeded.

STE RATING, PRELOADING

The STE rating calculation in this report is based on the assumption that the conductor has been operating at the temperature associated with its normal current rating prior to the incident. This assumption is needed to define the temperature rise that occurs during STE operation, in which a step change in loading is followed by a transient increase from the normal conductor temperature to the STE temperature. Since the conductor time constant is generally greater than 15 minutes, the conductor temperature will still be rising at the end of the STE period. A transient calculation is required to determine current that will cause the specified temperature rise in 15 minutes. The STE rating is the only one of the three ratings (Norm, LTE, STE) which takes advantage of the conductor's time constant. That is, following a step change in loading, it will take a while (minutes) for the conductor to reach a new steady-state temperature. Thus, the lower the starting point, the less "damage" is done in 15 minutes.

If the conductor is actually operating at less than (more than) normal steady-state temperature, the STE rating would increase (decrease).

Individual Companies may choose to use non-standard STE ratings for known actual operating conditions. This could be accomplished the same way dynamic ratings for known ambient conditions are accomplished today. The transient program provided with the IEEE Std 738-1993 can be used to calculate STE ratings for preload currents other than the normal rating value.

OVERHEAD CONDUCTOR
(References)

1. Current Carrying Capacity of ACSR - by H.E. House and P.D. Tuttle - AIEE Transactions, Power Apparatus and Systems, Vol. 77, Part III, 1958, pp. 1169-77.

IEEE Standards

2. IEEE Standard for the Calculating the Current-Temperature Relationship of Bare Overhead Conductors - IEEE Standard 738-1993

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SECTION V

Air Disconnect Switches

AIR DISCONNECT SWITCHES

Synopsis

The standard requirements for high voltage air disconnect switches are covered in ANSI Standards C37.30 to C37.37. These standards specify, in addition to other requirements, the rated current, the conditions under which the rated current is determined and the maximum allowable temperature rise limitations of the various components in the switch. For example, the maximum temperature rise for silver-to-silver contacts in air is 53°C. A formula is provided in ANSI Standard C37.30 for the calculation of the allowable continuous current at ambient temperature at which the switch can operate without exceeding its temperature rise limitations.

Prior to 1971, ANSI Standards allowed a 30°C temperature rise over a maximum ambient of 40°C, for a maximum overall temperature of 70°C. Switches manufactured in accordance with the 30°C temperature rise limit have a higher loading capability than switches manufactured in accordance with standards published in 1971 and later.

Two switch ratings are listed in the table. The ratings listed under 30°C rise apply to those switches designed in accordance with the 30°C rise limitation. The ratings listed under 53°C rise apply to those switches with silver-to-silver contacts designed in accordance with standards published in 1971 and later. The user must determine the criteria under which the switch was designed and determine the appropriate ratings.

A review of the switch formula for STE ratings in 1982 report disclosed that it was inconsistent with the design criteria recommended by ANSI. A formula developed by PJM member companies(Reference #2) has been adopted in this report. The new formula yields more conservative ratings which results in a small reduction in STE ratings in certain instances.

The rating factors for air disconnects are based on switches that are maintained in "factory new" condition. Any operation above nameplate rating imposes additional duty on switch contacts. If regular maintenance is not performed, a more conservative rating factor may be obtained by taking only 50 percent of the increase over the nominal rating.(Reference #3).

Discussion

The nameplate current ratings for all switches are based on a 40°C ambient temperature, no wind, and a finite temperature rise for the switch part at nameplate current rating. The allowable continuous current ratings at conditions other than specified in the standards can be determined from the following equation.

$$I_{max} = I_{rated}\sqrt{\left[\frac{\theta_{max} - \theta_a}{\theta_r}\right]}$$

Where I_{max} = maximum allowable continuous current (amperes)

I_{rated} = nameplate rating (amperes)

Θ_{max} = maximum allowable temperature for switch part (°C)

Θ_a = ambient temperature (°C)

Θ_r = limit of observable temperature rise (°C) at nameplate rating of the switch part.

For switches manufactured in accordance with the 30ºC rise temperature limit, the nameplate rating was based on a temperature rise of 30°C (Θ_r) at the rated nameplate current (I_r) over a 40°C ambient temperature (Θ_a) giving a maximum allowable temperature (Θ_{max}) of 70°C. For the emergency rating, silver to silver contacts were assumed and the maximum allowable temperature was limited to 105°C. With a maximum summer ambient of 35°C and winter ambient of 10°C, the normal and LTE ratings of these switches would calculate to be in percent of nameplate rating as follows:

Seasonal Rating Factors(%)
30ºC Rise Disconnect Switches

Ambient Temperature Θ_a	**Max Temp. of Switch Part (Θ_{max})**	**Allowable Loading**
35°C	70°C	108% (***Summer Normal***)
35°C	105°C	153% (***Summer LTE***)
10°C	70°C	141% (***Winter Normal***)
10°C	105°C	178% (***Winter LTE***)

For switches manufactured in accordance with ANSI C37.30-1971 and later standards, the normal rating was based on switches with silver-to-silver contacts having a 53°C temperature rise over a 40°C ambient, giving a maximum allowable temperature of 93°C at nameplate rating. For emergency operation the maximum allowable temperature of 120°C as accepted for silver-to-silver contacts based on IEEE Transactions Paper F78 213-1 published July-August 1979 (Reference #1). The normal and LTE ratings of these switches at 35^{0}C and 10°C ambients as a percent of nameplate rating are:

Seasonal Rating Factors(%)
53°C Rise Disconnect Switches

Ambient Temperature Θ_a	Max Temp. of Switch Part (Θ_{max})	Allowable Loading
35°C	93°C	105% (*Summer Normal*)
35°C	120°C	127% (*Summer LTE*)
10°C	93°C	125% (*Winter Normal*)
10°C	120°C	144% (*Winter LTE*)

When factory tests are available, the actual temperature rise Θr at the nameplate rating of the switch can be used. Generally, this factor will be less than the factor specified in ANSI C37.30, resulting in an increased loading capability.

Short Time Emergency Ratings

Short time emergency ratings are determined based on the switch thermal time constant which is a function of the heat storage capacity of the switch. Switch loading prior to applying the short time emergency rating is assumed to be 100 percent of the normal rating with switch contacts at normal allowable maximum temperature. An emergency allowable maximum temperature is utilized. The loss of tensile strength of copper and aluminum alloys due to annealing is expected to be negligible.

The short time 15 minute ratings were calculated, using the following formulas for silver-to-silver contacts. However, in all cases, the short time rating has been arbitrarily limited to 200 percent of nameplate ratings of all 30°C rise switches and 180 percent of nameplate ratings of the 53°C switches.

$$I_{et}^{*} = I\left[\frac{1}{\theta_r}\left(\frac{\theta_{maxe2} - \theta_{max_n}}{1 - e^{-t/T}} + \theta_{max_n} - \theta_a\right)\right]^{1/\eta}$$

Ref. #2

* Rating is limited to 180% of normal rating.(for 53 deg C rise designs)

Where

I_{et}	=	Emergency rating of less than 2 hours (amperes)
I	=	Rated continuous current
$\Theta_{max\ n}$	=	Normal allowable temperature for switch part (°C)
Θ_{maxe2}	=	STE Emergency allowable maximum temperature (20°C higher than maximum allowable LTE temperature for switch part)
Θ_a	=	ambient temperature (°C)
t	=	STE duration time (15 minutes)
T	=	thermal time constant of switch in minutes. This may be conservatively assumed to be 30 minutes.
η	=	empirical temperature rise exponent = 1.8

Example: Short time emergency loading for switch rated for Θ_r = 53°C temperature rise, t = 15 minutes, and ambient temperature Θ_a = 35°C.

1. Switch temperature at normal preload:

   $\Theta_{max\ n}$ = 93°C(53°C +40°C rated ambient)

2. Emergency allowable maximum temperature:

   Θ_{maxe2} = 120°C + 20°C = 140°C

   where 120°C = LTE max temperature
   20°C = STE transient rise

3. Solve for I_{et}

Because the calculated value is greater than the maximum recommended in the standard, the short time emergency rating would be 1.80I

RATINGS FACTORS(%) FOR
30 Degree Rise Switch

Ambient °C Temp.	**Normal Loading**	**LTE Loading**	**STE Loading**
-40	191	200	200
-35	187	200	200
-30	183	200	200
-25	178	200	200
-20	173	200	200
-15	168	200	200
-10	163	196	200
-5	158	191	200
0	153	187	200
5	147	183	200
10	141	178	200
15	135	173	200
20	129	168	200
25	122	163	200
30	115	158	200
35	108	153	200
40	100	147	200

Normal maximum allowable temperature = 70°C
LTE maximum allowable temperature limit 105°C
Limit of observable temperature rise = 30°C

RATINGS FACTORS(%) FOR
53 Degree Rise Switch

Ambient °C Temp.	Normal Loading	LTE Loading	STE Loading
-40	158	174	180
-35	155	171	180
-30	152	168	180
-25	149	165	180
-20	146	163	180
-15	143	160	180
-10	139	157	180
-5	136	154	180
0	132	150	180
5	129	147	180
10	125	144	180
15	121	141	180
20	117	137	180
25	113	134	180
30	109	130	180
35	105	127	180
40	100	123	180

Normal maximum allowable temperature = 93°C
LTE maximum allowable temperature limit 120°C
Limit of observable temperature rise = 53°C

AIR DISCONNECT SWITCHES
(References)

1. Loading of Substation Electrical Equipment with Emphasis on Thermal Capability, Part II - Application by I. S. Bendo, D. E. Cooper, D. O. Craghead, P. Q. Nelson - IEEE Transactions, Power Apparatus and Systems, Vol. PAS-98, No. 4, July/Aug. 1979, pp. 1403-19.
2. Determination of Disconnecting Switch Ratings for the Pennsylvania-New Jersey-Maryland Interconnection, by J.V. Barker,Jr, W.J. Beran, K.D. Hendrix, M.D. Hill, P.L. Kolarik, D.E. Massey - IEEE Transactions, Power Apparatus and Systems, Vol. PAS-91, Jan/June, 1972, pp. 404-411.
3. Continuous Overload Capability of Kearney Switches, by J.H. Ashton, Technical Paper 229-738, Kearney-National(Canada) Limited, September 23, 1977.

ANSI Standards

4.	C37.30 - 1992[3]	Definitions and Requirements for High Voltage Air Switches
5.	C29.10 - 1989[4]	Electrical and Mechanical Characteristics of Indoor Apparatus Insulators
6.	C37.32 - 1990[5]	Switchgear - High Voltage Air Switches - Rated Control Voltages and Their Ranges
7.	C37.33 - 1987	Rated Control Voltages and Their Ranges for High Voltage Air Switches
8.	C37.34 - 1971[1]	Test Code for High Voltage Air Switches, **Reaffirmed, 1987**.
9.	C37.35 - 1976[1]	Application, Installation, Operation and Maintenance of High Voltage Air Disconnecting and Load Interrupting Switches, **Reaffirmed, 1992**.
10.	C37.37 - 1979[1]	Loading Guide for AC High-Voltage Air Switches (in excess of 1000 volts), **Reaffirmed in 1987.**

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[3] *ANSI/IEEE Standard*

[4] *This standard replaces C37.31-1962,(rev 1976)Electrical and Mechanical Characteristics of Indoor Apparatus Insulators*

[5] *Formerly titled Schedules of Preferred Ratings, Manufacturing,Specifications and Application Guide for High Voltage Air Switches, Bus Supports and Switch Accessories.*

NYPP 1995 Tie-Line Rating Task Force

SECTION VI

High Voltage Power Circuit Breakers

HIGH VOLTAGE POWER CIRCUIT BREAKERS

Synopsis

The rating factors for circuit breakers are based on ANSI standard C37.010-1979, 'Application Guide for AC High Voltage Circuit Breakers' and its supplement C37.010b-1985 on 'Emergency Load Current - Carrying Capability' which covers the STE and LTE conditions. Continuous-current temperature limits of breaker components are not exceeded during normal loading. During LTE and STE loading, breaker component temperatures 15°C above the continuous-current limits are allowed, and some loss of life may result. Rating factors include the required adjustment for the NYPP summer and winter ambient temperatures, and remain the same as in the 1982 Tie Line Ratings Report. Optional short-time rating factors are given as provided for in the application guide.

Discussion

A. RATING FACTORS FOR NORMAL OPERATION

Rating factors for normal operation are obtained by adjusting the nameplate continuous load current capability for ambient temperatures other than 40°C as indicated in Section 4.4.3.2 of C37.010. The formula is:

$$\frac{I_a}{I_r} = \left[\frac{\theta_{max} - \theta_a}{\theta_r}\right]^{1/1.8}$$

I_a = Allowable load current at ambient temperature θ_a

I_r = Rated continuous current (nameplate)

θ_{max} = Allowable hottest spot total temperature = θ_r + 40°C

θ_a = Actual ambient temperature; °C

θ_r = Allowable hottest spot rise at rated current

The exponent of 1/1.8 in the formula is derived from the relationship, based on testing experience, that the temperature rise of a current-carrying component is proportional to current raised to an exponent that varies from 1.6 to 2. An average value of 1.8 for the exponent is used throughout the guide.

The formula indicates that the rating factor at actual ambient temperature θ_a depends on the limits of total temperature and temperature rise, θ_{max} and θ_r, of critical circuit breaker components. Temperature limits are listed in Table 1 of the guide, which is reproduced below as Table 1, columns 1-5, with the addition of calculated rating factors for NYPP summer and winter ambient temperatures. The application guide requires that for actual ambient temperatures less than 40ºC, θ_{max} and θ_r for the circuit breaker components with the highest temperature limit should be used to calculate rating factors. NYPP normal rating factors are for silver contacts in air(θ_{max}=105ºC).

In assigning breaker ratings, utilities should note that manufacturing practice may result in some units having components with higher capabilities than the nameplate rating. If load on a breaker is near its rating, an inquiry to its manufacturer may be advisable concerning the unit's actual capability.

B. RATING FACTORS FOR LTE CONDITIONS

Rating factors for LTE conditions are based on section 4.4.4.2 and 4.4.4.3 of ANSI C37.010b. Emergency load-carrying ability is achieved in the application guide by increasing the allowable total temperature and temperature rise of breaker components above the values allowed for continuous operation. The guide states that this may reduce the operating life of the breaker. Some conditions for using the emergency rating factors include:

1) Application is to outdoor breakers(metal-clad switchgear will have its own application guide).
2) The circuit breaker shall have been maintained in essentially new condition.
3) For a minimum of 2 hours following the emergency period, load current shall be limited to 95% of I_a, the rated continuous current for the selected ambient temperature(normal rating).
4) Mandatory inspection and maintenance procedures in the standard are required following emergency operation.
5) During and after emergency operation and prior to maintenance, the circuit breaker shall be capable of one operation at its rated short-circuit current.

The guide provides rating factors for four-hour and eight-hour periods of emergency operation. The factors are based on increased operating temperatures of 15°C for four hours and 10°C for eight hours, above the temperature limits for continuous operation. The four-hour and eight-hour periods must be separate, with inspection and maintenance required when the duration of separate periods of emergency operation totals 16 hours.

Rating factors are adjusted for ambient temperatures other than 40°C using a formula in standard section 4.4.4.3:

$$\frac{I_{ea}}{I_r} = \left[\left[\frac{I_a}{I_r}\right]^{1.8} + \left[\frac{I_e}{I_r}\right]^{1.8} - 1\right]^{1/1.8}$$

I_{ea} = emergency load current at actual ambient temperature.

I_a/I_r = rating factor for normal operation.

I_e/I_r = capability factor from ANSI C37.010b-1985 Table 2(a).

I_a = allowable load current at actual ambient temperature.

THE RATING FACTOR SHOULD NOT EXCEED 200% UNDER THIS APPLICATION GUIDE. The 40°C ambient rating factors are shown in table 2(a) of the standard corresponding to the limiting temperatures of breaker components. Table 1, columns 6-11, provide four-hour and eight-hour rating factors calculated for the 35°C and 10°C NYPP summer and winter ambient conditions. NYPP LTE rating factors are taken from Table 1, columns 7 and 8, for silver contacts in air.

C. RATING FACTORS FOR STE CONDITIONS

Rating factors for STE conditions are based on the provisions of section 4.4.4.4 of standard C37.010b. The same 15°C increase is allowed in the total temperature of circuit breaker components as for the four-hour emergency rating. Conditions for use of the short-time rating factors are:

1) Initial current shall not be greater than the normal rating.
2) Following application of a short-time emergency current, current must be reduced to below the four-hour emergency current(LTE rating) for the remainder of the four-hour period, or to not more than 95% of the rated continuous current(Normal rating) for a minimum of two hours.
3) Regarding inspection and maintenance requirements, each isolated short-time emergency event shall be considered equal to one four-hour emergency period unless it is part of a four-hour emergency period.

For the rating factor calculation, reference is made to C37.010 section 4.4.3.3, Figure 1. A value is required for the circuit breaker thermal time constant τ ; $\tau = 30$ min. is used, which the guide says is typical. The rating factor defines the current level for which the total temperature will reach the θ_{max} + 15°C level within a specified period which is 15 minutes for the NYPP STE rating. The resulting NYPP STE rating factors based on the temperature limit for silver contacts in air are: summer = 133% and winter = 149%.

The calculation method given in the 1982 Tie Line Rating Report is a valid alternative method, repeated here for information:

$$\frac{I_s}{I_r} = \left[\frac{\theta_{max} + [\Delta\theta/(1 - e^{-t/\tau})] - \theta_a}{\theta_a}\right]^{1/1.8} = \left[\frac{\theta_{max} + 38.5 - \theta_a}{\theta_a}\right]^{1/1.8}$$

where $\Delta\theta$ = Allowable increase in component temperature = 15°C

t = Time duration of STE loading = 15 min.

τ = Thermal time constant of breaker = 30 min.

I_s = Allowable STE current at ambient θ_a

The rating factors are calculated for $\Theta_{max} = 105°C$, the limit for silver contacts in air. The factors are applicable to oil and SF_6 breakers also, and are probably more conservative for those types than for air breakers.

TABLE 1: Breaker Component Temperature Limits and Rating Factors(%) Calculated for NYPP Summer and Winter Ambient Conditions

Column #	1	2	3	4	5	6	7	8	9	10	11
Component		θ_r	θ_{max}	**Summer Normal Rating Factor θ_a=35°C**	**Winter Normal Rating Factor θ_a=10°C**	θ_{max}	**4 Hour Rating Factor θ_a=35°C**	**4 Hour Rating Factor θ_a=10°C**	θ_{max}	**8 Hour Rating Factor θ_a=35°C**	**8 Hour Rating Factor θ_a=10°C**
Circuit breaker parts handled by the operator in the normal course of their duties		10°C	50°C	125	200						
Copper contacts, copper-in-copper conducing joints, external surfaces accessible to the operator in the normal course of his/her duties, external terminal connected to bushing		30°C	70°C	109	147	85°C	133	166	80°C	125	160
Top oil		40°C	80°C	107	136	95°C	125	151	90°C	119	146
Breaker terminals to be connected to 85°C insulated cable		45°C	85°C	106	132	100°C	122	146	95°C	117	141
Hottest spot of parts in contact with oil		50°C	90°C	105	129	105°C	119	141	100°C	115	137
Silver (or equal) contacts in air		65°C	105°C	104	123	120°C	116	133	115°C	112	133
External surfaces not accessible to an operator in the normal course of his/her duties		70°C	110°C	104	122	125°C	116	132	120°C	111	132
Honest spot winding temperature of 80°C dry-type current transformers		110°C	150°C	103	114	165°C	111	121	150°C	108	119

D. OPTIONAL SHORT-TIME RATINGS BASED ON THE STANDARDS

In addition to NYPP rating factors, ANSI standards for circuit breakers provide for other types of ratings that are included in this report for information. One type is the eight-hour rating already covered in part B of this section. Another is short-time ratings provided in C37.010 and C37.010b that may be employed when the initial current is at or below the normal ratings. In C37.010 the component total temperatures are limited to the values for continuous ratings. In C37.010b the temperatures are allowed to be 15ºC higher, with possible loss of operating life.

The short-time load current capability tables given in Table 2 are based on C37.010, in which total temperatures are limited to the continuous rating values from C37.010 Table 1. Use of higher temperature limits should be infrequent and should be limited to the LTE and STE ratings. The table provide rating factors for a range of ambient temperatures, so advantage may be taken of favorable ambient conditions. The rating factors may be applied under the following conditions:

1) Initial current is less than the rated current.
2) Short-time load current is limited to the indicated time period.

$$\frac{I_s}{I_r} = 100\left[\frac{I_i}{I_r}\right] x \left[1 + \frac{\theta_{max} - Y - \theta_a}{Y(1 - e^{-t_s/T})}\right]^{1/1.8}$$

$$Y = (\theta_{max} - 40)\left[\frac{I_i}{I_r}\right]^{1.8}$$

Rating factors are calculated from the following equations based on C37.010 section 4.4.3.3.2:
An example application of Table 2 is as follows:

Known conditions : Pre-contingency(initial) current I_i = 1125 amperes
Ambient temperature θ_a = 6ºC
Breaker Rated Current at 40ºC I_r = 3000 amperes
Breaker θ_{max} = 105ºC (from Table 1 for type of breaker)
Assumed condition: Anticipated short-time period t_s = 20 minutes

To obtain Short-time Rating Factor:

1) Calculate I_i/I_r 1125/3000 = .375
2) Round I_i/I_r and θ_a up to 0.4 and 10ºC.
3) Enter Table 2 section for θ_{max} = 105ºC and t_s = 20 min., in the column for I_i/I_r = .4 and the row for ambient temperature θ_a =10ºC, find the rating factor I_s/I_r = 177%.

Table 2: Short time rating factors (100 x I_s/I_r) for circuit breakers for selected values of initial current ratio I_i/I_r, θ_{max}, θ_a and t_s

			θ_{max} = 105°C t_c = 30 minutes							θ_{max} = 90°C t_c = 30 minutes						
t_s MIN	θ_a deg C	I_i/I_r=	.8	.7	.6	.5	.4	.3	.2	.8	.7	.6	.5	.4	.3	.2
10	40		140	155	167	177	166	19	197	140	155	187	177	186	192	197
	30		162	176	186	196	200			188	181	192	200	200		
	20		181	194	200					192	200					
	10		199													
15	40		126	136	144	151	157	161	176	126	136	144	151	157	161	155
	30		143	152	160	166	171	178	179	148	156	164	170	176	180	183
	20		169	167	174	180	185	189	192	167	175	182	188	193	197	200
	10		173	181	187	193	198	200	200	185	193	199	200			
	0		187	194	200	200				200						
	-10		199	200												
20	40		118	125	131	137	141	14	147	118	125	131	137	141	144	147
	30		133	139	145	150	154	15	158	137	143	149	154	157	181	169
	20		146	152	158	162	166	16	171	154	160	165	169	173	176	178
	10		159	164	169	174	177	18	182	169	175	180	184	187	190	192
	0		171	176	181	185	188	19	193	184	189	193	197	200	200	
	-10		182	187	191	195	198	20	200	197	200					
	-20		192	197	200	200										
	-30		200													
25	40		113	119	123	127	131	13	135	113	119	123	127	131	138	135
	30		126	131	136	139	143	14	147	130	135	139	143	146	148	150
	20		139	143	147	151	154	15	158	145	150	154	157	180	182	184
	10		150	154	158	161	164	16	168	159	164	167	170	173	175	177
	0		160	165	168	171	174	17	178	173	176	180	183	185	187	189
	-10		171	175	178	181	183	18	187	185	183	192	195	197	199	200
	-20		180	184	187	190	193	19	196	197	200					
	-30		189	193	196	199	200									
	-40		198	200												
30	40		110	114	118	121	124	12	128	110	114	118	121	124	126	128
	30		122	126	130	132	135	13	138	126	129	133	136	138	140	141
	20		133	137	140	143	145	14	148	140	143	146	149	151	153	154
	10		144	147	150	153	155	15	158	153	158	159	161	163	116	166
	0		154	157	160	162	164	16	167	165	168	171	173	175	177	178
	-10		163	168	169	171	173	17	176	176	179	182	184	186	187	189
	-20		172	175	178	180	182	18	184	187	190	192	195	196	198	199
	-30		181	183	186	188	190	19	193	198	200					
	-40		189	192	194	196	198	19	200							
40	40		106	109	111	113	116	117	118	106	109	111	113	115	117	118
	30		117	120	122	124	125	126	127	120	123	125	127	128	129	130
	20		127	129	131	133	135	136	137	133	135	137	138	140	141	142
	10		136	138	140	142	144	145	146	144	146	148	150	151	152	153
	0		145	147	149	151	152	153	154	155	157	159	160	162	163	164
	-10		154	156	157	159	160	161	162	165	167	169	171	172	173	174
	-20		162	164	165	167	168	168	170	175	177	179	180	181	182	183
	-30		169	171	173	174	175	176	177	185	187	188	189	191	191	192
	-40		177	179	180	182	183	184	184	194	195	197	198	199	200	200

CIRCUIT BREAKERS
(References)

ANSI Standards

1. C37.010 - 1979 Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis, **Reaffirmed in 1988**.

2. C37.010B - 1985 IEEE Standard for Emergency Load Current-Carrying Capability.

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SECTION VII

Power Transformers

Power Transformers

Synopsis

The determination of overload ratings for power transformers is a rather complex problem, not unlike the rating of cables, which must be solved by careful engineering and coordination. In the case of new transformer installations being planned, it is recommended that the required load cycle information and complete transformer performance criteria for all modes of operation (normal, LTE, STE) be provided to the manufacturers during the specification stage of the procurement so that appropriate overload requirements will be addressed in the design stage.

The larger problem remains to reliably rate existing system transformers. The recommended practice is to consult the transformer manufacturer for overload ratings, particularly for STE ratings. A utility engineer can not reasonably be expected to have the resources to obtain and analyze the detailed design data required to determine the stray flux heating limitation for STE loading, for instance, which is the limiting criterion in most contemporary transformer designs. In cases where this is not possible, it is recommended that a contemporary computer rating program which factors in the individual design parameters of the unit and the required load cycle and ambient temperature data, tempered by the maximum loading criteria stated in *"Table 3-Suggested Design Limits for New Transformers when Loading Information is Not Supplied"* in IEEE C57.115-1991, be used to determine both the normal transformer load capability under defined load cycle operation and the 4 hour LTE rating. A state-of-the-art transformer rating analysis program is available in Annex G of IEEE PC57.91 and the EPRI computer program 'PTLOAD' also has these capabilities plus a transformer gas bubble evolution module. Sample outputs for selected transformers are contained in appendix D**.** The use of these programs is encouraged.

Discussion

Power transformers are designed and constructed with varying characteristics, depending upon the class and type of service, environmental considerations, and the economic value of transformer losses. The three major classes of service are:

- Generation step-up
- System tie
- Substation

Generation step-up (GSU) service normally involves well-defined load patterns with GSU units being sized to the maximum capability of the associated generator on a continuous basis. Emergency overload conditions are rare except for multi-bank GSU configurations in which one of the banks fails without an available spare and the remaining units are loaded as much as possible until a replacement becomes available.

System tie service encompasses all major transmission system tie transformers. These transformers are typically over 100 MVA . System tie service also includes tie-line phase-angle regulators, voltage-regulators and combination voltage/phase angle regulators.

Substation service comprises those power and regulating transformers directly serving load, typically rated below 100 MVA.

Further design distinctions involve the type of cooling system used:

Liquid-Immersed Air-Cooled
- OA self-cooled
- OA/FA self-cooled/forced air-cooled
- OA/FA/FA self-cooled/forced air-cooled/forced-air cooled

Liquid-Immersed Air-Cooled/Forced Liquid-Cooled
- OA/FA/FOA[1] self-cooled/forced air-cooled/forced liquid air-cooled
- OA/FOA[1]/FOA[1] self-cooled/forced air-forced liquid-cooled/forced air-forced liquid-cooled

Liquid-Immersed Water-Cooled
- OW water-cooled
- OW/A water-cooled/self-cooled

Liquid-Immersed Forced Liquid-Cooled
- FOA[1] forced liquid-cooled with forced air-cooler
- FOW forced liquid-cooled, water-cooled

[1]FOA can be either **DFOA(directed FOA)** or **NDFOA(non-directed FOA)**

Finally, design distinctions exist among autotransformers, two- and three-winding transformers, single-phase versus three-phase units, tap-changers and ancillary equipment and the types of oil-preservation systems being used.

There are presently three IEEE loading guides in effect which are enumerated here:

- **ANSI/IEEE C57.91-1981** *Guide for loading mineral-oil-immersed overhead and pad-mounted distribution transformers rated 500 kVA and less with 65°C or 55°C average winding rise.*

- **ANSI/IEEE C57.92-1981** *Guide for loading mineral-oil-immersed power transformers up to and including 100 MVA with 55°C or 65°C winding rise.*

- **IEEE C57.115-1991** *IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers*

Rated in Excess of 100 MVA(65^{o}C Winding Rise)

All three of these guides have been merged into a single proposed guide, in Draft 11.2 status as of December 10, 1993, which addresses the modern concerns of transformer loading beyond nameplate:

- **IEEE PC57.91-199x** *IEEE Guide for Loading Mineral-Oil-Immersed Transformers*

The chairman of the IEEE Working Group which produced the new guide, Linden W. Pierce, presented a paper at the 1993 Minnesota Power Systems Conference entitled *"Current Developments for Predicting Transformer Loading Capability"*, which is included in Appendix C of this report. The first line of his abstract states "Recent investigations have shown that the transformer loading guide equations do not accurately reflect the fluid flow and heat transfer phenomena during transient conditions." In subclause 4.1 of the proposed Guide, the contemporary concerns of loading beyond nameplate rating are enumerated as follows:

"Applications of loads in excess of nameplate rating involve some degree of risk. It is the purpose of this guide to identify these risks and to establish limitations and guidelines, the application of which will minimize the risks to an acceptable level. While aging and long time mechanical deterioration of winding insulation have been the basis for the loading of transformers for many years, it is recognized that there are additional factors which may involve greater risk for transformers of higher megavoltampere and voltage ratings. The risk areas which should be considered when loading large transformers beyond nameplate rating are listed below. Further discussion regarding these risks is provided in Clause 9 - Power Transformers, or in Annexes, as noted.

> *(1)Evolution of free gas from insulation of winding and lead conductors (insulated conductors) heated by load and eddy currents (circulating currents between or within insulated conductor strands) which may jeopardize dielectric integrity. See Annex A for further discussion.*
>
> *(2)Evolution of free gas from insulation adjacent to metallic structural parts linked by electromagnetic flux produced by winding or lead currents may also reduce dielectric strength.*
>
> *(3)Loss of life calculations may be made as described in Clause 5. If a percent loss of total life calculation is made based on an arbitrary definition of a "Normal Life" in hours, one should recognize that the calculated results may not be as conservative for transformers rated above 100 MVA as they are for smaller units, since the calculation does not consider mechanical wear effects which may increase with megavoltampere rating.*

(4)Operation at high temperature will cause reduced mechanical strength of both conductor and structural insulation. These effects are of major concern during periods of transient overcurrent (through-fault) when mechanical forces reach their highest levels.

(5)Thermal expansion of conductors, insulation materials or structural parts at high temperatures may result in permanent deformations which could contribute to mechanical or dielectric failures.

(6)Pressure build-up in bushings for currents above rating could result in leaking gaskets, loss of oil, and ultimate dielectric failure. See Annex B for further discussion.

(7)Increased resistance in the contacts of tap changers can result from a build-up of oil decomposition products in a very localized high temperature region at the contact point when the tap changer is loaded beyond its rating. In the extreme, this could result in a thermal runaway condition with contact arcing and violent gas evolution. See Annex B for further discussion.

(8)Auxiliary equipment internal to the transformer, such as reactors and current transformers, may also be subject to some of the risk identified above. See Annex B for further discussion.

(9)When the temperature of the top oil exceeds 105°C (65°C rise over 40°C ambient according to ANSI/IEEE C57.12.00-1993), there is a possibility that oil expansion will be greater than the holding capacity of the tank and also result in a pressure which causes the pressure relief device to operate and expel the oil. The loss of oil may also create problems with the oil preservation system or expose electrical parts upon cooling."

Additional concerns are cited in Appendix D to the proposed (IEEE) guide, "Philosophy of guide applicable to transformers with 55 °C average winding rise (65 °C hottest spot rise) insulation systems", which is quoted as follows:

"Loading of transformers above nameplate is a controversial subject. Agreement on the loading limits can be agreed upon with the manufacturer if they have been clearly specified prior to the design of the transformer. However, since there has been new knowledge gained in recent years concerning stray flux fields and their effects of (sic) *metallic temperatures, it is desirable to confirm greater than nameplate load capabilities with the manufacturers of transformers on critical systems.*

Some users have considerable experience in loading power transformers above nameplate using computer programs in conjunction with ANSI/IEEE C57.92-1981 and NEMA TR98-1978 Guide for Loading Oil Immersed Power Transformers with 65 °C Average Winding Rise. Since this approach *deals with loss of life due to the effects of thermal aging of the windings it should always be accompanied with due consideration given to the load capabilities of all other components of the transformer. These components include bushings, tap changers and terminal boards, current transformers, and leads. Relay settings should also be checked so that load is not dumped. Consideration should also be given to oil expansion and its effect on possible mechanical relief device operation, subsequent possible operation of the fault-pressure relay, and oil clogging of breathing devices. Forced-oil cooler fouling should also be a consideration when determining load capability. This fouling is particularly found in areas having salt spray environments or dust and chemical contaminants present. These computer programs should be modified to reflect this new loading guide where its use may lead to more conservative loading. The loss of a single transformer of over 100 MVA rating rarely causes power interruption of customers. However, loss of one transformer due to its failure or due to the failure of some other part in the electrical circuit can result in increased loading of the back-up transformers. Most utilities do not design for second contingencies without loss of load. The adverse consequences are therefore rather great if the increased loading of the backup transformer results in a failure.*

Common sense and good planning is required to keep the economic gains in balance with the risks of failure. Because excessive transformer temperatures weaken the insulation structures physically and because many of the older transformers have low impedances, short-circuit failures should also be considered. The types of transformer construction are a factor in making this assessment. Most utilities load these transformers conservatively. Gas evolution in power transformers is not a new insulation contaminant. There are at least eight causes of gas within the transformer that have been documented. The risk of having a failure due to free gas in the insulating structure should take into consideration the insulation margins used and the construction of the insulation structures. The risk of failure increases considerably when the insulation levels are reduced three full steps from a typically accepted level such as use of 650 kV BIL on 230 kV transformers. The risk decreases when no insulation collars are used in highly stressed parts of these transformers with reduced BIL. Knowledgeable transformer engineers have paid close attention to gas evolution when specifying and designing these transformers.

The loading of transformers without thermally upgraded insulation (from an insulation aging point of view) can be considered to be similar to transformers with thermally upgraded insulation. The calculation of temperatures included in Clause 7 and Annex G may be applied equally well for transformers without thermally upgraded insulation. Equation 5.3 in Clause 5 gives the equation for the aging acceleration factor used to calculate equivalent aging and loss of life for transformers with 55 ^{o}C rise insulation systems. The normal loss of life ratings are loadings which result in a daily loss of life equal to that of a continuous winding hottest-spot temperature of 95 ^{o}C for 55 ^{o}C rise transformers.

The factor that determines the greatest risk associated with loading transformers above nameplate rating is the evolution of free gas from the insulation of winding and lead conductors. This gas will result from two major sources:

(1)Vaporization of water contained in the insulation. This process is discussed in Annex A of this guide.

(2)Thermal decomposition of cellulose. There is very little information available on the ratio of formation of these gases for transformers without thermally upgraded insulation".

Absolute Maximum Loading Limits

It is recommended that the limits listed *in "Table 3-Suggested Design Limits for New Transformers When Loading Information is Not Supplied"* in IEEE C57.115-1991 be observed for all transformers rated 100 MVA and above or 345 kV and above. The values in Table 3 agree with industry advisories previously issued by U.S. transformer manufacturers in the 1970's and 1980's, particularly regarding the stray flux heating limitations of large units, and should be taken as the maximum limiting rating. In effect, this means that STE ratings in excess of 150% of maximum nameplate rating for non-GSU units should not be used without the express agreement of the transformer manufacturer. This requirement relates to the overload margin to magnetic saturation. This is not to say that transformers with high STE capability can not be made anymore. It does means that high STE loading capability will demand careful attention to the core steel and shielding design saturation characteristics and other ancillary considerations, and these factors must be formally addressed in the planning/specification/procurement/design cycle. The referenced IEEE table is reproduced as follows:

Table 3-Suggested Design Limits for New Transformers When Loading Information is Not Supplied

Application	Maximum Load (% of Maximum Rating)	Duration (hours) *	Insulated Conductor Maximum Hottest-Spot Temperature Not to Exceed (°C)
Generation step-up	110	8	140
System tie	150	1	180**
Substation	150	1	180**

* Based on prior load of 100% of rated and 30 °C ambient.
** This limit is based upon consideration of thermal aging and does not take into account the risk of insulation breakdown because of bubble formation above 140 °C (See 2.2(1).)

This table does not directly apply to distribution transformers. Those distribution transformers whose characteristics are known and which have established successful overload patterns over the years should continue to be operated in the manner recommended by the manufacturer and/or the individual company's engineer. This may imply STE operation at up to 2.0 per unit load.

Note that the IEEE proposed guide PC57.91 has deleted Table 3. This does not eliminate the fact that stay flux heating remains the STE design limitation for many transformers, especially those 100 MVA and larger and/or 345kV and up. In particular, this applies to three phase shell form designs. The proposed guide lists a new Table 8 with a "other metallic hot-spot temperature limit of 200°C for STE loading", but then misleadingly describes a short-time emergency load method which neglects stray-flux heating. Utilities are not normally able to quantify the load saturation effects and stray-flux hot-spot temperatures in the core and other metallic parts. This would be necessary in order to evaluate the validity of assuming, for instance, 180°C insulated conductor hottest-spot temperature as the limiting risk in calculating an STE rating. PC57.91 states "Usually the limits on other metallic hot-spot temperature not in contact with heating are design limits and calculated by the manufacturer when an overload specification is submitted as part of the purchasing specifications." Therein lies the problem: many if not most of the transformers in service today were not purchased with an overload specification, invalidating a generic "180°C" approach to an STE rating calculation and reinforcing the generic limits of Table 3 listed above.

Loss-of-Life Criteria/Limiting Temperatures for Engineered Ratings

Within the constraints of the maximum absolute loading limits, it is possible to determine normal, LTE and STE transformer ratings based on limiting temperature rises of the winding insulation hot-spot and the top-oil. The recommended "loss-of-life" criterion for emergency operation is **0.25 percent per occurrence**, which is equivalent to approximately 19 days loss-of-life for the one day in which the emergency occurs, using the method described in IEEE PC57.91. This value will not be reached for STE operation given the short 15 minute time period and the other limiting criteria. Normal transformer operation should entail normal winding insulation loss-of-life.

The recommended limiting temperature rises for all modes of operation are listed in the following tables for 65°C and 55°C average winding rise rated transformers respectively:

Power Transformers Rated 65°C AWR(Average Winding Rise)
80 °C Hottest-Spot Rise

(extracted from IEEE PC57.91 Table 8)

Temperature Limit	**Normal Life Expectancy Loading**	**Long-Time Emergency Loading**	**Short-Time Emergency Loading**
Insulated conductor hottest-spot temperature, °C	120*	140	180**
Other metallic hot-spot temperature (in contact and not in contact with insulation), °C	140	160	200
Top oil temperature, °C	105	110	110

* 110 °C on a continuous 24 hour basis or; equivalent 24 hour variable temperature with 120 °C maximum.

**** Gassing may produce a potential risk to the dielectric strength of the transformer. This risk should be considered when this guide is applied refer to Annex A.**

Power Transformers Rated 55°C AWR(Average Winding Rise)
65 °C Hottest-Spot Rise

(Some Data from ANSI/IEEE C57.92-1981, Par. 5.2.2.4)

Temperature Limit	**Normal Life Expectancy Loading**	**Long-Time Emergency Loading**	**Short-Time Emergency Loading**
Insulated conductor hottest-spot temperature, °C	105*	140	150**
Other metallic hot-spot temperature (in contact and not in contact with insulation), °C	N/A	N/A	N/A
Top oil temperature, °C	95	100	100

* 95 °C on a continuous 24 hour basis or; equivalent 24 hour variable temperature with 105 °C maximum.

** **Gassing may produce a potential risk to the dielectric strength of the transformer. This risk should be considered**.

Application of Transformer Ratings

Transformer load capability is traditionally stated in terms of MVA. The true thermal loading of a transformer is determined by its load-side current, in amperes. The fact that a transformer can have "full capacity" taps has lead to the misnomer that transformers are "constant MVA" devices. It is true that a transformer with "full capacity taps" has "full MVA" at each tap setting, however, ***at any given tap position a transformer has a fixed ampere rating for a particular mode of operation***. This can best be demonstrated by means of an example. For any given "full-capacity tap equipped" transformer MVA rating, the **true tap ampacity** will vary inversely with off-nominal rated voltage. For example, take a three phase autotransformer rated 200 MVA at 345 kV/115 kV nominal, with ± 5% NLTC in 2.5% steps, used in step-down service. The nameplate ampacity at rated nominal 115 kV voltage is simply calculated as:

$$Irated amperes = \frac{MVA3\varnothing}{\sqrt{3} \times kVratedtap} \times 1000 = \frac{200}{\sqrt{3} \times 115} \times 1000 = 1004 amperes$$

The complete ampacity table for the transformer as a function of tap position, which would be shown on the transformer nameplate, is as follows:

Ampacity as a Function of Tap Position

Tap Position	Rated kV @ Tap Position	Rated Tap Current, Amperes
-5%	109.25	1057
-2.5%	112.125	1030
Neutral	115	1004
+2.5%	117.875	980
+5%	120.75	956

It is significant to note that for any given mode of transformer operation, in this case normal nameplate rating, the real thermal capability is dependent on the tap position of the transformer. There is no "constant MVA" capability unless the transformer happens to be operating at a system voltage equal to the output tap rated voltage, which is seldom the case. Indeed, transformers whose operating tap position voltage ratings are below the operating system voltage will achieve a "greater than nameplate" MVA for the tap-rated current. Conversely, transformers whose operating tap position voltage ratings are above the actual system operating voltage will realize a "less than nameplate" MVA for the tap-rated current.

Reduced Capacity Taps

Some transformers are purchased with "reduced capacity taps", in which the inverse current capability is limited at some absolute value, greater than or equal to the rated neutral tap current.

These limitations can be due to winding current limits or tap-changer, bushing, internal cable or other related restrictions.

Tap-Position Impact on Overall Circuit Ratings

Given the significance of the variability of the tap rated current for any transformer (equal in percentage to the percentage tap range), tap positions must be factored into the transformer circuit ratings. In cases where no-load tap changers (NLTC) are involved, a simple static rating for each operating mode (Normal, LTE, STE, both Summer and Winter) at a stated fixed tap position will suffice. For transformers with load tap changers (LTC), a table of transformer circuit ampacity vs. tap position is required. It is important for system operators to view transformers as current(ampere)-limited devices, in the same manner as say cables. In determining quasi-megawatt ratings for NYPP, it is necessary to ascertain a minimum typical system operating voltage and to assume a minimum load power-factor based on judicious operating experience.

Voltage Regulators and/or Phase Shifting Transformers

Voltage regulators, phase-angle regulators and combination voltage & phase angle regulators have rated transformer ampacities which are a function of tap position. The rating analyses for such devices should result in a tabulation the circuit ratings as a function of the full range of tap positions. A phase angle regulator consists of both a series transformer and an exciting transformer. As phase shift increases from zero degrees, the exciting transformer progressively carries more current. In most cases the exciting transformer limits the phase shifter output resulting in the minimum rating at maximum phase shift.

POWER TRANSFORMERS
(References)

ANSI Standards

1. C57.92 - 1981 — Guide for Loading Mineral-Oil-Immersed Power Transformers up to and Including 100MVA with 55ºC or 65ºC Winding Rise, **Reaffirmed in 1991**.

3. C57.115 - 1991 — (Redesignation of IEEE STD 795): IEEE guide for loading mineral-oil-immersed power transformers rated in excess of 100 mva (65C winding rise)

4. C57.19.101 - 1989 — Trial use guide for loading power apparatus bushings.

5. PC57.91-199x — IEEE Guide for Loading Mineral-Oil-Immersed Transformers

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SECTION VIII

Current Transformers

CURRENT TRANSFORMERS

Synopsis

Thermal ratings of current transformers will usually require a review of each application and each manufacturer's and owner's practice. A single set of rating factors can not be expected to cover the variety of installations that are possible. Thermal overload of devices in the secondary circuit must be considered. A careful review of the application is mandatory for any current transformer that is the limiting component in rating a transmission facility.

Methods of rating current transformers recommended in this report are based on ANSI/IEEE Standards, including: ANSI/IEEE C57.13-1978 (Reference #1), ANSI Standards C57.91 (1981) (Reference #2) and C57.92 (1981) (Reference #3), guides for transformer loading.

C.T. Secondary Circuitry

The effective thermal circuit limits imposed by relay components installed on secondary C.T. circuits should be coordinated so as not to impose a limit on the overall transmission circuit. In existing cases where relay circuits are limiting, action should be taken, where feasible, to remove these restrictions. To assist the engineer in this regard, relay overload capability of selected GE and Westinghouse relays are included at the end of this section, titled 'Thermal Capabilities of Components in the Current Circuit Starting at the CT Terminals'. This information was obtained from the 'Capacity Rating Procedures by The System Design Task Force of the NEPOOL Planning Committee', revised August 1984.

Discussion

To develop normal ratings for all types of current transformers, the continuous thermal current rating factor (CTCRF) must be used. The CTCRF is defined in standard C57.13, and is one of the required ratings. Manufacturers design their products with rating factors according to their own usual practice, or the owner may specify a rating factor when the unit is purchased. The normal ratings in the table are taken from Figure No. 1 of C57.13, using the curve for a CTCRF of 1.0 and average daily ambient temperatures of 30°C and 5°C respectively for summer and winter. For CTCRF values other than 1.0, the curve for the proper CTCRF value from Figure 1 of C57.13 should be used to determine normal rating factors at 30°C and 5°C.

Standard C57.13 does not provide methods to determine LTE and STE ratings, so these are discussed separately for free-standing and bushing-type current transformers

Limits on emergency ratings may be imposed by relay coils, meter coils and like devices in the C.T. secondary circuit that may be thermally overloaded by secondary current in excess of normal values. The secondary circuit should be included in any review of specific installations.

Free Standing C.T.'s

The LTE and STE rating factors in the table are for oil filled units installed separately from other equipment. Since these units are similar in construction to power transformers, the equations for transient heating that are found in Section 6.7 of Standard C57.92 (1981) was used to develop LTE and STE ratings.

Parameter values and the calculations are the same as for power transformers in this report, assuming a 55°C average winding rise in accordance with the limit given in C57.13 for instrument transformers. With no requirements stated in C57.13, current and power transformers were assumed to have the same parameter values for hottest-spot temperature related to loss of life and ratio of load to no-load loss. Thermal time constant was assumed equal to that of a forced air coiled power transformer.

Bushing-Type C.T.'s

The LTE and STE ratings of bushing-type current transformers will normally be at least as great as the rating of the circuit breaker or power transformer in which the C.T.'s are installed. The manufacturer of the major equipment can provide C.T.'s with thermal performance that is adequate, taking into account the ambient temperature at which they will operate in or on the equipment and other factors. Confirmation of the LTE and STE ratings should be sought from the equipment manufacturer.

If the tap used on a bushing C.T. is less than its maximum ratio, additional continuous thermal capability, beyond the tap rating, may be available. A curve used to determine the additional capacity has the equation:

$$\frac{I_a}{I_{tr}} = \sqrt{\left[\frac{I_r}{I_{tr}}\right]}$$

Where I_a = allowable secondary current for connected tap
I_{tr} = rating of connected tap
I_r = rating of full winding

If the connected tap is 50 percent of the full winding, for example, the C.T. will have a continuous rating of 141 percent of the tap rating. One manufacturer recommends a limit of 200 percent on the rating factor so determined. This higher rating can be treated as a nameplate rating and can be multiplied by the LTE and STE rating factors to obtain emergency ratings. Confirmation should be obtained from the manufacturer before using this rating.

CURRENT TRANSFORMER RATINGS FACTORS

Current Transformers	Summer			Winter		
	N	LTE	STE	N	LTE	STE
Bushing Type	Same rating factors as transformer or breaker					
Free-Standing	100%	128%	150%	122%	148%	150%

CURRENT TRANSFORMERS

ANSI Standards

1. C57.13 - 1978 Requirements for Instrument Transformers, (**Reaffirmed in 1986**)

2. C57.91 - 1981 Guide for Loading Mineral Oil Immersed Overhead and Pad-Mounted Distribution Transformers Rated 500KVA and less with 65ºC or 55ºC Averageg Winding Rise, (**Reaffirmed in 1991**)

3. C57.92 - 1981 Guide for Loading Oil Immersed Distribution and Power Transformers up to and including 100 MVA with 55ºC and 65ºC Winding Rise, (**Reaffirmed in 1991**)

THERMAL CAPABILITIES OF COMPONENTS
IN THE CURRENT CIRCUIT STARTING AT THE CT TERMINALS[1]

Protective Relays

A. The thermal capabilities of relay current coils in amperes used on transmission line terminal equipment are tabulated on the following pages. The relays are not expected to operate at these currents (or more) to trip a circuit breaker and thus protect themselves from overheating. The list does not include all possible or available relays. For further information consult the manufacturer.

B. **General Electric Relays**

Comments by the manufacturer:

1. Relays as designed by Power Systems Management Business Department have a conservative design life of 20 years.

2. Relays 20 years old or older should be considered as having no overload capability.

3. The design standard is ANSI C37.90 (IEEE 313) 1971, which defines Class A insulated relays as having a total coil temperature of 105°C (55°C ambient plus 50°C rise).

4. If the 55°C ambient temperature is exceeded, then the values listed are not applicable.

5. It is assumed that those relays having potential circuits (either ac or dc) are being operated at or below rated voltage.

6. Overload capability calculations were based on "Insulating Materials for Design and Engineering Practice" by Franie M. Clark. John Wiley Publishers. Library of Congress #62-17460.

7. Those relays having the same rating for 1/2 hour* and continuous are limited by components other than the insulation system. These components may be resistors, capacitors, rheostats, etc., and these limitations are considered confidential information.

8. The 10, 2 or 0.5 hour* values assume at least 24 hours at rated current (or less) will exist before the relays are again subjected to the values shown.

****The GE list of relays cover four time periods:Continuous, 10Hrs., 2,Hrs.,and .5 Hrs. These have been converted to the following time periods.***

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

9. Where a relay has more than one current tap, the value listed is for a particular tap such as 5 amp. The current at other taps (T_N) may be calculated from the formula:

$(I_5)^2\ T_N = (I_N)\ ^2T_5$ Where I_5 is listed current at 5 amp tap. I_N is desired current. T_5 is the listed tap, in this example is 5.

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

General Electric Relay Ampere Ratings

General Electric Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
Static Equipments							
MOD11	7.5	7.5	7.5	7.5	7.5	7.5	
MOD111	10.0	10.0	10.0	10.0	10.0	10.0	#1
Electromechanical Equipments							
BDD	10.0	18.5	17.0	10.0	18.5	16.0	
CAP15A	10.0	18.5	17.0	10.0	18.5	16.0	
CAP15B	10.0	13.8	12.0	10.0	13.8	12.0	
CEB12B	8.0	8.0	8.0	8.0	8.0	8.0	#5
CEB12B	10.0	10.0	10.0	10.0	10.0	10.0	#2, #5
CEB13	7.5	7.5	7.5	7.5	7.5	7.5	#3, #5
CEB16	7.5	7.5	7.5	7.5	7.5	7.5	#3, #5
CEB17A	7.5	7.5	7.5	7.5	7.5	7.5	#5
CEB51	7.5	7.5	7.5	7.5	7.5	7.5	#3
CEB52A	8.5	8.5	8.5	8.5	8.5	8.5	#5
CEB52A	10.0	10.0	10.0	10.0	10.0	10.0	#2, #5
CEX17E	6.5	6.5	6.5	6.5	6.5	6.5	#5
CEX17E	7.5	7.5	7.5	7.5	7.5	7.5	#2, #5
CEX19A1	7.5	7.5	7.5	7.5	7.5	7.5	#5
CEX19A2	8.5	8.5	8.5	8.5	8.5	8.5	#2, #5
CEX20	5.0	5.0	5.0	5.0	5.0	5.0	#3, #10
CEX57	5.0	5.0	5.0	5.0	5.0	5.0	#3, #10
CEXG20	5.0	5.0	5.0	5.0	5.0	5.0	#3, #11
CEXG20	5.0	5.0	5.0	5.0	5.0	5.0	#2, #3, #11
CEY12	5.0	5.0	5.0	5.0	5.0	5.0	#3, #10
CEY14	7.5	7.5	7.5	7.5	7.5	7.5	#3, #5
CEY14	10.0	10.0	10.0	10.0	10.0	10.0	#2, #3, #5
CEY15A	7.5	7.5	7.5	7.5	7.5	7.5	#5
CEY15A	10.0	10.0	10.0	10.0	10.0	10.0	#2, #5
CEY15B3	7.5	7.5	7.5	7.5	7.5	7.5	#5
CEY15B	10.0	10.0	10.0	10.0	10.0	10.0	#2, #5
CEY16G	7.5	7.5	7.5	7.5	7.5	7.5	#5
CEY16G	10.0	10.0	10.0	10.0	10.0	10.0	#2, #5
CEY20	5.0	5.0	5.0	5.0	5.0	5.0	#3, 10

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

General Electric Relay Ampere Ratings

General Electric Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
CEY51	8.0	8.0	8.0	8.0	8.0	8.0	#5
CEY52	8.0	8.0	8.0	8.0	8.0	8.0	#5
CEY52	10.0	10.0	10.0	10.0	10.0	10.0	#2, #5
CEYB12	6.5	6.5	6.5	6.5	6.5	6.5	#5
CEYB13	7.5	7.5	7.5	7.5	7.5	7.5	#2, #5
CEYB52	5.0	5.0	5.0	5.0	5.0	5.0	#3, #10
CEYG51	8.5	8.5	8.5	8.5	8.5	8.5	#3, #5
CEYG53	5.0	5.0	5.0	5.0	5.0	5.0	#3, #11
CFW11E	6.0	14.0	12.5	6.0	14.0	12.0	
CFZ	5.5	NC	NC	5.5	NC	NC	#3
CHC11	4.0	9.2	8.5	4.0	9.2	8.0	#8
CJC15	5.0	NC	NC	5.0	NC	NC	#3, #11, #12
CPD11	8.0	NC	NC	8.0	NC	14.5	
GCX17A	6.5	6.5	6.5	6.5	6.5	6.5	#5
GCX17A	7.5	7.5	7.5	7.5	7.5	7.5	#2, #5
GCX17B	6.5	6.5	6.5	6.5	6.5	6.5	#3, #4, #5
GCX17B	7.5	7.5	7.5	7.5	7.5	7.5	#2, #3, #4, #5
GCX17G	6.5	6.5	6.5	6.5	6.5	6.5	#5
GCX17G	7.5	7.5	7.5	7.5	7.5	7.5	#2, #5
GCX17M	6.5	6.5	6.5	6.5	6.5	6.5	#3, #4, #5
GCX17M	7.5	7.5	7.5	7.5	7.5	7.5	#2, #3, #4, #5
GCX17N	6.5	6.5	6.5	6.5	6.5	6.5	#3, #4, #5
GCX17N	7.5	7.5	7.5	7.5	7.5	7.5	#2, #3, #4, #5
GCX51	7.5	7.5	7.5	7.5	7.5	7.5	#5
GCX51	8.5	8.5	8.5	8.5	8.5	8.5	#2
GCXG51	8.0	8.0	8.0	8.0	8.0	8.0	#5
GCXG51	9.5	9.5	9.5	9.5	9.5	9.5	#2, #5
GCXY51	7.5	7.5	7.5	7.5	7.5	7.5	#3, #5
GCXY51	8.5	8.5	8.5	8.5	8.5	8.5	#2, #3, #5
GCY12	7.5	7.5	7.5	7.5	7.5	7.5	#5
GCY51	8.0	8.0	8.0	8.0	8.0	8.0	#5
GCY51	10.0	10.0	10.0	10.0	10.0	10.0	#2, #5
GYC	8.0	8.0	8.0	8.0	8.0	8.0	#3, #5

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

General Electric Relay Ampere Ratings

General Electric Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
GYC	10.0	10.0	10.0	10.0	10.0	10.0	#2, #3, #5
IAC51	10.0	19.0	17.0	10.0	19.0	16.0	#6
IAC53	10.0	19.0	17.0	10.0	19.0	16.0	#6
IAC60B	10.0	19.0	17.0	10.0	19.0	16.0	#6
JBC51E-L	10.0	19.0	17.0	10.0	19.0	16.0	#6
JBC51M	6.0	11.0	9.0	6.0	11.0	6.0	#9
JBC53E-L	10.0	19.0	17.0	10.0	19.0	16.0	#6
JBC53M	6.0	11.0	9.0	6.0	11.0	6.0	#9
JBC77E-L	10.0	19.0	17.0	10.0	19.0	16.0	#6
JBC77M	6.0	11.0	9.0	6.0	11.0	6.0	#9
NHC11	8.0	9.0	9.0	8.0	9.0	9.0	#7
PJC31	12.0	22.0	20.0	12.0	22.0	19.0	#4, #6
SBC	10.0	NC	NC	10.0	NC	NC	#3
SBD	10.0	NC	NC	10.0	NC	NC	#3
SFC	12.0	NC	NC	12.0	NC	NC	#3
SGC	6.5	NC	NC	6.5	NC	NC	#3
SLC20	10.0	NC	NC	10.0	NC	NC	#3
SLC51	10.0	NC	NC	10.0	NC	NC	#3
SLCG	5.0	NC	NC	5.0	NC	NC	#3
SLCN51	10.0	NC	NC	10.0	NC	NC	#3
SLD	5.0	NC	NC	5.0	NC	NC	#3
SLL	5.0	NC	NC	5.0	NC	NC	#3
SLPG	5.0	NC	NC	5.0	NC	NC	#3
SLX	5.0	NC	NC	5.0	NC	NC	#3
SLXG	5.0	NC	NC	5.0	NC	NC	#3
SLY	5.0	NC	NC	5.0	NC	NC	#3
SLYG	5.0	NC	NC	5.0	NC	NC	#3
SLYG81	10.0	NC	NC	10.0	NC	NC	#3
SLYL	5.0	NC	NC	5.0	NC	NC	#3
SLYP	10.0	NC	NC	10.0	NC	NC	#3
STD	5.0	NC	NC	5.0	NC	NC	#3

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

<u>Notes</u>

#1 Suffix "50" series
#2 Short reach relays
#3 NC = Not Calculated
#4 Relay must not be operated continuously picked up
#5 Thermal limits are independent of the relat setting

<u>Notes</u> (con't)
#6 4 - 16 Amp range. Limit is same on all taps
#7 1 Amp unit
#8 1 - 4 Amp unit
#9 Directional unit has 6 amp continuous rating
#10 Continuous rating from instruction book one second rating assumed
#11 Continuous rating and one sec rating from instruction book
#12 1 - 4, 2 - 8, 4 - 16 Ranges

(1) The remaining information contained in this section was obtained from the '<u>Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee</u>', revised August 1984

C. Westinghouse Relays

Comments by the manufacturer:

1. The current ratings given do not reflect any difference based on the 50°F winter ambient and 100°F summer ambient. The 100°F (37°C) summer ambient is within the 40°C (104°F) average specified in ANSI 37.90 Std. and IEEE 313 Std.

   (NOTE: ANSI C37.90 states that the limit of observable temperature rise above 55°C ambient for relay coils as measured by the resistance method is 50°C for Class A insulation. For the purpose of meeting this requirement, certain existing electromechanical relay designs may have a 15°C rise greater than the above if the average ambient temperature that the relay is subjected to throughout its life does not exceed 40°C with a maximum 55°C.)

2. Both electromechanical and solid state phase distance relays have continuous current ratings based on a maximum torque angle of less than nominal. For example, the nominal maximum torque angle of the 0.75 - 20 ohm range KD-4 is 75° for both the three phase and phase-to-phase units. If the relay is applied using a max torque angle setting for less than 75°, then the currents given in the table apply. Where there is a limit of less than 10 amps, the 10 amp rating may be obtained by using a maximum torque angle equal to or greater than nominal. If the reduced angle is necessary, the 10 amp rating may be obtained by either reducing or increasing the setting ohms, since the setting affects the thermal capability.

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(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
CO-5 (0.5/2.5)	2.7	2.7	2.7	2.7	2.7	2.7	0.5A Tap
	3.1	3.1	3.1	3.1	3.1	3.1	0.6A Tap
	3.7	3.7	3.7	3.7	3.7	3.7	0.8A Tap
	4.1	4.1	4.1	4.1	4.1	4.1	1.0A Tap
	5.7	5.7	5.7	5.7	5.7	5.7	1.5A Tap
	6.8	6.8	6.8	6.8	6.8	6.8	2.0A Tap
	7.7	7.7	7.7	7.7	7.7	7.7	2.5A Tap
(2/6)	9.7	9.7	9.7	9.7	9.7	9.7	3.0A Tap
	10.4	10.4	10.4	10.4	10.4	10.4	3.5A Tap
	11.2	11.2	11.2	11.2	11.2	11.2	4.0A Tap
	12.5	12.5	12.5	12.5	12.5	12.5	5.0A Tap
	13.7	13.7	13.7	13.7	13.7	13.7	6.0A Tap
(4/12)	16.0	16.0	16.0	16.0	16.0	16.0	4.0A Tap
CO-6	Same as CO-5						
CO-7	Same as CO-5						
CO-8	Same as CO-5						
CO-9	Same as CO-5						
CO-11 (0.5/2/5)	1.7	1.7	1.7	1.7	1.7	1.7	0.5A Tap
	1.9	1.9	1.9	1.9	1.9	1.9	0.6A Tap
	2.2	2.2	2.2	2.2	2.2	2.2	0.8A Tap
	2.5	2.5	2.5	2.5	2.5	2.5	1.0A Tap
	3.0	3.0	3.0	3.0	3.0	3.0	1.5A Tap
	3.5	3.5	3.5	3.5	3.5	3.5	2.0A Tap
	3.8	3.8	3.8	3.8	3.8	3.8	2.5A Tap
(2/6)	8.3	8.3	8.3	8.3	8.3	8.3	3.0A Tap
	9.0	9.0	9.0	9.0	9.0	9.0	3.5A Tap
	10.0	10.0	10.0	10.0	10.0	10.0	4.0A Tap
	11.0	11.0	11.0	11.0	11.0	11.0	5.0A Tap
	12.0	12.0	12.0	12.0	12.0	12.0	6.0A Tap

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
(4/12)	14.0	14.0	14.0	14.0	14.0	14.0	4.0A Tap
CO Hi Lo	Same as CO						
CKO	Same as CO						
COD	Same as CO						
COM	Same as CO						
COV	Same as CO						
CR	Same as CO						
CRN-1	5.0	8.0	5.0	5.0	8.0	5.0	
H-3	5.0	5.0	5.0	5.0	5.0	5.0	
HCB	10.0	10.0	10.0	10.0	10.0	10.0	
HCB-1	10.0	10.0	10.0	10.0	10.0	10.0	
HU	10.0	10.0	10.0	10.0	10.0	10.0	
HU-1	10.0	10.0	10.0	10.0	10.0	10.0	
HU-3	5.0	5.0	5.0	5.0	5.0	5.0	
IRV							
0.5 - 2	10.0	10.0	10.0	10.0	10.0	10.0	Dir Unit
2 - 6	10.0	10.0	10.0	10.0	10.0	10.0	Dir Unit
4 - 12	12.0	12.0	12.0	12.0	12.0	12.0	Dir Unit
0.5 - 2	5.0	5.0	5.0	5.0	5.0	5.0	Inst Unit
1 - 4	8.0	8.0	8.0	8.0	8.0	8.0	Inst Unit
2 - 8	8.0	8.0	8.0	8.0	8.0	8.0	Inst Unit
4 - 16	10.0	10.0	10.0	10.0	10.0	10.0	Inst Unit
ITH	0.5	0.5	0.5	0.5	0.5	0.5	0.25 - 0.5A
	1.0	1.0	1.0	1.0	1.0	1.0	0.5 - 1.0A
	2.0	2.0	2.0	2.0	2.0	2.0	1 - 2A
	4.0	4.0	4.0	4.0	4.0	4.0	2 - 4A
	8.0	8.0	8.0	8.0	8.0	8.0	2 - 8A
	12.0	12.0	12.0	12.0	12.0	12.0	6 - 12A
KC-2	5.0	5.0	5.0	5.0	5.0	5.0	0.5 - 2A

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes) Normal	Winter Emergency 15 Min.	Winter Emergency 4 Hrs.	Summer Rating(Amperes) Normal	Summer Emergency 15 Min.	Summer Emergency 12 Hrs.	Notes
	8.0	8.0	8.0	8.0	8.0	8.0	1 - 4A
	8.0	8.0	8.0	8.0	8.0	8.0	2 - 8A
	10.0	10.0	10.0	10.0	10.0	10.0	4 - 16A
KC-4	Same as KC-2						
KD-3	10.0	10.0	10.0	10.0	10.0	10.0	0.759-2.612ZC all ZA
	8.0	8.0	8.0	8.0	8.0	8.0	2.609-3.529ZC all ZA
KD-3	6.0	6.0	6.0	6.0	6.0	6.0	3.652-4.942ZC all ZA
	5.0	5.0	5.0	5.0	5.0	5.0	5.043-6.824ZC all ZA
	10.0	10.0	10.0	10.0	10.0	10.0	7.059-9.882ZC all ZA
	8.5	8.5	8.5	8.5	8.5	8.5	10.09-13.65ZC all ZA
	10.0	10.0	10.0	10.0	10.0	10.0	13.85-14.82ZC all ZA
	8.5	8.5	8.5	8.5	8.5	8.5	15.13-20.47ZC all ZA
KD-4 (0.2 - 4.35)	15.0	15.0	15.0	15.0	15.0	15.0	0.23 - 0.59 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	0.6 - 1.447 Ω
	15.0	15.0	15.0	15.0	15.0	15.0	1.47 - 2.09 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	2.14 - 2.89 Ω
	15.0	15.0	15.0	15.0	15.0	15.0	3.03 - 3.14 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	3.21 - 4.34 Ω
KD-4 (0.75 - 20)	10.0	10.0	10.0	10.0	10.0	10.0	0.737 - 2.39 Ω
	8.0	8.0	8.0	8.0	8.0	8.0	2.46 - 3.41 Ω
	6.0	6.0	6.0	6.0	6.0	6.0	3.44 - 4.78 Ω
	5.0	5.0	5.0	5.0	5.0	5.0	4.92 - 7.07 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	7.26 - 9.55 Ω
	8.5	8.5	8.5	8.5	8.5	8.5	9.83 - 14.14 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	14.8 Ω
	9.5	9.5	9.5	9.5	9.5	9.5	14.7 - 21.2 Ω
KD-4 (1.1 - 30)	10.0	10.0	10.0	10.0	10.0	10.0	1.1 - 3.59 Ω
	8.0	8.0	8.0	8.0	8.0	8.0	3.69 - 5.12 Ω
	6.0	6.0	6.0	6.0	6.0	6.0	5.16 - 7.17 Ω

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes) Normal	Winter Emergency 15 Min.	Winter Emergency 4 Hrs.	Summer Rating(Amperes) Normal	Summer Emergency 15 Min.	Summer Emergency 12 Hrs.	Notes
	5.0	5.0	5.0	5.0	5.0	5.0	7.38 - 10.61 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	10.89 - 14.33 Ω
	8.5	8.5	8.5	8.5	8.5	8.5	14.75 - 21.21 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	22.2 Ω
	9.5	9.5	9.5	9.5	9.5	9.5	22.1 - 31.8 Ω
KD-5 (0.2-4.35)	Same as KD-4 (0.2 - 4.35)						
KD-5 (.75-20)	Same as KD-4 (0.75 - 20)						
KD-5(1.1-30)	Same as KD-4 (1.1 - 30)						
KD-10	10.0	10.0	10.0	10.0	10.0	10.0	0.2 - 4.5Ω
	10.0	10.0	10.0	10.0	10.0	10.0	0.75 - 21.2 Ω
KD-10 (1.27-36.7)	10.0	10.0	10.0	10.0	10.0	10.0	1.27 - 5.90 Ω
	7.0	7.0	7.0	7.0	7.0	7.0	5.94 - 8.25 Ω
	6.0	6.0	6.0	6.0	6.0	6.0	8.5 - 12.2 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	12.5 - 16.5 Ω
	8.0	8.0	8.0	8.0	8.0	8.0	17.0 - 24.4 Ω
	9.0	9.0	9.0	9.0	9.0	9.0	25.5 - 36.7 Ω
KD-11	Same as KD-10						
KD-41	Same as KD-4						
KDTG	10.0	10.0	10.0	10.0	10.0	10.0	
KDXG	10.0	10.0	10.0	10.0	10.0	10.0	
KH-1	5.0	5.0	5.0	5.0	5.0	5.0	
KO-3	5.0	5.0	5.0	5.0	5.0	5.0	0.5 - 2A
	8.0	8.0	8.0	8.0	8.0	8.0	1 - 4, 2 - 8A
	10.0	10.0	10.0	10.0	10.0	10.0	
KRV	5.0	5.0	5.0	5.0	5.0	5.0	0.5 - 2A
	8.0	8.0	8.0	8.0	8.0	8.0	1 - 4, 2 - 8A
	10.0	10.0	10.0	10.0	10.0	10.0	4 - 16, 10 - 40A
KS (0.75 - 20)	10.0	10.0	10.0	10.0	10.0	10.0	0.87 - 3 Tap
	7.0	7.0	7.0	7.0	7.0	7.0	4.2 Tap

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
	5.0	5.0	5.0	5.0	5.0	5.0	5.8 Tap
KS (0.51 - 30)	10.0	10.0	10.0	10.0	10.0	10.0	0.6 - 3.68 Tap
	7.0	7.0	7.0	7.0	7.0	7.0	5.5 Tap
	5.0	5.0	5.0	5.0	5.0	5.0	8.2 Tap
KST	10.0	10.0	10.0	10.0	10.0	10.0	0.757 - 3.54 Ω
(0.75 - 20)	7.0	7.0	7.0	7.0	7.0	7.0	3.65 - 4.96 Ω
KST (0.75-20) con't	5.0	5.0	5.0	5.0	5.0	5.0	5.04 - 6.84 Ω
	7.0	7.0	7.0	7.0	7.0	7.0	7.30 - 9.91 Ω
	5.0	5.0	5.0	5.0	5.0	5.0	10.1 - 13.7 Ω
	7.0	7.0	7.0	7.0	7.0	7.0	14.86 Ω
	5.0	5.0	5.0	5.0	5.0	5.0	15.13 - 20.5 Ω
POQ	5.0	5.0	5.0	5.0	5.0	5.0	
SA-1	20.0	20.0	20.0	20.0	20.0	20.0	
SBF	8.0	8.0	8.0	8.0	8.0	8.0	0.5 - 2A
SBF	10.0	10.0	10.0	10.0	10.0	10.0	1 - 4A
SBFU	Same as SBF						
SC	1.5	1.5	1.5	1.5	1.5	1.5	0.5 - 2A
	3.0	3.0	3.0	3.0	3.0	3.0	1 - 4A
	6.0	6.0	6.0	6.0	6.0	6.0	2 - 8A
	12.0	12.0	12.0	12.0	12.0	12.0	4 - 16A
SC-1	Same as SC						
SCO (0.5 - 12)	1.6	1.6	1.6	1.6	1.6	1.6	0.5 Tap
	3.3	3.3	3.3	3.3	3.3	3.3	1.0 Tap
	4.9	4.9	4.9	4.9	4.9	4.9	1.5 Tap
	6.5	6.5	6.5	6.5	6.5	6.5	2.0 Tap
	8.1	8.1	8.1	8.1	8.1	8.1	2.5 Tap
	9.8	9.8	9.8	9.8	9.8	9.8	3.0 Tap
	11.4	11.4	11.4	11.4	11.4	11.4	3.5 Tap
	13.0	13.0	13.0	13.0	13.0	13.0	4.0 Tap
	16.3	16.3	16.3	16.3	16.3	16.3	5.0 Tap

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
SD-2	5.0	5.0	5.0	5.0	5.0	5.0	T=6.4, 12.8
	10.0	10.0	10.0	10.0	10.0	10.0	T=0.8, 1.6, 3.2
SDB	10.0	10.0	10.0	10.0	10.0	10.0	1.51 - 3.5 Tap
	8.0	8.0	8.0	8.0	8.0	8.0	5.0 Tap
	6.0	6.0	6.0	6.0	6.0	6.0	7.1 Tap
	5.0	5.0	5.0	5.0	5.0	5.0	10.0 Tap
SDBU-2	Same as SDB						
SDG	10.0	10.0	10.0	10.0	10.0	10.0	
SDGU	10.0	10.0	10.0	10.0	10.0	10.0	
SDU-1	10.0	10.0	10.0	10.0	10.0	10.0	
SI	6.0	6.0	6.0	6.0	6.0	6.0	0.25 - 1A
	8.0	8.0	8.0	8.0	8.0	8.0	0.5 - 2A
	10.0	10.0	10.0	10.0	10.0	10.0	1 - 4A
SI	12.0	12.0	12.0	12.0	12.0	12.0	2 - 8A
	15.0	15.0	15.0	15.0	15.0	15.0	4 - 16A
SI-1	Same as SI						
SI-T(0.5 - 16)	7.0	7.0	7.0	7.0	7.0	7.0	0.5 - 2A
SI-T(0.5 - 16)	15.0	15.0	15.0	15.0	15.0	15.0	2 - 8A
SIU	Same as SI						
SIU	3.5	3.5	3.5	3.5	3.5	3.5	0.25 - 1A
Compensated	7.0	7.0	7.0	7.0	7.0	7.0	0.5 - 2A
SKB	10.0	10.0	10.0	10.0	10.0	10.0	
SKB-1	Same as SKB						
SKBU	Same as SKB						
SKBU-1	Same as SKB						
SKBU-2	Same as SKB						
SKBU-2A	Same as SKB						
SKBU-11	7.0	7.0	7.0	7.0	7.0	7.0	
SKBU-21	Same as SKBU-11						

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
SKD (0.2 - 4.35)	10.0	10.0	10.0	10.0	10.0	10.0	0.195 - 0.571 Ω
	8.0	8.0	8.0	8.0	8.0	8.0	0.585 - 0.758 Ω
	6.0	6.0	6.0	6.0	6.0	6.0	0.78 - 1.01 Ω
	5.0	5.0	5.0	5.0	5.0	5.0	1.04 - 1.50 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	1.56 - 2.02 Ω
	8.5	8.5	8.5	8.5	8.5	8.5	2.08 - 3.0 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	3.03 Ω
	9.5	9.5	9.5	9.5	9.5	9.5	3.13 - 4.5 Ω
SKD(.73-21.0)	10.0	10.0	10.0	10.0	10.0	10.0	0.737 - 2.39 Ω
SKD (.73-21.0) (con't)	8.0	8.0	8.0	8.0	8.0	8.0	2.46 - 3.41 Ω
	6.0	6.0	6.0	6.0	6.0	6.0	3.44 - 4.77 Ω
	5.0	5.0	5.0	5.0	5.0	5.0	4.92 - 7.08 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	7.26 - 9.55 Ω
	8.5	8.5	8.5	8.5	8.5	8.5	9.85 - 14.1 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	14.3 Ω
	9.5	9.5	9.5	9.5	9.5	9.5	14.7 - 21.3 Ω
SKD	10.0	10.0	10.0	10.0	10.0	10.0	1.11 - 3.59 Ω
(1.1 - 31.8)	8.0	8.0	8.0	8.0	8.0	8.0	3.68 - 5.11 Ω
	6.0	6.0	6.0	6.0	6.0	6.0	5.16 - 7.17 Ω
	5.0	5.0	5.0	5.0	5.0	5.0	7.37 - 10.6 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	10.9 - 14.3 Ω
	8.5	8.5	8.5	8.5	8.5	8.5	14.71 - 21.2 Ω
	10.0	10.0	10.0	10.0	10.0	10.0	21.5 Ω
	9.5	9.5	9.5	9.5	9.5	9.5	22.1 - 31.8Ω
SKD-IT	Same as SKD						
SKD-T	Same as SKD						
SKDU	Same as SKD						
SKDU-1	Same as SKD						
SKDU-3							
(1.4 - 40)							1.39 - 6.57Ω

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
(1.74 - 50)							1.74 - 8.16 Ω
Combined	10.0	10.0	10.0	10.0	10.0	10.0	
(1.4 - 40)							6.72 - 13.3 Ω
(1.74 - 50)							8.4 - 16.1 Ω
Combined	5.0	5.0	5.0	5.0	5.0	5.0	
(1.4 - 40)							13.8 - 40.0 Ω
(1.74 - 50)							16.8 - 50.0 Ω
Combined	8.5	8.5	8.5	8.5	8.5	8.5	
(1.4 - 40)							1.39 - 6.57* Ω
(1.74 - 50)							1.74 - 8.16* Ω
Combined	10.0	10.0	10.0	10.0	10.0	10.0	* S=2 setting
(1.4 - 40)							1.39 - 6.57* Ω
(1.74 - 50)							1.74 - 8.16** Ω
Combined	10.0	10.0	10.0	10.0	10.0	10.0	** S=3 setting
SKDU-31	Same as SKDU-3						
SKSU							
LR							1.11 - 3.59Ω
SR							0.87 - 2.03 Ω
Combined	10.0	10.0	10.0	10.0	10.0	10.0	
LR							3.68 - 5.11 Ω
SR							2.9 Ω
Combined	8.0	8.0	8.0	8.0	8.0	8.0	
LR							5.16 - 7.17 Ω
SR							4.06 Ω
Combined	6.0	6.0	6.0	6.0	6.0	6.0	
LR							7.37 - 10.6 Ω
SR							5.8 Ω
Combined	5.0	5.0	5.0	5.0	5.0	5.0	
LR							10.9 - 14.3Ω
SR							4.06 Ω

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

Westinghouse Relay Ampere Ratings

Westinghouse Relay Type	Winter Rating(Amperes)			Summer Rating(Amperes)			Notes
	Normal	Emergency		Normal	Emergency		
		15 Min.	4 Hrs.		15 Min.	12 Hrs.	
Combined	10.0	10.0	10.0	10.0	10.0	10.0	
LR							14.71 - 21.2 Ω
SR							5.8 Ω
Combined	8.5	8.5	8.5	8.5	8.5	8.5	
LR							21.5 Ω
SR							4.06 Ω
Combined	10.0	10.0	10.0	10.0	10.0	10.0	
LR							22.1 - 31.8 Ω
SR							5.8 Ω
Combined	9.5	9.5	9.5	9.5	9.5	9.5	
SLB	5.0	5.0	5.0	5.0	5.0	5.0	
SP	Same as SKD						
SP-1	Same as SKD						
SPCU	10.0	10.0	10.0	10.0	10.0	10.0	
SPCU-1	Same as SPCU						

(1) The remaining information contained in this section was obtained from the 'Capacity Rating Procedures by the System Design Task Force of the NEPOOL Planning Committee', revised August 1984

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SECTION IX

Line Traps

LINE TRAPS

A line trap usually consists of an air-core inductance coil in series with a power line conductor and tuned to parallel resonance by means of a tuning pack. NEMA Standard SG-11-1955 was the only industry standard covering line traps until November 1971 when it was rescinded. In 1981 ANSI published a new standard for line traps to replace the old NEMA Standard. This ANSI Standard has titled "Requirement for Power Line Carrier Line Traps" ANSI C93.3-1981, dated Sept 12, 1980(later withdrawn)(Reference #1). The following statement is extracted from the 1981 Standard:

> 'Line traps are designed within temperature rise limitations to ensure normal life expectancy. Any value of current in excess of the rated current in this standard may cause the designed temperature rise to be exceeded and may shorten the life expectancy of the line trap. Table A-1, however, shows percentages of rated continuous current that have been selected to minimize the reduction in operating life and should be applied with great care'.

During the 1994 review of the 'FINAL REPORT NEW YORK POWER POOL TASK FORCE ON TIE LINE RATINGS, June, 1982', it was discovered that the proposed standards for line traps has been withdrawn and consequently there is no formal standard for this piece of equipment. However, since a letter from Trench Electric(date unknown), confirms some Table A-1 entries and refutes none, it is the recommendation of the 1995 New York Power Pool Task Force on Tie Line Ratings to remain with the same ratings developed by the 1982 Task Force on Tie Line Ratings.

Table A-1 has been supplemented to include normal continuous ratings at various ambient temperatures, and to include rating factors for 35°C and 10°C. These adjustments are based on the following equation from "Rate Substation Equipment for Short Time Overloads", by Cronin and Bayless of Westinghouse, Electrical World Magazine, April 15, 1972 (Reference #2):

$$I_p = I_R\left[1 + \left(\frac{40^oC - \theta_a^oC}{400}\right)\right] \qquad \text{Equation 1}$$

where I_p = Permissible continuous load at actual ambient (I_p not to exceed ± 110 percent of I_R)

I_R = Rated continuous load at 40°C ambient

θ_a = Actual ambient temperature, degrees C

TABLE A-1

Normal and Emergency Overload Current is a Percentage of Rated Continuous Current					
Ambient	**Emergency**		**Period**		**Normal[1]**
Temperature °C	**15 Minutes**	**30 Minutes**	**1 Hour**	**4 Hours**	**Continuous**
45	138	128	118		98
40	140	130	120	110	100
35[1]	141	131	121	111	101
20	145	135	125	115	105
10[1]	150	139	129	118	107
0	150	140	130	120	110
-20[2]	155	145	135	125	110
-40[2]	160	150	140	130	110

Note: 1) These rating factors were derived using Equation No. 1. All other rating factors are from ANSI Standard C93.3-1981. Unfortunately, line trap standard activity has ceased and C93.3 was been withdrawn.

2) These entries come from a Trench Electric letter which also confirms many of the other table entries.

The rating factors to be used in the New York Power Pool for line traps are:

Season	Normal	LTE	STE
Summer(35°C)	101%	111%	141%
Winter(10°C)	107%	118%	150%

DISCUSSION of NEPOOL RATING CALCULATION

The Task Force obtained an application guide from New England which made use of the following formula to determine NORMAL ratings:

$$\sqrt{\frac{T_H - T_A}{T_H - T_D}}$$

T_H is a hottest spot temperature rise from ANSI C93.3, Table 6, plus 40ºC design ambient. That table refers to an "**Insulation Index**", about which we were not able to locate any information.

T_A is the actual ambient.

T_D is the design ambient temperature(40ºC if manufactured to ANSI Standards)

When the results of using this formula were compared to the present NYPP formula, the rating factors were higher for all values of the "insulation index". Therefore, without further information, this formula is not recommended.

LINE TRAPS

ANSI Standards

1. C93.2 - 197X Requirements for Power Line Carrier Line Traps

2. Rate Substations Equipment for Short Time Overloads, by J. H. Cronin and R. S. Bayless, Electrical World, April 15, 1972

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SECTION X

Substation Bus Conductors

SUBSTATION BUS CONDUCTORS

Synopsis

Ampacity requirements for bus conductors are usually determined by the full-load ratings of the attached equipment or transmission lines. Temperature limitations of the connected equipment may be a factor in determining conductor loading limits when operation of conductors at excessive temperatures may cause damage to the connected equipment by transfer of heat. Bus conductor ampacity limits are affected by conductor size, material, wind velocity, ambient temperature, convective heat loss, radiation heat loss and solar heat gain.

Ampacity rating factors for rigid bus conductors are based on information given in ANSI/IEEE Std. 605-1987 (Reference #1). Ampacity rating factors for bare cable bus conductors are determined using the rating factors used for transmission line conductors, except that for substation bus conductor ampacity calculations, a wind velocity to two feet per second (fps) must be considered.

Discussion

Substation electric power equipment have full-load ratings which are set by the limitations of the actual operating temperature. Accordingly, bus conductors should not be operated at temperatures which would cause heat to flow into the equipment. This requires that the calculated bus conductor ampacity ratings and operating temperatures be closely coordinated with the full-load ratings and thermal limitations of any connected equipment.

The general temperature rise equation for calculation of bus conductor loading amperes for normal and LTE operating conditions are:

Where

- I = conductor loading amperes
- q_c = convective heat loss
- q_r = radiation heat loss
- q_s = solar heat gain
- R = direct current resistance at the conductor temperature
- F = skin effect co-efficient for 60 Hz. current

An important factor in the computation of bus conductor ampacity is the assumption of a wind velocity in connection with forced convection losses. For substation bus conductor ampacity calculations a 2 fps wind velocity is recommended as a conservative, but realistic approach (Reference #1 and #2).

The appropriate equations for determination of the ampacity factors for rigid bus conductors are defined in Appendix B on substation bus conductors. The ampacity factors for bare cable conductors are defined in Appendix A on transmission line conductors except that a wind velocity of 2 fps should be utilized.

The temperature limitation rating factors apply for both rigid bus and strain bus conductors. More conservative temperature limitation rating factors may be required for bus conductors directly connected to electrical equipment. Conductors connected to electrical equipment should not be operated at temperatures which would cause heat to flow into equipment. If the thermal limits of the equipment is unknown, the following conductor temperature limitations should be applied for conductors connected to electrical equipment.

BUS CONDUCTOR TEMPERATURE LIMITATIONS

	Summer			**Winter**		
	N	**LTE**	**STE**	**N**	**LTE**	**STE**
Aluminum	85°C	95°C	105°C	85°C	95°C	105°c
ACSR	95°C	115°C	125°C	95°C	115°C	125°c
Copper	75°C	100°C	125°C	75°C	100°C	125°C
Equipment Connections	85°C	95°C	105°C	85°C	95°C	105°C

SUBSTATION BUS CONDUCTORS

1. **ANSI/IEEE Std 605-1987**, IEEE Guide for Design of Substation Rigid-Bus Structures.

2. Loading of Substation Equipment with Emphasis on Thermal Capability, Part I: Principles, by B. J. Conway, D. W. McMullen, A. J. Peat and J. M. Scofield - IEEE Transactions, Power Apparatus and Systems Vol. PAS-98, No. 4, July/Aug. 1979 pp. 1394-1402

3. Loading of Substation Equipment with Emphasis on Thermal Capability, Part II: Application, by I. S. Benko, D. E. Cooper, D. O. Craghead and P. Q. Nelson - IEEE Transactions, Power Apparatus and Systems Vol. PAS-98, No. 4, July/Aug. 1979 pp.1403-1419

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SECTION XI

Current Limiting Reactors

SERIES REACTORS

The use of series reactors on the existing NYPP Bulk Power System is limited to a few locations. The standard covering the use of series reactors in the American Standard Requirement, Terminology, and Test Code for Current-Limiting Reactors, C57.16-1958. The ANSI's Appendix C57.99, the Guide for Loading Dry-Type and Oil-Immersed Current-Limiting Reactor published in 1965 is being used by the industry. This guide is believed to be under consideration for review.

One NYPP member's practice is to request the reactor manufacturers to match the rating of the transmission lines containing the planned series reactor(s). After the series reactor is installed, the rating used for the reactor supplied by the manufacturers is used. Presently, the NYPP System has a limited use of series reactors. The Task Force recommends the use ratings provided by the manufacturers.

The guide provides general recommendations for loading both Dry-Type and Oil-Immersed current limiting reactors. It covers physical limitation, reactor life expectancy, rated load, effect of temperature of loading, etc.

The following example shows one of the many tables from the guide. It indicates the "Daily Peak Loads Above Name Plate Rating to Give Normal Life Expectancy in 30 C Average Ambient for Dry-Type 55°C or 80°C Rise Self-Cooled":

Peak Load Time in Hour	**Time Rated Amperes Dry-Type 55°C or 80°C Rise Self-Cooled(AA) Following and Followed by a Constant Load of**		
	90 Percent	**70 Percent**	**50 Percent**
1/2	1.21	1.51	1.70
1	1.09	1.25	1.34
2	1.04	1.09	1.13
4	1.00	1.01	1.03
8	1.00	1.00	1.00

Other tables in the guide have similar data for Forced-Air-Cooled, Forced-Oil etc.

The thermal time constant formula for a Dry-Type reactor at rated load is shown below:

$$T_r = \frac{C\theta_{rl}}{W_t}$$

T_r = Time constant at rated load.
C = 0.06(weight of coil assembly in pounds, less weight of bottom disc and mounting insulators).
θ_{rl} = Temperature at rated load.
W_t = Watts loss at 75°C at rated load.

The following table indicates the "Daily Peak Loads Above Name Plate Rating to Give Normal Life Expectancy in 30 C Average Ambient":

Peak Load Time in Hour	**Time Rated Amperes Oil-Immersed self-cooled or water-cooled (OA or OW)* Following and Followed by a Constant Load of**		
	90 Percent	**70 Percent**	**50 Percent**
1/2	1.64	1.78	1.89
1	1.39	1.49	1.58
2	1.24	1.32	1.37
4	1.13	1.17	1.19
8	1.06	1.07	1.08

*Average ambient of 25°C for water-cooled reactors. Minimum water temperature must be 0°C.

The thermal time constant formula for Oil-Immersed reactor for any load and for any specific temperature differential between the ultimate oil rise and the initial oil rise is given by the equation:

$$T = \frac{C(\theta_{hu} - \theta_{hi})}{W_i - W_u}$$

T: Thermal time constant

C: Thermal capacity of reactor, watts-hours per degree C

Θ_{hu}: Ultimate hottest-spot winding temperature

Θ_{hi}: Initial hottest-spot winding temperature

W_i: Initial watts loss at 75°C

W_u: Ultimate watts loss at 75°C

DRY TYPE CURRENT LIMITING REACTORS -- RATING FACTORS(%) --

Season	*SUMMER*				*WINTER*			
Operating Conditions	Ambient	Normal/ 8 hour	LTE 4 hours	STE 30 min.	Ambient	Normal/ 8 hours	LTE 4 hours	STE 30 min.
55ºC rise - dry-type, self-cooled	35ºC	96%	96%	116%	10ºC	114%	114%	140%
* Following and followed by a constant load of 90 percent	30ºC	100%	100%	121%	5ºC	118%	118%	142%
* Altitude does not exceed 3,300 feet	25ºC	104%	104%	125%	0ºC	121%	121%	146%
80ºC rise - dry-type, self-cooled	35ºC	98%	98%	118%	10ºC	109%	109%	109%
* Following and followed by a constant load of 90 percent	30ºC	100%	100%	121%	5ºC	111%	111%	136%
* Altitude does not exceed 3,300 feet	25ºC	102%	102%	124%	0ºC	114%	114%	137%

NOTE 1: The shaded area numbers are taken from the Guide. Other numbers are calculated.

NOTE 2: The following factors from the Guide are used for the calculations:

For 55ºC RISE DRY-TYPE: 0.85% decrease for each degree C temperature ABOVE 30ºC
0.70% increase for each degree C temperature BELOW 30ºC

For 80ºC RISE DRY-TYPE: 0.50% decrease for each degree C temperature ABOVE 30ºC
0.45% increase for each degree C temperature BELOW 30ºC

SERIES REACTORS
(References)

ANSI Standards

1. C57.16-1958 Requirement, Technology, and Test Code for Current-Limiting Reactors.

2. Appendix C57.99-1965. ApplicationGuide for Loading Dry-Type and Oil-Immersed Current-Limiting Reactors.

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SECTION XII

Series Capacitors

SERIES CAPACITORS

Synopsis

The standard requirements for series capacitors are covered in ANSI Standards 824-1985. This standard applies to capacitors and assemblies of capacitors, insulation means, switching and protective equipment, and control accessories that form a complete installation for inserting in series with a transmission or distribution line.

The capacitor bank shall be designed for continuous operation in outdoor locations with unrestricted ventilation and direct sunlight under the ambient temperatures given in Table 1.

Table 1

	Maximum Ambient Air Temperature (^{0}C)	
Mounting Arrangement	**24 Hour Average**	**Normal Annual**
Isolated capacitor	46	35
Single row of capacitors	46	35
Multiple rows and tiers of capacitors	40	25
Metal-enclosed or housed capacitors	40	25

The series capacitor bank shall be capable of withstanding the rated continuous current, system swing, emergency loading, continuous current as specified by the user in the general form illustrated in Fig 1.

The life of a capacitor may be shortenend by overstressing, overheating,or physical damage. Therefore, the life depends upon the control of operating conditions involving voltage, temperature limits, and physical care. Table 2 indicates the short-time capability based on the occurrence of overvoltage when the internal temperature of the capacitor unit is less than 0 ^{0}C.

Table 2
Transient Overvoltage and Overcurrent

Probable No. of Switching Operations Per Year	**Permissible Peak Transient Voltage (Multiplying Factor to be Applied to RMS Rated Voltage)**	**Permissible Peak Transient Current (Multiplying Factor to be Applied to RMS Rated Current)**
4	5	1500
40	4	1150
400	3.4	800
4000	2.9	400

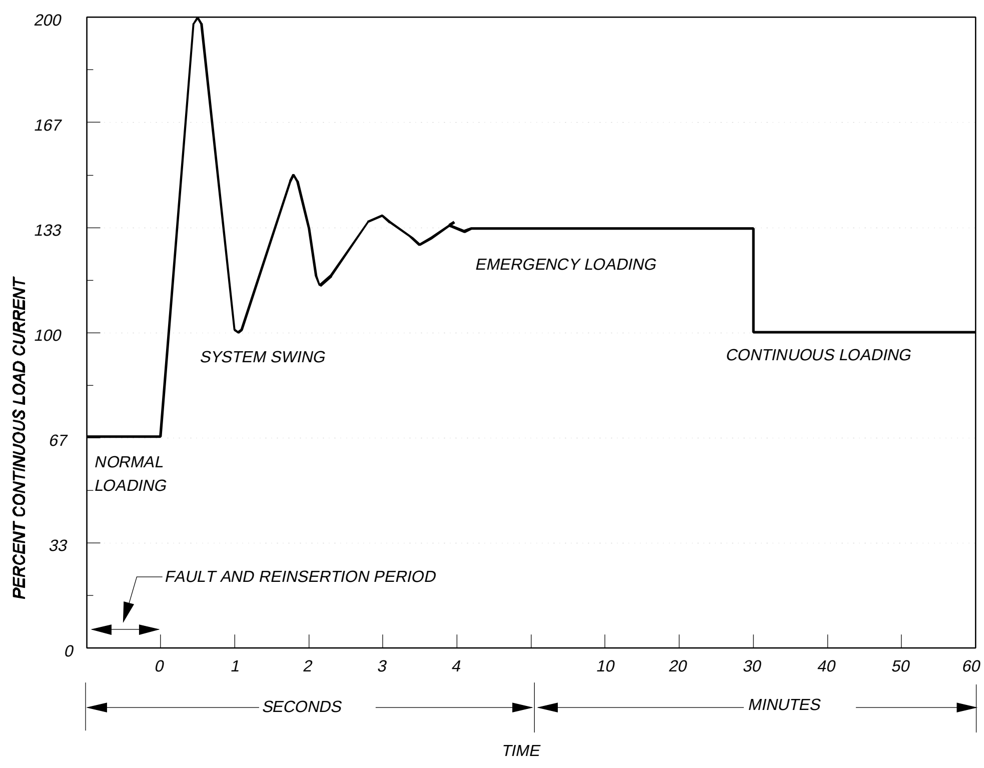

Figure 1
Typical Time-Current Profile on Reinsertion of Capacitor Bank
(After Fault and Loss of Parallel Line)

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Appendix A

Calculation of Overhead Conductor Ampacities

MANUAL METHOD
OF
CALCULATING CONDUCTOR AMPACITY

Calculating the ratings of a conductor involves steady-state and transient heat flow calculations. What follows is a brief review of the basic steps involved in making such calculations. *The IEEE Std 738-1993 includes both a computer program listing(basic) and a floppy disk containing the runtime version for calculating steady-state and transient conductor ratings.* The manual methods presented are based on the IEEE Standard.

The fundamental relationships for steady-state convected heat loss for horizontal wires discussed in the House and Tuttle AIEE Paper Current Carrying Capacity of ACSR are also covered in the book Heat Transmission by W. H. McAdams, McGraw-Hill Book Co.; and in an Alcoa booklet, Section 6 of Alcoa Conductor Engineering Handbook Series, titled: Current - Temperature Characteristics of Aluminum Conductors. A third reference, Principles of Heat Transfer by Frank Kreith, the International Textbook Company, Scranton, Pennsylvania, covers the subject of thermal transients. The material which follows was drawn primarily from these four references, and from *the IEEE Standard 738-1993*, *Calculating the Current Temperature Relationship of Bare Overhead Conductors. This new standard includes a wind angle factor formula. The angle used is that between the wind and the conductor(0^o=parallel, 90^o=perpendicular). This factor has been added to this section of the 1995 report.*

A conductor under transient loading conditions may be classified as a heat flow system with negligible internal thermal resistance. A justifiable assumption is that the thermal resistance between the surface of the system and the surrounding air (the film resistance) is so large compared to the internal thermal resistance of the system that it controls the heat transfer process.

Terms used in this appendix are defined hereunder:

CONDUCTION — A process by which heat flows from a region of higher temperature to a region of lower temperature within a medium (solid, liquid, or gaseous) or between different mediums, in direct physical contact. The subscript for conduction is "k".

RADIATION — A process by which heat is transferred from a high temperature body to a body at a lower temperature when the bodies are separated in space, even when a vacuum exists between them. The subscript for radiation is "r".

CONVECTION — A process of energy transfer by combined action of heat conduction , energy storage and mixing motion. It is most important as a mechanism of energy transfer between a solid surface and a liquid or a gas. The subscript for convection is "c".

HEAT RADIATED q_r — $q_r = \sigma (A_s) \epsilon [(T_1)^4 - (T_2)^4]$
where σ (sigma) is the Stefan-Boltzmann constant with a value equal to .5275 x 10^{-8} watts per square foot per $^oK^4$ and ϵ (Epsilon) is the emissivity factor, with an agreed upon average value of 0.6 to be used for NYPP ratings.

HEAT ABSORBED q_s — Energy absorbed from the sun's radiation which results in a temperature rise (sun effect) of a conductor.

HEAT CAPACITY, Conductor — The quantity of heat energy required to raise the temperature of one linear foot of conductor by 1 degree in a specified way, watt-sec/ft-^{o}C.

SPECIFIC HEAT — The quantity of heat required to raise the temperature of a unit of weight of material by 1 degree, Cal/gm-^{o}C or watt-sec/lb-^{o}C.

TRANSIENT FLOW — A heat flow process in a system is transient when the temperature at various points in the system changes with time.

Since there are many variables involved, Table I has been included and is a complete listing of all physical quantities with brief definitions, symbols and a consistent system of units.

TABLE I
SYMBOLS, DEFINITIONS AND UNITS

I	=	Conductor current - amperes at 60 Hz.
q_c	=	Convected heat loss - watts per lineal foot of conductor
q_r	=	Radiated heat loss - watts per lineal foot of conductor
q_s	=	Heat gain from the sun - watts per lineal foot of conductor
Q_s	=	Total solar and sky radiated heat - watts per sq. ft. (Table III)
$r_{ac}(T_c)$	=	60 Hz. AC resistance per lineal foot of conductor at temperature T_c (Table VII)
T_a	=	Ambient temperature - degreec C
$°K_a$	=	Ambient temperature - degrees Kelvin = $T_a + 273$
T_c	=	Conductor temperature - degrees C
$°K_c$	=	Conductor temperature - degrees Kelvin = $T_c + 273$
T_f	=	Air film temperature - degrees C; $T_f = (T_c + T_a)/2$
$\triangle T$	=	Temperature difference - degrees C
$\triangle t$	=	Time increment
D	=	Diameter of conductor - inches
D_o	=	Diameter of conductor - feet
A	=	Cross sectional area - square feet
A_s	=	Conductor surface area - square feet per foot $= \pi D/12$
A'	=	Projected area of conductor - square feet per lineal foot = D/12
V	=	Velocity of air stream - feet per hour
K_{ang}	=	wind direction factor
ρ_f	=	Density of air at film temperature - lbs/cubic foot (Table II)
μ_f	=	Absolute viscosity of air at film temperature - lbs/(hr) (ft) (Table II)
k_f	=	Thermal conductivity of air at film temperature - watts/(sq. ft.) (°C) (Table II)
ϵ	=	Coefficient of emissivity, 0.23 - 0.91; use 0.6 for average value
α	=	Coefficient of absorption, 0.23 - 0.95; use 0.6 for average value
		Note: above values are recommended for consistency of NYPP member calculations
θ	=	Effective angle of incidence of sun's rays
H_c	=	Altitude of sun - degrees (Table III)
Z_c	=	Azimuth of sun - degrees (Table III)
$Z\ell$	=	Azimuth of line - degrees (Table III)
c	=	Specific heat of conductor metal - cal./gm.-°C (Table IX)
W	=	Weight of conductor - lbs./lineal foot (Table VIII)
ϕ	=	Angle between the wind and conductor axis
τ	=	Time constant - minutes
al	=	Subscript for aluminum
st	=	Subscript for steel

AMPACITY CALCULATION PROCEDURE

The ampacity ratings may be determined as follows:

1. For a particular conductor, it is first necessary to calculate the Normal and LTE ratings as described in the House and Tuttle reference for steady-state conditions, section 6 of the Alcoa Conductor Engineering Handbook, and IEEE Standard 738-1993, making use of the following equations:

   Fundamental Steady-State Heat Balance Equation

   $q_c + q_r = q_s + I^2 r_{ac}$ This equation states that at steady state the heat input due to conductor current and the sun is equal to heat loss by convection and radiation.

   The ampacity rating is the value of current that satisfies this equation. Note that q_c, q_r and $r_{ac}(T)$ must be calculated for the relevant design conductor temperature(Normal or LTE).

$$I=\sqrt{\frac{q_c+q_r-q_s}{r_{ac}(T)}}$$

Forced Convection Heat Loss

Air density ρ_f, air viscosity, μ_f, and coefficient of thermal conductivity of the air film at the conductor surface, k_f, are taken from Table II at air film temperature T_f where:

$$T_f=\frac{T_c+T_f}{2}$$

The convective heat loss term now includes the wind direction factor K_{ang}, where ϕ is the angle between the wind direction and the conductor axis:

$$K_{ang} = 1.194 - \cos(\phi) + .194\cos(2\phi) + .368\sin(2\phi)$$

The following sample values were generated from this formula:

ϕ	K_{ang}
90°	1.000
45°	0.855
30°	0.744
20°	0.639

0°	0.388

Two formulas are used to calculate convection heat loss as follows:

The first formula

$$q_c = K_{Ang}[1.01 + 0.371[\frac{D\rho_f V}{\mu_f}]^{0.52} k_f (T_c - T_a) watts/ft. of conductor$$

is for values of $\frac{D_o \rho_f V}{\mu_f}$ = 0.1 to 1,000, where D_o= conductor diameter in feet.

The second formula

$$q_c = 0.1695 K_{Ang}[\frac{D_o \rho_f V}{\mu_f}]^{0.6} k_f (T_c - T_a) watts/ft. of conductor$$

is for $\frac{D_o \rho_f V}{\mu_f}$ values ranging between 1,000 to 18,000(i.e. for higher values of wind speed,V)

The IEEE Standard 738 recommends using the <u>larger</u> of the two q_c values for a given conductor diameter.

A formula for natural convection heat loss is also provided in this standard. It is recommended to use the larger of the natural or forced convection heat loss. No combined effect is considered. Natural convection heat loss is numerically about the same as forced convection loss with a wind speed of 3 ft/sec and a wind angle of zero degrees.

<u>Radiated Heat Loss</u>

$$q_r = \sigma \varepsilon A_s (K_c^4 - K_a^4) = 0.5275 x 10^{-8} [\frac{\pi D}{12}] \varepsilon [(K_c^4 - K_a^4)]$$

$$q_r = 0.138 D \varepsilon [(\frac{K_c^o}{100})^4 - (\frac{K_a^o}{100})^4] watts/ft. of conductor$$

Solar Heat Gain

$q_s = \alpha Q_s(\sin(\theta)A'$

Effective angle of incidence of solar radiation(see Tables III through VI):

$\theta = \mathrm{Cos}^{-1}\left[(\cos H_c) \cos(Z_x - Z_l) \right]$

solar absorbtivity:

$\alpha = 0.6$

2. From the above calculate the net rate of heat loss:

$q_{normal} = (q_c + q_r)_{NORMAL} - q_s$ watts/ft of conductor and $q_{lte} = (q_c + q_r)_{LTE} - q_s$ watts/ft of conductor

Calculate normal and LTE current ratings:

$$I_{normal} = \sqrt{\frac{q_{normal}}{r_{ac}(T_{normal})}} amperes \qquad I_{lte} = \sqrt{\frac{q_{lte}}{r_{ac}(T_{lte})}} amperes$$

CALCULATING THE SHORT-TIME RATING

Because the short-time rating period is limited to 15 minutes, most conductors can actually carry a heavier current without exceeding a selected maximum temperature than they would if the current were allowed to continue flowing until steady-state conductor heating was reached. The relationship between the changing conductor temperature and time is given by the "time constant" equation. The equation is:

$$T_c(t) = T_i + (T_{ult} - T_i)(i - \varepsilon^{-t/\tau})$$

At the equation shows, the rate of conductor temperature rise depends on T_{ult}, the ultimate steady-state temperature that would result if the STE current was continuous, and time constant τ. Time constant is defined as the time required, after the step increase to STE current, for the temperature to equal 63% of the difference between T_{ult} and initial temperature T_i. For NYPP ratings, T_i is the Normal rating conductor temperature limit.

1. Computer Calculation

The STE current ratings and the T_{ult} and τ parameters can be determined by use of the IEEE Std. 738-1993 software. The STE time period and limiting temperature, and T_i are input, and the program starts an iterative procedure. A trial starting value of STE current is selected by the program, and the temperature rise ΔT_c during a time increment Δt is calculated from:

$$\Delta T_c = \frac{(I^2R + q_s - q_r - q_c)\Delta t}{CW} = \frac{NetHeatInput}{HeatCapacity}$$

The values of q_s, q_r and q_c are calculated from the same equations as for steady-state with the assumption that these are valid for the transient period. Temperature increment ΔT_c is added to T_i to get a new conductor temperature $T_c = T_i + \Delta T_c$. Heat input I^2R and losses q_r and q_c are then recalculated for the new T_c and ΔT_c is calculated for the next time increment using the new q_r and q_c. The process continues to the end of the STE time period. The resulting conductor temperature is then compared to the STE limiting temperature. If they are not sufficiently close, the program selects a new STE current and calculates another temperature -vs - time curve. The process continues until the curve passes through the temperature limit at t=15 minutes. The current for this curve is the STE rating.

Having found the STE current, parameters T_{ult} and τ can then be found by the following steps, using the IEEE Std. program:

1. Calculate the steady state conductor temperature due to the STE current using NYPP ambient conditions. This is parameter T_{ult}.

2. Calculate conductor temperature $T_c = T_i + .0.63(T_{ult} - T_i)$

3. From the temperature - vs - time curve provided by the program, find the time corresponding to the Tc value. This is the time constant τ.

Another way to calculate the time constant is from IEEE Std 738-1993, Annex F; equation F3, which provides a good approximation for most conductors and an underestimate for small conductors(4/0 and smaller).

STE rating calculations for a range of ACSR conductors, Table A-1 and figure A-1, show that for 477 kcm and larger conductors, the temperature vs time curves are very similar during the 15 minute period(note temp. @ 5 min). This is true even though there is considerable variation in T_{ult} and τ. Temperature rise is more rapid for small conductors, which are seen in figure A-1 to reach steady-state within 15 minutes. Wind angle and wind speed also have small effect on the rate of temperature rise(see Table A-1), although they greatly affect convective heat loss, due to time and temperature constraints of the STE rating.

It is expected that the IEEE Std. method of calculating STE ratings will be more accurate than the method included in the 1982 NYPP Tie Line Rating Report. The IEEE method is easily handled by a computer, and is recommended in place of the 1982 report method.

Table A-1
Calculated values of T_{ult}, T_i and conductor temperature at 5 minutes after the start of STE operation, IEEE method, ambient 35ºC.

ACSR Conductor	Stranding	Wind Speed Ft/sec	Wind Angle Degrees	T_{ult} Degree C	τ Min.	T_c @ t=5 min. Degree C
1/0	6/1	3	90	125	2.9	119.7
4/0	6/1	3	90	127	4.9	115.5
477	30/7	3	90	132	8.9	110.9
795	26/7	3	90	137	11.9	109.4
795	26/7	1	90	145	16.2	108.3
795	26/7	3	20	143	15.2	108.5
2385	72/7	3	90	157	22.4	107.4

While it is not required, the mean conductor temperature during the STE transient period can be calculated from a formula obtained by integrating the time constant equation:

$$\overline{T_c} = T_{ult} + \frac{\tau}{\Delta t}(T_{ult} - T_i)(e^{-\Delta t/\tau} - 1) \quad where \; \Delta t = duration \; of \; STE \; operation$$

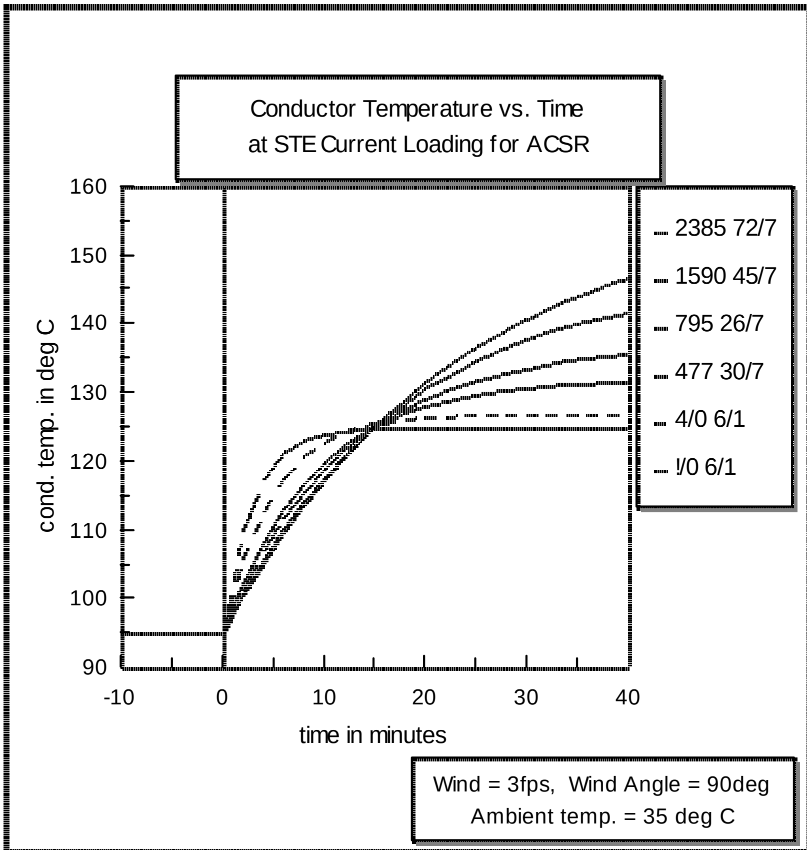

Figure A-1 Temperature vs Time for STE operation for a range of ACSR conductors, NYPP summer ambient.

2. Manual Calculation

The STE Rating for overhead conductors can be estimated by a manual method based on equations used in the IEEE Standard. A manual method can only provide an approximation. Simplifying assumptions must be made to handle the non-linear variation of radiated heat loss with conductor temperature. Results within a few percent of computer calculated ratings are still attainable.

The following empirical calculation method makes use of the observation that temperature-vs.-time curves such as those in figure A-1, fall in a narrow range for a number of common conductor sizes. This is due to the time and conductor temperature constraints of STE operation. Consequently, the mean conductor temperature during the STE transient period is nearly the same for each conductor type. For the manual STE rating calculation it is assumed that heat input and losses are constant for the full STE period. Heat input and losses are assumed to have values corresponding to a fixed temperature that is near the mean value of conductor temperature during the STE time period. The formula below can then be used to equate conductor temperature rise during a specified time to net heat energy input divided by the conductor heat capacity. The temperature rise is the increase from the Normal to the STE temperature limits(e.g. for ACSR, 95C to 125C). The equation is

$$\Delta T_c = T_{ste} - T_n = \frac{(I^2 r_{ac}(T_{cx}) + q_s - q_c - q_r)\Delta t}{CW}$$

Solving the equation for current I results in a formula for I_{ste}:

$$I_{ste} = \sqrt{\frac{1}{r_{ac}(T_c)}\left[\frac{CW(T_{ste} - T_n)}{\Delta t} - q_s + q_r + q_c\right]}$$

where Δt = duration of the STE current = 15 minutes or 900 sec. The term $\frac{CW(T_{ste} - T_n)}{\Delta t}$

is the constant rate of heat input required to raise the conductor temperature from T_n to T_{ste} in time Δt.

In using the formula, parameters q_c, q_r, $r_{ac}(T_c)$ and CW are calculated at the fixed temperature for the conductor type. The temperatures are:

Conductor Type	**T, Deg. C**
ACSR	110
SAC	95
ACAR	110
Copper, CWC	100

Solar heat gain q_s is the same for Normal and LTE calculations. In calculating heat capacity CW, the specific heat value from Table IX must be multiplied by the factor 1898.76 to convert the units to watt-sec/lb-deg C. For ACSR and other composites the sum of the heat capacities of each material is used, i.e.:

$$CW = C_{al}W_{al} + C_{st}W_{st}$$

Results from the above procedure will be within a few percent of the computer calculation. For mid-range and larger conductors the manual results will be on the high side. If assured conservative values of I_{ste} are required, results from the formula can be reduced by 3-5 percent.

For small conductors that closely approach or reach steady-state by the end of the STE time period, another method must be used. A reasonable estimate of the STE rating can be calculated by the method used for Normal and LTE ratings. Heat losses and $r_{ac}(T_c)$ are calculated at the STE temperature limit.

TABLE II
Viscosity, Density and Thermal Conductivity of Air

Temperature				Absolute Viscosity ① lb/(hr) (ft) μ_f	Density ② Air lb/cu. ft. ρ_f				Thermal Conductivity of Air ③ watts/(sq ft) (°C) k_f
°F	°C	°K	$(°K/100)^4$		Sea Level	5,000 ft.	10,000 ft.	15,000 ft.	
32	0	273	55.55	0.0415	0.0807	0.0671	0.0554	0.0455	0.00739
41	5	278	59.73	0.0421	0.0793	0.0660	0.0545	0.0447	0.00750
50	10	283	64.14	0.0427	0.0779	0.0648	0.0535	0.0439	0.00762
59	15	288	68.80	0.0433	0.0765	0.0636	0.0526	0.0431	0.00773
68	20	293	73.70	0.0439	0.0752	0.0626	0.0517	0.0424	0.00784
77	25	298	78.86	0.0444	0.0740	0.0616	0.0508	0.0417	0.00795
86	30	303	84.29	0.0450	0.0728	0.0606	0.0500	0.0411	0.00807
95	35	308	89.99	0.0456	0.0716	0.0596	0.0492	0.0404	0.00818
104	40	313	95.98	0.0461	0.0704	0.0586	0.0484	0.0397	0.00830
113	45	318	102.26	0.0467	0.0693	0.0577	0.0476	0.0391	0.00841
122	50	323	108.85	0.0473	0.0683	0.0568	0.0469	0.0385	0.00852
131	55	328	115.74	0.0478	0.0672	0.0559	0.0462	0.0379	0.00864
140	60	333	122.96	0.0484	0.0661	0.0550	0.0454	0.0373	0.00875
149	65	338	130.52	0.0489	0.0652	0.0542	0.0448	0.0367	0.00886
158	70	343	138.41	0.0494	0.0643	0.0535	0.0442	0.0363	0.00898
167	75	348	146.66	0.0500	0.0634	0.0527	0.0436	0.0358	0.00909
176	80	353	155.27	0.0505	0.0627	0.0522	0.0431	0.0354	0.00921
185	85	358	164.26	0.0510	0.0616	0.0513	0.0423	0.0347	0.00932
194	90	363	173.63	0.0515	0.0608	0.0506	0.0418	0.0343	0.00943
203	95	368	183.40	0.0521	0.0599	0.0498	0.0412	0.0338	0.00952
212	100	373	193.57	0.0526	0.0591	0.0492	0.0406	0.0333	0.00966

① (605) HH Senrath and Touloukian, "The Viscosity, Thermal Conductivity and Prandtl Number for Air and Other Gases," *ASME Transactions*, Vol 76, 1954, pp. 967-981
② (606) Richard D. Madison, Editor, *Fan Engineering*, 5th edition, Buffalo Forge Company, Buffalo, New York, 1948.
③ (604) W. H. McAdams, *Heat Transmission*, 3rd edition, McGraw-Hill Book Company, New York, 1954.

TABLE III

FACTORS FOR DETERMINING SUN EFFECT WHEN CALCULATING TRANSMISSION LINE AMPACITY SUMMER AND WINTER CONDITIONS NEW YORK STATE AREA

Factors	Summer	Winter
Latitude (1)	42°	42°
Longitude (1)	76°	76°
Declination (2)	+23°	-23°
Altitude of Sun (Hc) 10:00am and 2:00 pm (2)	59°	19°
Altitude of Sun (Hc) 12:00 N (2)	71°	25°
Average Altitude (2)	65°	22°
Azimuth of Sun (Zc) 10:00 am (2)	118°	152°
Azimuth of Sun (Zc) 12:00 N (2)	180°	180°
Average Azimuth, 10:00am and 12:00 N	149°	166°
Effect of Sun, Qs watts/sq. ft. (3)	94	67
Assumed Direction of Line	E to W	E to W
Azimuth of Line Z_ℓ	270°W	270°W

(1) For a point in vicinity of Binghamton, NY.

(2) Declination and sun's altitude are averages for June 10 and July 13 for summer; and December 13 and January 2 for winter. Data obtained from SIGHT REDUCTION TABLES FOR AIR NAVIGATION, U.S. Navy Hydrographic Office, H.O. Publication No. 29, Volume III.

(3) From Table III, CURRENT CARRYING CAPACITY OF ACSR, by House and Tuttle, AIEE Transcations, Power Apparatus and Systems, Volume 77, Part III, 1959, page 1170.

TABLE IV
ALTITUDE AND AZIMUTH IN DEGREES OF THE SUN AT VARIOUS LATITUDES
DECLINATION 23.0° - NORTHERN HEMISPHERE - JUNE 10 AND JULY 3

Degrees North Latitude	Local Sun Time					
	10:00 am		12:00 N		2:00 pm	
	H_c	Z_c	H_c	Z_c	H_c	Z_c
20	62	78	87	0	62	282
25	62	88	88	180	62	272
30	62	98	83	180	62	262
35	61	107	78	180	61	253
40	60	115	73	180	60	245
45	57	122	68	180	57	238
50	54	128	63	180	54	232
60	47	137	53	180	47	233
70	40	143	43	180	40	217

TABLE V
TOTAL HEAT RECEIVED BY A SURFACE
AT SEA LEVEL NORMAL TO THE SUN'S RAYS

Solar Altitude Degrees H_c	Q_s watts/ sq. ft. (See Table VI)	
	Clear Atmosphere	Industrial Atmosphere
5	21.7	12.6
10	40.2	22.3
15	54.2	30.5
20	64.4	39.2
25	71.5	46.6
30	77.0	53.0
35	81.5	57.5
40	84.8	61.5
45	87.4	64.5
50	90.0	67.5
60	92.9	71.6
70	95.0	75.2
80	95.8	77.4
90	96.4	78.9

TABLE VI
SOLAR HEAT MULTIPLYING FACTORS FOR HIGH ALTITUDES

Elevation Above Sea Level, feet	Multiplier for Values in Table V
0	1.00
5,000	1.15
10,000	1.25
15,000	1.30

TABLE VII

Note: See also tables in EPRI Transmission Line Reference Book 345kV and Above, 1975 for conductor tables containing a-c resistance.

RESISTANCE AND STRANDING OF BARE ACSR

Code Name	Alum. Area MCM	Stranding			AC Resistance 60 cps - ohms per miles *			
		No. of Wires		Layers of Alum.	25°C	50°C	75°C	100°C
		Alum.	Steel					
Starling	715.5	26	7	2	0.1260	0.1390	0.1510	0.1640
Redwing	715.5	30	19	2	0.1260	0.1390	0.1510	0.1640
Tern	795.0	45	7	3	0.1160	0.1280	0.1390	0.1510
Condor	795.0	54	7	3	0.1150	0.1270	0.1380	0.1500
Drake	795.0	26	7	2	0.1140	0.1250	0.1370	0.1480
Mallard	795.0	30	19	2	0.1140	0.1250	0.1370	0.1480
Crane	874.5	54	7	3	0.1050	0.1160	0.1260	0.1370
Canary	900.0	54	7	3	0.1020	0.1120	0.1220	0.1330
Rail	954.0	45	7	3	0.0978	0.1080	0.1170	0.1270
Cardinal	954.0	54	7	3	0.0963	0.1060	0.1160	0.1250
Ortian	1,033.5	45	7	3	0.0905	0.0996	0.1090	0.1180
Curlew	1,033.5	54	7	3	0.0893	0.0983	0.1070	0.1160
Bluejay	1,113.0	45	7	3	0.0844	0.0929	0.1010	0.1100
Finch	1,113.0	54	19	3	0.0832	0.0915	0.0999	0.1080
Bunting	1,192.5	45	7	3	0.0792	0.0871	0.0951	0.1030
Grackle	1,192.5	54	19	3	0.0778	0.0856	0.0934	0.1010
Bittern	1,272.0	45	7	3	0.0746	0.0821	0.0896	0.0970
Pheasant	1,272.0	54	19	3	0.0732	0.0805	0.0879	0.0952
Dipper	1,351.5	45	7	3	0.0705	0.0776	0.0846	0.0917
Martin	1,351.5	54	19	3	0.0692	0.0761	0.0831	0.0900
Bobolink	1,431.0	45	7	3	0.0668	0.0735	0.0802	0.0869
Plover	1,431.0	54	19	3	0.0657	0.0723	0.0739	0.0855
Nutharch	1,510.5	45	7	3	0.0636	0.0700	0.0764	0.0827
Parrot	1,510.5	54	19	3	0.0625	0.0688	0.0750	0.0813
Lapwing	1,590.0	45	7	3	0.0608	0.0669	0.0730	0.0791
Falcon	1,590.0	54	19	3	0.0589	0.0648	0.0707	0.0766
Chukar	1,780.0	84	19	4	0.0548	0.0603	0.0658	0.0713

* The 60 cycle AC resistance is for ACSR conductors with two or four layers of aluminum of 62 per cent conductivity and allows for skin effect in the aluminum and losses in the steel core. For ACSR conductors with three layers of aluminum, the values in the table should be multiplied by the following factors when greater accuracy is desired: (a) for current densities of 1000 amperes per 1000 MCM multiply by 1.006 for 45/7 conductors and by 1.025 for 54/7 and 54/19 (b) for current densities of 1300 amperes per 1000 MCM multiply by 1.0075 for 45/7 conductors and by 1.03 for 54/7 and 54/19. Additional information on this subject is available in the source reference Alcoa Engineering Data Handbook, Section 5, Resistance and Reactance of Aluminum Conductors.

TABLE VIII

Code Word	PHYSICAL PROPERTIES											
	Size and Area, ACSR			Standing Individual Wires				Diameter Inches		Weight Pounds Per Ft.		
	Aluminum		Alum. and Steel Square Inches	Aluminum		Steel						
	CM	Square Inches		No.	Dia. Inches	No.	Dia. Inches	Steel Core	Over All	Alum	Steel	Total
Mallard	795,000	0.6244	0.7668	30	0.1628	19	0.0977	0.489	1.140	.752	.483	1.235
Ruddy	900,000	0.7069	0.7558	45	0.1414	7	0.0943	0.283	1.131	.849	.166	1.015
Canary	900,000	0.7069	0.7985	54	0.1291	7	0.1291	0.387	1.162	.849	.310	1.159
Rail	954,000	0.7493	0.8011	45	0.1456	7	0.0971	0.291	1.165	.900	.175	1.075
Cardinal	954,000	0.7493	0.8464	54	0.1329	7	0.1329	0.399	1.196	.900	.329	1.229
Ortotan	1,033,500	0.8117	0.8678	45	0.1515	7	0.1010	0.303	1.212	.975	.190	1.165
Curlew	1,033,500	0.8117	0.9169	54	0.1383	7	0.1383	0.415	1.245	.975	.356	1.331
Blue Jay	1,113,000	0.8742	0.9346	45	0.1573	7	0.1049	0.315	1.258	1.050	.205	1.255
Finch	1,113,000	0.8742	0.9851	54	0.1436	19	0.0862	0.431	1.293	1.055	.376	1.431
Bunting	1,192,500	0.9366	1.001	45	0.1628	7	0.1085	0.326	1.302	1.125	.219	1.344
Grackle	1,192,500	0.9366	1.055	54	0.1486	19	0.0892	0.446	1.338	1.130	.463	1.533
Bittern	1,272,000	0.9990	1.068	45	0.1681	7	0.1121	0.336	1.345	1.200	.234	1.434
Pheasant	1,272,000	0.9990	1.126	54	0.1535	19	0.0921	0.461	1.382	1.206	.429	1.635
Dipper	1,351,500	1.061	1.134	45	0.1733	7	0.1155	0.346	1.386	1.275	.248	1.523
Martin	1,351,500	1.061	1.195	54	0.1582	19	0.0949	0.475	1.424	1.281	.456	1.737
Bobolink	1,431,000	1.124	1.202	45	0.1783	7	0.1189	0.357	1.426	1.350	.263	1.613
Plever	1,431,000	1.124	1.266	54	0.1628	19	0.0977	0.489	1.465	1.357	.483	1.840
Nuthatch	1,510,500	1.186	1.268	45	0.1832	7	0.1221	0.366	1.466	1.425	.277	1.702
Parrot	1,510,500	1.186	1.336	54	0.1672	19	0.1003	0.502	1.505	1.432	.510	1.942
Lapwing	1,590,000	1.249	1.335	45	0.1880	7	0.1253	0.376	1.504	1.499	.293	1.792
Falcon	1,590,000	1.249	1.407	54	0.1716	19	0.1030	0.515	1.545	1.507	.537	2.044
Chukar	1,780,000	1.398	1.512	84	0.1456	19	0.0874	0.437	1.602	1.687	.387	2.074
Bluebird	2,156,000	1.693	1.831	84	0.1602	19	0.0961	0.491	1.762	2.044	.467	2.511
Kiwi	2,167,000	1.702	1.776	72	0.1735	7	0.1157	0.347	1.735	2.054	.249	2.303
HIGH STRENGTH ACSR												
Grouse	80,000	0.0628	0.0947	8	0.1000	1	0.1670	0.167	0.367	.075	.074	.149
Petrel	101,800	0.0800	0.1266	12	0.0921	7	0.0921	0.276	0.461	.096	.158	.254
Minorca	110,800	0.0870	0.1378	12	0.0961	7	0.0961	0.288	0.481	.105	.172	.277
Leghorn	134,600	0.1057	0.1674	12	0.1059	7	0.1059	0.318	0.530	.127	.209	.336
Guinea	159,000	0.1249	0.1977	12	0.1151	7	0.1151	0.345	0.576	.150	.247	.397
Dotterel	176,900	0.1389	0.2199	12	0.1214	7	0.1214	0.364	0.607	.167	.275	.442
Dorking	190,800	0.1499	0.2373	12	0.1261	7	0.1261	0.378	0.631	1.80	.296	.476
Brahma	203,200	0.1596	0.3020	16	0.1127	19	0.0977	0.489	0.714	.192	.485	.677
Cochin	211,300	0.1660	0.2628	12	0.1327	7	0.1327	0.389	0.664	.199	.328	.527

TABLE IX

SPECIFIC HEAT
Variation With Temperature

°C	Pb	Za	Al	Ag	Au	Cu	Ni	Fe	Co	Quartz
0°C	0.0350	0.0878	0.2220	0.0573	0.0317	0.1008	0.1005	0.1055	0.0912	
100	0.0336	0.0965	0.2297	0.0583	0.0320	0.1014	0.1200	0.1168	0.0998	0.2372
200	0.0313	0.1052	0.2374	0.0594	0.0322	0.1020	0.1305	0.1282	0.1073	0.2416
300	0.0200	0.1139	0.2451	0.0605	0.0325	0.1026	0.1409	0.1396	0.1154	0.2460
400	0.0266	0.1226	0.2529	0.0616	0.0328	0.1032	0.1294	0.1509	0.1235	0.2504
500	0.0259	0.1173	0.2606	0.0627	0.0330	0.1038	0.1294	0.1623	0.1316	0.2548
600	0.0252	0.1141	0.2683	0.0638	0.0333	0.1045	0.1294	0.1737	0.1396	0.2592
700	0.0246	0.1100	0.2523	0.0649	0.0335	0.1051	0.1295	0.1850	0.1477	0.2636
800	0.0239	0.1076	0.2571	0.0660	0.0338	0.1057	0.1295	0.1592	0.1558	0.2680
900	0.0233	0.1044	0.2619	0.0671	0.0341	0.1063	0.1295	0.1592	0.1639	0.2724
1000	0.0226	0.1012	0.2667	0.0637	0.0343	0.1069	0.1295	0.1448		0.2768
1100				0.0694	0.0329	0.1028	0.1296	0.1448	0.1424	0.2812
1200				0.0750	0.0346	0.1159	0.1296	0.1448	0.1454	0.2856
1300				0.0807	0.0364	0.1291	0.1296	0.1449	0.1483	0.2900
1400							0.1296	0.1449	0.1512	0.2944
1500							0.1388	0.2142	0.1472	0.2988
1600								0.1501	0.1472	

Variation With Temperature (Interpolated Values) CAL./gm-°C.

°F	°C	Aluminum	Steel	Copper
32	0	0.2220	0.10450	0.10080
68	20	0.2235	0.10700	0.10092
167	75	0.2278	0.11388	0.10125
176	80	0.2282	0.11450	0.10128
185	85	0.2285	0.11513	0.10131
194	90	0.2289	0.11575	0.10134
203	95	0.2293	0.11638	0.10137
212	100	0.2297	0.11700	0.10140
221	105	0.2301	0.11763	0.10143
230	110	0.2305	0.11825	0.10146
239	115	0.2309	0.11888	0.10149
248	120	0.2312	0.11950	0.10152
257	125	0.2316	0.12013	0.10155

To convert to watt-sec/lb-°C, multiply by 1898.76

NUMERICAL EXAMPLE OF MANUAL CALCULATION
NYPP SUMMER NORMAL, LTE AND STE RATINGS

Assume Lapwing ACSR Conductor
D = 1.504"

Wt./foot	Aluminum	1.500 lbs.
	Steel	.292
	Total	1.792

α	=	0.6
Ta	=	35°C
Tc	=	95°C Operating
Tc	=	115°C Emergency
Tc	=	125°C Short-Time
$r_{ac(25^oC)}$	=	.0622 ohms/mi.
$r_{ac(100^oC)}$	=	.0622 ohms/mi.
ϕ	=	90^o

$\epsilon = 0.6$
V = 3ft/sec x 3600 = 10,800 ft./hr.

Change in resistance/^{o}C:

$(r_{ac(110^oC)} - r_{ac(25^oC)})/ 75 = .000224$

$$r_{ac} @ 95°C = \frac{.0790 - 5(.000224)}{5280} = 14.8 \times 10^{-6} \text{ ohm/ft.}$$

$$115°C = \frac{.0790 + 15(.000224)}{5280} = 15.6 \times 10^{-6} \text{ ohm/ft.}$$

$$110°C = \frac{.0790 + 10(.000224)}{5280} = 15.39 \times 10^{-6} \text{ ohm/ft.}$$

FACTORS FOR NORMAL RATING

^oK_c = 95°C + 273° = 368°
^oK_a = 35°C + 273° = 308°

$$T_f = \frac{95° + 35°}{2} = 65°C$$

From Table II for $T_f = 65^oC$,
ρ_f = .0652 lb./cu. ft.
μ_f = .0489 lb./hr. ft.
k_f = .00886 watts/sq. ft.-°C

FACTORS FOR LTE RATING

^oK_c = 115°C + 273°= 388°
^oK_a = 35°C + 273° = 308°

$$T_f = \frac{115° + 35°}{2} = 75°C$$

From Table II for $T_f = 75^oC$,
ρ_f = .0634 lb./cu. ft.
μ_f = .0500 lb./hr. ft.
k_f = .00909 watts/sq. ft.-°C

FACTORS FOR SHORT-TIME RATING

$°K_c$	=	110°C + 273°=	383°	
$°K_a$	=	35°C + 273° =	308°	
T_f	=	$\frac{110° + 35°}{2}$ =	72.5°C	

From Table II for T_f = 72.5°C,

ρ_f = .0638 lb./sq. ft.

μ_f = .0498 lb./hr. ft.

k_f = .00904 watts/sq. ft.-°C

CALCULATING THE SUMMER NORMAL RATING

A. Convection Heat Loss

$$q_c = K_{ang}\left(1.01 + \left(\frac{D\rho_f V}{\mu_f}\right)^{0.52} 0.371\, k_f\, (T_c - T_a)\right) \text{watts/ft. of conductor}$$

$$=(1.0)\left[1.01+0.371\left(\frac{(1.504)(.0652)(10800)}{.0489}\right)^{0.52}\right] (.00886)\ (95\text{-}35)$$

= 35.98 watts/ft. of conductor

Note that for this particular conductor, the two alternative formulas give the same value for q_c. Normally the higher value from the two formulas should be used for a given conductor. Since the wind angle is 90° in this example, K_{ang} = 1.0.

B Radiated Heat Loss

$$q_r = 0.138 D\varepsilon\left[\left[\frac{°K_c}{100}\right]^4 - \left[\frac{°K_a}{100}\right]^4\right] \text{watts/ft. of conductor}$$

$$=0.138(1.504)(0.6)\left[\left[\frac{368}{100}\right]^4 - \left[\frac{308}{100}\right]^{-4}\right]$$

= 11.63 watts/ft. of conductor

C. Assume line runs E-W at latitude 42°N in clear atmosphere. Take average altitude and average azimuth of sun between 10:00 am and noon.

H_c = 65° Z_c = 149° - from Table III Q_s = 94.0

from Table III

$\theta = \cos^{-1}$ [(cos 65°) cos (149° - 270°)] = 102.5°; and sin 102.5° = 0.976

Solar Heat Gain

$q_s = aQ_s$ (Sin θ) A'. Assume coefficient of absorption $\alpha = 0.6$

$q_s = (0.6)\ (94.0)\ (.976)\ \frac{1.504}{12} = 6.88$ watts/ft. of conductor

D. Summer Normal Rating:

(a) With Sun:

$$I_{NORMAL} = \sqrt{\left[\frac{q_c + q_r - q_s}{r_{ac_{95}C}}\right]} = \sqrt{\left[\frac{35.98 + 11.63 - 6.88}{14.8x10^{-6}}\right]} = 1659 Amperes$$

(b) Without Sun:

$$I_{NORMAL} = \sqrt{\frac{35.98 + 11.63}{14.8x10^{-6}}} = 1794 Amperes$$

CALCULATING THE LTE RATING

Max Conductor Temperature for ACSR = 115°C

$$q_c = (1.0)\left[1.01 + 0.371\left(\frac{(1.504)(0.0634)(10800)}{0.0500}\right)^{0.52}\right] \quad (0.00909)\ (80)$$

= 47.96 watts/ft.

$$q_r = (0.138)\ (1.504)\ (0.6) \quad \left[\left[\frac{388}{100}\right]^{-4} - \left[\frac{308}{100}\right]^{4}\right]$$

= 17.02 watts/ft.

The sun effect is unchanged qs = 6.88 watts/ft.

Summer LTE Rating:

(a) With Sun:

$$I_{LTE} = \sqrt{\left[\frac{47.96 + 17.02 - 6.88}{15.7x10^{-6}}\right]} = 1924 Amperes$$

(b) Without Sun:

$$I_{LTE} = \sqrt{\left[\frac{47.96 + 17.02}{15.7x10^{-6}}\right]} = 2034 Amperes$$

CALCULATING THE STE RATING

Since the conductor is ACSR, $r_{ac}(T)$, CW, q_c and q_r will be calculated at $T_c = 110^oC$.

A.. Since $\phi = 90^o$, $K_{ang} = 1.0$

$$q_c = 1.0x(1.01 + (.371)(\frac{1.504x.0638x10800)}{.0498})^{.52})x.00904x(110 - 35)$$

= 44.95 watts/ft

B.

$$q_r = (.138)x(1.504)x(0.6)[(\frac{383}{100})^4 - (\frac{308}{100})^4]$$

= 15.59 watts/ft

C. CW = ((.2305 x 1.500) + (.11825 x .292)) x 1898.76

= 722.06 watt-sec/ft-^oC

D.

$$I_{ste} = \sqrt{\frac{1}{15.39x10^{-6}}[\frac{722.06x(125 - 95)}{900} + 44.95 + 15.59 - 6.88]}$$

$$= \sqrt{\frac{77.73}{15.39x10^{-6}}}$$

= 2247 Amperes

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Appendix

B

Calculation of
Rigid Bus Conductor
STE Ampere Rating

APPENDIX 'B'

Manual Method of Calculating Substation Rigid Bus Conductor Short-Time Current Rating

The general temperature rise equation for calculation of bus conductor loading amperes for normal and LTE operating conditions is:

$$I = \sqrt{\left[\frac{q_c + q_r - q_s}{RF}\right]}$$

Where I = conductor loading amperes
q_c = convective heat loss
q_r = radiation heat loss
q_s = solar heat gain
R = direct current resistance at the conductor temperature
F = skin effect coefficient for 60 Hz. current

An important factor in the computation of bus conductor ampacity is the assumption of a wind velocity in connection with forced convection losses. For substation bus conductor ampacity calculations, a 2 fps wind velocity is recommended as a conservative but realistic approach (Ref. #1) (Ref. #2).

Convective Heat Loss (q_c)

A bus conductor loses heat through natural or forced convection. Natural convection is a function of: (1) the temperature difference between the conductor surface and the ambient air temperature; (2) the orientation of the conductor's surface; (3) the width of the conductor's surface and (4) the conductor's surface area. Forced convective heat loss is a function of: (1) the temperature difference between the conductor's surface and the ambient air temperature; (2) the length of flow path over the conductor; (2) the wind velocity and (4) the conductor's surface area.

For rigid tubing bus conductors the summation of natural forced convection losses is determined by:

$q_c = 0.377\ \Delta t d^{0.6}$ (watt/ft)

where Δt = temperature difference between conductor temperature and ambient temperature (°C)

d = outside diameter of tubing (inches)

Radiation Heat Loss (q_r)

A conductor loses heat through the emission of radiated heat. The heat lost is a function of: (1) the difference in the absolute temperature of the conductor and the surrounding bodies; (2) the emissivity of the conductor's surface and (3) the conductor's surface area.

For rigid tubing bus conductors, the radiation heat loss is determined by:

$$qr = 1390\ \epsilon d\ (T_c^4 - T_a^4) \times 10^{-12}\ \text{(watts/ft)}$$

where ϵ = emissivity coefficient which varies with the surface condition of the conductor. Typical values are ϵ = 0.5 for weathered aluminum and ϵ = 0.8 for weathered copper.

d = outside diameter of tubing (inches)

T_c = conductor temperature (°K) = °C + 273°

T_a = ambient temperature (°K) = °C + 273°

<u>Solar Heat Gain (q_s)</u>

The amount of solar heat gained is a function of: (1) the total solar and sky radiation; (2) the coefficient of solar absorption for the conductor surface; (3) the projected area of the conductor; (4) the altitude of the conductor and (5) the orientation of the conductor with respect to the sun's rays.

For rigid tubing bus conductors, the solar heat gain is determined by:

$$q_s = 0.00695\ \epsilon'\ Q_s\ A'K\ (\sin\phi)\ \text{(watts/ft)}$$

where ϵ'=coefficient of solar absorption, usually somewhat higher than emittance, but generally taken as equal to that used for radiation loss (ϵ = 0.5 for weather aluminum and ϵ = 0.8 for weathered copper).

Q_s = total solar sky radiated heat on a surface normal to sun's rays, (watts/sq. ft.), based on the altitude of the sun. From Table III (Appendix A) the average altitude of the sun for New York State is 65° (summer) and 22° (winter). From Table 1(reference 1), this corresponds to 94 watts/sq. ft.(summer) and 67 watts/sq. ft. (winter).

A'= projected area of conductor (square inches per foot), based on area casting shadow.

K = heat multiplying factor for high altitude.

Elevation above Sea Level (ft)	K

0	1.0
5,000	1.15
10,000	1.25
15,000	1.30

ϕ = effective angle of incidence of sun
= $\cos^{-1} [\cos H_c \cos (Z_c - Z_i)]$
where
H_c = altitude of sun (degrees)
Z_c = azimuth of sun (degrees)
Z_i = azimuth of conductor line (degrees)

0 or 180 for N-S
90 or 270 for E-W

From Table III (Appendix A)

	Summer	Winter
H_c	65°	22°
Z_c	149°	166°

Direct Current Resistance (R)

The direct current resistance (R) of a conductor may be obtained from published data or calculated as follows:

For copper and copper alloys

$$R = \frac{8.145x10^{-4}}{C^{/}A_2}\left[1 + \frac{0.00393C^{/}}{100}(T_2 - 20)\right]$$

For aluminum alloys

$$R = \frac{8.145x10^{-4}}{C^{/}A_2}\left[1 + \frac{0.00403C^{/}}{61}(T_2 - 20)\right]$$

Where C' = conductivity as % IACS
A_2 = cross-sectional area (square inches)
T_2 = conductor temperature (°C)

Skin Effect Coefficient for 60 Hz. Current (F)

Skin effect coefficients are a function of resistance, frequency and geometry. The factors are readily available for simple shapes from published data such as Alcoa Bus Conductor Handbook.

Bus Conductor Temperature Limits

Bus conductor temperature limits are shown on page 86 for aluminum, ACSR and copper conductors.

Sample calculations of rigid bus conductor ampacity.

I. Determination of summer "normal operating condition" conductor loading amperes for 3-1/2" aluminum tubing, 6063-T6, Schedule 40, 35°C ambient and 85°C conductor temperature. Bus orientated east-west.

% IACS = 53%
O.D. = 4"
Wall thickness = 0.226"
Area = 2.6795 in^2
$\epsilon = 0.5$

A. Conductive heat loss (q_c)

$q_c = 0.377\ \Delta t\ d^{0.6}$
$\Delta t = 85° - 35° = 50°$
$d = 4.0$
$q_c = 0.377\ (50)\ (4.0)^{0.6} = 43.31$ watts/ft.

B. Radiation heat loss (q_r)

$q_r = 1390\ \epsilon d\ (Tc^4 - Ta^4) \times 10^{-12}$
$\epsilon = 0.5$
d = 4.0"
$T_c = 85 + 273 = 358°K$
$T_a = 35 + 273 = 308°K$
$q_r = 1390\ (.5)\ (4)\ [(358)^4 - (308)^4] \times 10^{-12} = 20.65$ watts/ft.

C. Solar heat gain (q_s)

$q_s = 0.00695 \epsilon\ Q_s\ A'\ K\ (\mathrm{Sin}\ \phi)$

$\epsilon = 0.5$
$Q_s = 94$ watts/ft^2
A = 4" x 12" = 48 inch^2
K = 1.0
$\phi = Cos^{-1}$ [Cos H_c Cos (Z_c-Z_i)]
= Cos^{-1} [Cos 65° Cos (145 - 90)] = 77.4°
qs = 0.00695 (0.5) (94) (48) (1.0) (Sin 77.4 °) = 15.30 watts/ft.

D. Direct current resistance at 85°C

$$R = \frac{8.145x10^{-4}}{C^{/}A_2}\left[1 + \frac{0.00403C^{/}}{61}(T_c - 20)\right]$$

C' = 53
A_2 = 2.6795 inch^2
T_c = 85

$$R = \frac{8.145x10^{-4}}{(53)(2.6795)}\left[1 + \frac{0.00403(53)}{61}(85 - 20)\right]$$

= 7.06 x 10^{-6} ohms/ft.

E. Skin effect coefficient F based on Alcoa Handbook, Figure 34

determine (1)

$$\frac{wall - thickness}{dia.} = \frac{0.226}{4.0} = 0.06$$

(2)

$$\sqrt{\left[\frac{f}{R_{dc}}\right]}$$

f = 60 Hz.
R_{dc} = ohms per 1000 ft = R x 10^3

$$\sqrt{\left[\frac{60}{7.04x10^{-6}x10^3}\right]} = 92$$

(3) From figure 34, F = 1.0

F. Calculated ampacity of tubing

$$I = \sqrt{\left[\frac{q_c + q_r - q_s}{RF}\right]} = \sqrt{\left[\frac{43.31 + 20.65 - 15.30}{7.04x10^{-6}x1.0}\right]} = 2632 amperes$$

II. Determination of summer "LTE Operating Condition" conductor ampere loading where conductor temperature = 95°C

A. q_c = 51.96 watts/ft.

B. q_r = 25.97 watts/ft.

C. q_s = 15.30 watts.ft.

D. R = 7.24 x 10^{-6} ohms/ft.

E. F = 1.0

F. I = 2942 amperes

III. Determination of summer "STE Operating Condition" conductor ampere loading where conductor temperature limit = 105°C. Ampacity calculation based on methodology for calculation of short-time rating described in appendix A.

Initial Conductor Temperature = 85°C
Maximum Conductor Temperature = 105°C
Average Conductor Temperature = (85 + 105)/2 = 95°C
Weight of Conductor = 3.151 lb/ft
Specific heat of aluminum = 0.2305
The heat storage capacity per foot of conductor equals:

c = ((4.186)x(453.6)x(0.2305)x(3.151))/60

= 22.99 watt-minutes lb-°C

Calculation for q_c and q_r using rigid bus factors

$q_c = 0.377\ (95 - 35)\ (4.0)^{0.6} = 51.97$ watts/ft.
$q_r = 1390\ (.5)\ (4)\ [(368)^4 - (308)^4] \times 10^{-12} = 25.97$ watts/ft.

I_{ste} calculations by Appendix A methods give:

Using the IEEE Std. computer program, I_{ste} = 4664 Amperes

Using the manual calculation formula,

$$I_{STE} = \sqrt{\frac{1}{7.24x10^{-6}}[\frac{22.99x3.151(105-85)}{15} + 51.96 + 25.97 - 15.30]}$$

$$I_{STE} = \sqrt{\frac{159.22}{7.24x10^{-6}}} = 4690 Amperes$$

NYPP 1995 Tie-Line Rating Task Force

Appendix C

Current Developments for Predicting Xformer Ldg. Capability

CURRENT DEVELOPMENTS FOR PREDICTING TRANSFORMER LOADING CAPABILITY

by

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for
1993 Minnesota Power Systems Conference
University of Minnesota
St. Paul, Minnesota

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CURRENT DEVELOPMENTS FOR PREDICTING TRANSFORMER LOADING CAPABILITY

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ABSTRACT

Recent investigations have shown that the transformer loading guide equations do not accurately reflect the fluid flow and heat transfer phenomena during transient loading. During overloads there is a time lag between the top oil temperature rise in the tank and the oil temperature rise in the winding cooling ducts. This results in winding hottest spot temperatures higher than predicted by the present loading guide equations for naturally cooled (OA and FA) transformers. The inaccurate simplifying assumptions used to derive the present loading guide equations are reviewed. Improved loading equations were developed for inclusion in a revision of the loading guide. These improved equations predict more loading capability for non-directed FOA units and less loading capability for FA rated units during high short time overloads in agreement with recent test data. Research with fiber optic hot spot detectors gives valuable information about transformer loading but reliability should be improved.

INTRODUCTION

In the decade of the 1990's the technology focus in the transformer industry is on thermal performance and loadability. Many transformers undergo planned overloading by utilities to maximize the return on the investment in this expensive equipment. As reported recently by W. J. McNutt [1], "...all loadability decisions are based on hottest conductor temperature, but that parameter is never measured during a thermal test, and some manufacturers never actually calculate what it would be for rated loading. ..The thermal equations provided in the loading guide are recognized to be grossly inaccurate for some cooling modes and not precisely correct for others."

There are currently three [2,3,4] loading guides for oil immersed transformers. All three guides contain identical equations for predicting the top oil and hot spot temperatures during overloading. These equations are identical to the loading guide equations first proposed in 1945 [5] and documented in technical papers from 1925 to 1947. Since 1945 additional values of exponents for forced air and forced oil cooling were added. An IEEE test procedure [6] is under development to describe test methods to obtain data for the exponents and time constants to use in the loading equations for specific transformer designs. The distribution transformer loading guide [3] suggests a correction for resistance change with temperature which was first proposed in 1962. At the time the equations were first developed there was almost no test data of actual hot spot temperatures during overload conditions. These equations are based on interpolation of steady state predictions from the era of the slide rule. The equations have been in existence for so long that many have forgotten the simplifying assumptions upon which the equations were based.

The transformer is illustrated in Figure one. The dielectric cooling fluid is cooled by the radiator assembly and flows into the bottom of the winding cooling ducts at the bottom oil temperature. The fluid flows vertically up the winding ducts, is heated by the winding, and exits the winding ducts at the top winding duct oil temperature. The fluid enters the radiators (or heat exchanger) at the top oil temperature in the main tank. The four modes of cooling used in liquid filled transformers are; natural convection of oil in the transformer and natural convection of cooling air over the radiator (OA), natural convection of oil with forced convection of air over the radiator (FA), directed forced oil flow and forced air flow (DFOA), and non-directed forced oil flow and forced air flow (NDFOA). For directed flow forced oil (DFOA), the oil from the radiator or heat exchanger is forced to flow at high velocity into the winding by piping (not shown) from the heat exchanger exit to the bottom of the winding. Several high flow pumps are required due to the flow resistance of the piping and winding ducts.

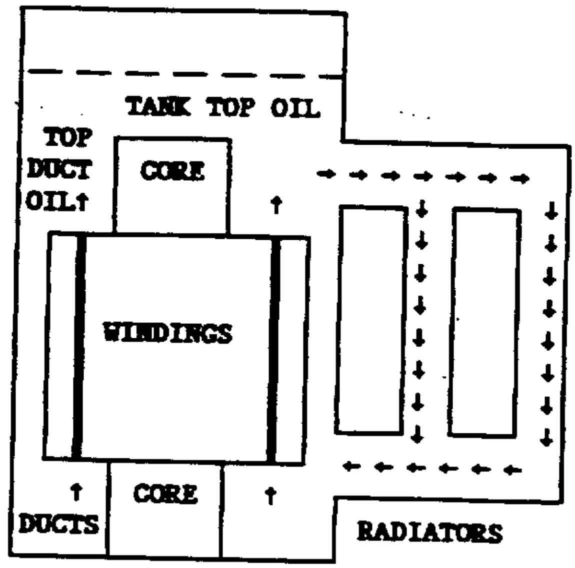

Figure 1. Transformer Fluid Flow

The IEEE Loading Guide [2] equations are based on the assumption that the temperature of the oil exiting the winding ducts is the same temperature as the top oil in the tank. The hottest spot temperature is assumed to consist of three components given by the following equation:

$$T_{HS} = T_A + \Theta_{TO} + \Delta T_g \,.$$

Where

- T_{HS} hottest spot winding temperature, °C
- T_A ambient temperature, °C
- Θ_{TO} top oil rise over ambient temperature, °C
- ΔT_g hottest spot conductor rise over top oil temperature, °C.

The variation of the top oil temperature from initial steady state conditions to final steady state conditions is given by the following exponential expression containing an oil time constant.

$$\Theta_{TO} = (\Theta_u - \Theta_i)\left(1 - \exp^{\frac{-t}{\tau_o}}\right) + \Theta_i$$

Where

Θ_u ultimate oil rise if overload continued to steady state, °C
Θ_i initial oil rise at start of overload, °C
t time, hours
τ_o oil time constant, hours.

The above equation is a simple solution of the differential equation from the conservation of energy, that is, during a change in load the heat generated equals the heat stored and the heat lost. This simple case was given by Cooney [7] in 1925. In the simplifying assumptions it was assumed that the temperature rise Θ is directly proportional to the heat loss W, or in equation form,

$$\Theta = k\ W^n\ with\ n = 1$$

If the exponent n = 1.0, the above exponential equation is correct for any load and any starting temperature. If n is less than 1 the equation is incorrect and the time constant must be modified for different overload cycles as shown below:

$$\tau_o = \tau_r \frac{\left(\frac{\Theta_u}{\Theta_{fl}}\right) - \left(\frac{\Theta_i}{\Theta_{fl}}\right)}{\left(\frac{\Theta_u}{\Theta_{fl}}\right)^{\frac{1}{n}} - \left(\frac{\Theta_i}{\Theta_{fl}}\right)^{\frac{1}{n}}}$$

Where

τ_r time constant for cold start up at rated load, hours
Θ_{fl} top oil rise at rated load, °C.

The derivation of the time constant correction is given in a 1947 paper by Narbutovskih [8] who claimed he suggested the correction to the AIEE Transformers Subcommittee for inclusion in the first guide proposed in 1945. A very similar equation for n=.8 was given in a 1934 paper by Nichols [9]. Narbutovskih developed the correction to the time constant to make the initial rate of temperature change equal to the actual and the final temperature rise equal to the actual. However, the intermediate values of the temperature rise were allowed to deviate from the actual! In making overload calculations the ultimate or final rise is calculated and substituted into the exponential heating equation to calculate the intermediate values. The ultimate value is never reached and the intermediate values are the most important since these are the values that determine when limiting top oil and hot spot temperatures are reached.

The time constant at rated kVA is given by:

$$\tau_r = \frac{C\,\Theta_{fl}}{P_{fl}}$$

Where

C	thermal capacity, watt-hours/°C
P_{fl}	total loss at rated load, watts

The thermal capacity is given by the following equation for non-directed flow transformers:

$$C = 0.06\,(\text{weight of core and coil assembly in pounds}) + 0.04\,(\text{weight of tank and fittings in pounds}) + 1.33\,(\text{gallons of oil})$$

If the actual specific heats and mass of oil and steel are used to calculate the thermal capacity a discrepancy is noted in the above equation. The origin of the above equation is the paper by Cooney from 1925. The derivation of the exponential heating equation for a lumped mass is based on the average temperature rise of the lumped mass. In the case of the transformer this would be the average oil temperature. However the top oil is the variable measured by temperature indicators or thermocouples during thermal tests. Cooney stated that the ratio of average oil rise to top oil rise varied from 75 per cent to 95 percent. In the thermal capacitance equation Cooney used 2/3 's of the weight of the tank and 86 per cent of the specific heat of the oil.

In later editions of the loading guide the thermal capacitance equation for directed forced oil transformers was given as:

$$C = 0.06\,(\text{weight of core and coil assembly in pounds}) + 0.06\,(\text{weight of tank and fittings in pounds}) + 1.93\,(\text{gallons of oil})$$

In this equation the thermal capacities agree with the actual values since for forced oil transformers the top oil and average oil rises are very close. The 1972 and 1991 IEC loading guides [10,11] give an exponential heating equation but no equations for calculating the time constant.

The guide contains the following equation for determining the ultimate oil rise,

$$\Theta_U = \Theta_{fl}\left[\frac{K^2R + 1\,)}{(R + 1\,)}\right]^n$$

Where

K	ratio of overload to rated load
R	ratio of load loss at rated load to no-load loss.

The equation is an approximation of the variation of losses with load but does not correct the losses for increased resistance due to temperature. A review of the early papers indicates that the authors realized that the oil rise varied with losses to the .8 exponent for self cooled transformers and not with per unit load squared.

In the loading guide the hot spot rise over top oil is given by,

$$\Theta_g = \Theta_g(fl)\ K^{2m}$$

Where

Θ_g hot spot rise over top oil at per unit load K, °C
$\Theta_g(fl)$ hot spot rise over top oil at rated load, °C.

At the time (1945) the equation was first proposed for the loading guide, no thermocouples had been inserted into full size windings and transient data taken. The Montsinger and Ketchum 1942 paper [12] contains data apparently from a small model coil which was first reported by Cooney in 1925. Vogel and Narbutoviskih [13] also reported hot spot data but these were for "model coils". These tests on model coils failed to discover that in full size windings or transformers the oil temperature in the winding cooling ducts exceeds the top oil temperature in the main tank during overloads. Montsinger and Ketchum investigated resistance change and viscosity effects on the hot spot temperature. For an overload condition they reported calculations of 60.4 °C without a correction and 67.5 °C with resistance and viscosity corrections. They concluded, "But, since in making overload calculations the bases of the assumptions are approximations, it should be satisfactory to neglect the corrections."

In evaluating overloads the loading guide assumes a two step approximation of the load cycle. The load is assumed to consist of a prior load plus an overload. The values of the prior load and overload are determined by the RMS average of the load. This requires some judgement whether to include part of the cycle as part of the prior load or the overload. In computer implementation of the load cycle the load profile is assumed to consist of step load cycles of one hour duration and the exponential approximation equation used to compute the top oil temperature. The RMS method described in the loading guide is difficult to apply for actual load cycles used by utilities for planned overloading.

The loading guide assumes a constant ambient temperature and gives no provisions for evaluating the effect of changing ambient temperatures during a load cycle.

MODERN DEVELOPMENTS

Since the loading guide equations were first proposed in 1945 many papers and trade press articles have been written on transformer loading using these equations. It is generally stated that the equations are conservative without giving test data to substantiate this statement. The equations have been incorporated into computer programs by consultants and utilities. Until recently little research had been performed on measurements of hot spots in windings of full size transformers during transient loading.

Thermal research has centered on computer modeling of steady state performance with tests on model windings to obtain data to validate the models. The purpose of these studies was to more accurately predict thermal performance at nameplate ratings to minimize the manufacturer's cost.

Investigations to determine the hot spot temperature at nameplate rating using a factory heat run test to rate transformers by hot spot were conducted in the 1970's. These investigations were initiated by the proposal of the "multiflow" principal of E. T. Norris [14,15,16]. Norris proposed that transformers be rated by hot spot temperature and that the winding hot spot temperature could be determined from factory heat run tests by measurements of the oil temperature in the cooling ducts of individual windings. Lampe, Persson, and Carlsson [17] in 1972 proposed an equation for calculation of hot spot temperature based on tested average winding, top oil temperature rise in the windings, and bottom oil temperatures. Attempts to measure the oil temperature in the cooling ducts is difficult. Gogot [18] reported that the oil temperatures at the top of the cooling channels differed by 10 to 15 °C from each other in the same transformer.

Hot Spot Investigations - Full Size Windings

A comprehensive test program was run on a full size winding assembly with imbedded thermocouples and the results reported in a recent paper by the author [22]. The tests indicated that the industry loading guides were not valid for all modes of cooling and all loading conditions. During overloads there is a time lag between the top oil temperature rise in the tank and the oil rise in the winding cooling ducts. The tests indicated that the duct oil temperature rises rapidly at a time constant equal to the winding. For non-directed FOA units the oil temperature in the cooling ducts is always higher than the top oil temperature in the main tank. This results in winding hottest spot temperatures higher than predicted by the loading guide for the naturally cooled (OA and FA) transformers and less than predicted by the loading guide for non-directed FOA cooled transformers. Similar results were reported by Aubin and Langhame [21] who also investigated viscosity effects. Two other papers investigated temperatures during cold start performance by Lampe [19] and Northrup and Thompson [20]. Curves were presented in the papers showing that the oil temperatures in the cooling ducts increased considerable over the top oil temperature in the main tank. These recent investigations indicate that the loading guide equations should be revised to more accurately predict winding hottest spot temperatures for high short term overload conditions.

The author's test results for the full size winding are shown in the figures on the next page two pages. Figures 2A shows the load profile for an overload test for the FA cooling mode and figure 2B shows the increase in hot spot temperature rise compared with the loading guide equation prediction. The increase in hot spot rise was significantly higher than predicted by the ANSI/IEEE loading guide. Figure 3A shows the overload profile for a test of the non directed FOA cooling mode and figure 3B shows the increase in hot spot rise compared with the ANSI/IEEE loading guide equation. For the non-directed FOA cooling mode the tested hot spot rise was about 10 degrees less than predicted by the loading guide. Due to a lower top oil rise the overload could be sustained for 4 hours compared with 2 hours for the FA cooling mode.

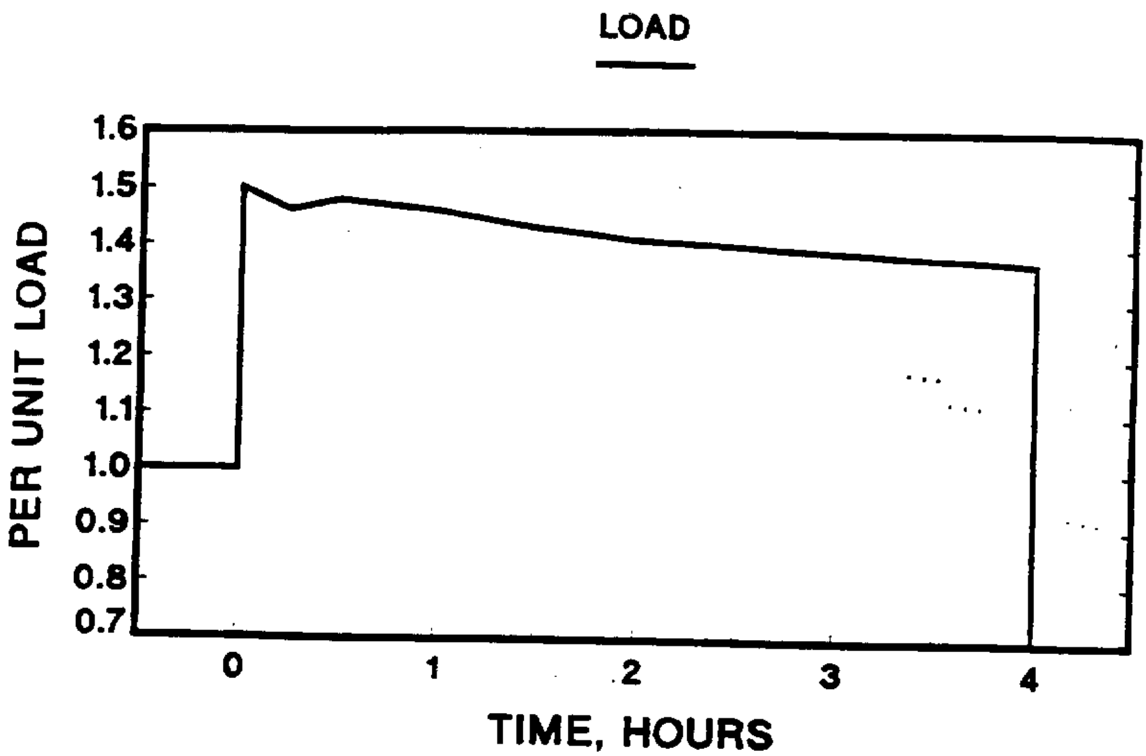

Figure 3A. Load Profile for Non-Directed FOA Overload Test

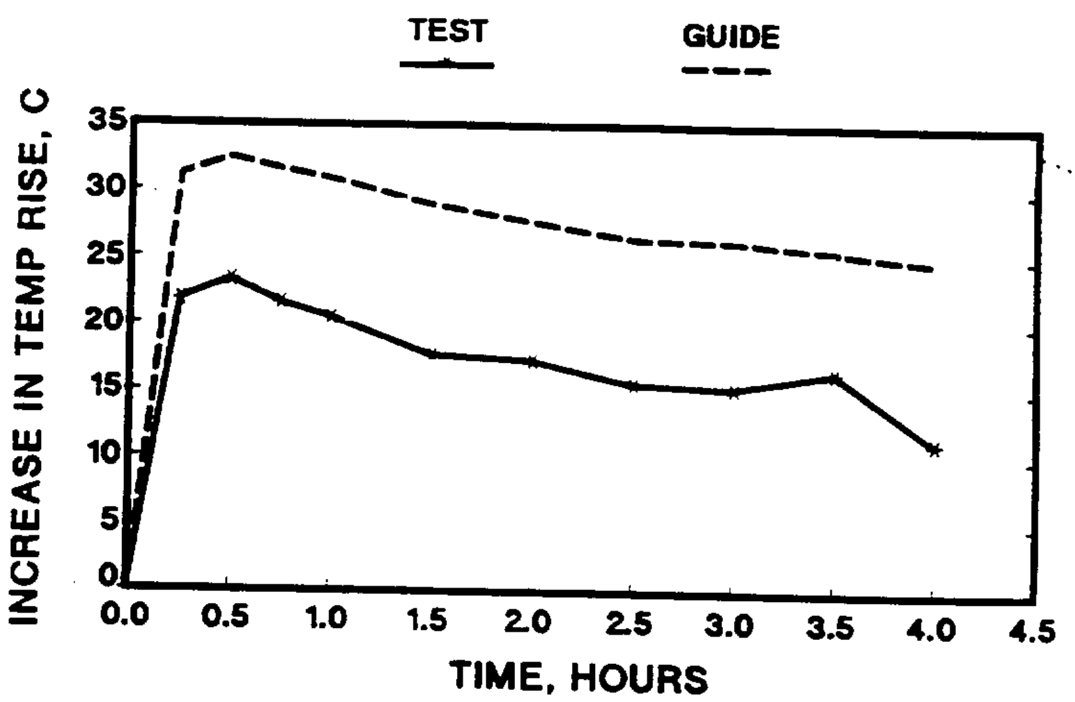

Figure 3B. Increase in Hot Spot Rise Over Top Oil

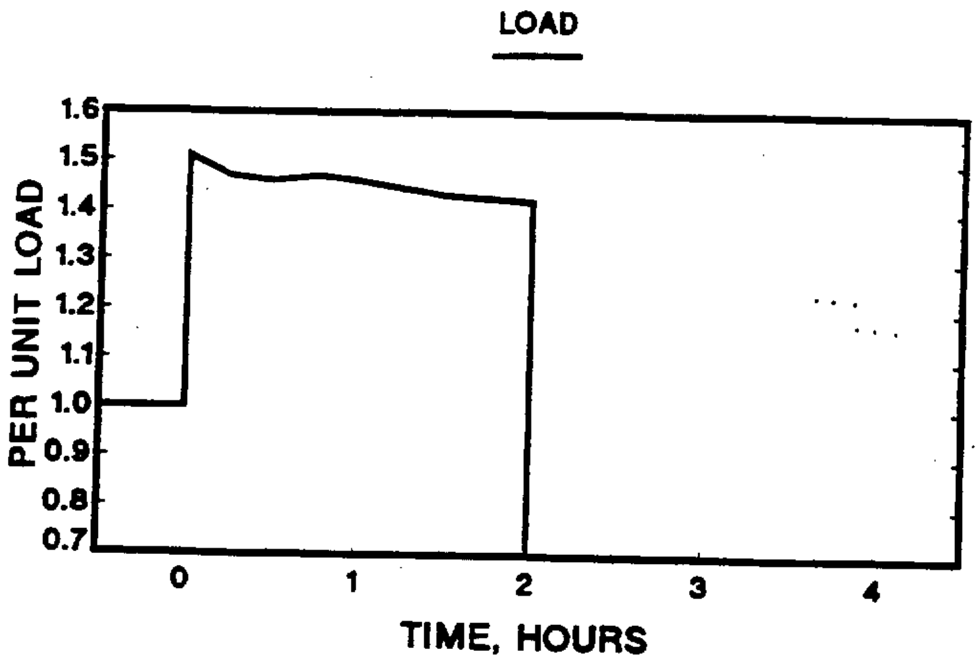

Figure 2A. Load Profile for FA Overload Test

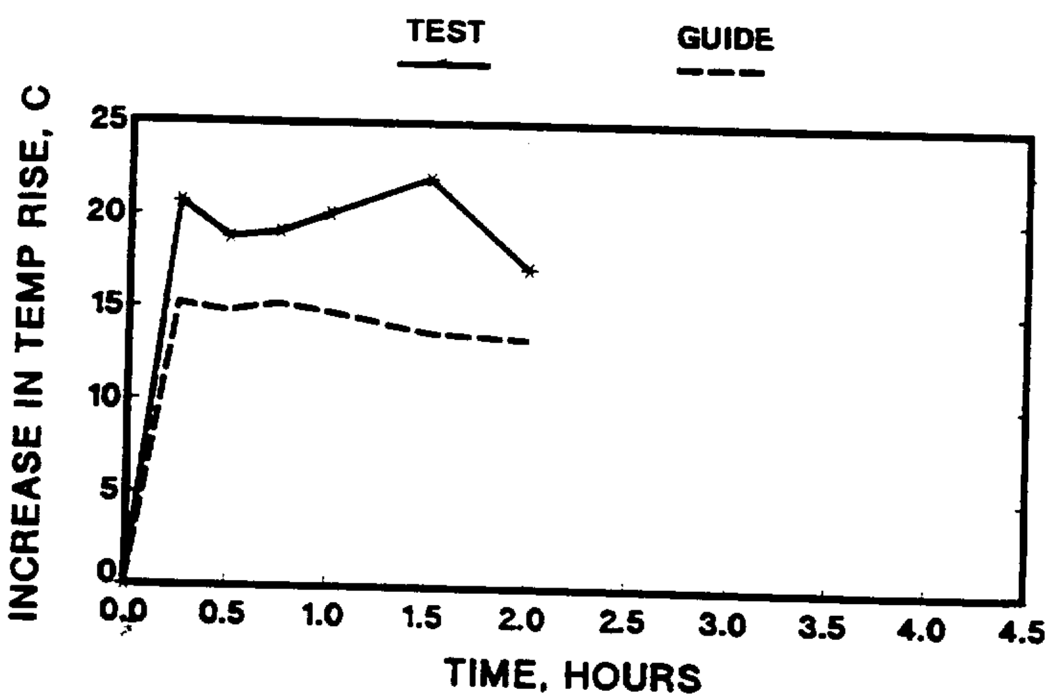

Figure 2B. Increase in Hot Spot Rise Over Top Oil

Top Oil Rise Comparison, FA vs. NDFOA

The loading tables based on assumed transformer characteristics in the 1981 guide [2] assumed identical 45 °C top oil rises for OA/FA/FA and OA/FA/FOA transformers and assumed a lower top oil rise exponent for FA rated units.The guide tables using these characteristics predicts slightly better performance for FA rated units than NDFOA rated units due to the slightly lower oil exponent and identical top oil rises.

The author recently performed comparative thermal tests of three different production units in the thermal test facility of the author's company. A thermal test at the non-directed forced oil (NDFOA) rating was first performed with oil rises and average winding rises measured. The pump was shut off and the test repeated with the same number of fans until temperatures stabilized. Average winding rises were similar however the top oil rises for the NDFOA cooling mode were about 10 °C less for the NDFOA cooling mode. The results are summarized in the table below:

	MAX	TOP OIL RISE, °C		
UNIT	MVA	FA	FOA	DIF.
1	25	54.5	43.7	-10.5
2	25	61.7	54.4	- 7.3
3	52.3	60.8	45.3	-15.5

A survey of transformer test reports from several manufactures indicated an average of 10 °C less top oil rise with non-directed FOA. Typical values of top oil rise are 55 °C for an FA rated unit and 45 °C for a ND FOA unit. Any unit cooled by FA only will have a lower top oil rise when a low flow pump is added. Analysis of test data indicates a top oil exponent of .9 is valid for both FA and NDFOA units rated at more than 1.33 % above the self cooled rating. Since the industry loading guide places a limit of 110 °C on the top oil during overload, a NDFOA unit can sustain more overload or sustain an overload longer than a FA rated unit before the top oil temperature limit is reached.

Improved Loading Equations

Modern computer technology now permits more refined calculations of loading capability. An improved system of equations was developed by the author [23] for inclusion in the next loading guide [24]. The improved system of loading equations is based on the fluid flow conditions occurring in the transformer during transient conditions. The equations and computer program also incorporated an improved method of calculation for variable load cycles and variable ambient temperatures. The properties of the low flammability fluids polydimethylsiloxane (silicone) and high temperature hydrocarbon (hthc) were also incorporated into the improved loading equations.

The hottest spot temperature is made up of the following components:

$$T_{HS} = T_A + \Theta_{BO} + \Delta T_{WO} + \Delta T_{HSWO}$$

Where

Θ_{BO} bottom oil temperature rise over ambient, °C
ΔT_{WO} oil rise at winding hottest spot location over bottom oil, °C
ΔT_{HSWO} winding hottest spot rise over winding duct oil at hottest spot location, °C.

For overload conditions the oil temperature rise at the hottest spot location ΔT_{WO} is the temperature rise of the oil in the winding cooling ducts above the bottom oil temperature. When the load is reduced the winding duct oil temperature falls but a portion of the upper winding may still remain in the hotter top oil of the main tank. When the winding duct oil temperature is less than the top oil in the main tank, ΔT_{WO} is assumed to equal the tank top oil rise over the bottom oil.

The temperature rises are obtained from an equation for the conservation of energy during a small instant of time Δt. The system of equations constitute a transient forward marching finite difference calculation procedure. The equations were formulated so that temperatures obtained from the calculation at the prior time t_i are used to compute the temperatures at the next instant of time $t_i + \Delta t$ or t_k. The time is incremented again by Δt and the last calculated temperatures are used to calculate the temperatures for the next time step. At each time step the losses were calculated for the load and corrected for the resistance change with temperature. With this approach the required accuracy is achieved by using a small time increment Δt of 0.5 minutes. The programming approach was very simple, no iteration was required, and the PC BASIC language program very short.

Oil viscosity changes and loss variation with temperature are not accounted for in the present loading guides. The guide suggests that the two effects are offsetting however an IEEE progress report [25] states that this may not be true for all transient conditions. Some utility computer loading programs consider the loss variation with temperature but use the same exponent given the loadings guides. With the computer model resistance and viscosity effects were easily incorporated into the system of equations.

The revised loading equations confirmed that non-directed FOA transformers can sustain higher overloads or longer duration overloads than FA rated transformers in agreement with the test data.

FIBER OPTIC HOT SPOT DETECTORS

In the 1980's direct measurement of winding hot spot using fiber optic detectors became feasible and data presented by Lampe [26] taken during heat run testing gave conflicting results about the validity of the multiflow principal and the IEC hot spot equation. Lampe reported that measured hot spot temperatures often deviate from calculated ones according to IEC and the multiflow method with considerable differences between IEC and the multiflow method. Nordman, Hiironniemi, and Pesonen, [27] however concluded that hot spot temperature rises can be determined with reasonable accuracy by indirect methods based on the multiflow principle at a normal heat run.

In the 1990's thermal research is moving into studies of overload performance using measurements of hot spot temperature with fiber optic detectors. Poittevin et. al. [28], reported overload data on a 100 MVA transformer at 1.15 per unit and at 1.5 per unit for 15 minutes and reported, "It has been noticed that a simple model with two time constants compiled from 1.15 per unit test, is not able to simulate the measured temperature during 1.5 per unit test. This difficulty probably comes from the impossibility to consider the oil temperature evolution as a simple exponential law for thermal phenomena, the duration of which is in the same order than the copper time constant". A further study should permit to provide a thermal model able to simulate the transformer behavior for short overload duration". A CIGRE paper by Cosaert [29] relating to thermal issues and fiber optic detectors was presented at the most recent 1992 session. Testing was still in progress at the time of presentation however a preliminary conclusion was that the classic thermal model with only one fixed time constant does not reflect the dynamic behavior of the transformer correctly.

Due to the high cost of the fiber optic devices and poor reliability of the fiber optic devices their use appears to be primarily as a research tool to measure hot spot during factory thermal tests on transformers and for use on selected units to obtain dynamic loading data under actual field conditions. Due to the poor reliability, redundant probes must be used. Experience such as that reported in a recent Doble paper by Troisi [30] indicates that even with extreme care in installation about 25 to 33 percent of the probes can be expected to fail due to damage. Reported data and the author's experience indicates that the location of the hot spot is difficult to determine. A recent CIGRE [31] survey reported that two to eight sensors would be adequate if placed in the winding where the higher temperature is expected but for prototype transformers it was estimated that twenty to thirty sensors would be required".

INSULATION AGEING STUDIES

Accurate hot spot temperature predictions are required to predict insulation life. The subject of insulation ageing comprises a separate subject beyond the scope of this paper. The recent paper by McNutt [32] gives a new insulation ageing equation for mineral oil immersed transformers with background data. This equation will be incorporated into a revised loading guide and this paper is suggested for review.

CONCLUSIONS

The current loading guide equations, based on simplifying assumptions from the slide rule era, do not accurately predict transformer thermal performance under planned or emergency overloads. Modern computer technology now permits more accurate temperature predictions by using equations which more accurately reflect the fluid flow and heat transfer phenomena during transient conditions. These equations consider the effect of different cooling modes and predict more loading capability for non-directed FOA units and less loading capability for FA rated units when compared with the current inaccurate loading guide equations. Fiber optic hot spot detectors are an important research tool to confirm hot spot temperatures in transformers and obtain data during transient loading. Extensive use of these devices will not occur until the cost is reduced and reliability improved.

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[31] Working Group 09 of Study Committee 12, "Direct Measurement of Hot-Spot Temperature of Transformers", *CIGRE Electra* No. 129, March 1990, pp. 48-51.

[32] W. J. McNutt, "Insulation Thermal Life Considerations for Transformer Loading Guides," *IEEE Transactions on Power Delivery*, Vol. 7, No. 1, January 1992, pp 392-401.

NYPP 1995 Tie-Line Rating Task Force

Appendix

D

Sample Calculation
of
Thermal Ratings
for
Selected
Transformers

APPENDIX D

The two previous Task Forces provided 'Rating Factors' for power transformers. Since 1982 continued research has increased the knowledge of thermal dynamics of the power transformers including moisture bubble formation above 140°C. As a result the Task Force believes that because of the complexity of the thermal dynamics, there is a risk of misapplication of generalized transformer rating factors. In lieu of these factors, each transformer should be rated based upon specific test data and physical characteristics.

Assumptions & Criteria

Oil temperatures assumed when calculating transformer ratings are the most critical criteria. They impact the 'loss of life' in the insulation which ultimately determines the useful life of the transformer. The proposed standard is recommending a normal insulation life expectancy of 180,000 hours (7500 days) or approximately twenty years. At first glance it does not seem realistic that a transformer would be designed to last this relatively short period of time when many systems have transformers older than 40 or 50 years. The principle reasons for this, as is explained below are the ambient and transformer temperatures used to establish the insulation life. They are far from the actual loading and temperature conditions experienced during daily operation. To begin with, the 180,000 hours of insulation life in a transformer assumes the transformer is loaded to its nameplate continuously with an average ambient of 30°C and maximum temperature of 40°C for this period. Normal life expectancy will result from operating with a continuous 'hottest spot conductor temperature' of 110°C (hottest spot rise of 80°C + average 30°C ambient)for 65°C transformers and 95°C (hottest spot rise of 65°C + average 30°C ambient) for 55°C transformers. Given these assumptions, to calculate percent loss of life for any hottest spot conductor temperature values over a twenty four hour period the proposed standard uses an 'Aging Acceleration Factor', F_{AA}. The formula for a 65°C transformer F_{AA} is

$$F_{AA}=EXP^{\left[\frac{15000}{383}-\frac{15000}{T_{HS}+273}\right]}$$

The formula for 55^{o}C transformer insulation is the same with the exception of changing 383 (273 + 110) to 368 (273 +95) in the denominator of the first term of the exponent. A value is then calculated for each time interval, usually a twenty four hour load cycle, then averaged. This equivalent aging factor F_{EQA} is then used to calculate the percent loss of life as shown below:

$$\% \, Loss \; of \; Life = \frac{F_{EQA} x \, 24 x \, 100}{Normal \; Insulation \; Life}$$

In the case of normal life expectancy the F_{EQA} value is one. The recommended percent loss of life for emergency overload of a transformer is .25% per occurrence. One additional assumption needed to calculate a transformer rating is 'Hot Spot Conductor Temperature Rise over Top Oil', the value used herein is 15^{o}C. The following table summarizes the assumptions used in rating the transformers:

Average Winding Temperature (AWR)	Normal Rating			LTE Rating		
	Hottest Spot	Top Oil	Loss/Life	Hottest Spot	Top Oil	Loss/Life
55^{o}C	105^{o}C$^{(1)}$	95^{o}C	.0133%$^{(2)}$	140^{o}C	100^{o}C	.25%$^{(2)}$
65^{o}C	120^{o}C$^{(3)}$	105^{o}C	.0133%	140^{o}C	110^{o}C	.25%

(1) 65^{o}C(winding hot spot rise over ambient) + 40^{o}C(peak ambient)
(2) Based upon an insulation life of 180,000 hours
(3) 80^{o}C(winding hot spot rise over ambient + 40^{o}C(peak ambient)

The increased availability of the PC as an engineering tool makes calculating transformer ratings easier than it was in past years. The sample of transformer ratings contained in this appendix were obtained using the EPRI's 'PTLOAD' program. There are many similar transformer rating programs, including one in the proposed new transformer standard. The program allows the calculation of normal and emergency rating based upon a three variable criteria consisting of Hot Spot Temperature, Top Oil Temperature and Loss-of-Life for the cycle.

Temperature & Load Profile Parametric Analysis

The temperature profiles where selected to conform to NYPP recommendations of an average of 5°C in winter and 30°C in summer. It is not suggested that these are typical profiles, but are used only to calculate ratings on a consistent basis. Each member company should develop their own profiles for determining their particular transformer ratings. The ANSI/IEEE standard's profile

Temperature Profiles

HOUR	SUMMER (NYPP)	SUMMER (ANSI/IEEE)	WINTER (NYPP)
	Temperature Deg. C	Temperature Deg. C	Temperature Deg. C
0	28	22	4
1	28	23	4
2	28	24	3
3	28	25	3
4	28	26	3
5	29	27	2
6	30	28	2
7	31	29	3
8	32	30	4
9	33	31	5
10	35	32	6
11	35	35	6
12	35	36	7
13	35	38	7
14	35	40	9
15	35	40	10
16	35	38	9
17	34	36	9
18	33	34	7
19	32	29	6
20	31	28	5
21	30	25	4
22	29	23	3
23	28	21	3

has the same average summer temperature but has a peak value of 40°C and has no recommended winter temperature profile. Transformer test report data and nameplate information on weight and gallons of oil is also required as input data to calculate transformer. The following table of transformer ratings is presented to give the reader a sense of variation in thermal ratings of transformers for ambient temperature and a constant nameplate load profile. The normal rating is based upon a constant nameplate load for a twenty four period, the emergency ratings are also based upon a preload of nameplate rating. Most computer programs have the flexibility of having a variable load profile, as this one, this approach was taken to be consistent with other rating calculations contained in this report.

Summer & Winter Transformer Normal & LTE Ratings

Based upon EPRI's PTLOAD Program

Transformer ID	Nameplate Data	Insulation CLASS	Summer NORMAL % of Nameplate[1]		Summer LTE % of Nameplate[1]				Winter NORMAL % of Nameplate[1]		Winter LTE % of Nameplate[1]			
			%	Criteria	% 4 hour	Criteria	% 8 hour	Criteria	%	Criteria	% 4 Hour	Criteria	% 8 hour	Criteria
#1	30/40/50 MVA 115/34.5kV	55ºC	115	loss of life[2]	148	Top Oil	142	Top Oil	140	loss of life[2]	181	Top Oil	174	Top Oil
#2	33.4/44.8/56 MVA 115/34.5kV	65ºC	119	loss of life[2]	143	Hot Spot	140	Hot Spot	139	loss of life[2]	161	Hot Spot	159	Hot Spot
#3	200 MVA FOA-T 354/118kV	55ºC	114	loss of life[2]	156	Hot Spot	151	Hot Spot	137	loss of life(2	173	Hot Spot	171	Hot Spot
#4	224 MVA FOA-T 126/69kV	65ºC	114	loss of life[2]	137	Hot Spot	134	Hot Spot	133	loss of life(2	155	Hot Spot	153	Hot Spot

(1) See information in this appendix for specific transformer ID.

(2) Program input adjusted to reflect the proposed standard recommendation.

NYPP 1995 Tie-Line Rating Task Force

APPENDIX
D

Transformer ID
#1

50 MVA, 55°C, FOA

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER n o r m a l RATING CALCULATION
Transformers: Transformer ID #1
Comments: OA/FA/FOA 30/40/50 MVA
Tested 2/21/61

Transformer Operates at Top MVA Cooling Mode for All Conditions

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
3.	50.000	Non-directed Flow FOA, FOW, OA/FA/FOA	0.80	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	6.9	Input
Top Oil Rise Ambient	34.7	Input
Avg Winding Rise Amb.	59.4	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	28.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	129	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of one repeated daily load cycle.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 105 C
- Top Oil Temperature: 95 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #1

SUMMER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	92.8	0.782591	0.782591
2	92.2	0.731605	1.514196
3	91.8	0.699387	2.213583
4	91.6	0.683788	2.897371
5	91.4	0.668521	3.565892
6	91.3	0.66101	4.226902
7	91.6	0.683788	4.910691
8	92.2	0.731605	5.642296
9	92.9	0.791411	6.433707
10	93.8	0.875158	7.308865
11	94.7	0.967291	8.276156
12	96	1.116795	9.392951
13	96.8	1.219454	10.6124
14	97.3	1.288106	11.90051
15	97.6	1.331045	13.23156
16	97.8	1.360422	14.59198
17	98	1.390416	15.98239
18	98	1.390416	17.37281
19	97.7	1.345657	18.71847
20	97.1	1.260216	19.97868
21	96.4	1.167052	21.14573
22	95.6	1.0686	22.21433
23	94.7	0.967291	23.18163
24	93.8	0.875158	24.05678

% Loss - of - Life = 0.013365 %

Normal Loss of Life is .0133%

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

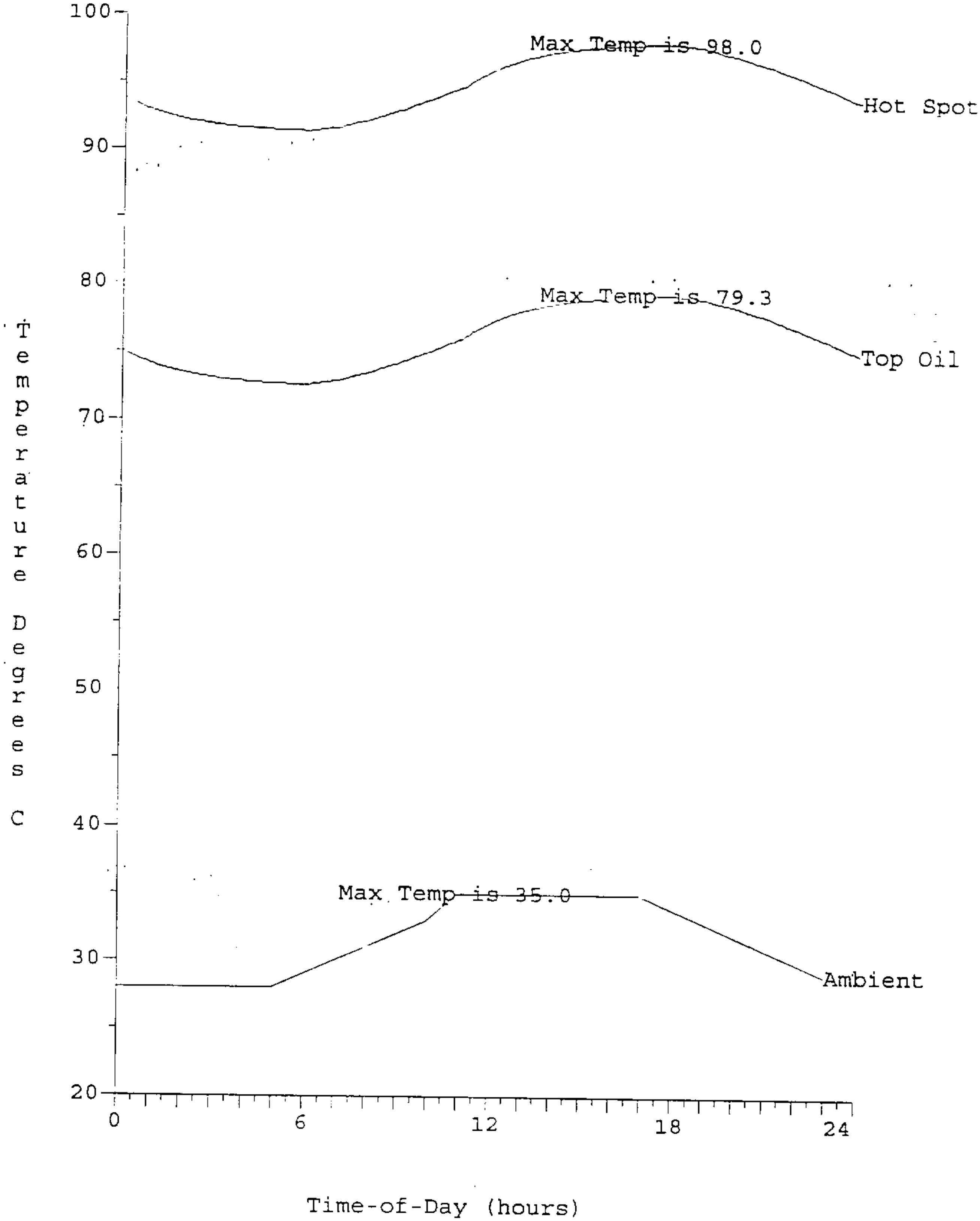
Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	74.1	92.8	0.00124	965	1.149	57.466
2:00	28.0	73.5	92.2	0.00238	965	1.149	57.466
3:00	28.0	73.1	91.8	0.00345	965	1.149	57.466
4:00	28.0	72.8	91.6	0.00449	965	1.149	57.466
5:00	28.0	72.7	91.4	0.00550	965	1.149	57.466
6:00	29.0	72.6	91.3	0.00649	965	1.149	57.466
7:00	30.0	72.9	91.6	0.00751	965	1.149	57.466
8:00	31.0	73.5	92.2	0.00858	965	1.149	57.466
9:00	32.0	74.2	92.9	0.00974	965	1.149	57.466
10:00	33.0	75.0	93.8	0.01101	965	1.149	57.466
11:00	35.0	75.9	94.7	0.01242	965	1.149	57.466
12:00	35.0	77.2	96.0	0.01404	965	1.149	57.466
13:00	35.0	78.1	96.8	0.01586	965	1.149	57.466
14:00	35.0	78.6	97.3	0.01783	965	1.149	57.466
15:00	35.0	78.9	97.6	0.01989	965	1.149	57.466
16:00	35.0	79.1	97.8	0.02201	965	1.149	57.466
17:00	35.0	79.2	98.0	0.02418	965	1.149	57.466
18:00	34.0	79.3	98.0	0.02637	965	1.149	57.466
19:00	33.0	79.0	97.7	0.02852	965	1.149	57.466
20:00	32.0	78.4	97.1	0.03056	965	1.149	57.466
21:00	31.0	77.7	96.4	0.03245	965	1.149	57.466
22:00	30.0	76.8	95.6	0.03417	965	1.149	57.466
23:00	29.0	75.9	94.7	0.03572	965	1.149	57.466
24:00	28.0	75.0	93.8	0.03711	965	1.149	57.466

The results based on this load and temperature cycle are:

- o Maximum Capability: 57.5 MVA.
- o Maximum Current: 965 amps.
- o Maximum Hot-Spot Temperature: 98.0 C at 6:00 pm.
- o Maximum Top Oil Temperature: 79.3 C at 6:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.03711 %.
- o Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

Power Transformer Temperature Profile for <ID1SNOR>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER 1 t e 4 hour pk starting @ 1 PM
Transformers: Transformer ID #1
Comments: OA/FA/FOA 30/40/50 MVA
Tested 2/21/61

Transformer Operates at Top MVA Cooling Mode for All Conditions.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
3.	50.000	Non-directed Flow FOA, FOW, OA/FA/FOA	0.80	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	6.9	Input
Top Oil Rise Ambient	34.7	Input
Avg Winding Rise Amb.	59.4	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	28.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	129	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 20.00 hours, followed by a constant higher load for 4.00 hours. The constant higher load is applied at 1 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #1

SUMMER LTE (4 Hour) RATING ,starting @ 1 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	80.1	0.179064	0.179064
2	79.2	0.160643	0.339707
3	78.6	0.149382	0.489089
4	78.3	0.144038	0.633127
5	78.1	0.140577	0.773704
6	77.9	0.137195	0.910899
7	78.2	0.142297	1.053196
8	78.8	0.15305	1.206246
9	79.5	0.166573	1.372819
10	80.3	0.183422	1.556241
11	81.2	0.204316	1.760557
12	82.5	0.238539	1.999096
13	83.3	0.262243	2.261339
14	110.4	5.140955	7.402294
15	119.1	12.24751	19.6498
16	124.6	20.79082	40.44062
17	128.1	28.89625	69.33687
18	103.7	2.563528	71.9004
19	96.3	1.15429	73.05469
20	91.2	0.653579	73.70826
21	87.7	0.438263	74.14653
22	85.1	0.324046	74.47057
23	83.1	0.256115	74.72669
24	81.5	0.211771	74.93846

% Loss - of - Life = 0.041632 %

Emergency operation criteria Loss of Life is .25% per occcurence

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures (Deg C) > Ambient	Top Oil	Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	65.1	80.1	0.00026	840	1.000	50.000
2:00	28.0	64.2	79.2	0.00049	840	1.000	50.000
3:00	28.0	63.6	78.6	0.00070	840	1.000	50.000
4:00	28.0	63.3	78.3	0.00090	840	1.000	50.000
5:00	28.0	63.1	78.1	0.00109	840	1.000	50.000
6:00	29.0	62.9	77.9	0.00127	840	1.000	50.000
7:00	30.0	63.2	78.2	0.00146	840	1.000	50.000
8:00	31.0	63.8	78.8	0.00166	840	1.000	50.000
9:00	32.0	64.5	79.5	0.00188	840	1.000	50.000
10:00	33.0	65.3	80.3	0.00211	840	1.000	50.000
11:00	35.0	66.2	81.2	0.00238	840	1.000	50.000
12:00	35.0	67.5	82.5	0.00269	840	1.000	50.000
13:00	35.0	68.3	83.3	0.00304	1243	1.480	74.014
14:00	35.0	82.3	110.4	0.00780	1243	1.480	74.014
15:00	35.0	91.0	119.1	0.02336	1243	1.480	74.014
16:00	35.0	96.5	124.6	0.05482	1243	1.480	74.014
17:00	35.0	100.0	128.1	0.10340	840	1.000	50.000
18:00	34.0	88.7	103.7	0.11257	840	1.000	50.000
19:00	33.0	81.3	96.3	0.11526	840	1.000	50.000
20:00	32.0	76.2	91.2	0.11655	840	1.000	50.000
21:00	31.0	72.7	87.7	0.11733	840	1.000	50.000
22:00	30.0	70.1	85.1	0.11786	840	1.000	50.000
23:00	29.0	68.1	83.1	0.11826	840	1.000	50.000
24:00	28.0	66.5	81.5	0.11858	840	1.000	50.000

The results based on this load and temperature cycle are:

- Maximum Capability: 74.0 MVA.
- Maximum Current: 1243 amps.
- Maximum Hot-Spot Temperature: 128.1 C at 5:00 pm.
- Maximum Top Oil Temperature: 100.0 C at 5:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.11858 %.
- Limiting Criteria was Top-Oil

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 68 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 83 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 83 deg C Insul H2O ppm Vol	0.50% mm Hg
H_2O	3,742	2	3,256	7	3,256	5
CO_2	0	0	0	0	0	0
O_2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N_2	500	4	512	4	512	4
Total Pressure		6 mm Hg		11 mm Hg		9 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 91 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 120 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 120 deg C Insul H2O ppm Vol	0.50% mm Hg
H_2O	3,742	3	41,773	45	28,822	31
CO_2	0	0	219	0	219	0
O_2	0	0	0	0	0	0
CO	0	0	38	0	38	0
N_2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		48 mm Hg		34 mm Hg

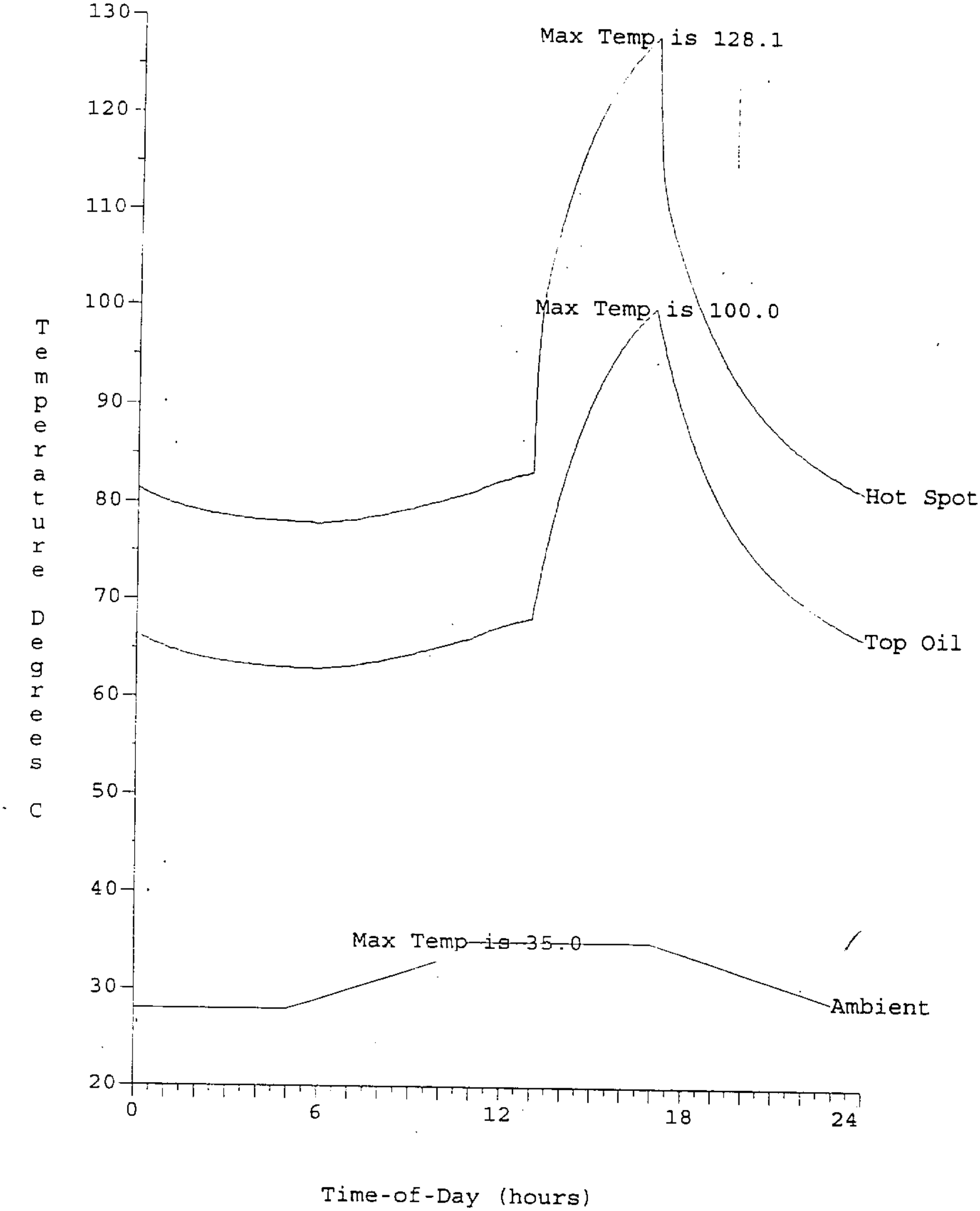
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID1S4LTE>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc

Station: SUMMER 1 t e 8 hour pk starting @ 10 AM
Transformers: Transformer ID #1
Comments: OA/FA/FOA 30/40/50 MVA
Tested 2/21/61

Transformer Operates at Top MVA Cooling Mode for All Conditions.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
3.	50.000	Non-directed Flow FOA, FOW, OA/FA/FOA	0.80	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	6.9	Input
Top Oil Rise Ambient	34.7	Input
Avg Winding Rise Amb.	59.4	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	28.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	129	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 16.00 hours, followed by a constant higher load for 8.00 hours. The constant higher load is applied at 10 am.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #1

SUMMER LTE (8 Hour) RATING ,starting @ 10 AM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	80.5	0.187881	0.187881
2	79.5	0.166573	0.354454
3	78.8	0.15305	0.507504
4	78.4	0.145799	0.653303
5	78.1	0.140577	0.793879
6	78	0.138876	0.932756
7	78.2	0.142297	1.075053
8	78.8	0.15305	1.228103
9	79.5	0.166573	1.394675
10	80.3	0.183422	1.578097
11	104.2	2.702474	4.280571
12	112.8	6.557574	10.83815
13	118.2	11.21566	22.05381
14	121.6	15.60657	37.66037
15	123.7	19.08535	56.74572
16	125	21.59426	78.33998
17	125.9	23.51081	101.8508
18	126.4	24.64404	126.4948
19	103.4	2.483447	128.9783
20	95.7	1.08046	130.0587
21	90.5	0.603744	130.6625
22	86.8	0.394965	131.0574
23	84.2	0.291589	131.349
24	82.1	0.227466	131.5765

% Loss - of - Life = 0.073098 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	65.5	80.5	0.00028	840	1.000	50.000
2:00	28.0	64.5	79.5	0.00052	840	1.000	50.000
3:00	28.0	63.8	78.8	0.00073	840	1.000	50.000
4:00	28.0	63.4	78.4	0.00093	840	1.000	50.000
5:00	28.0	63.1	78.1	0.00113	840	1.000	50.000
6:00	29.0	63.0	78.0	0.00131	840	1.000	50.000
7:00	30.0	63.2	78.2	0.00150	840	1.000	50.000
8:00	31.0	63.8	78.8	0.00170	840	1.000	50.000
9:00	32.0	64.5	79.5	0.00192	840	1.000	50.000
10:00	33.0	65.3	80.3	0.00216	1196	1.424	71.207
11:00	35.0	77.8	104.2	0.00466	1196	1.424	71.207
12:00	35.0	86.4	112.8	0.01257	1196	1.424	71.207
13:00	35.0	91.8	118.2	0.02871	1196	1.424	71.207
14:00	35.0	95.2	121.6	0.05376	1196	1.424	71.207
15:00	35.0	97.3	123.7	0.08668	1196	1.424	71.207
16:00	35.0	98.6	125.0	0.12572	1196	1.424	71.207
17:00	35.0	99.5	125.9	0.16916	1196	1.424	71.207
18:00	34.0	100.0	126.4	0.21559	840	1.000	50.000
19:00	33.0	88.4	103.4	0.22439	840	1.000	50.000
20:00	32.0	80.7	95.7	0.22693	840	1.000	50.000
21:00	31.0	75.5	90.5	0.22812	840	1.000	50.000
22:00	30.0	71.8	86.8	0.22882	840	1.000	50.000
23:00	29.0	69.2	84.2	0.22930	840	1.000	50.000
24:00	28.0	67.1	82.1	0.22966	840	1.000	50.000

The results based on this load and temperature cycle are:

- Maximum Capability: 71.2 MVA.
- Maximum Current: 1196 amps.
- Maximum Hot-Spot Temperature: 126.4 C at 6:00 pm.
- Maximum Top Oil Temperature: 100.0 C at 6:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.22966 %.
- Limiting Criteria was Top-Oil

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 65 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 80 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 80 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	6	3,256	4
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		10 mm Hg		8 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 87 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 113 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 113 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	32,803	34	22,563	23
CO2	0	0	116	0	116	0
O2	0	0	0	0	0	0
CO	0	0	20	0	20	0
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		36 mm Hg		25 mm Hg

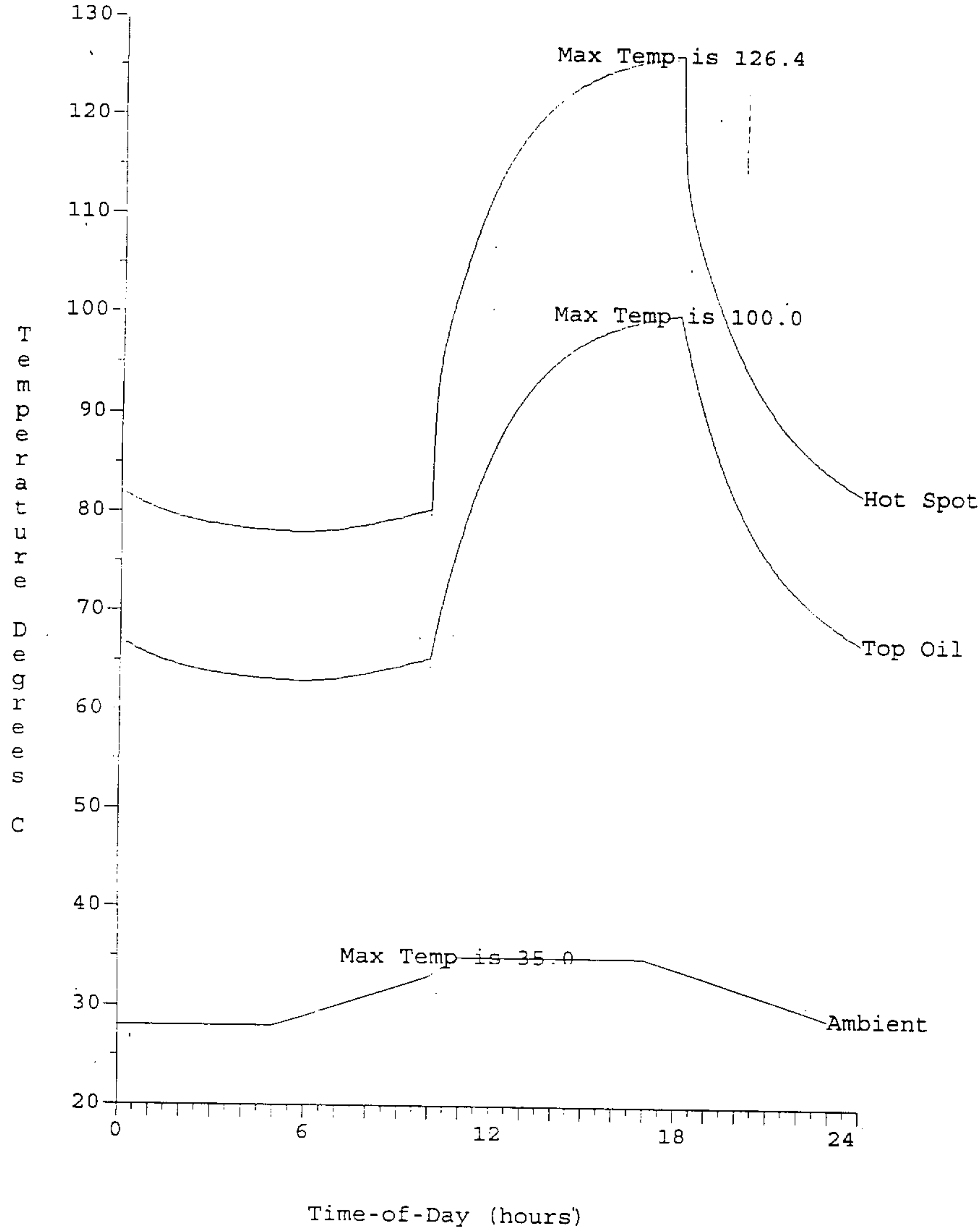
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID1S8LTE>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc

Station: WINTER n o r m a l RATING CALCULATION
Transformers: Transformer ID #1
Comments: OA/FA/FOA 30/40/50 MVA
Tested 2/21/61

Transformer Operates at Top MVA Cooling Mode for All Conditions.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
3.	50.000	Non-directed Flow FOA, FOW, OA/FA/FOA	0.80	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	6.9	Input
Top Oil Rise Ambient	34.7	Input
Avg Winding Rise Amb.	59.4	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	28.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	129	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of one repeated daily load cycle.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 105 C
- Top Oil Temperature: 95 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #1

WINTER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	93.6	0.85585	0.85585
2	93.3	0.827645	1.683494
3	93	0.800325	2.483819
4	92.9	0.791411	3.275231
5	92.4	0.748238	4.023469
6	92.1	0.72342	4.746889
7	92.3	0.739877	5.486767
8	92.8	0.782591	6.269358
9	93.5	0.846348	7.115706
10	94.3	0.925259	8.040964
11	94.8	0.978079	9.019043
12	95.5	1.056864	10.07591
13	95.9	1.104556	11.18046
14	96.9	1.2329	12.41336
15	97.9	1.375341	13.78871
16	98.2	1.421037	15.20974
17	98.4	1.452298	16.66204
18	97.7	1.345657	18.0077
19	97	1.246487	19.25418
20	96.1	1.129163	20.38335
21	95.2	1.022388	21.40574
22	94.2	0.915025	22.32076
23	93.6	0.85585	23.17661
24	93.6	0.85585	24.03246

% Loss - of - Life = 0.013351 %

Normal Loss of Life is .0133%

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

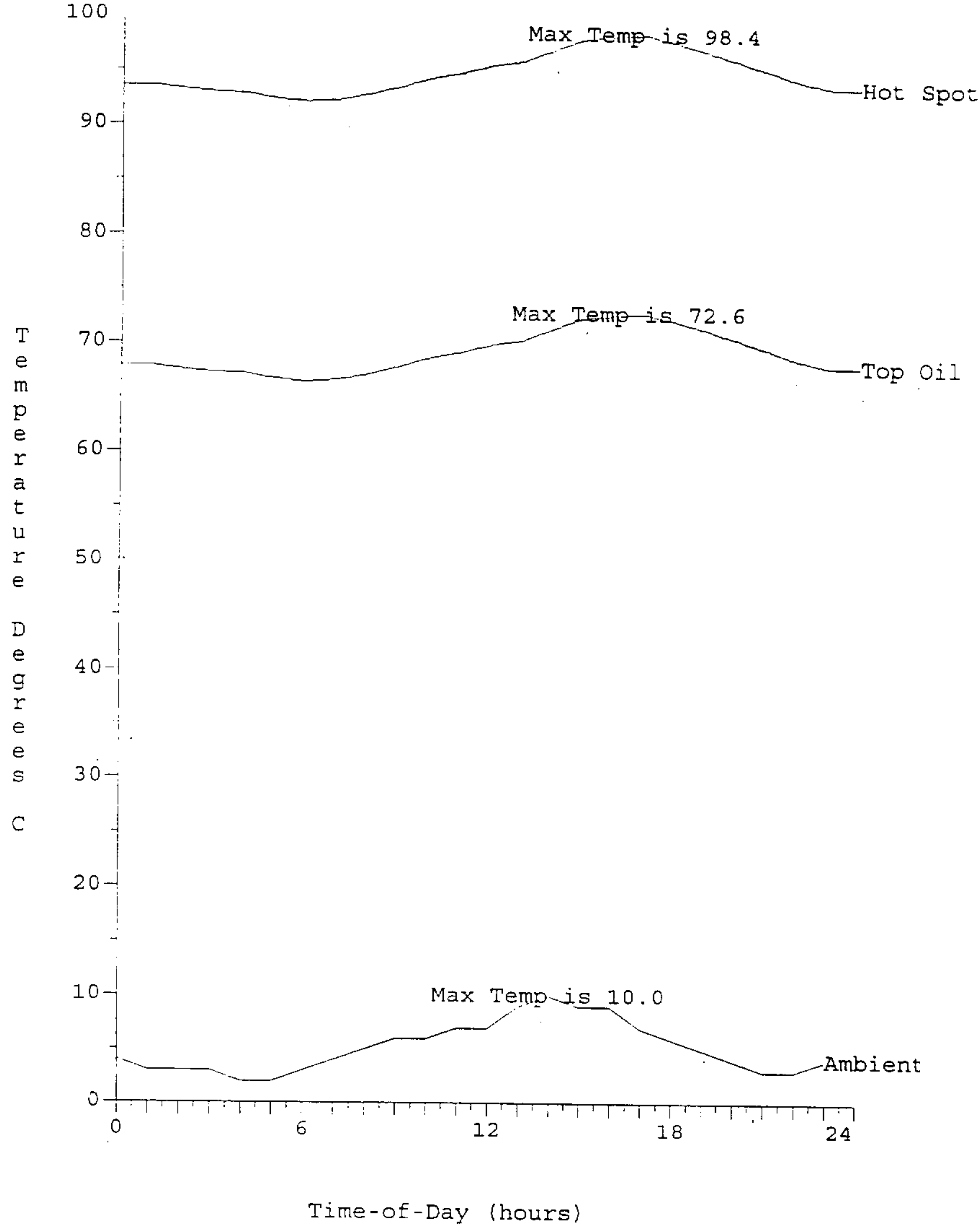
Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	67.9	93.6	0.00131	1177	1.401	70.055
2:00	3.0	67.5	93.3	0.00259	1177	1.401	70.055
3:00	3.0	67.3	93.0	0.00382	1177	1.401	70.055
4:00	2.0	67.2	92.9	0.00502	1177	1.401	70.055
5:00	2.0	66.7	92.4	0.00618	1177	1.401	70.055
6:00	3.0	66.4	92.1	0.00729	1177	1.401	70.055
7:00	4.0	66.6	92.3	0.00840	1177	1.401	70.055
8:00	5.0	67.1	92.8	0.00955	1177	1.401	70.055
9:00	6.0	67.8	93.5	0.01080	1177	1.401	70.055
10:00	6.0	68.6	94.3	0.01215	1177	1.401	70.055
11:00	7.0	69.1	94.8	0.01362	1177	1.401	70.055
12:00	7.0	69.8	95.5	0.01519	1177	1.401	70.055
13:00	9.0	70.2	95.9	0.01686	1177	1.401	70.055
14:00	10.0	71.2	96.9	0.01870	1177	1.401	70.055
15:00	9.0	72.2	97.9	0.02076	1177	1.401	70.055
16:00	9.0	72.5	98.2	0.02298	1177	1.401	70.055
17:00	7.0	72.6	98.4	0.02524	1177	1.401	70.055
18:00	6.0	72.0	97.7	0.02743	1177	1.401	70.055
19:00	5.0	71.2	97.0	0.02945	1177	1.401	70.055
20:00	4.0	70.4	96.1	0.03128	1177	1.401	70.055
21:00	3.0	69.5	95.2	0.03292	1177	1.401	70.055
22:00	3.0	68.5	94.2	0.03440	1177	1.401	70.055
23:00	4.0	67.9	93.6	0.03575	1177	1.401	70.055
24:00	4.0	67.9	93.6	0.03706	1177	1.401	70.055

The results based on this load and temperature cycle are:

- Maximum Capability: 70.1 MVA.
- Maximum Current: 1177 amps.
- Maximum Hot-Spot Temperature: 98.4 C at 5:00 pm.
- Maximum Top Oil Temperature: 72.6 C at 5:00 pm
- Cumulative Loss-of-Life for Cycle: 0.03706 %.
- Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

Power Transformer Temperature Profile for <ID1WNOR>



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TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WINTER 1 t e 4 hour pk starting @ 4 PM
Transformers: Transformer ID #1
Comments: OA/FA/FOA 30/40/50 MVA
Tested 2/21/61

Transformer Operates at Top MVA Cooling Mode for All Conditions

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
3.	50.000	Non-directed Flow FOA, FOW, OA/FA/FOA	0.80	1.00

The insulation system is rated for 55 C rise over ambient

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	6.9	Input
Top Oil Rise Ambient	34.7	Input
Avg Winding Rise Amb.	59.4	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	28.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	129	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 20.00 hours, followed by a constant higher load for 4.00 hours. The constant higher load is applied at 4 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR
55 deg. C Class

Transformer ID #1

WINTER LTE (4 Hour) RATING ,starting @ 4 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	59.5	0.012882	0.012882
2	56.9	0.009028	0.02191
3	55.4	0.007335	0.029245
4	54.4	0.00638	0.035624
5	53.4	0.005544	0.041168
6	52.8	0.005094	0.046263
7	52.7	0.005023	0.051285
8	53.1	0.005315	0.0566
9	53.7	0.005783	0.062383
10	54.4	0.00638	0.068763
11	54.9	0.006841	0.075604
12	55.6	0.007541	0.083145
13	56	0.007972	0.091117
14	57	0.009153	0.10027
15	58	0.0105	0.110771
16	58.3	0.01094	0.121711
17	108.3	4.144435	4.266146
18	123.9	19.45248	23.71863
19	133.4	47.05988	70.7785
20	138.9	77.03529	147.8138
21	92.2	0.731605	148.5454
22	77.5	0.130663	148.6761
23	68.3	0.041224	148.7173
24	62.9	0.020338	148.7376

% Loss - of - Life = 0.082632 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	44.5	59.5	0.00002	840	1.000	50.000
2:00	3.0	41.9	56.9	0.00003	840	1.000	50.000
3:00	3.0	40.4	55.4	0.00004	840	1.000	50.000
4:00	2.0	39.4	54.4	0.00005	840	1.000	50.000
5:00	2.0	38.4	53.4	0.00005	840	1.000	50.000
6:00	3.0	37.8	52.8	0.00006	840	1.000	50.000
7:00	4.0	37.7	52.7	0.00006	840	1.000	50.000
8:00	5.0	38.1	53.1	0.00007	840	1.000	50.000
9:00	6.0	38.7	53.7	0.00007	840	1.000	50.000
10:00	6.0	39.4	54.4	0.00008	840	1.000	50.000
11:00	7.0	39.9	54.9	0.00009	840	1.000	50.000
12:00	7.0	40.6	55.6	0.00010	840	1.000	50.000
13:00	9.0	41.0	56.0	0.00010	840	1.000	50.000
14:00	10.0	42.0	57.0	0.00011	840	1.000	50.000
15:00	9.0	43.0	58.0	0.00013	840	1.000	50.000
16:00	9.0	43.3	58.3	0.00014	840	1.000	50.000
17:00	7.0	69.3	108.3	0.00273	1525	1.816	90.789
18:00	6.0	85.0	123.9	0.02287	1525	1.816	90.789
19:00	5.0	94.4	133.4	0.08817	1525	1.816	90.789
20:00	4.0	100.0	138.9	0.21772	1525	1.816	90.789
21:00	3.0	77.2	92.2	0.22517	840	1.000	50.000
22:00	3.0	62.5	77.5	0.22562	840	1.000	50.000
23:00	4.0	53.3	68.3	0.22571	840	1.000	50.000
24:00	4.0	47.9	62.9	0.22575	840	1.000	50.000

The results based on this load and temperature cycle are:

- Maximum Capability: 90.8 MVA.
- Maximum Current: 1525 amps.
- Maximum Hot-Spot Temperature: 138.9 C at 8:00 pm.
- Maximum Top Oil Temperature: 100.0 C at 8:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.22575 %.
- Limiting Criteria was Top-Oil

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 43 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 58 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 58 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	2	3,256	1
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		6 mm Hg		5 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 86 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 125 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 125 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	49,858	57	34,382	39
CO2	0	0	247	0	247	0
O2	0	0	0	0	0	0
CO	0	0	43	0	43	0
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		60 mm Hg		42 mm Hg

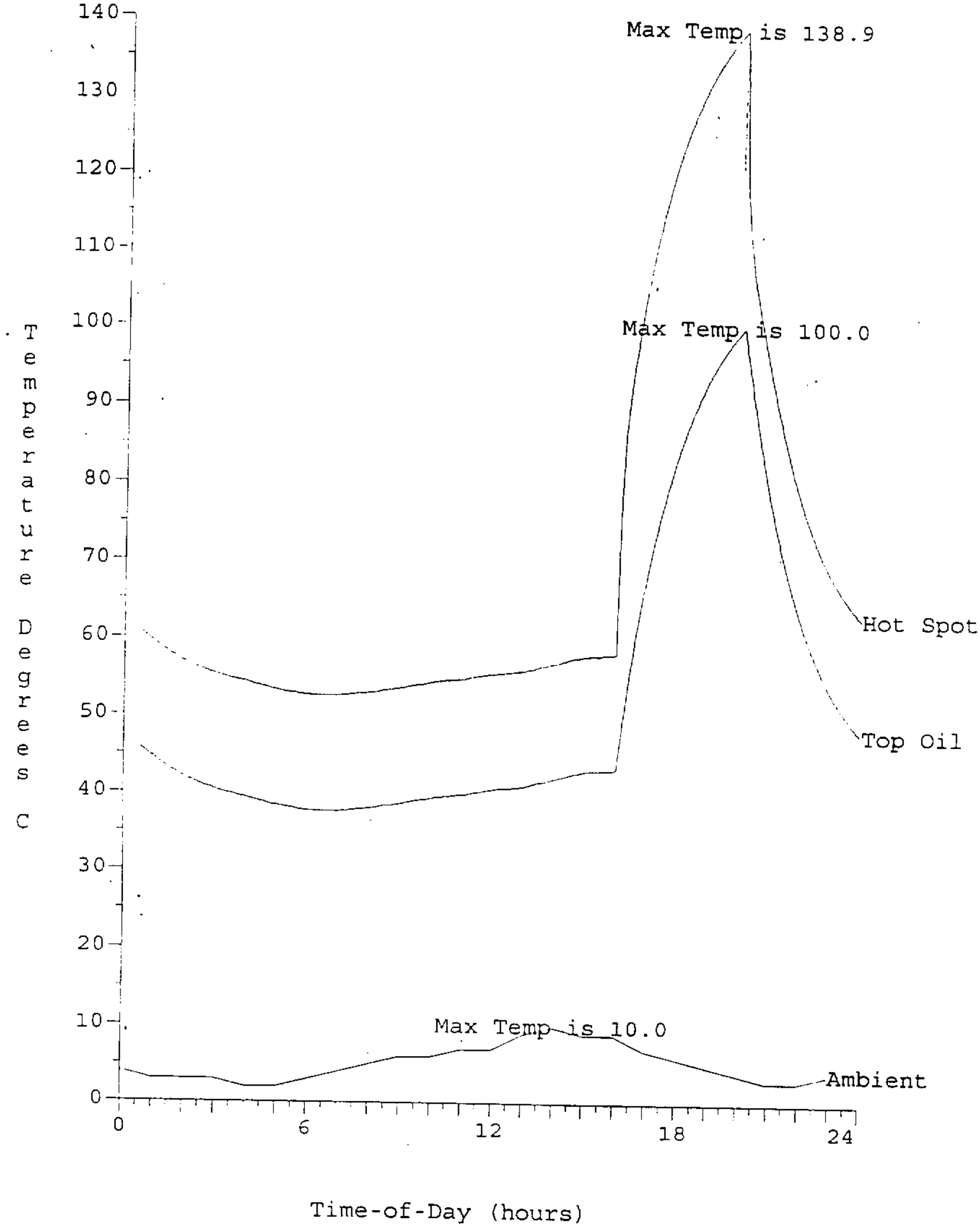
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID1W4LTE>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WINTER 1 t e 8 hour pk starting @ 2 PM
Transformers: Transformer ID #1
Comments: OA/FA/FOA 30/40/50 MVA
Tested 2/21/61

Transformer Operates at Top MVA Cooling Mode for All Conditions

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
3.	50.000	Non-directed Flow FOA, FOW, OA/FA/FOA	0.80	1.00

The insulation system is rated for 55 C rise over ambient

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	6.9	Input
Top Oil Rise Ambient	34.7	Input
Avg Winding Rise Amb.	59.4	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	28.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	129	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 16.00 hours, followed by a constant higher load for 8.00 hours. The constant higher load is applied at 2 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR
55 deg. C Class

Transformer ID #1

WINTER LTE (8 Hour) RATING ,starting @ 2 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	68.7	0.0434	0.0434
2	62.8	0.020069	0.063469
3	59	0.012036	0.075505
4	56.7	0.008782	0.084288
5	54.8	0.006746	0.091034
6	53.7	0.005783	0.096817
7	53.3	0.005467	0.102284
8	53.5	0.005623	0.107906
9	53.9	0.005948	0.113854
10	54.6	0.006561	0.120415
11	55	0.006937	0.127352
12	55.6	0.007541	0.134894
13	56	0.007972	0.142866
14	57	0.009153	0.152019
15	102.7	2.30573	2.457748
16	117.5	10.47067	12.92841
17	126.8	25.58766	38.51607
18	131.9	41.04567	79.56174
19	134.7	52.93744	132.4992
20	136.1	60.0404	192.5396
21	136.6	62.78874	255.3283
22	136.5	62.22973	317.5581
23	91.8	0.699387	318.2575
24	77.6	0.132267	318.3897

% Loss - of - Life = 0.176883 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	53.7	68.7	0.00010	840	1.000	50.000
2:00	3.0	47.8	62.8	0.00013	840	1.000	50.000
3:00	3.0	44.0	59.0	0.00015	840	1.000	50.000
4:00	2.0	41.7	56.7	0.00016	840	1.000	50.000
5:00	2.0	39.8	54.8	0.00017	840	1.000	50.000
6:00	3.0	38.7	53.7	0.00017	840	1.000	50.000
7:00	4.0	38.3	53.3	0.00018	840	1.000	50.000
8:00	5.0	38.5	53.5	0.00019	840	1.000	50.000
9:00	6.0	38.9	53.9	0.00019	840	1.000	50.000
10:00	6.0	39.6	54.6	0.00020	840	1.000	50.000
11:00	7.0	40.0	55.0	0.00021	840	1.000	50.000
12:00	7.0	40.6	55.6	0.00021	840	1.000	50.000
13:00	9.0	41.0	56.0	0.00022	840	1.000	50.000
14:00	10.0	42.0	57.0	0.00023	1467	1.746	87.302
15:00	9.0	66.1	102.7	0.00167	1467	1.746	87.302
16:00	9.0	80.9	117.5	0.01214	1467	1.746	87.302
17:00	7.0	90.2	126.8	0.04594	1467	1.746	87.302
18:00	6.0	95.3	131.9	0.11215	1467	1.746	87.302
19:00	5.0	98.1	134.7	0.20769	1467	1.746	87.302
20:00	4.0	99.5	136.1	0.32359	1467	1.746	87.302
21:00	3.0	100.0	136.6	0.44983	1467	1.746	87.302
22:00	3.0	99.9	136.5	0.57838	840	1.000	50.000
23:00	4.0	76.8	91.8	0.58528	840	1.000	50.000
24:00	4.0	62.6	77.6	0.58573	840	1.000	50.000

The results based on this load and temperature cycle are:

- Maximum Capability: 87.3 MVA.
- Maximum Current: 1467 amps.
- Maximum Hot-Spot Temperature: 136.6 C at 9:00 pm.
- Maximum Top Oil Temperature: 100.0 C at 9:00 pm
- Cumulative Loss-of-Life for Cycle: 0.58573 %.
- Limiting Criteria was Top-Oil

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 42 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 57 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 57 deg C Insul H20 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	2	3,256	1
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		6 mm Hg		5 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 82 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 118 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 118 deg C Insul H20 0.50% ppm Vol	mm Hg
H2O	3,742	3	39,409	43	27,098	29
CO2	0	0	134	0	134	0
O2	0	0	0	0	0	0
CO	0	0	23	0	23	0
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		45 mm Hg		32 mm Hg

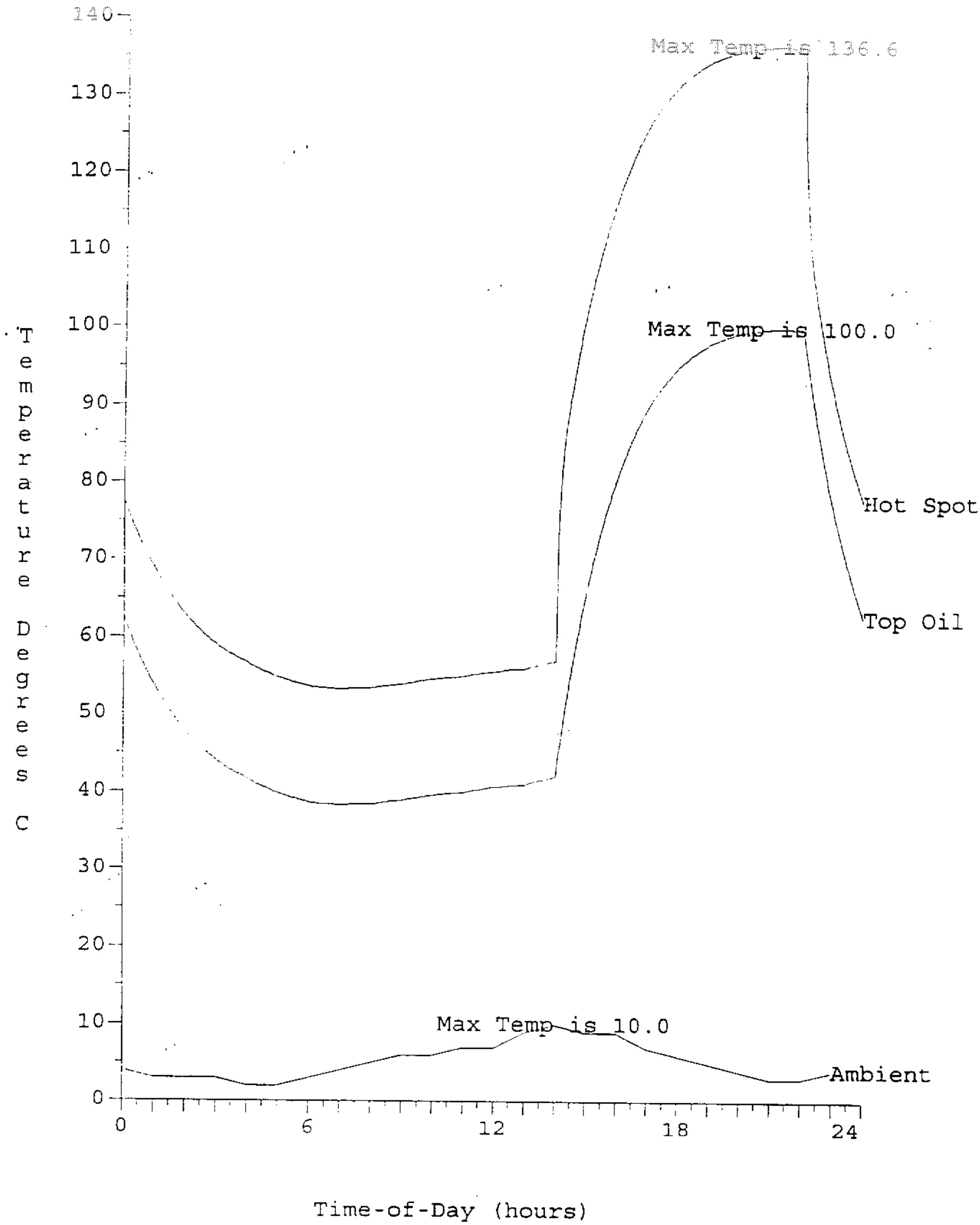
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID1W8LTE>



NYPP 1995 Tie-Line Rating Task Force

APPENDIX
D

Transformer ID
#2

56 MVA, 65°C, FOA

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 62 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 80 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 80 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	6	3,256	4
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		10 mm Hg		8 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 85 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 133 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 133 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	67,860	81	47,467	55
CO2	0	0	865	1	865	1
O2	0	0	0	0	0	0
CO	0	0	152	1	152	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		85 mm Hg		59 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER n o r m a l Rating Calculation
Transformers: Transformer ID #2 30/40/50 OA/FOA/FOA
Comments: McGraw-Edison 55/65 Deg . C
33.6/44.8/56 MVA for 65 deg C

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	56.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	9.3	Input
Top Oil Rise Ambient	37.0	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	35.0	Calc
Winding Time Constant	5	Input
Oil Time Constant	136	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle
consists of one repeated daily load cycle.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak
load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 120 C
- o Top Oil Temperature: 105 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #2

SUMMER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	106.9	0.726451	0.726451
2	106.7	0.711499	1.43795
3	106.5	0.696839	2.134789
4	106.4	0.689617	2.824406
5	106.7	0.711499	3.535905
6	107.2	0.74944	4.285345
7	107.9	0.805797	5.091142
8	108.7	0.875126	5.966268
9	109.6	0.959881	6.92615
10	110.9	1.096163	8.022312
11	111.7	1.188948	9.211261
12	112.2	1.250672	10.46193
13	112.6	1.302227	11.76416
14	112.8	1.328754	13.09291
15	112.9	1.34221	14.43512
16	113	1.355794	15.79092
17	112.7	1.315427	17.10634
18	112.2	1.250672	18.35702
19	111.5	1.165077	19.52209
20	110.7	1.074064	20.59616
21	109.8	0.979746	21.5759
22	108.9	0.893323	22.46923
23	107.9	0.805797	23.27502
24	107.3	0.757256	24.03228

% Loss - of - Life = 0.013351 %

Normal Loss of Life is .0133%

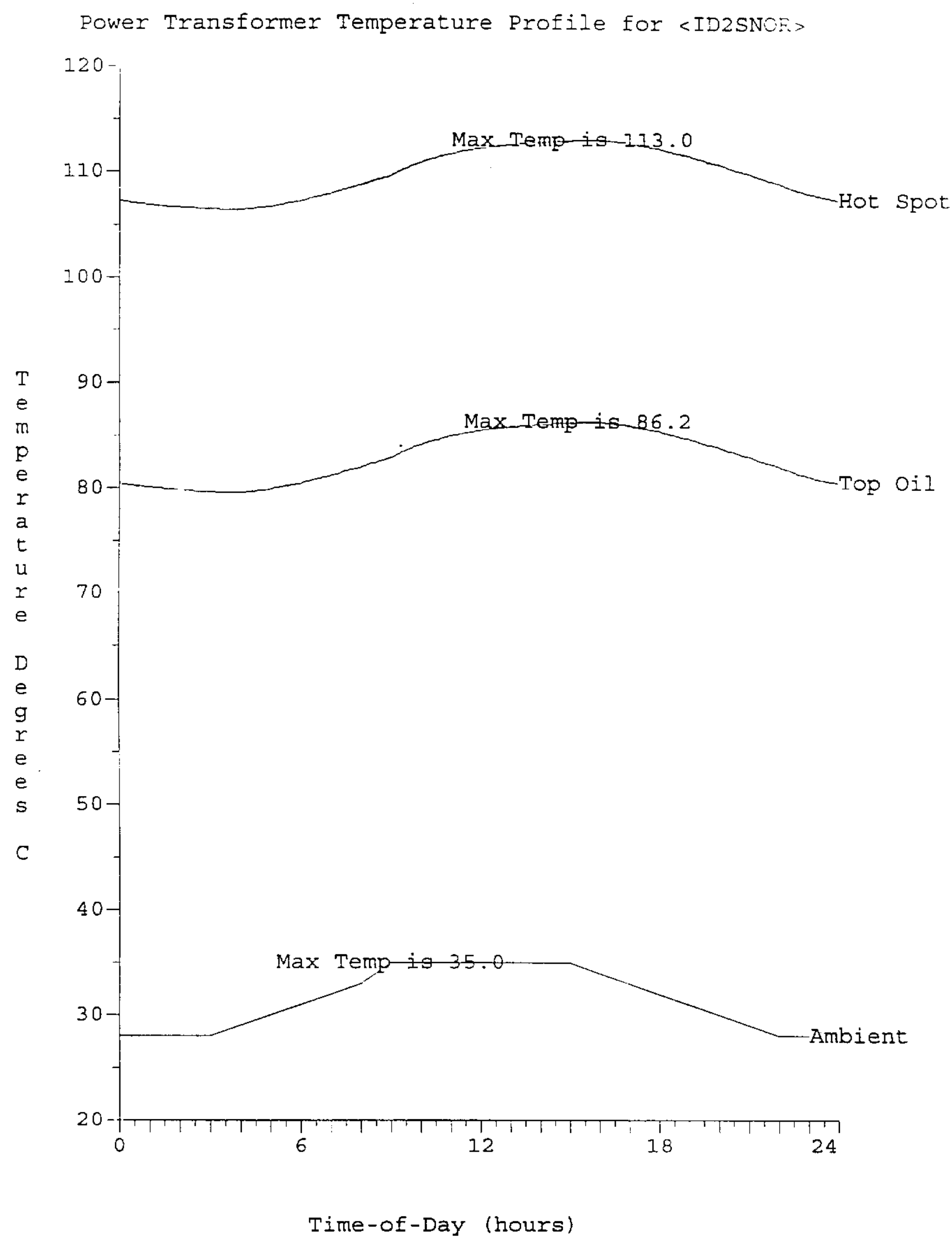
TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	80.1	106.9	0.00111	1122	1.196	66.975
2:00	28.0	79.8	106.7	0.00219	1122	1.196	66.975
3:00	28.0	79.7	106.5	0.00324	1122	1.196	66.975
4:00	29.0	79.6	106.4	0.00428	1122	1.196	66.975
5:00	30.0	79.9	106.7	0.00533	1122	1.196	66.975
6:00	31.0	80.4	107.2	0.00643	1122	1.196	66.975
7:00	32.0	81.1	107.9	0.00762	1122	1.196	66.975
8:00	33.0	81.9	108.7	0.00890	1122	1.196	66.975
9:00	35.0	82.8	109.6	0.01032	1122	1.196	66.975
10:00	35.0	84.1	110.9	0.01191	1122	1.196	66.975
11:00	35.0	84.9	111.7	0.01370	1122	1.196	66.975
12:00	35.0	85.4	112.2	0.01561	1122	1.196	66.975
13:00	35.0	85.8	112.6	0.01761	1122	1.196	66.975
14:00	35.0	86.0	112.8	0.01968	1122	1.196	66.975
15:00	35.0	86.1	112.9	0.02178	1122	1.196	66.975
16:00	34.0	86.2	113.0	0.02391	1122	1.196	66.975
17:00	33.0	85.9	112.7	0.02601	1122	1.196	66.975
18:00	32.0	85.4	112.2	0.02801	1122	1.196	66.975
19:00	31.0	84.7	111.5	0.02988	1122	1.196	66.975
20:00	30.0	83.8	110.7	0.03160	1122	1.196	66.975
21:00	29.0	83.0	109.8	0.03317	1122	1.196	66.975
22:00	28.0	82.0	108.9	0.03459	1122	1.196	66.975
23:00	28.0	81.1	107.9	0.03587	1122	1.196	66.975
24:00	28.0	80.5	107.3	0.03704	1122	1.196	66.975

The results based on this load and temperature cycle are:

- o Maximum Capability: 67.0 MVA.
- o Maximum Current: 1122 amps.
- o Maximum Hot-Spot Temperature: 113.0 C at 4:00 pm.
- o Maximum Top Oil Temperature: 86.2 C at 4:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.03704 %.
- o Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.


Power Transformer Temperature Profile for <ID2SNOR>
Max Temp is 113.0
Hot Spot
Max Temp is 86.2
Top Oil
Max Temp is 35.0
Ambient
Temperature Degrees C
120
110
100
90
80
70
60
50
40
30
20
0
6
12
18
24
Time-of-Day (hours)

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER 1 t e 4 hour pk starting @ 1 PM
Transformers: Transformer ID #2 30/40/50 OA/FOA/FOA
Comments: McGraw-Edison 55/65 Deg . C
33.6/44.8/56 MVA for 65 deg C

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	56.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	9.3	Input
Top Oil Rise Ambient	37.0	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	35.0	Calc
Winding Time Constant	5	Input
Oil Time Constant	136	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle
consists of a constant 1.00 P.U. Rated Load for a period of
20.00 hours, followed by a constant higher load for 4.00 hours.
The constant higher load is applied at 1 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak
load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE'. THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #2

SUMMER LTE (4 Hour) RATING ,starting @ 1 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	85.3	0.067214	0.067214
2	84.8	0.063395	0.130609
3	84.4	0.060489	0.191098
4	84.2	0.059084	0.250183
5	84.4	0.060489	0.310672
6	84.9	0.064142	0.374814
7	85.5	0.068803	0.443616
8	86.3	0.07552	0.519137
9	87.2	0.083824	0.60296
10	88.5	0.097365	0.700326
11	89.3	0.106708	0.807034
12	89.8	0.112973	0.920007
13	90.1	0.116899	1.036906
14	123.2	3.68704	4.723946
15	131.5	8.017868	12.74181
16	136.9	13.06843	25.81025
17	140	17.19946	43.00971
18	108.8	0.88418	43.89389
19	101.3	0.402397	44.29629
20	96.1	0.228801	44.52509
21	92.4	0.151615	44.67671
22	89.7	0.111693	44.7884
23	87.6	0.087787	44.87618
24	86.2	0.074648	44.95083

% Loss - of - Life = 0.024973 %

Emergency operation criteria Loss of Life is .25% per occcurence.

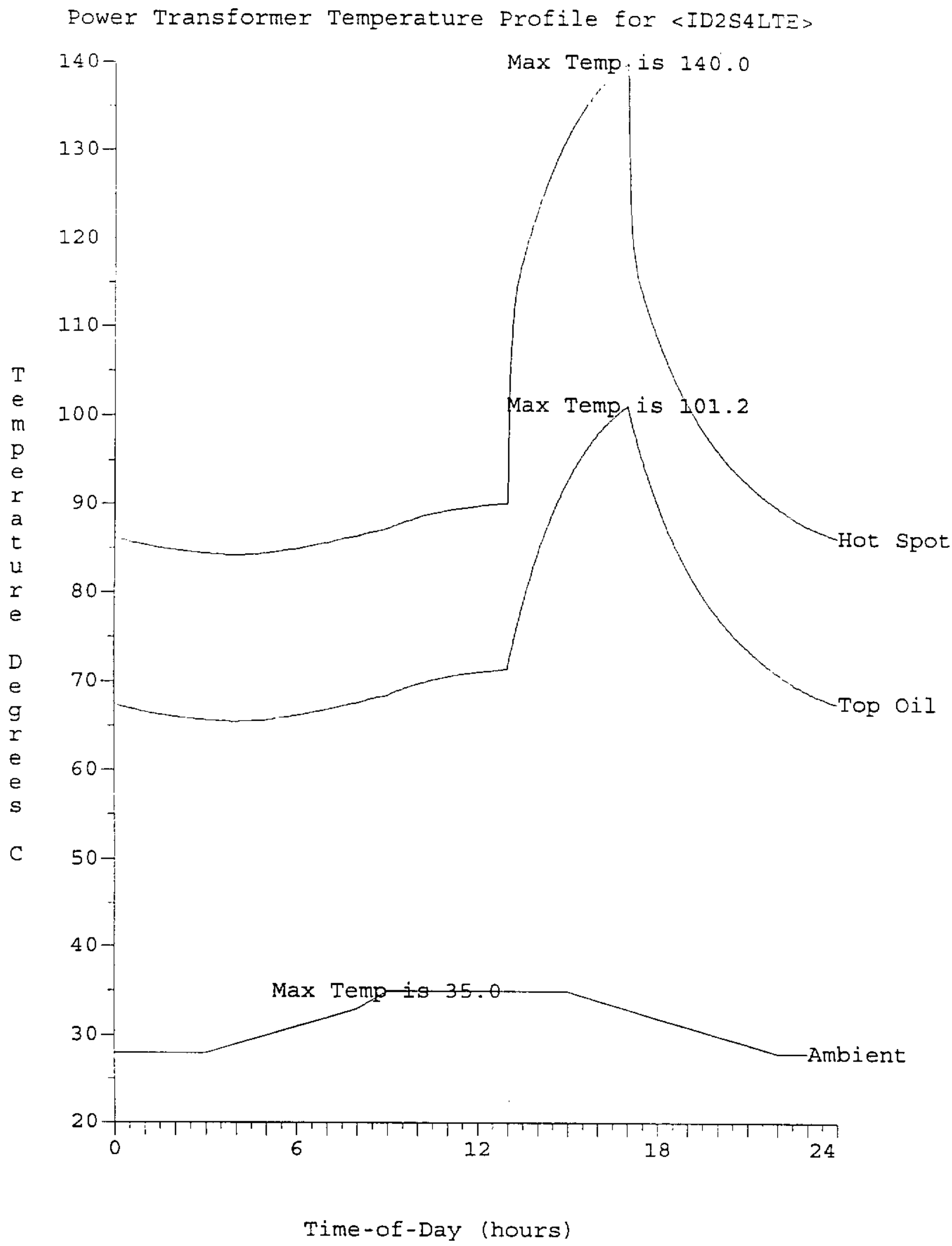
TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	66.6	85.3	0.00009	938	1.000	56.000
2:00	28.0	66.0	84.8	0.00017	938	1.000	56.000
3:00	28.0	65.7	84.4	0.00025	938	1.000	56.000
4:00	29.0	65.4	84.2	0.00033	938	1.000	56.000
5:00	30.0	65.6	84.4	0.00040	938	1.000	56.000
6:00	31.0	66.1	84.9	0.00048	938	1.000	56.000
7:00	32.0	66.8	85.5	0.00056	938	1.000	56.000
8:00	33.0	67.6	86.3	0.00066	938	1.000	56.000
9:00	35.0	68.4	87.2	0.00076	938	1.000	56.000
10:00	35.0	69.7	88.5	0.00088	938	1.000	56.000
11:00	35.0	70.5	89.3	0.00101	938	1.000	56.000
12:00	35.0	71.1	89.8	0.00116	938	1.000	56.000
13:00	35.0	71.4	90.1	0.00131	1350	1.439	80.568
14:00	35.0	84.4	123.2	0.00480	1350	1.439	80.568
15:00	35.0	92.7	131.5	0.01502	1350	1.439	80.568
16:00	34.0	98.1	136.9	0.03437	1350	1.439	80.568
17:00	33.0	101.2	140.0	0.06281	938	1.000	56.000
18:00	32.0	90.0	108.8	0.06596	938	1.000	56.000
19:00	31.0	82.5	101.3	0.06683	938	1.000	56.000
20:00	30.0	77.4	96.1	0.06725	938	1.000	56.000
21:00	29.0	73.7	92.4	0.06750	938	1.000	56.000
22:00	28.0	70.9	89.7	0.06767	938	1.000	56.000
23:00	28.0	68.8	87.6	0.06780	938	1.000	56.000
24:00	28.0	67.5	86.2	0.06790	938	1.000	56.000

The results based on this load and temperature cycle are:

- Maximum Capability: 80.6 MVA.
- Maximum Current: 1350 amps.
- Maximum Hot-Spot Temperature: 140.0 C at 5:00 pm.
- Maximum Top Oil Temperature: 101.2 C at 5:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.06790 %.
- Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.


Power Transformer Temperature Profile for <ID2S4LTE>
Max Temp is 140.0
Max Temp is 101.2
Max Temp is 35.0
Hot Spot
Top Oil
Ambient
Temperature Degrees C
140
130
120
110
100
90
80
70
60
50
40
30
20
0
6
12
18
24
Time-of-Day (hours)

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

	Bulk Oil Region		Hot Spot #1		Hot Spot #2	
	71 deg C		90 deg C		90 deg C	
Gas	Bulk H2O	1.00%	Insul H2O	0.64%	Insul H2O	0.50%
Component	ppm Vol	mm Hg	ppm Vol	mm Hg	ppm Vol	mm Hg
H2O	3,742	2	3,256	11	3,256	7
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		14 mm Hg		11 mm Hg

Immediately After the Contingency

	Bulk Oil Region		Hot Spot #1		Hot Spot #2	
	93 deg C		132 deg C		132 deg C	
Gas	Bulk H2O	1.00%	Insul H2O	0.64%	Insul H2O	0.50%
Component	ppm Vol	mm Hg	ppm Vol	mm Hg	ppm Vol	mm Hg
H2O	3,742	3	65,940	78	46,025	54
CO2	0	0	763	1	763	1
O2	0	0	0	0	0	0
CO	0	0	134	1	134	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		82 mm Hg		57 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER 1 t e 8 hour pk starting @ 10 AM
Transformers: Transformer ID #2 30/40/50 OA/FOA/FOA
Comments: McGraw-Edison 55/65 Deg . C
33.6/44.8/56 MVA for 65 deg C

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	56.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	9.3	Input
Top Oil Rise Ambient	37.0	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	35.0	Calc
Winding Time Constant	5	Input
Oil Time Constant	136	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 16.00 hours, followed by a constant higher load for 8.00 hours. The constant higher load is applied at 10 am.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #2

SUMMER LTE (8 Hour) RATING ,starting @ 10 AM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	85.9	0.072087	0.072087
2	85.1	0.065661	0.137748
3	84.6	0.061926	0.199674
4	84.3	0.059783	0.259457
5	84.5	0.061203	0.32066
6	84.9	0.064142	0.384802
7	85.6	0.06961	0.454412
8	86.4	0.076403	0.530815
9	87.2	0.083824	0.614639
10	88.5	0.097365	0.712004
11	119.4	2.555355	3.267359
12	127.4	5.484651	8.75201
13	132.6	8.866165	17.61817
14	135.9	11.94969	29.56786
15	138.1	14.54167	44.10953
16	139.5	16.4587	60.56823
17	140	17.19946	77.7677
18	140	17.19946	94.96716
19	109.5	0.950093	95.91726
20	101.4	0.406728	96.32399
21	95.8	0.221361	96.54535
22	91.9	0.143322	96.68867
23	89	0.103109	96.79178
24	87.1	0.08286	96.87464

% Loss - of - Life = 0.053819 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	67.2	85.9	0.00010	938	1.000	56.000
2:00	28.0	66.4	85.1	0.00019	938	1.000	56.000
3:00	28.0	65.9	84.6	0.00027	938	1.000	56.000
4:00	29.0	65.6	84.3	0.00034	938	1.000	56.000
5:00	30.0	65.7	84.5	0.00042	938	1.000	56.000
6:00	31.0	66.2	84.9	0.00050	938	1.000	56.000
7:00	32.0	66.8	85.6	0.00059	938	1.000	56.000
8:00	33.0	67.6	86.4	0.00068	938	1.000	56.000
9:00	35.0	68.5	87.2	0.00078	938	1.000	56.000
10:00	35.0	69.7	88.5	0.00090	1320	1.408	78.833
11:00	35.0	82.2	119.4	0.00329	1320	1.408	78.833
12:00	35.0	90.3	127.4	0.01014	1320	1.408	78.833
13:00	35.0	95.5	132.6	0.02301	1320	1.408	78.833
14:00	35.0	98.8	135.9	0.04218	1320	1.408	78.833
15:00	35.0	100.9	138.1	0.06687	1320	1.408	78.833
16:00	34.0	102.3	139.5	0.09591	1320	1.408	78.833
17:00	33.0	102.8	140.0	0.12750	1320	1.408	78.833
18:00	32.0	102.8	140.0	0.15977	938	1.000	56.000
19:00	31.0	90.8	109.5	0.16328	938	1.000	56.000
20:00	30.0	82.6	101.4	0.16419	938	1.000	56.000
21:00	29.0	77.1	95.8	0.16460	938	1.000	56.000
22:00	28.0	73.1	91.9	0.16484	938	1.000	56.000
23:00	28.0	70.2	89.0	0.16500	938	1.000	56.000
24:00	28.0	68.4	87.1	0.16512	938	1.000	56.000

The results based on this load and temperature cycle are:

- Maximum Capability: 78.8 MVA.
- Maximum Current: 1320 amps.
- Maximum Hot-Spot Temperature: 140.0 C at 5:00 pm.
- Maximum Top Oil Temperature: 102.8 C at 5:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.16512 %.
- Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 70 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 89 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 89 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	10	3,256	7
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		14 mm Hg		10 mm Hg

Immediately After the Contingency

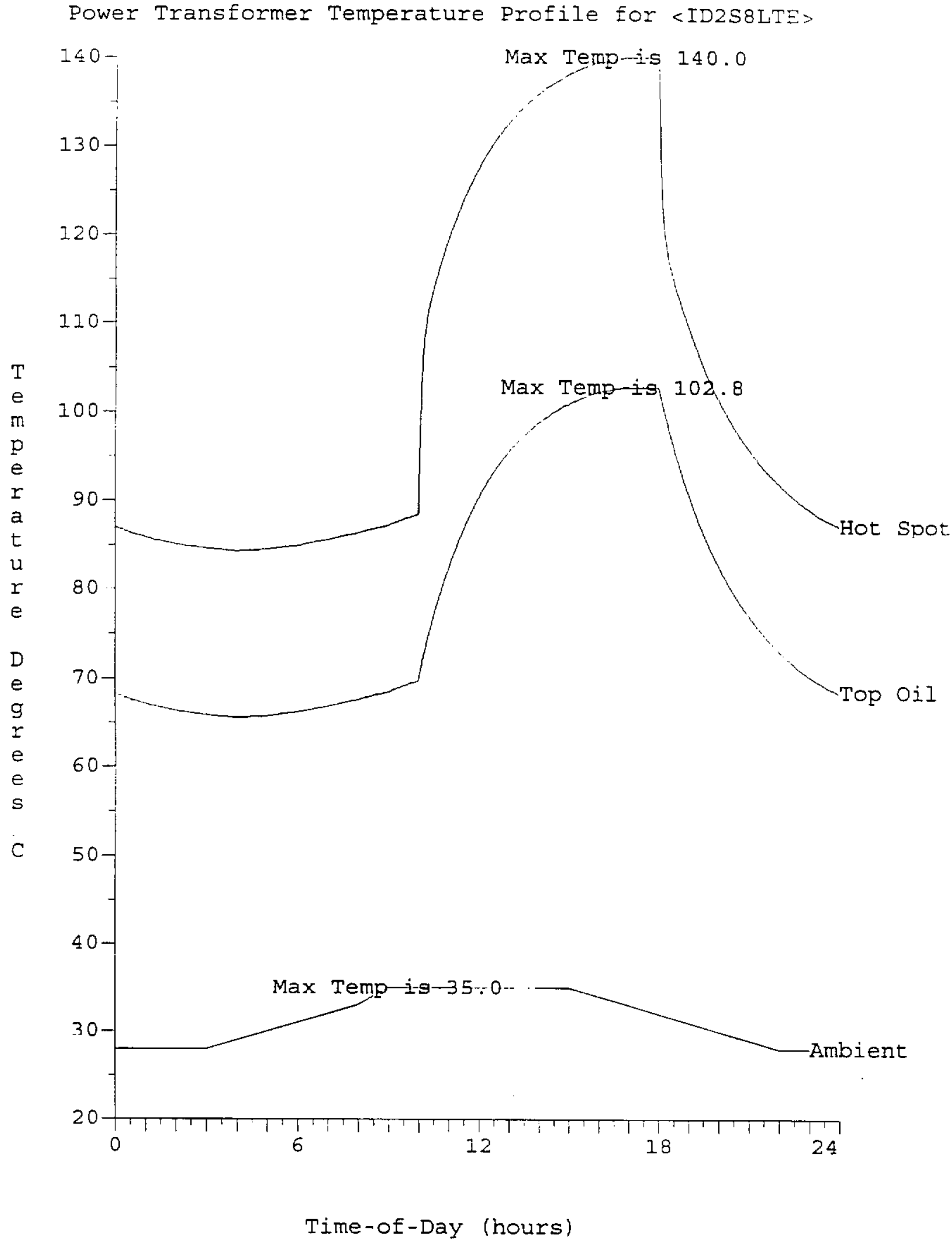
Gas Component	Bulk Oil Region 91 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 128 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 128 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	56,932	66	39,567	45
CO2	0	0	524	1	524	1
O2	0	0	0	0	0	0
CO	0	0	92	1	92	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		69 mm Hg		48 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.


Power Transformer Temperature Profile for <ID2S8LTE>
Max Temp is 140.0
Max Temp is 102.8
Max Temp is 35.0
Hot Spot
Top Oil
Ambient
Temperature Degrees C
140
130
120
110
100
90
80
70
60
50
40
30
20
0
6
12
18
24
Time-of-Day (hours)

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WiINTER n o r m a l RATING CALCULATION
Transformers: Transformer ID #2 30/40/50 OA/FOA/FOA
Comments: McGraw-Edison 55/65 Deg . C
33.6/44.8/56 MVA for 65 deg C

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	56.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	9.3	Input
Top Oil Rise Ambient	37.0	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	35.0	Calc
Winding Time Constant	5	Input
Oil Time Constant	136	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of one repeated daily load cycle.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 115 C
- o Top Oil Temperature: 105 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #2

WINTER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	108.3	0.839783	0.839783
2	108.1	0.822623	1.662406
3	107.9	0.805797	2.468202
4	107.5	0.773119	3.241321
5	107.2	0.74944	3.990761
6	107.3	0.757256	4.748017
7	107.8	0.797506	5.545523
8	108.5	0.857282	6.402805
9	109.2	0.921293	7.324098
10	109.7	0.969765	8.293863
11	110.4	1.041706	9.33557
12	110.8	1.08506	10.42063
13	111.8	1.201057	11.62169
14	112.8	1.328754	12.95044
15	113.1	1.369509	14.31995
16	113.3	1.397334	15.71728
17	112.7	1.315427	17.03271
18	112	1.225626	18.25834
19	111.1	1.118693	19.37703
20	110.2	1.020651	20.39768
21	109.3	0.9308	21.32848
22	108.7	0.875126	22.20361
23	108.7	0.875126	23.07873
24	108.7	0.875126	23.95386

% Loss - of - Life = 0.013308 %

Normal Loss of Life is .0133%

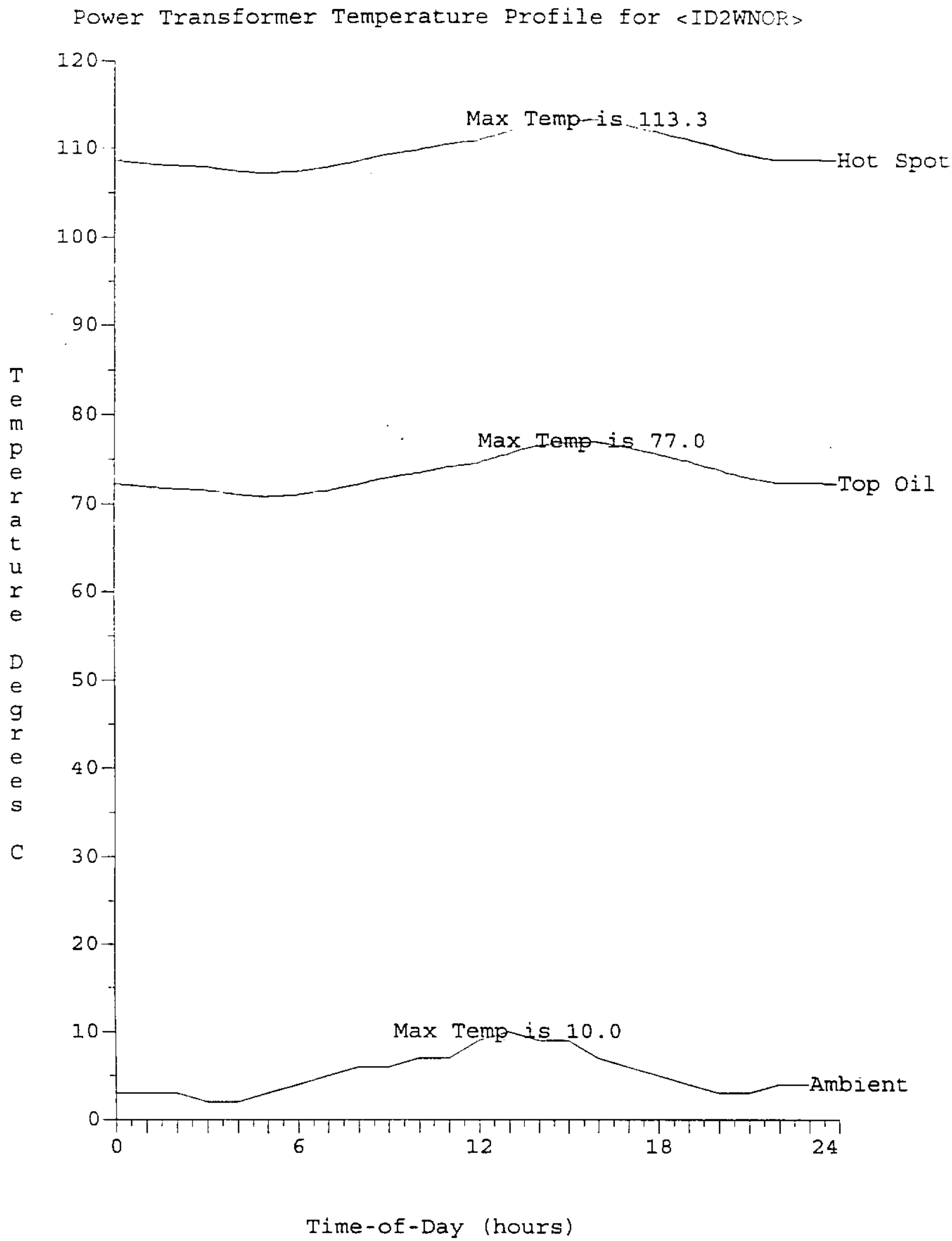
TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	Ambient (Deg C)	Top Oil (Deg C)	Hot Spot (Deg C)	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	72.0	108.3	0.00130	1306	1.392	77.944
2:00	3.0	71.7	108.1	0.00256	1306	1.392	77.944
3:00	2.0	71.6	107.9	0.00379	1306	1.392	77.944
4:00	2.0	71.1	107.5	0.00497	1306	1.392	77.944
5:00	3.0	70.8	107.2	0.00611	1306	1.392	77.944
6:00	4.0	71.0	107.3	0.00725	1306	1.392	77.944
7:00	5.0	71.5	107.8	0.00843	1306	1.392	77.944
8:00	6.0	72.1	108.5	0.00969	1306	1.392	77.944
9:00	6.0	72.9	109.2	0.01105	1306	1.392	77.944
10:00	7.0	73.4	109.7	0.01251	1306	1.392	77.944
11:00	7.0	74.1	110.4	0.01406	1306	1.392	77.944
12:00	9.0	74.5	110.8	0.01572	1306	1.392	77.944
13:00	10.0	75.5	111.8	0.01751	1306	1.392	77.944
14:00	9.0	76.5	112.8	0.01951	1306	1.392	77.944
15:00	9.0	76.8	113.1	0.02164	1306	1.392	77.944
16:00	7.0	77.0	113.3	0.02382	1306	1.392	77.944
17:00	6.0	76.4	112.7	0.02594	1306	1.392	77.944
18:00	5.0	75.6	112.0	0.02792	1306	1.392	77.944
19:00	4.0	74.8	111.1	0.02973	1306	1.392	77.944
20:00	3.0	73.9	110.2	0.03138	1306	1.392	77.944
21:00	3.0	73.0	109.3	0.03287	1306	1.392	77.944
22:00	4.0	72.4	108.7	0.03424	1306	1.392	77.944
23:00	4.0	72.4	108.7	0.03558	1306	1.392	77.944
24:00	3.0	72.3	108.7	0.03691	1306	1.392	77.944

The results based on this load and temperature cycle are:

- o Maximum Capability: 77.9 MVA.
- o Maximum Current: 1306 amps.
- o Maximum Hot-Spot Temperature: 113.3 C at 4:00 pm.
- o Maximum Top Oil Temperature: 77.0 C at 4:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.03691 %.
- o Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.



Power Transformer Temperature Profile for <ID2WNOR>
Max Temp is 113.3
Hot Spot
Max Temp is 77.0
Top Oil
Max Temp is 10.0
Ambient
Temperature Degrees C
120
110
100
90
80
70
60
50
40
30
20
10
0
0
6
12
18
24
Time-of-Day (hours)

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WiINTER 1 t e 4 hour peak starting @ 4 PM
Transformers: Transformer ID #2 30/40/50 OA/FOA/FOA
Comments: McGraw-Edison 55/65 Deg . C
33.6/44.8/56 MVA for 65 deg C

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	56.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	9.3	Input
Top Oil Rise Ambient	37.0	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	35.0	Calc
Winding Time Constant	5	Input
Oil Time Constant	136	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 20.00 hours, followed by a constant higher load for 4.00 hours. The constant higher load is applied at 4 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #2

WINTER LTE(4 hour) RATING, starting @ 4 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	82.1	0.046091	0.046091
2	77.1	0.025213	0.071304
3	83.2	0.052514	0.123818
4	77.4	0.026155	0.149972
5	83.6	0.055054	0.205026
6	77.6	0.026801	0.231827
7	82.8	0.050085	0.281913
8	78.8	0.031012	0.312925
9	80.6	0.03853	0.351455
10	80.6	0.03853	0.389984
11	79.4	0.033347	0.423332
12	82.1	0.046091	0.469423
13	78.7	0.030639	0.500062
14	82.7	0.049495	0.549557
15	77.9	0.0278	0.577357
16	83.6	0.055054	0.63241
17	127.2	5.382923	6.015333
18	134	10.06893	16.08426
19	138	14.41314	30.4974
20	140.2	17.5045	48.0019
21	91.6	0.138555	48.14046
22	79.9	0.03542	48.17588
23	81.3	0.041898	48.21777
24	78.2	0.028834	48.24661

% Loss - of - Life = 0.026804 %

Emergency operation criteria for Loss of Life is .25% per occurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	63.3	82.1	0.00004	938	1.000	56.000
2:00	3.0	58.4	77.1	0.00009	938	1.000	56.000
3:00	2.0	64.5	83.2	0.00014	938	1.000	56.000
4:00	2.0	58.6	77.4	0.00018	938	1.000	56.000
5:00	3.0	64.8	83.6	0.00023	938	1.000	56.000
6:00	4.0	58.9	77.6	0.00028	938	1.000	56.000
7:00	5.0	64.1	82.8	0.00033	938	1.000	56.000
8:00	6.0	60.1	78.8	0.00037	938	1.000	56.000
9:00	6.0	61.9	80.6	0.00042	938	1.000	56.000
10:00	7.0	61.8	80.6	0.00046	938	1.000	56.000
11:00	7.0	60.7	79.4	0.00052	938	1.000	56.000
12:00	9.0	63.3	82.1	0.00056	938	1.000	56.000
13:00	10.0	59.9	78.7	0.00061	938	1.000	56.000
14:00	9.0	63.9	82.7	0.00065	938	1.000	56.000
15:00	9.0	59.2	77.9	0.00070	938	1.000	56.000
16:00	7.0	64.9	83.6	0.00075	1518	1.619	90.647
17:00	6.0	78.0	127.2	0.00626	1518	1.619	90.647
18:00	5.0	84.9	134.0	0.02008	1518	1.619	90.647
19:00	4.0	88.9	138.0	0.04280	1518	1.619	90.647
20:00	3.0	91.1	140.2	0.07296	938	1.000	56.000
21:00	3.0	72.9	91.6	0.07402	938	1.000	56.000
22:00	4.0	61.1	79.9	0.07411	938	1.000	56.000
23:00	4.0	62.6	81.3	0.07415	938	1.000	56.000
24:00	3.0	59.5	78.2	0.07420	938	1.000	56.000

The results based on this load and temperature cycle are:

- o Maximum Capability: 90.6 MVA.
- o Maximum Current: 1518 amps.
- o Maximum Hot-Spot Temperature: 140.2 C at 8:00 pm.
- o Maximum Top Oil Temperature: 91.1 C at 8:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.07420 %.
- o Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 65 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 84 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 84 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	7	3,256	5
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		11 mm Hg		9 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 85 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 134 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 134 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	72,402	87	50,808	59
CO2	0	0	1,053	1	1,053	1
O2	0	0	0	0	0	0
CO	0	0	185	1	185	1
N2	500	4	512	3	512	3
Eff. Total Pressure		5 mm Hg		91 mm Hg		64 mm Hg

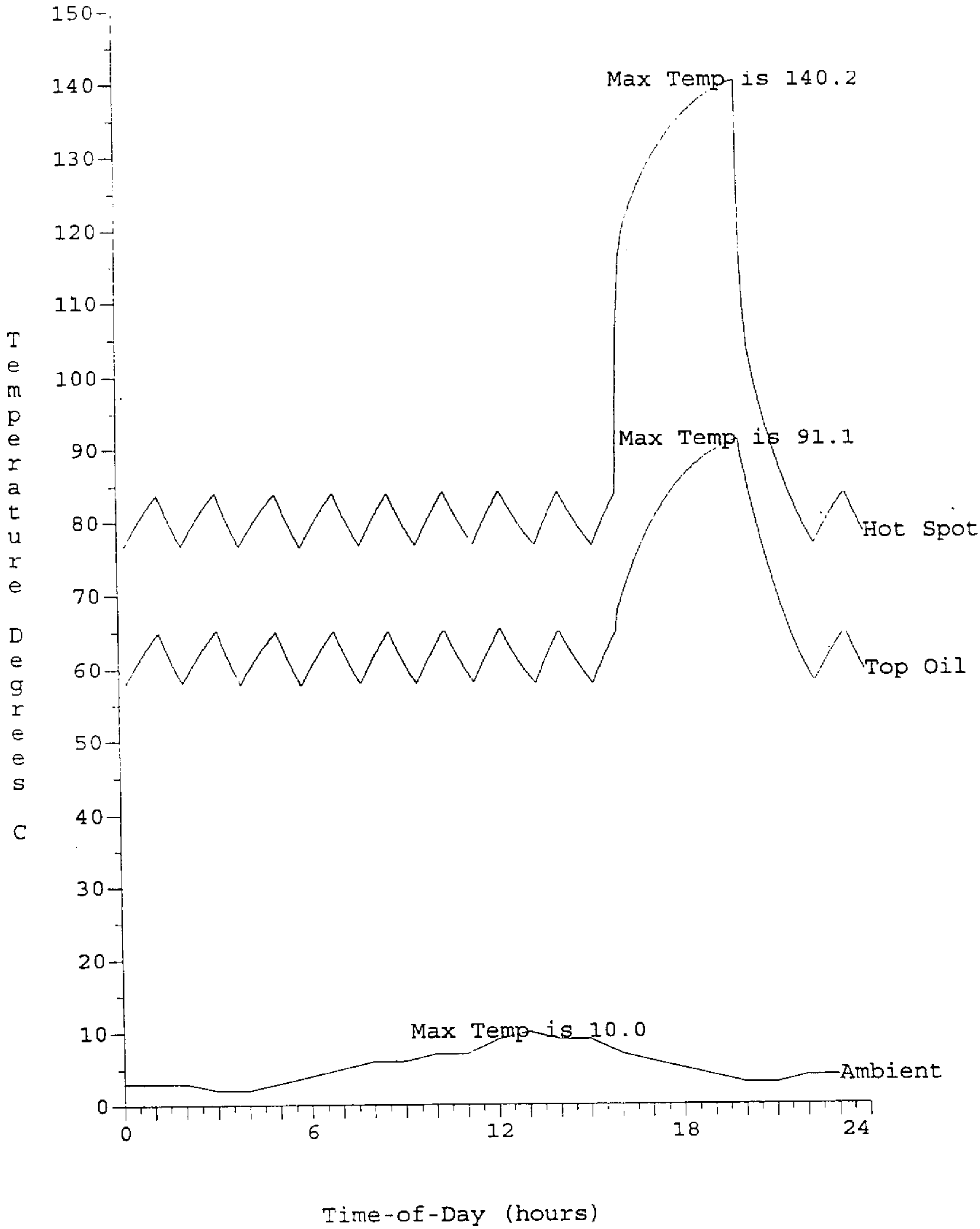
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID2W4LTE>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WiINTER 1 t e 8 hour peak starting @ 2 PM
Transformers: Transformer ID #2 30/40/50 OA/FOA/FOA
Comments: McGraw-Edison 55/65 Deg . C
33.6/44.8/56 MVA for 65 deg C

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	56.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	9.3	Input
Top Oil Rise Ambient	37.0	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	35.0	Calc
Winding Time Constant	5	Input
Oil Time Constant	136	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 16.00 hours, followed by a constant higher load for 8.00 hours. The constant higher load is applied at 2 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #2

WINTER LTE(8 hour) RATING, starting @ 2 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	80.3	0.037167	0.037167
2	79.8	0.034996	0.072163
3	80.9	0.039941	0.112103
4	79.2	0.032551	0.144654
5	81.4	0.042402	0.187056
6	78.5	0.029904	0.21696
7	82.3	0.0472	0.26416
8	77.4	0.026155	0.290315
9	83.9	0.057035	0.34735
10	77.6	0.026801	0.374151
11	81.6	0.043426	0.417578
12	79.5	0.033753	0.45133
13	80.1	0.036283	0.487614
14	80.3	0.037167	0.52478
15	124.9	4.334372	4.859153
16	132.3	8.626754	13.48591
17	136.3	12.38586	25.87177
18	138.6	15.20071	41.07248
19	139.7	16.75132	57.82379
20	140	17.19946	75.02326
21	139.9	17.04884	92.07209
22	139.8	16.89946	108.9716
23	92.5	0.153327	109.1249
24	80.8	0.039465	109.1643

% Loss - of - Life = 0.060647 %

Emergency operation criteria for Loss of Life is .25% per occurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	61.5	80.3	0.00004	938	1.000	56.000
2:00	3.0	61.1	79.8	0.00009	938	1.000	56.000
3:00	2.0	62.2	80.9	0.00013	938	1.000	56.000
4:00	2.0	60.4	79.2	0.00019	938	1.000	56.000
5:00	3.0	62.6	81.4	0.00022	938	1.000	56.000
6:00	4.0	59.8	78.5	0.00028	938	1.000	56.000
7:00	5.0	63.5	82.3	0.00032	938	1.000	56.000
8:00	6.0	58.6	77.4	0.00037	938	1.000	56.000
9:00	6.0	65.2	83.9	0.00042	938	1.000	56.000
10:00	7.0	58.9	77.6	0.00046	938	1.000	56.000
11:00	7.0	62.9	81.6	0.00052	938	1.000	56.000
12:00	9.0	60.7	79.5	0.00055	938	1.000	56.000
13:00	10.0	61.4	80.1	0.00061	938	1.000	56.000
14:00	9.0	61.5	80.3	0.00064	1498	1.597	89.435
15:00	9.0	77.0	124.9	0.00494	1498	1.597	89.435
16:00	7.0	84.4	132.3	0.01635	1498	1.597	89.435
17:00	6.0	88.5	136.3	0.03566	1498	1.597	89.435
18:00	5.0	90.7	138.6	0.06140	1498	1.597	89.435
19:00	4.0	91.8	139.7	0.09131	1498	1.597	89.435
20:00	3.0	92.2	140.0	0.12316	1498	1.597	89.435
21:00	3.0	92.0	139.9	0.15524	1498	1.597	89.435
22:00	4.0	92.0	139.8	0.18699	938	1.000	56.000
23:00	4.0	73.8	92.5	0.18811	938	1.000	56.000
24:00	3.0	62.1	80.8	0.18821	938	1.000	56.000

The results based on this load and temperature cycle are:

- o Maximum Capability: 89.4 MVA.
- o Maximum Current: 1498 amps.
- o Maximum Hot-Spot Temperature: 140.0 C at 8:00 pm.
- o Maximum Top Oil Temperature: 92.2 C at 8:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.18821 %.
- o Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

	Bulk Oil Region		Hot Spot #1		Hot Spot #2	
	62 deg C		80 deg C		80 deg C	
Gas	Bulk H2O	1.00%	Insul H2O	0.64%	Insul H20	0.50%
Component	ppm Vol	mm Hg	ppm Vol	mm Hg	ppm Vol	mm Hg
H2O	3,742	2	3,256	6	3,256	4
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		10 mm Hg		8 mm Hg

Immediately After the Contingency

	Bulk Oil Region		Hot Spot #1		Hot Spot #2	
	85 deg C		133 deg C		133 deg C	
Gas	Bulk H2O	1.00%	Insul H2O	0.64%	Insul H20	0.50%
Component	ppm Vol	mm Hg	ppm Vol	mm Hg	ppm Vol	mm Hg
H2O	3,742	3	67,860	81	47,467	55
CO2	0	0	865	1	865	1
O2	0	0	0	0	0	0
CO	0	0	152	1	152	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		85 mm Hg		59 mm Hg

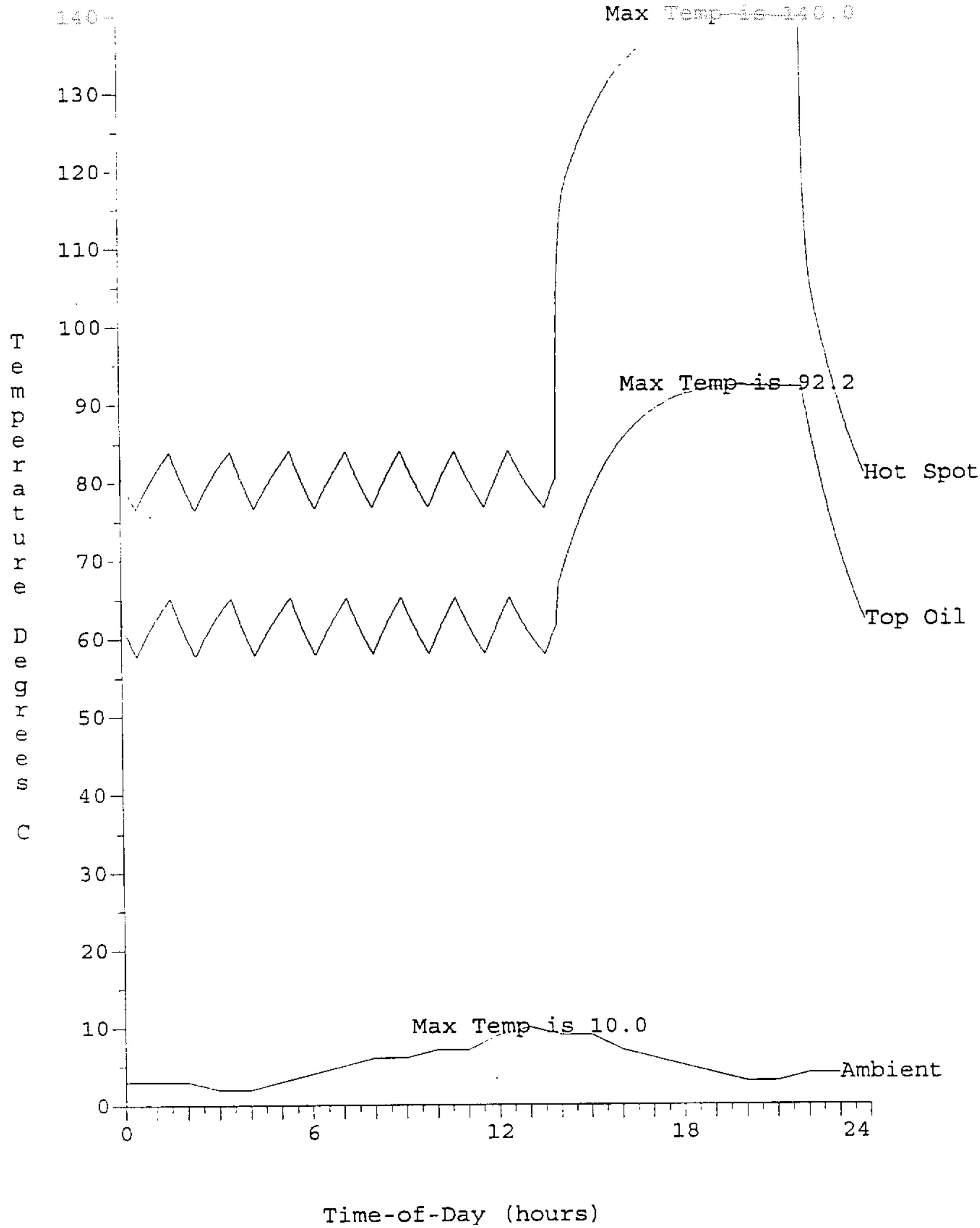
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <1D2W8LTE>



NYPP 1995 Tie-Line Rating Task Force

APPENDIX
D

Transformer ID
#3

200 MVA, 55°C, FOA

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 59 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 78 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 78 deg C Insul H20 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	5	3,256	4
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		9 mm Hg		8 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 74 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 128 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 128 deg C Insul H20 0.50% ppm Vol	mm Hg
H2O	3,742	3	58,496	68	40,768	46
CO2	0	0	628	1	628	1
O2	0	0	0	0	0	0
CO	0	0	110	1	110	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		71 mm Hg		50 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER n o r m a l RATING CALCULATION
Transformers: Trans former ID #3 FOA-T 200MVA, 354/118kV
Comments: General Electric, 3/1961
Data based on tap position #9

Transformer Operates Under Hot Spot Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	200.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	4.9	Input
Top Oil Rise Ambient	31.2	Input
Avg Winding Rise Amb.	65.0	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	29.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	179	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of one repeated daily load cycle.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 105 C
- o Top Oil Temperature: 95 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #3

SUMMER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	92.9	0.791411	0.791411
2	92.4	0.748238	1.53965
3	92.1	0.72342	2.26307
4	91.8	0.699387	2.962457
5	91.7	0.691546	3.654002
6	91.8	0.699387	4.353389
7	92.2	0.731605	5.084994
8	92.8	0.782591	5.867585
9	93.5	0.846348	6.713933
10	94.3	0.925259	7.639191
11	95.4	1.045251	8.684443
12	96.2	1.141661	9.826103
13	96.8	1.219454	11.04556
14	97.2	1.274088	12.31965
15	97.5	1.316583	13.63623
16	97.7	1.345657	14.98189
17	97.9	1.375341	16.35723
18	97.7	1.345657	17.70288
19	97.3	1.288106	18.99099
20	96.7	1.206148	20.19714
21	96	1.116795	21.31393
22	95.2	1.022388	22.33632
23	94.4	0.935601	23.27192
24	93.5	0.846348	24.11827

% Loss - of - Life = 0.013399 %

Normal Loss of Life is .0133%

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

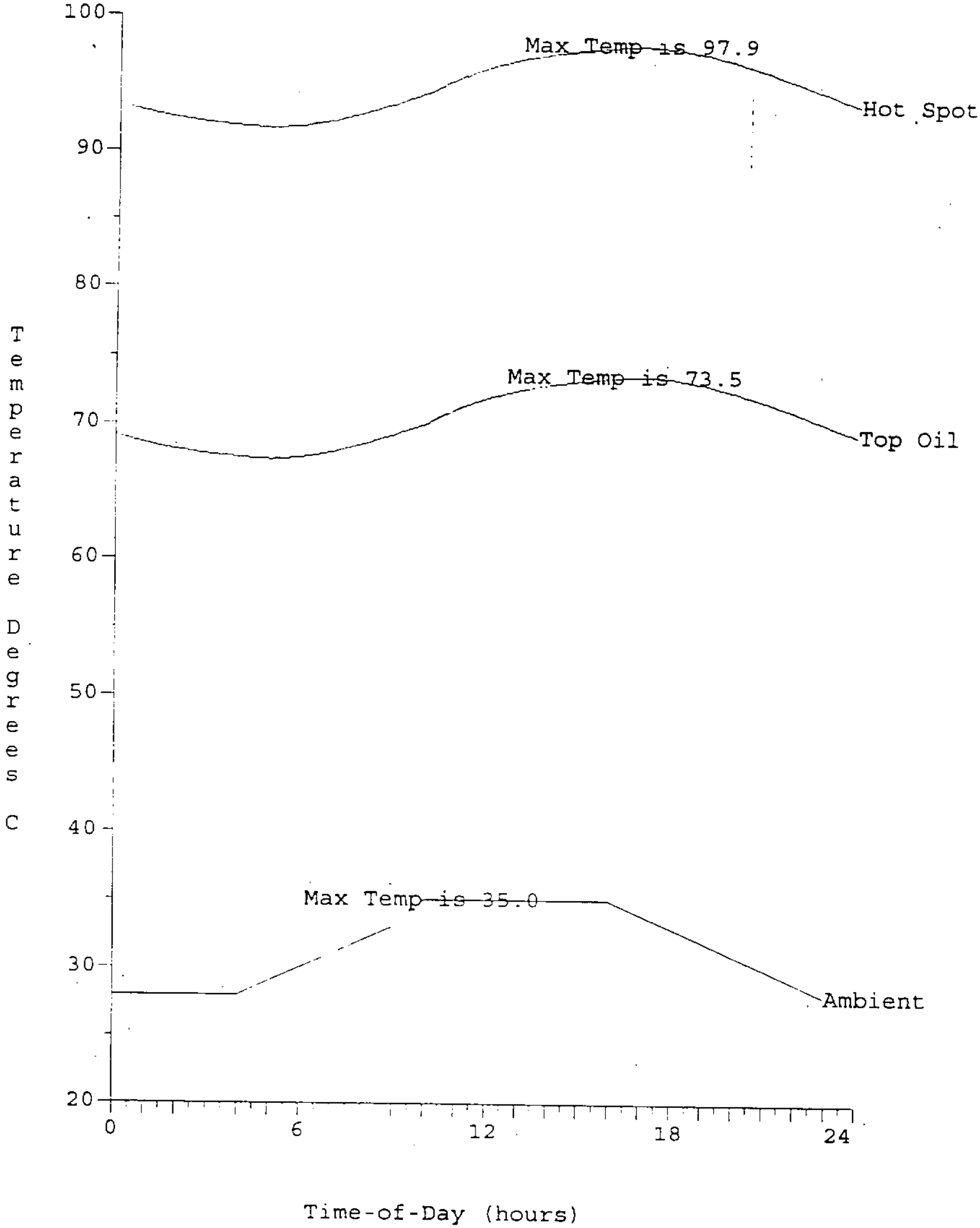
Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	68.5	92.9	0.00123	1139	1.139	227.838
2:00	28.0	68.1	92.4	0.00239	1139	1.139	227.838
3:00	28.0	67.7	92.1	0.00349	1139	1.139	227.838
4:00	28.0	67.5	91.8	0.00456	1139	1.139	227.838
5:00	29.0	67.3	91.7	0.00560	1139	1.139	227.838
6:00	30.0	67.5	91.8	0.00664	1139	1.139	227.838
7:00	31.0	67.9	92.2	0.00773	1139	1.139	227.838
8:00	32.0	68.5	92.8	0.00888	1139	1.139	227.838
9:00	33.0	69.2	93.5	0.01012	1139	1.139	227.838
10:00	35.0	70.0	94.3	0.01147	1139	1.139	227.838
11:00	35.0	71.1	95.4	0.01300	1139	1.139	227.838
12:00	35.0	71.9	96.2	0.01470	1139	1.139	227.838
13:00	35.0	72.5	96.8	0.01655	1139	1.139	227.838
14:00	35.0	72.9	97.2	0.01850	1139	1.139	227.838
15:00	35.0	73.2	97.5	0.02054	1139	1.139	227.838
16:00	35.0	73.4	97.7	0.02263	1139	1.139	227.838
17:00	34.0	73.5	97.9	0.02477	1139	1.139	227.838
18:00	33.0	73.4	97.7	0.02690	1139	1.139	227.838
19:00	32.0	73.0	97.3	0.02896	1139	1.139	227.838
20:00	31.0	72.4	96.7	0.03090	1139	1.139	227.838
21:00	30.0	71.7	96.0	0.03270	1139	1.139	227.838
22:00	29.0	70.9	95.2	0.03435	1139	1.139	227.838
23:00	28.0	70.0	94.4	0.03584	1139	1.139	227.838
24:00	28.0	69.2	93.5	0.03719	1139	1.139	227.838

The results based on this load and temperature cycle are:

- o Maximum Capability: 227.8 MVA.
- o Maximum Current: 1139 amps.
- o Maximum Hot-Spot Temperature: 97.9 C at 5:00 pm.
- o Maximum Top Oil Temperature: 73.5 C at 5:00 pm
- o Cumulative Loss-of-Life for Cycle: 0.03719 %.
- o Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

Power Transformer Temperature Profile for <ID3SNOR>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER 1 t e 4 hour pk staring @ 1 PM
Transformers: Trans former ID #3 FOA-T 200MVA, 354/118kV
Comments: General Electric, 3/1961
Data based on tap position #9

Transformer Operates Under Hot Spot Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	200.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	4.9	Input
Top Oil Rise Ambient	31.2	Input
Avg Winding Rise Amb.	65.0	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	29.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	179	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 20.00 hours, followed by a constant higher load for 4.00 hours. The constant higher load is applied at 1 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #3

SUMMER LTE (4 Hour) RATING ,starting @ 1 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	81.5	0.211771	0.211771
2	80.5	0.187881	0.399653
3	79.7	0.170641	0.570294
4	79.2	0.160643	0.730937
5	78.9	0.154915	0.885853
6	78.9	0.154915	1.040768
7	79.2	0.160643	1.201411
8	79.7	0.170641	1.372053
9	80.3	0.183422	1.555475
10	81.1	0.201887	1.757362
11	82.2	0.230188	1.98755
12	83	0.253102	2.240652
13	83.5	0.26851	2.509162
14	122.2	16.53375	19.04292
15	130.2	35.11009	54.15301
16	135.9	58.97324	113.1262
17	140	84.88157	198.0078
18	104.4	2.76003	200.7678
19	98.3	1.436587	202.2044
20	93.7	0.865453	203.0699
21	90	0.570385	203.6403
22	87.2	0.41368	204.054
23	84.8	0.312862	204.3668
24	82.9	0.250123	204.6169

% Loss - of - Life = 0.113676 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	62.7	81.5	0.00032	1000	1.000	200.000
2:00	28.0	61.7	80.5	0.00059	1000	1.000	200.000
3:00	28.0	61.0	79.7	0.00083	1000	1.000	200.000
4:00	28.0	60.5	79.2	0.00105	1000	1.000	200.000
5:00	29.0	60.1	78.9	0.00127	1000	1.000	200.000
6:00	30.0	60.1	78.9	0.00148	1000	1.000	200.000
7:00	31.0	60.4	79.2	0.00169	1000	1.000	200.000
8:00	32.0	60.9	79.7	0.00191	1000	1.000	200.000
9:00	33.0	61.6	80.3	0.00216	1000	1.000	200.000
10:00	35.0	62.3	81.1	0.00242	1000	1.000	200.000
11:00	35.0	63.4	82.2	0.00272	1000	1.000	200.000
12:00	35.0	64.2	83.0	0.00306	1000	1.000	200.000
13:00	35.0	64.8	83.5	0.00342	1569	1.569	313.844
14:00	35.0	76.0	122.2	0.02138	1569	1.569	313.844
15:00	35.0	84.0	130.2	0.07098	1569	1.569	313.844
16:00	35.0	89.7	135.9	0.16641	1569	1.569	313.844
17:00	34.0	93.8	140.0	0.31727	1000	1.000	200.000
18:00	33.0	85.7	104.4	0.32770	1000	1.000	200.000
19:00	32.0	79.6	98.3	0.33087	1000	1.000	200.000
20:00	31.0	74.9	93.7	0.33257	1000	1.000	200.000
21:00	30.0	71.3	90.0	0.33360	1000	1.000	200.000
22:00	29.0	68.4	87.2	0.33430	1000	1.000	200.000
23:00	28.0	66.1	84.8	0.33481	1000	1.000	200.000
24:00	28.0	64.1	82.9	0.33520	1000	1.000	200.000

The results based on this load and temperature cycle are:

- o Maximum Capability: 313.8 MVA.
- o Maximum Current: 1569 amps.
- o Maximum Hot-Spot Temperature: 140.0 C at 5:00 pm.
- o Maximum Top Oil Temperature: 93.8 C at 5:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.33520 %.
- o Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 65 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 84 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 84 deg C Insul H2O ppm Vol	0.50% mm Hg
H2O	3,742	2	3,256	7	3,256	5
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		11 mm Hg		9 mm Hg

Immediately After the Contingency

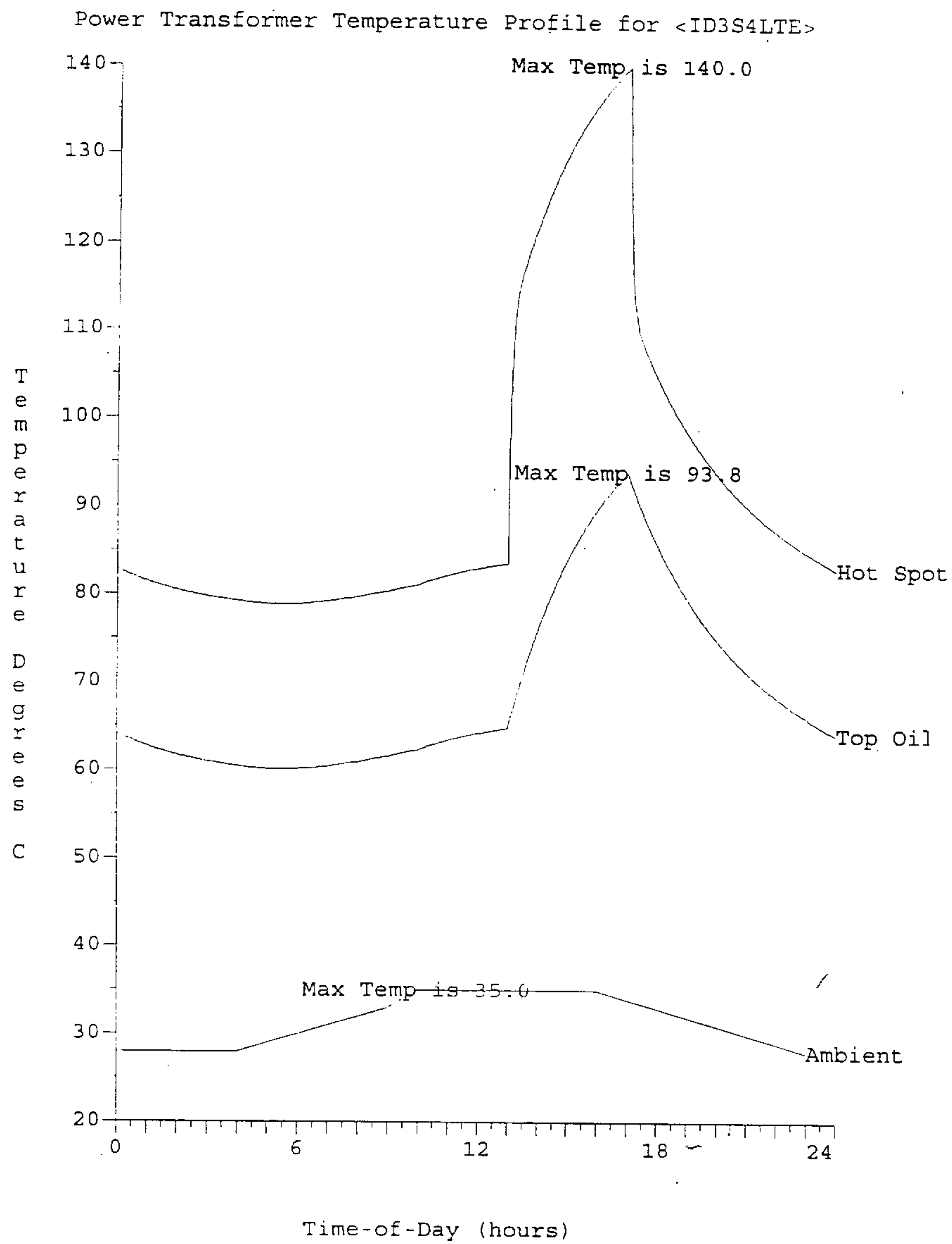
Gas Component	Bulk Oil Region 84 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 131 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 131 deg C Insul H2O ppm Vol	0.50% mm Hg
H2O	3,742	3	62,906	74	43,853	51
CO2	0	0	685	1	685	1
O2	0	0	0	0	0	0
CO	0	0	120	1	120	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		78 mm Hg		54 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.



Power Transformer Temperature Profile for <ID3S4LTE>
Max Temp is 140.0
Max Temp is 93.8
Max Temp is 35.0
Hot Spot
Top Oil
Ambient
Temperature Degrees C
140
130
120
110
100
90
80
70
60
50
40
30
20
0
6
12
18
24
Time-of-Day (hours)

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc

Station: SUMMER 1 t e 8 hour pk starting @ 10 AM
Transformers: Trans former ID #3 FOA-T 200MVA, 354/118kV
Comments: General Electric, 3/1961
Data based on tap position #9

Transformer Operates Under Hot Spot Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	200.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 55 C rise over ambient

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	4.9	Input
Top Oil Rise Ambient	31.2	Input
Avg Winding Rise Amb.	65.0	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	29.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	179	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle
consists of a constant 1.00 P.U. Rated Load for a period of
16.00 hours, followed by a constant higher load for 8.00 hours.
The constant higher load is applied at 10 am.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak
load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #3

SUMMER LTE (8 Hour) RATING ,starting @ 10 AM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	82.5	0.238539	0.238539
2	81.2	0.204316	0.442855
3	80.3	0.183422	0.626277
4	79.6	0.168595	0.794873
5	79.2	0.160643	0.955516
6	79.1	0.158712	1.114228
7	79.3	0.162597	1.276825
8	79.8	0.172711	1.449536
9	80.4	0.185639	1.635175
10	81.1	0.201887	1.837062
11	116.1	9.119075	10.95614
12	123.7	19.08535	30.04149
13	129.2	32.00818	62.04966
14	133.1	45.79406	107.8437
15	135.8	58.44641	166.2901
16	137.8	69.87799	236.1681
17	139.3	79.80561	315.9737
18	140	84.88157	400.8553
19	106.4	3.403349	404.2587
20	99.4	1.618662	405.8773
21	94.2	0.915025	406.7923
22	90.1	0.576913	407.3693
23	86.9	0.399567	407.7688
24	84.4	0.298522	408.0673

% Loss - of - Life = 0.226704 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P:U. NP)	Load (MVA)
1:00	28.0	63.8	82.5	0.00037	1000	1.000	200.000
2:00	28.0	62.5	81.2	0.00068	1000	1.000	200.000
3:00	28.0	61.6	80.3	0.00094	1000	1.000	200.000
4:00	28.0	60.9	79.6	0.00118	1000	1.000	200.000
5:00	29.0	60.4	79.2	0.00140	1000	1.000	200.000
6:00	30.0	60.3	79.1	0.00162	1000	1.000	200.000
7:00	31.0	60.6	79.3	0.00183	1000	1.000	200.000
8:00	32.0	61.0	79.8	0.00206	1000	1.000	200.000
9:00	33.0	61.7	80.4	0.00231	1000	1.000	200.000
10:00	35.0	62.4	81.1	0.00258	1515	1.515	303.031
11:00	35.0	73.0	116.1	0.01221	1515	1.515	303.031
12:00	35.0	80.7	123.7	0.03827	1515	1.515	303.031
13:00	35.0	86.1	129.2	0.08784	1515	1.515	303.031
14:00	35.0	90.0	133.1	0.16562	1515	1.515	303.031
15:00	35.0	92.8	135.8	0.27242	1515	1.515	303.031
16:00	35.0	94.8	137.8	0.40608	1515	1.515	303.031
17:00	34.0	96.2	139.3	0.56278	1515	1.515	303.031
18:00	33.0	97.0	140.0	0.73565	1000	1.000	200.000
19:00	32.0	87.6	106.4	0.74872	1000	1.000	200.000
20:00	31.0	80.7	99.4	0.75250	1000	1.000	200.000
21:00	30.0	75.4	94.2	0.75437	1000	1.000	200.000
22:00	29.0	71.4	90.1	0.75544	1000	1.000	200.000
23:00	28.0	68.2	86.9	0.75613	1000	1.000	200.000
24:00	28.0	65.6	84.4	0.75662	1000	1.000	200.000

The results based on this load and temperature cycle are:

- o Maximum Capability: 303.0 MVA.
- o Maximum Current: 1515 amps.
- o Maximum Hot-Spot Temperature: 140.0 C at 6:00 pm.
- o Maximum Top Oil Temperature: 97.0 C at 6:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.75662 %.
- o Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 62 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 81 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 81 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	6	3,256	4
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		10 mm Hg		8 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 81 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 124 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 124 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	49,510	56	34,304	38
CO2	0	0	373	0	373	0
O2	0	0	0	0	0	0
CO	0	0	65	0	65	0
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		59 mm Hg		41 mm Hg

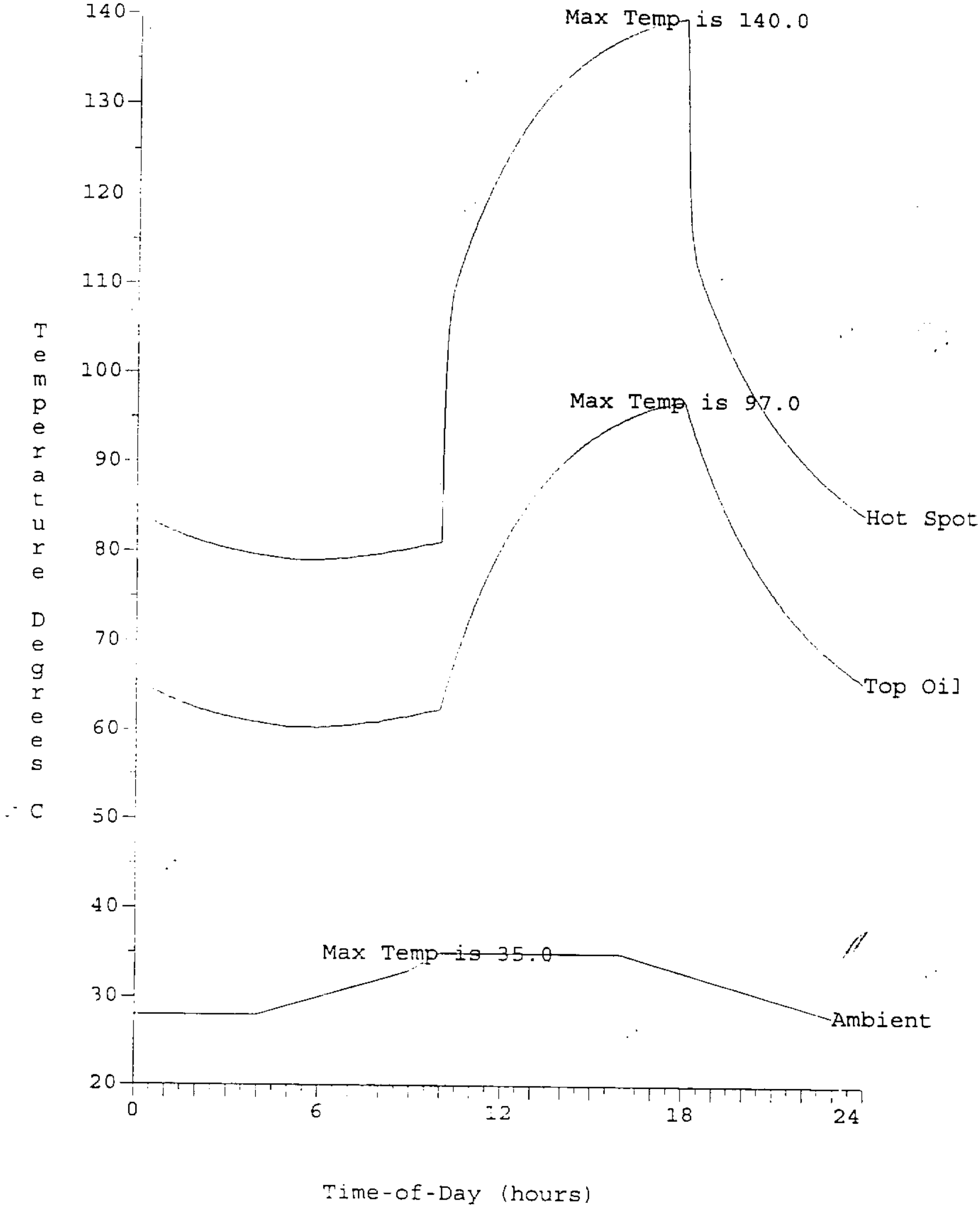
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID3S8LTE>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc

Station: WINTER n o r m a l RATING CALCULATION
Transformers: Transformer ID #3 FOA-T 200MVA, 354/118kV
Comments: General Electric, 3/1961
Data based on tap position #9

Transformer Operates Under Hot Spot Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	200.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	4.9	Input
Top Oil Rise Ambient	31.2	Input
Avg Winding Rise Amb.	65.0	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	29.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	179	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 24.00 hours, followed by a constant higher load for 0 minutes. The constant higher load is applied at 12 am.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 105 C
- o Top Oil Temperature: 95 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #3

WINTER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	94	0.894881	0.894881
2	93.9	0.884967	1.779848
3	93.6	0.85585	2.635697
4	93.3	0.827645	3.463342
5	93.1	0.809335	4.272677
6	92.7	0.773865	5.046542
7	92.4	0.748238	5.79478
8	92.5	0.75669	6.55147
9	92.8	0.782591	7.334061
10	93.3	0.827645	8.161706
11	94	0.894881	9.056587
12	94.5	0.946053	10.00264
13	95.1	1.011135	11.01377
14	95.5	1.056864	12.07064
15	96.4	1.167052	13.23769
16	97.3	1.288106	14.5258
17	97.7	1.345657	15.87145
18	98	1.390416	17.26187
19	97.6	1.331045	18.59291
20	97.1	1.260216	19.85313
21	96.4	1.167052	21.02018
22	95.6	1.0686	22.08878
23	94.8	0.978079	23.06686
24	94.2	0.915025	23.98189

% Loss - of - Life = 0.013323 %

Normal Loss of Life is .0133%

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

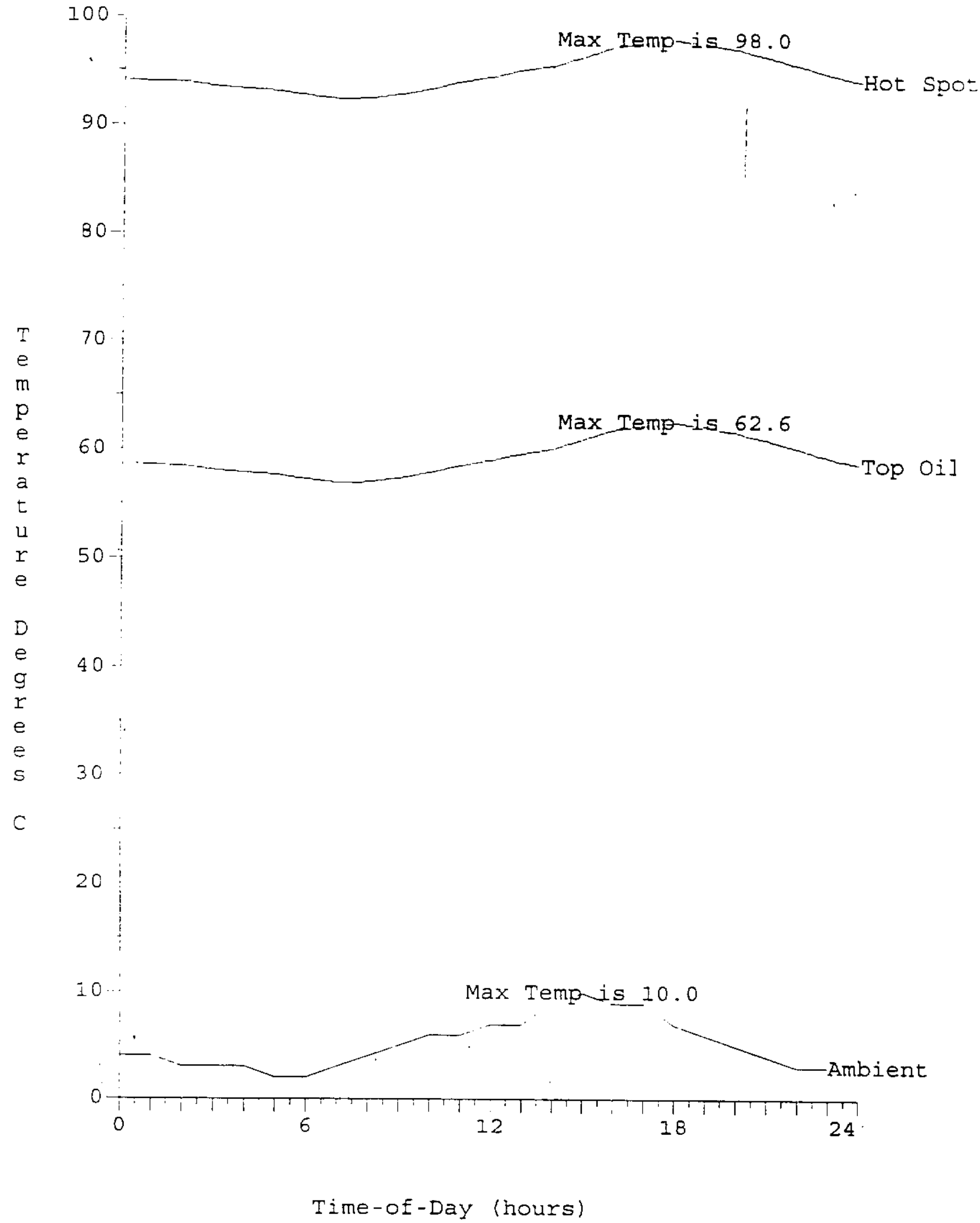
Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	4.0	58.6	94.0	0.00138	1374	1.374	274.858
2:00	3.0	58.5	93.9	0.00274	1374	1.374	274.858
3:00	3.0	58.1	93.6	0.00406	1374	1.374	274.858
4:00	3.0	57.9	93.3	0.00533	1374	1.374	274.858
5:00	2.0	57.7	93.1	0.00657	1374	1.374	274.858
6:00	2.0	57.3	92.7	0.00777	1374	1.374	274.858
7:00	3.0	57.0	92.4	0.00891	1374	1.374	274.858
8:00	4.0	57.1	92.5	0.01005	1374	1.374	274.858
9:00	5.0	57.4	92.8	0.01121	1374	1.374	274.858
10:00	6.0	57.9	93.3	0.01244	1374	1.374	274.858
11:00	6.0	58.6	94.0	0.01375	1374	1.374	274.858
12:00	7.0	59.1	94.5	0.01516	1374	1.374	274.858
13:00	7.0	59.7	95.1	0.01667	1374	1.374	274.858
14:00	9.0	60.1	95.5	0.01827	1374	1.374	274.858
15:00	10.0	61.0	96.4	0.02001	1374	1.374	274.858
16:00	9.0	61.9	97.3	0.02194	1374	1.374	274.858
17:00	9.0	62.3	97.7	0.02402	1374	1.374	274.858
18:00	7.0	62.6	98.0	0.02617	1374	1.374	274.858
19:00	6.0	62.2	97.6	0.02830	1374	1.374	274.858
20:00	5.0	61.6	97.1	0.03032	1374	1.374	274.858
21:00	4.0	61.0	96.4	0.03219	1374	1.374	274.858
22:00	3.0	60.2	95.6	0.03391	1374	1.374	274.858
23:00	3.0	59.3	94.8	0.03548	1374	1.374	274.858
24:00	4.0	58.7	94.2	0.03691	1374	1.374	274.858

The results based on this load and temperature cycle are:

- Maximum Capability: 274.9 MVA.
- Maximum Current: 1374 amps.
- Maximum Hot-Spot Temperature: 98.0 C at 6:00 pm.
- Maximum Top Oil Temperature: 62.6 C at 6:00 pm
- Cumulative Loss-of-Life for Cycle: 0.03691 %.
- Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

Power Transformer Temperature Profile for <ID3WN>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WINTER 1 t e 4 hour peak starting @ 4 PM
Transformers: Transformer ID #3 FOA-T 200MVA, 354/118kV
Comments: General Electric, 3/1961
Data based on tap position #9

Transformer Operates Under Hot Spot Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	200.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	4.9	Input
Top Oil Rise Ambient	31.2	Input
Avg Winding Rise Amb.	65.0	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	29.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	179	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 20.00 hours, followed by a constant higher load for 4.00 hours. The constant higher load is applied at 4 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #3

WINTER LTE (4 Hour) RATING ,starting @ 4 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	76.5	0.115604	0.115604
2	79	0.156803	0.272407
3	77.5	0.130663	0.403069
4	70.5	0.054626	0.457695
5	73.6	0.080727	0.538422
6	76.3	0.112798	0.65122
7	78.3	0.144038	0.795257
8	79.9	0.174804	0.970062
9	72.9	0.073957	1.044019
10	72.2	0.067732	1.111751
11	76.4	0.114193	1.225943
12	79.5	0.166573	1.392516
13	74.6	0.09143	1.483946
14	70.1	0.051914	1.535861
15	75.8	0.106063	1.641924
16	80.2	0.18123	1.823154
17	127.1	26.31771	28.14087
18	133.4	47.05988	75.20074
19	137.4	67.43485	142.6356
20	140	84.88157	227.5172
21	88.6	0.486056	228.0032
22	78.7	0.151205	228.1544
23	71.4	0.061229	228.2157
24	73.1	0.075834	228.2915

% Loss - of - Life = 0.126829 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	4.0	57.8	76.5	0.00013	1000	1.000	200.000
2:00	3.0	60.2	79.0	0.00031	1000	1.000	200.000
3:00	3.0	58.7	77.5	0.00053	1000	1.000	200.000
4:00	3.0	51.7	70.5	0.00064	1000	1.000	200.000
5:00	2.0	54.9	73.6	0.00072	1000	1.000	200.000
6:00	2.0	57.6	76.3	0.00085	1000	1.000	200.000
7:00	3.0	59.5	78.3	0.00102	1000	1.000	200.000
8:00	4.0	61.2	79.9	0.00124	1000	1.000	200.000
9:00	5.0	54.2	72.9	0.00139	1000	1.000	200.000
10:00	6.0	53.4	72.2	0.00147	1000	1.000	200.000
11:00	6.0	57.7	76.4	0.00159	1000	1.000	200.000
12:00	7.0	60.7	79.5	0.00178	1000	1.000	200.000
13:00	7.0	55.9	74.6	0.00196	1000	1.000	200.000
14:00	9.0	51.4	70.1	0.00204	1000	1.000	200.000
15:00	10.0	57.1	75.8	0.00214	1000	1.000	200.000
16:00	9.0	61.4	80.2	0.00234	1739	1.739	347.879
17:00	9.0	70.3	127.1	0.03403	1739	1.739	347.879
18:00	7.0	76.7	133.4	0.10720	1739	1.739	347.879
19:00	6.0	80.7	137.4	0.22577	1739	1.739	347.879
20:00	5.0	83.3	140.0	0.38617	1000	1.000	200.000
21:00	4.0	69.9	88.6	0.38979	1000	1.000	200.000
22:00	3.0	60.0	78.7	0.39018	1000	1.000	200.000
23:00	3.0	52.6	71.4	0.39030	1000	1.000	200.000
24:00	4.0	54.3	73.1	0.39038	1000	1.000	200.000

The results based on this load and temperature cycle are:

- Maximum Capability: 347.9 MVA.
- Maximum Current: 1739 amps.
- Maximum Hot-Spot Temperature: 140.0 C at 8:00 pm.
- Maximum Top Oil Temperature: 83.3 C at 8:00 pm
- Cumulative Loss-of-Life for Cycle: 0.39038 %.
- Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 61 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 80 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 80 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	6	3,256	4
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		10 mm Hg		8 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 77 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 134 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 134 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	71,196	85	49,961	58
CO2	0	0	1,035	1	1,035	1
O2	0	0	0	0	0	0
CO	0	0	181	1	181	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		90 mm Hg		63 mm Hg

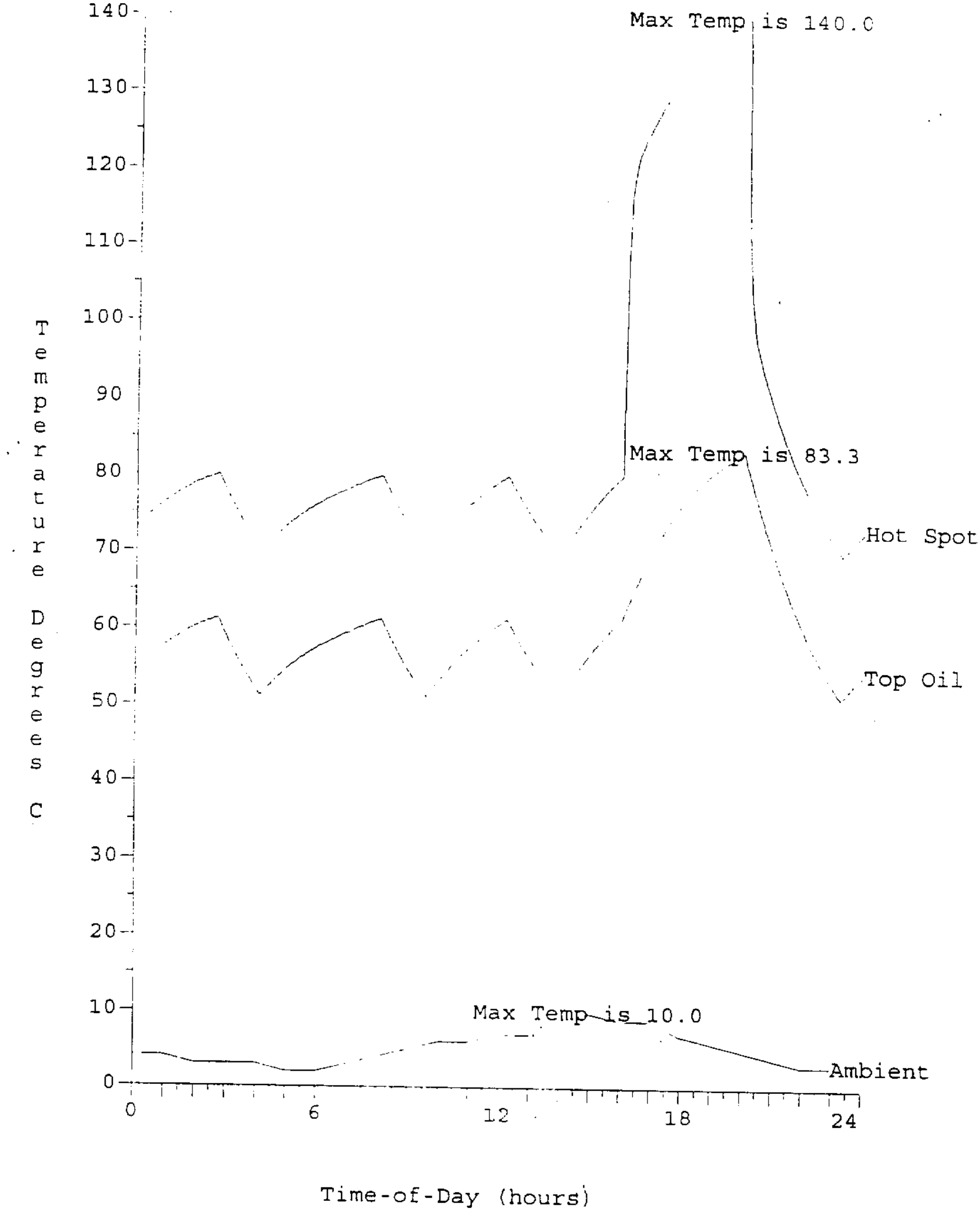
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID3W4LTE>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WINTER 1 t e 8 hour peak starting @ 2 PM
Transformers: Transformer ID #3 FOA-T 200MVA, 354/118kV
Comments: General Electric, 3/1961
Data based on tap position #9

Transformer Operates Under Hot Spot Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	200.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 55 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	4.9	Input
Top Oil Rise Ambient	31.2	Input
Avg Winding Rise Amb.	65.0	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	29.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	179	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 16.00 hours, followed by a constant higher load for 8.00 hours The constant higher load is applied at 2 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 100 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

55 deg. C Class

Transformer ID #3

WINTER LTE (8 Hour) RATING ,starting @ 2 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	71.6	0.062796	0.062796
2	73.1	0.075834	0.138631
3	76.2	0.111419	0.25005
4	78.5	0.14758	0.39763
5	79.6	0.168595	0.566225
6	71.7	0.063594	0.629819
7	72.6	0.071225	0.701045
8	75.9	0.107379	0.808424
9	78.5	0.14758	0.956004
10	77.2	0.125959	1.081963
11	71.2	0.059699	1.141662
12	73.8	0.082767	1.224429
13	77.9	0.137195	1.361624
14	77.8	0.135533	1.497157
15	121.8	15.91001	17.40717
16	128.2	29.16686	46.57403
17	132.5	43.35842	89.93245
18	135.6	57.40607	147.3385
19	137.2	66.24378	213.5823
20	138.1	71.765	285.3473
21	138.4	73.70011	359.0474
22	138.4	73.70011	432.7475
23	88.7	0.491663	433.2392
24	78.5	0.14758	433.3867

% Loss - of - Life = 0.24077 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	4.0	52.8	71.6	0.00012	1000	1.000	200.000
2:00	3.0	54.3	73.1	0.00020	1000	1.000	200.000
3:00	3.0	57.5	76.2	0.00033	1000	1.000	200.000
4:00	3.0	59.7	78.5	0.00050	1000	1.000	200.000
5:00	2.0	60.8	79.6	0.00072	1000	1.000	200.000
6:00	2.0	53.0	71.7	0.00086	1000	1.000	200.000
7:00	3.0	53.9	72.6	0.00093	1000	1.000	200.000
8:00	4.0	57.1	75.9	0.00105	1000	1.000	200.000
9:00	5.0	59.8	78.5	0.00122	1000	1.000	200.000
10:00	6.0	58.5	77.2	0.00143	1000	1.000	200.000
11:00	6.0	52.4	71.2	0.00155	1000	1.000	200.000
12:00	7.0	55.0	73.8	0.00163	1000	1.000	200.000
13:00	7.0	59.1	77.9	0.00177	1000	1.000	200.000
14:00	9.0	59.1	77.8	0.00198	1699	1.699	339.867
15:00	10.0	67.6	121.8	0.02061	1699	1.699	339.867
16:00	9.0	74.0	128.2	0.06389	1699	1.699	339.867
17:00	9.0	78.3	132.5	0.13629	1699	1.699	339.867
18:00	7.0	81.4	135.6	0.23909	1699	1.699	339.867
19:00	6.0	83.1	137.2	0.36678	1699	1.699	339.867
20:00	5.0	83.9	138.1	0.51009	1699	1.699	339.867
21:00	4.0	84.3	138.4	0.66157	1699	1.699	339.867
22:00	3.0	84.2	138.4	0.81498	1000	1.000	200.000
23:00	3.0	70.0	88.7	0.81862	1000	1.000	200.000
24:00	4.0	59.8	78.5	0.81900	1000	1.000	200.000

The results based on this load and temperature cycle are:

- Maximum Capability: 339.9 MVA.
- Maximum Current: 1699 amps.
- Maximum Hot-Spot Temperature: 138.4 C at 9:00 pm.
- Maximum Top Oil Temperature: 84.3 C at 9:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.81900 %.
- Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 59 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 78 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 78 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	5	3,256	4
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		9 mm Hg		8 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 74 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 128 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 128 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	58,496	68	40,768	46
CO2	0	0	628	1	628	1
O2	0	0	0	0	0	0
CO	0	0	110	1	110	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		71 mm Hg		50 mm Hg

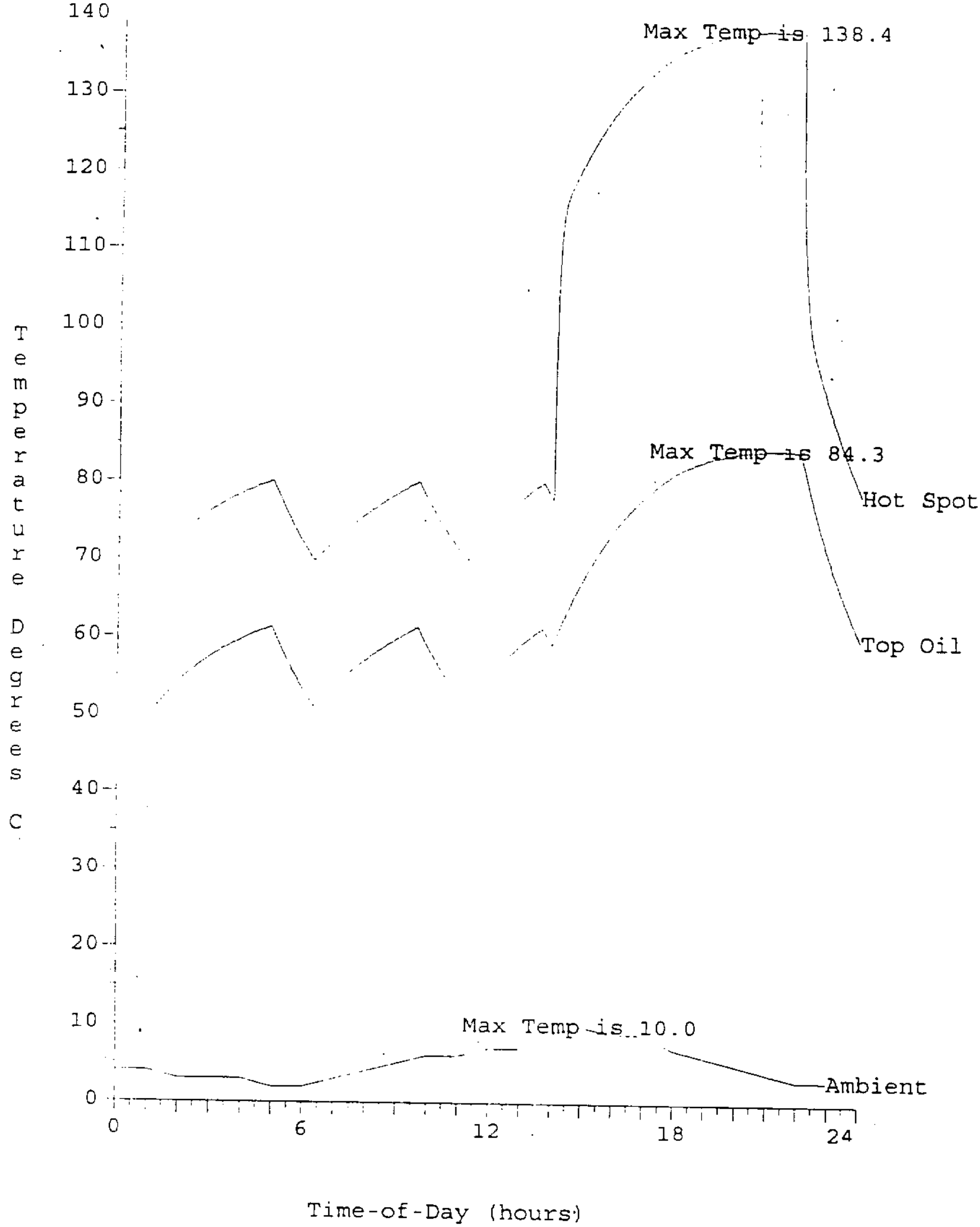
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID3W8LTE>



NYPP 1995 Tie-Line Rating Task Force

APPENDIX

D

Transformer ID
#4

224 MVA, 65°C, FOA

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER n o r m a l RATING CALCULATION
Transformers: Transformer ID #4 224(MVA(65 Deg C) foa-t
Comments: General Electric, 3/1965
126/69 kV

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	224.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	7.4	Input
Top Oil Rise Ambient	42.2	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	40.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	132	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of one repeated daily load cycle

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 120 C
- Top Oil Temperature: 105 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #4

SUMMER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	106.8	0.718938	0.718938
2	106.5	0.696839	1.415777
3	106.4	0.689617	2.105394
4	106.3	0.682466	2.787861
5	106.6	0.704133	3.491993
6	107.1	0.741702	4.233695
7	107.8	0.797506	5.031201
8	108.7	0.875126	5.906328
9	109.6	0.959881	6.866209
10	110.8	1.08506	7.951269
11	111.7	1.188948	9.140217
12	112.2	1.250672	10.39089
13	112.5	1.289152	11.68004
14	112.7	1.315427	12.99547
15	112.9	1.34221	14.33768
16	113	1.355794	15.69347
17	112.6	1.302227	16.9957
18	112.1	1.238089	18.23379
19	111.4	1.153313	19.3871
20	110.5	1.052388	20.43949
21	109.6	0.959881	21.39937
22	108.7	0.875126	22.2745
23	107.8	0.797506	23.072
24	107.2	0.74944	23.82144

% Loss - of - Life = 0.013234 %

Normal Loss of Life is .0133%

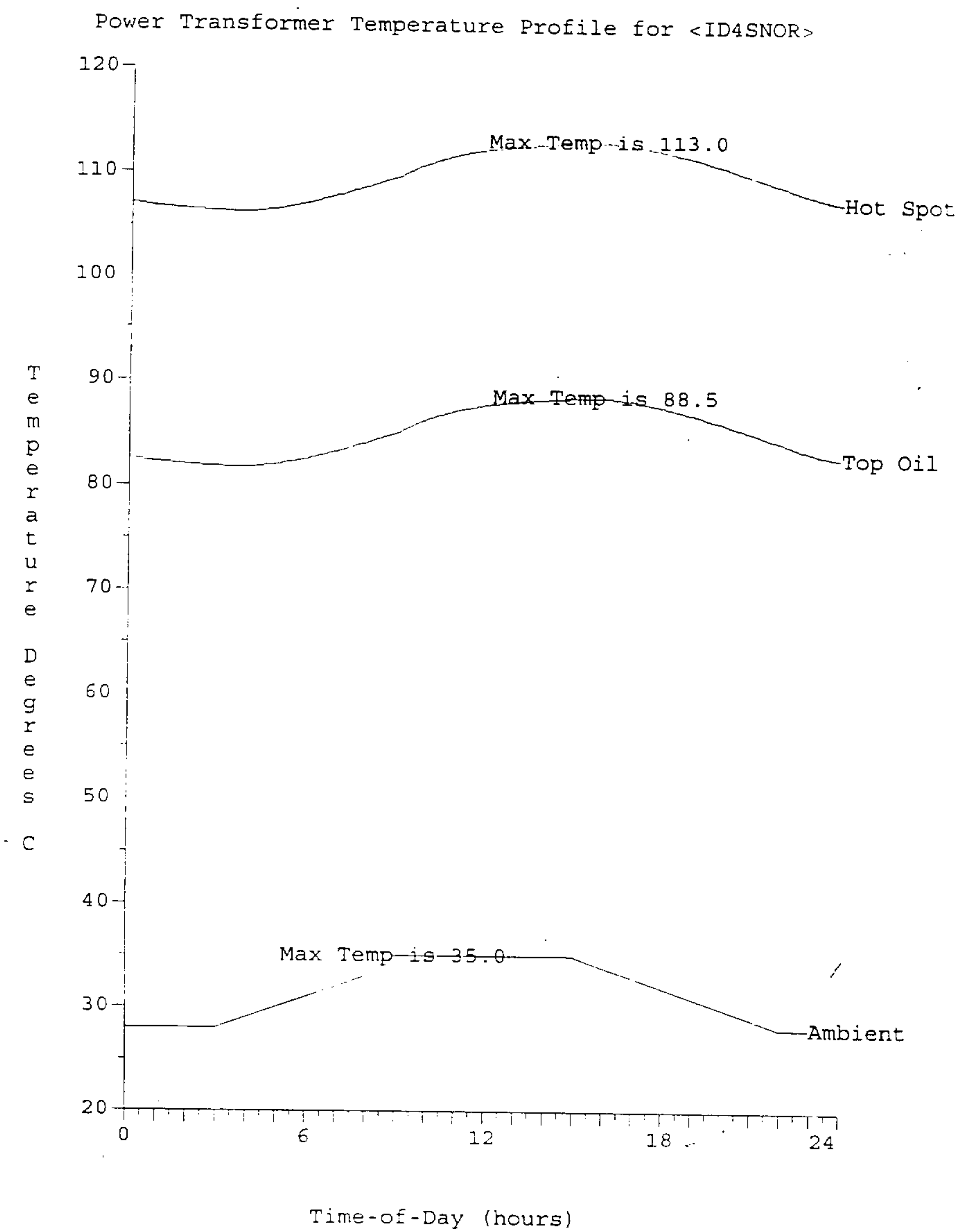
TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures (Deg C) > Ambient	Top Oil	Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	82.3	106.8	0.00110	2383	1.143	256.041
2:00	28.0	82.0	106.5	0.00216	2383	1.143	256.041
3:00	28.0	81.9	106.4	0.00319	2383	1.143	256.041
4:00	29.0	81.8	106.3	0.00422	2383	1.143	256.041
5:00	30.0	82.1	106.6	0.00525	2383	1.143	256.041
6:00	31.0	82.6	107.1	0.00635	2383	1.143	256.041
7:00	32.0	83.3	107.8	0.00752	2383	1.143	256.041
8:00	33.0	84.2	108.7	0.00880	2383	1.143	256.041
9:00	35.0	85.1	109.6	0.01020	2383	1.143	256.041
10:00	35.0	86.4	110.8	0.01179	2383	1.143	256.041
11:00	35.0	87.2	111.7	0.01356	2383	1.143	256.041
12:00	35.0	87.7	112.2	0.01547	2383	1.143	256.041
13:00	35.0	88.0	112.5	0.01746	2383	1.143	256.041
14:00	35.0	88.2	112.7	0.01951	2383	1.143	256.041
15:00	35.0	88.4	112.9	0.02159	2383	1.143	256.041
16:00	34.0	88.5	113.0	0.02371	2383	1.143	256.041
17:00	33.0	88.1	112.6	0.02578	2383	1.143	256.041
18:00	32.0	87.6	112.1	0.02776	2383	1.143	256.041
19:00	31.0	86.9	111.4	0.02961	2383	1.143	256.041
20:00	30.0	86.0	110.5	0.03131	2383	1.143	256.041
21:00	29.0	85.1	109.6	0.03285	2383	1.143	256.041
22:00	28.0	84.2	108.7	0.03425	2383	1.143	256.041
23:00	28.0	83.3	107.8	0.03550	2383	1.143	256.041
24:00	28.0	82.7	107.2	0.03666	2383	1.143	256.041

The results based on this load and temperature cycle are:

- Maximum Capability: 256.0 MVA.
- Maximum Current: 2383 amps.
- Maximum Hot-Spot Temperature: 113.0 C at 4:00 pm.
- Maximum Top Oil Temperature: 88.5 C at 4:00 pm
- Cumulative Loss-of-Life for Cycle: 0.03666 %.
- Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.



Power Transformer Temperature Profile for <ID4SNOR>
120
110
100
90
80
70
60
50
40
30
20
Temperature Degrees C
Max Temp is 113.0
Hot Spot
Max Temp is 88.5
Top Oil
Max Temp is 35.0
Ambient
0
6
12
18
24
Time-of-Day (hours)

Date 08-08-1995 and Time 11:06

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER 1 t e 4 hour peak starting @ 1 PM
Transformers: Transformer ID #4 224(MVA(65 Deg C) foa-t
Comments: General Electric, 3/1965
126/69 kV

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	224.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	7.4	Input
Top Oil Rise Ambient	42.2	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	40.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	132	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 20.00 hours, followed by a constant higher load for 4.00 hours. The constant higher load is applied at 1 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #4

SUMMER LTE (4 Hour) RATING ,starting @ 1 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	90.4	0.120955	0.120955
2	89.8	0.112973	0.233928
3	89.5	0.109173	0.343101
4	89.3	0.106708	0.449809
5	89.5	0.109173	0.558982
6	90.1	0.116899	0.675882
7	90.7	0.125144	0.801025
8	91.6	0.138555	0.939581
9	92.4	0.151615	1.091195
10	93.7	0.175366	1.266561
11	94.5	0.191698	1.458259
12	95	0.202629	1.660888
13	95.4	0.211798	1.872686
14	124.4	4.133589	6.006275
15	132.3	8.626754	14.63303
16	137.2	13.42291	28.05594
17	140	17.19946	45.2554
18	112.6	1.302227	46.55763
19	105.4	0.621201	47.17883
20	100.5	0.369298	47.54813
21	97	0.252574	47.8007
22	94.4	0.18958	47.99028
23	92.4	0.151615	48.1419
24	91.2	0.132434	48.27433

% Loss - of - Life = 0.026819 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U, NP)	Load (MVA)
1:00	28.0	71.6	90.4	0.00017	2085	1.000	224.000
2:00	28.0	71.1	89.8	0.00032	2085	1.000	224.000
3:00	28.0	70.8	89.5	0.00047	2085	1.000	224.000
4:00	29.0	70.6	89.3	0.00061	2085	1.000	224.000
5:00	30.0	70.8	89.5	0.00075	2085	1.000	224.000
6:00	31.0	71.3	90.1	0.00090	2085	1.000	224.000
7:00	32.0	72.0	90.7	0.00106	2085	1.000	224.000
8:00	33.0	72.8	91.6	0.00124	2085	1.000	224.000
9:00	35.0	73.7	92.4	0.00144	2085	1.000	224.000
10:00	35.0	75.0	93.7	0.00166	2085	1.000	224.000
11:00	35.0	75.8	94.5	0.00191	2085	1.000	224.000
12:00	35.0	76.3	95.0	0.00218	2085	1.000	224.000
13:00	35.0	76.6	95.4	0.00247	2868	1.376	308.113
14:00	35.0	89.0	124.4	0.00657	2868	1.376	308.113
15:00	35.0	96.8	132.3	0.01779	2868	1.376	308.113
16:00	34.0	101.7	137.2	0.03812	2868	1.376	308.113
17:00	33.0	104.5	140.0	0.06701	2085	1.000	224.000
18:00	32.0	93.8	112.6	0.07132	2085	1.000	224.000
19:00	31.0	86.7	105.4	0.07266	2085	1.000	224.000
20:00	30.0	81.7	100.5	0.07335	2085	1.000	224.000
21:00	29.0	78.3	97.0	0.07377	2085	1.000	224.000
22:00	28.0	75.7	94.4	0.07407	2085	1.000	224.000
23:00	28.0	73.7	92.4	0.07430	2085	1.000	224.000
24:00	28.0	72.4	91.2	0.07449	2085	1.000	224.000

The results based on this load and temperature cycle are:

- Maximum Capability: 308.1 MVA.
- Maximum Current: 2868 amps.
- Maximum Hot-Spot Temperature: 140.0 C at 5:00 pm.
- Maximum Top Oil Temperature: 104.5 C at 5:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.07449 %.
- Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 77 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 95 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 95 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	3,256	14	3,256	10
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		18 mm Hg		13 mm Hg

Immediately After the Contingency

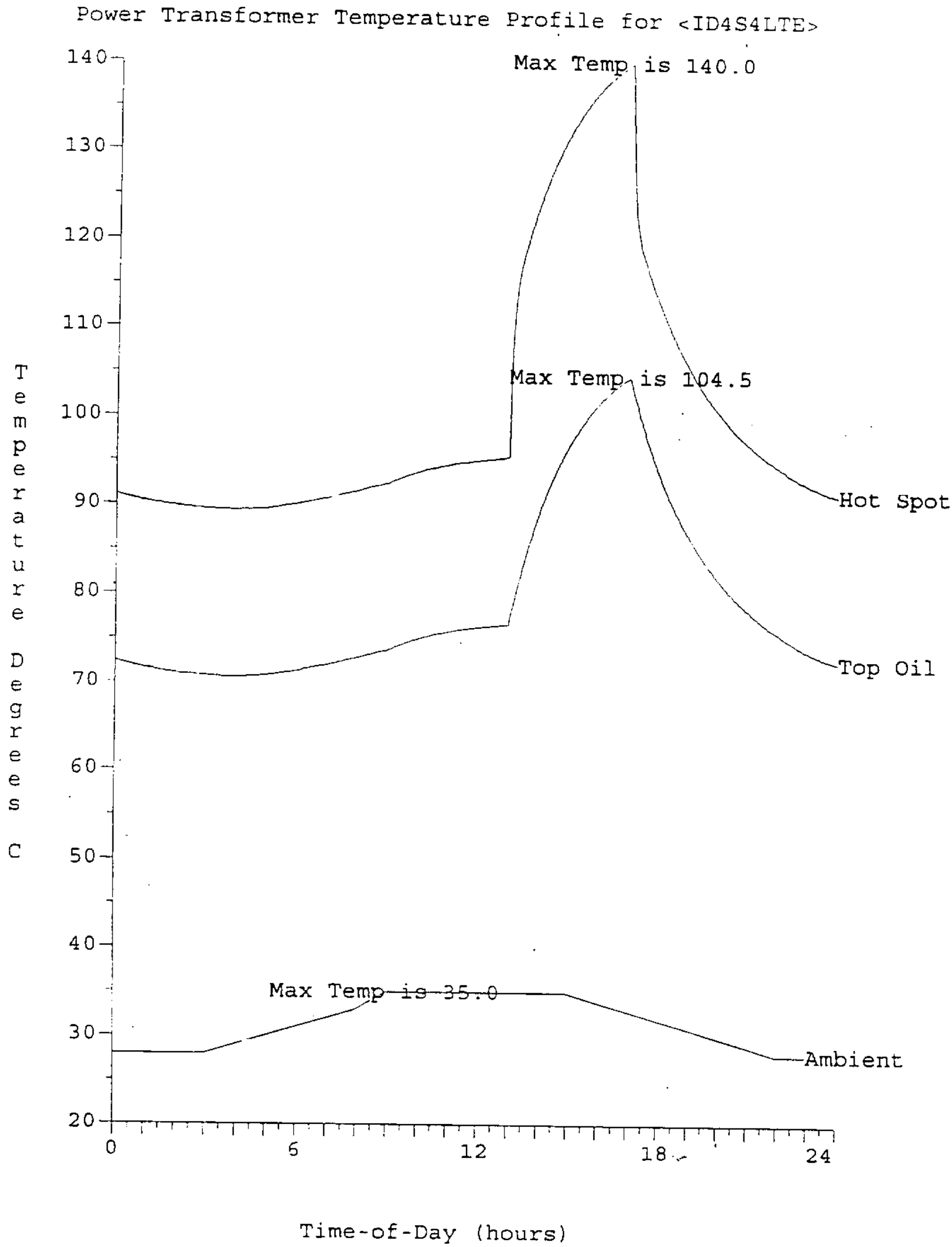
Gas Component	Bulk Oil Region 97 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 133 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 133 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	68,004	81	47,542	55
CO2	0	0	847	1	847	1
O2	0	0	0	0	0	0
CO	0	0	149	1	149	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		85 mm Hg		60 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.



Power Transformer Temperature Profile for <ID4S4LTE>
Max Temp is 140.0
Max Temp is 104.5
Max Temp is 35.0
Hot Spot
Top Oil
Ambient
Temperature Degrees C
140
130
120
110
100
90
80
70
60
50
40
30
20
0
6
12
18
24
Time-of-Day (hours)

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: SUMMER 1 t e 8 hour peak starting @ 10 AM
Transformers: Transformer ID #4 224(MVA(65 Deg C) foa-t
Comments: General Electric, 3/1965
126/69 kV

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	224.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	7.4	Input
Top Oil Rise Ambient	42.2	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	40.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	132	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 16.00 hours, followed by a constant higher load for 8.00 hours. The constant higher load is applied at 10 am.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 140 C
- Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #4

SUMMER LTE (8 Hour) RATING ,starting @ 10 AM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	90.8	0.126571	0.126571
2	90.2	0.118236	0.244807
3	89.7	0.111693	0.3565
4	89.4	0.107934	0.464434
5	89.6	0.110426	0.57486
6	90.1	0.116899	0.691759
7	90.8	0.126571	0.81833
8	91.6	0.138555	0.956885
9	92.4	0.151615	1.1085
10	93.7	0.175366	1.283866
11	121	2.984478	4.268344
12	128.6	6.134283	10.40263
13	133.4	9.535694	19.93832
14	136.4	12.49723	32.43555
15	138.4	14.93378	47.36933
16	139.6	16.6044	63.97373
17	140	17.19946	81.17319
18	139.9	17.04884	98.22203
19	113	1.355794	99.57783
20	105.3	0.614725	100.1926
21	100.1	0.353735	100.5463
22	96.4	0.236479	100.7828
23	93.7	0.175366	100.9581
24	91.9	0.143322	101.1015

% Loss - of - Life = 0.056167 %

Emergency operation criteria Loss of Life is .25% per occcurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	Ambient (Temperatures Deg C)	Top Oil (Temperatures Deg C)	Hot Spot (Temperatures Deg C)	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	28.0	72.1	90.8	0.00018	2085	1.000	224.000
2:00	28.0	71.4	90.2	0.00034	2085	1.000	224.000
3:00	28.0	71.0	89.7	0.00049	2085	1.000	224.000
4:00	29.0	70.7	89.4	0.00064	2085	1.000	224.000
5:00	30.0	70.9	89.6	0.00078	2085	1.000	224.000
6:00	31.0	71.4	90.1	0.00093	2085	1.000	224.000
7:00	32.0	72.0	90.8	0.00109	2085	1.000	224.000
8:00	33.0	72.8	91.6	0.00127	2085	1.000	224.000
9:00	35.0	73.7	92.4	0.00147	2085	1.000	224.000
10:00	35.0	75.0	93.7	0.00169	2811	1.348	302.050
11:00	35.0	86.9	121.0	0.00460	2811	1.348	302.050
12:00	35.0	94.5	128.6	0.01244	2811	1.348	302.050
13:00	35.0	99.3	133.4	0.02651	2811	1.348	302.050
14:00	35.0	102.3	136.4	0.04681	2811	1.348	302.050
15:00	35.0	104.3	138.4	0.07237	2811	1.348	302.050
16:00	34.0	105.5	139.6	0.10192	2811	1.348	302.050
17:00	33.0	105.9	140.0	0.13369	2811	1.348	302.050
18:00	32.0	105.8	139.9	0.16583	2085	1.000	224.000
19:00	31.0	94.3	113.0	0.17048	2085	1.000	224.000
20:00	30.0	86.6	105.3	0.17185	2085	1.000	224.000
21:00	29.0	81.3	100.1	0.17251	2085	1.000	224.000
22:00	28.0	77.6	96.4	0.17291	2085	1.000	224.000
23:00	28.0	74.9	93.7	0.17319	2085	1.000	224.000
24:00	28.0	73.2	91.9	0.17340	2085	1.000	224.000

The results based on this load and temperature cycle are:

- Maximum Capability: 302.0 MVA.
- Maximum Current: 2811 amps.
- Maximum Hot-Spot Temperature: 140.0 C at 5:00 pm.
- Maximum Top Oil Temperature: 105.9 C at 5:00 pm
- Cumulative Loss-of-Life for Cycle: 0.17340 %.
- Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 75 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 94 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 94 deg C Insul H2O ppm Vol	0.50% mm Hg
H2O	3,742	3	3,256	13	3,256	9
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		17 mm Hg		13 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 95 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 129 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 129 deg C Insul H2O ppm Vol	0.50% mm Hg
H2O	3,742	3	59,373	69	41,337	47
CO2	0	0	604	1	604	1
O2	0	0	0	0	0	0
CO	0	0	106	1	106	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		73 mm Hg		51 mm Hg

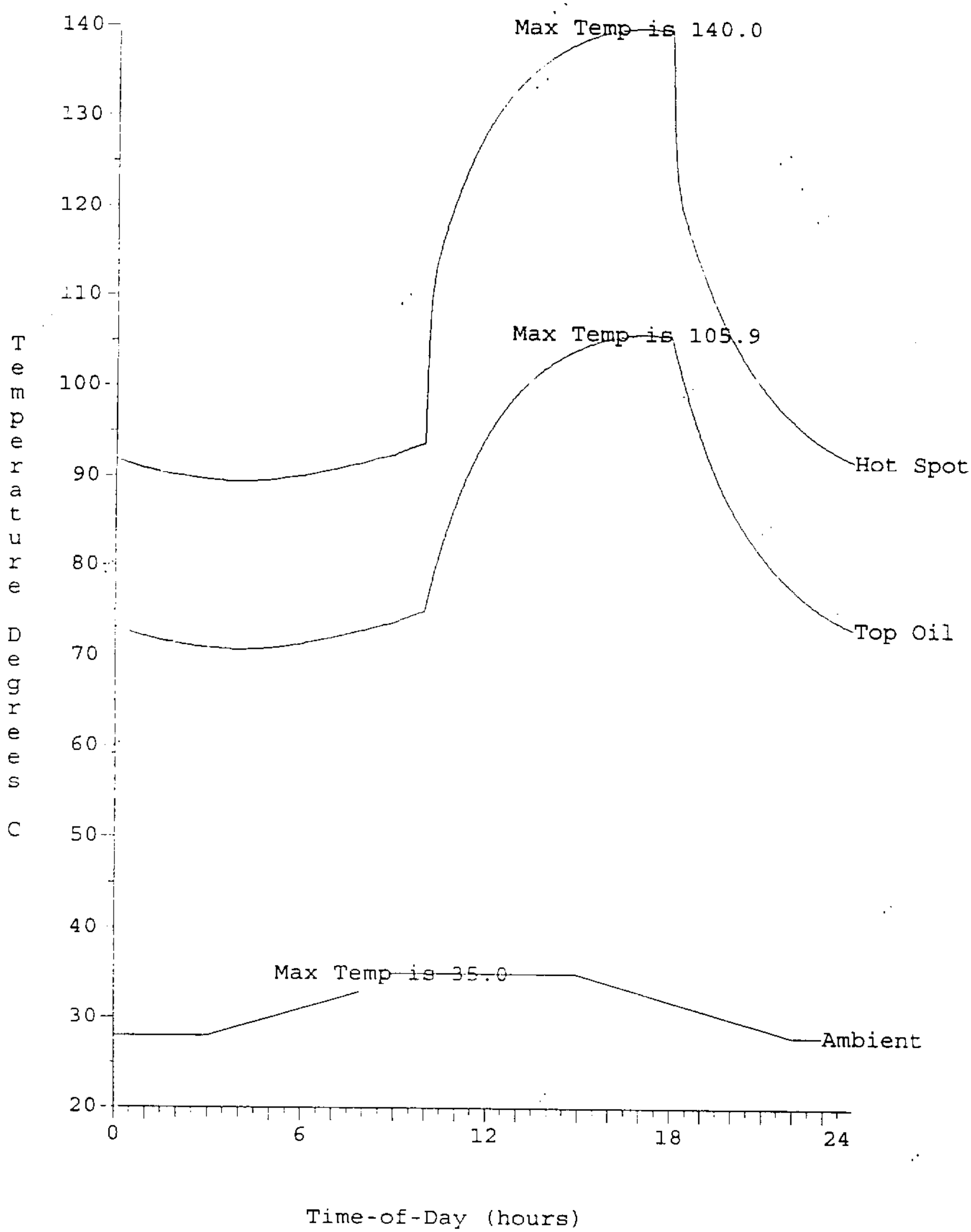
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID4S8LTE>



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TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc

Station: WINTER n o r m a l RATING CALCULATION
Transformers: Transformer ID #4 224(MVA(65 Deg C) foa-t
Comments: General Electric, 3/1965
126/69 kV

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	224.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	7.4	Input
Top Oil Rise Ambient	42.2	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	40.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	132	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 24.00 hours, followed by a constant higher load for 0 minutes. The constant higher load is applied at 12 am.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- Hot Spot Temperature: 120 C
- Top Oil Temperature: 105 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR
65 deg. C Class

Transformer ID #4

WINTER NORMAL RATING

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	108.3	0.839783	0.839783
2	108.1	0.822623	1.662406
3	107.9	0.805797	2.468202
4	107.5	0.773119	3.241321
5	107.2	0.74944	3.990761
6	107.3	0.757256	4.748017
7	107.8	0.797506	5.545523
8	108.5	0.857282	6.402805
9	109.3	0.9308	7.333605
10	109.8	0.979746	8.31335
11	110.5	1.052388	9.365738
12	110.9	1.096163	10.4619
13	111.9	1.213283	11.67518
14	112.9	1.34221	13.01739
15	113.2	1.383355	14.40075
16	113.4	1.411447	15.81219
17	112.7	1.315427	17.12762
18	112	1.225626	18.35325
19	111.1	1.118693	19.47194
20	110.2	1.020651	20.49259
21	109.3	0.9308	21.42339
22	108.7	0.875126	22.29852
23	108.7	0.875126	23.17364
24	108.7	0.875126	24.04877

% Loss - of - Life = 0.01336 %

Normal Loss of Life is .0133%

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	74.9	108.3	0.00130	2783	1.335	298.973
2:00	3.0	74.7	108.1	0.00256	2783	1.335	298.973
3:00	2.0	74.5	107.9	0.00379	2783	1.335	298.973
4:00	2.0	74.1	107.5	0.00498	2783	1.335	298.973
5:00	3.0	73.8	107.2	0.00612	2783	1.335	298.973
6:00	4.0	73.9	107.3	0.00726	2783	1.335	298.973
7:00	5.0	74.4	107.8	0.00844	2783	1.335	298.973
8:00	6.0	75.1	108.5	0.00971	2783	1.335	298.973
9:00	6.0	75.9	109.3	0.01108	2783	1.335	298.973
10:00	7.0	76.4	109.8	0.01254	2783	1.335	298.973
11:00	7.0	77.1	110.5	0.01411	2783	1.335	298.973
12:00	9.0	77.5	110.9	0.01577	2783	1.335	298.973
13:00	10.0	78.5	111.9	0.01758	2783	1.335	298.973
14:00	9.0	79.5	112.9	0.01960	2783	1.335	298.973
15:00	9.0	79.8	113.2	0.02174	2783	1.335	298.973
16:00	7.0	80.0	113.4	0.02394	2783	1.335	298.973
17:00	6.0	79.3	112.7	0.02607	2783	1.335	298.973
18:00	5.0	78.6	112.0	0.02805	2783	1.335	298.973
19:00	4.0	77.7	111.1	0.02986	2783	1.335	298.973
20:00	3.0	76.8	110.2	0.03151	2783	1.335	298.973
21:00	3.0	75.9	109.3	0.03300	2783	1.335	298.973
22:00	4.0	75.3	108.7	0.03437	2783	1.335	298.973
23:00	4.0	75.3	108.7	0.03570	2783	1.335	298.973
24:00	3.0	75.3	108.7	0.03703	2783	1.335	298.973

The results based on this load and temperature cycle are:

- o Maximum Capability: 299.0 MVA.
- o Maximum Current: 2783 amps.
- o Maximum Hot-Spot Temperature: 113.4 C at 4:00 pm.
- o Maximum Top Oil Temperature: 80.0 C at 4:00 pm.
- o Cumulative Loss-of-Life for Cycle: 0.03703 %.
- o Limiting Criteria was Loss-of-Life

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 75 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 109 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 109 deg C Insul H2O ppm Vol	0.50% mm Hg
H2O	3,742	3	3,256	27	3,256	19
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		31 mm Hg		22 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 75 deg C Bulk H2O ppm Vol	1.00% mm Hg	Hot Spot #1 109 deg C Insul H2O ppm Vol	0.64% mm Hg	Hot Spot #2 109 deg C Insul H2O ppm Vol	0.50% mm Hg
H2O	3,742	3	27,409	27	18,734	19
CO2	0	0	4	0	4	0
O2	0	0	0	0	0	0
CO	0	0	1	0	1	0
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		30 mm Hg		21 mm Hg

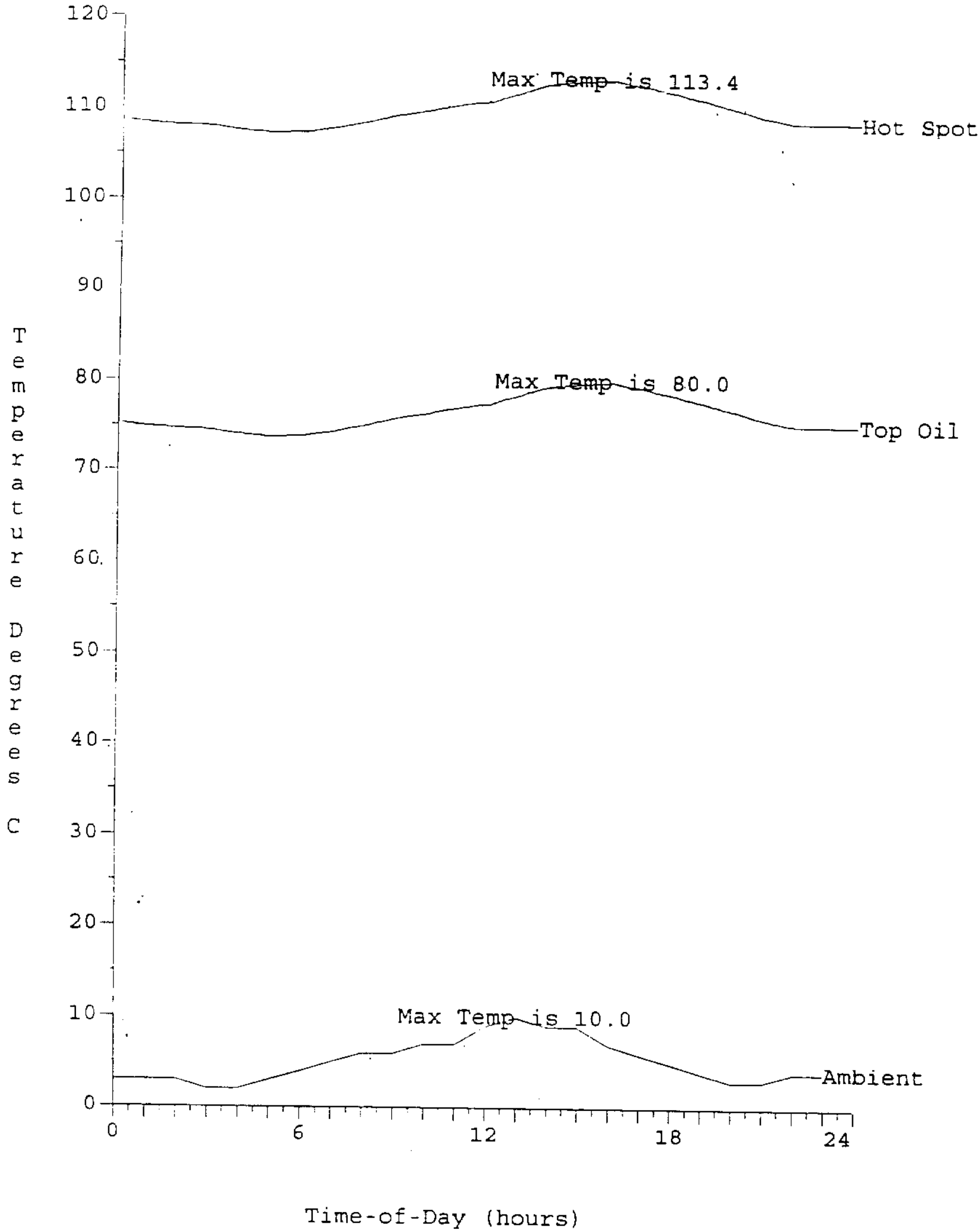
Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Power Transformer Temperature Profile for <ID4WNOR>



TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc.

Station: WINTER 1 t e 4 hour pk staring @ 4 PM
Transformers: Transformer ID #4 224(MVA(65 Deg C) foa-t
Comments: General Electric, 3/1965
126/69 kV

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	224.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	7.4	Input
Top Oil Rise Ambient	42.2	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	40.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	132	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 20.00 hours, followed by a constant higher load for 4.00 hours. The constant higher load is applied at 4 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #4

WINTER LTE(4 hour) RATING, starting @ 4 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	81.1	0.040908	0.040908
2	78	0.02814	0.069049
3	83.2	0.052514	0.121562
4	78.6	0.030269	0.151831
5	79.7	0.034577	0.186408
6	82.5	0.048335	0.234743
7	78	0.02814	0.262883
8	83	0.051286	0.314169
9	77.1	0.025213	0.339382
10	81.4	0.042402	0.381784
11	77.4	0.026155	0.407938
12	80.8	0.039465	0.447403
13	76.8	0.024303	0.471706
14	81.7	0.043947	0.515653
15	77.4	0.026155	0.541808
16	82.2	0.046643	0.588451
17	123.2	3.68704	4.275491
18	131.8	8.241274	12.51676
19	136.9	13.06843	25.5852
20	139.8	16.89946	42.48465
21	95.1	0.204885	42.68954
22	83.7	0.055707	42.74525
23	76.9	0.024603	42.76985
24	81.1	0.040908	42.81076

% Loss - of - Life = 0.023784 %

Emergency operation criteria for Loss of Life is .25% per occurence.

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	62.3	81.1	0.00004	2085	1.000	224.000
2:00	3.0	59.3	78.0	0.00009	2085	1.000	224.000
3:00	2.0	64.5	83.2	0.00014	2085	1.000	224.000
4:00	2.0	59.8	78.6	0.00018	2085	1.000	224.000
5:00	3.0	61.0	79.7	0.00023	2085	1.000	224.000
6:00	4.0	63.8	82.5	0.00027	2085	1.000	224.000
7:00	5.0	59.3	78.0	0.00032	2085	1.000	224.000
8:00	6.0	64.3	83.0	0.00037	2085	1.000	224.000
9:00	6.0	58.4	77.1	0.00041	2085	1.000	224.000
10:00	7.0	62.6	81.4	0.00047	2085	1.000	224.000
11:00	7.0	58.7	77.4	0.00050	2085	1.000	224.000
12:00	9.0	62.0	80.8	0.00056	2085	1.000	224.000
13:00	10.0	58.1	76.8	0.00059	2085	1.000	224.000
14:00	9.0	62.9	81.7	0.00065	2085	1.000	224.000
15:00	9.0	58.6	77.4	0.00069	2085	1.000	224.000
16:00	7.0	63.4	82.2	0.00074	3249	1.558	349.077
17:00	6.0	77.6	123.2	0.00406	3249	1.558	349.077
18:00	5.0	86.3	131.8	0.01447	3249	1.558	349.077
19:00	4.0	91.4	136.9	0.03415	3249	1.558	349.077
20:00	3.0	94.3	139.8	0.06247	2085	1.000	224.000
21:00	3.0	76.4	95.1	0.06384	2085	1.000	224.000
22:00	4.0	65.0	83.7	0.06398	2085	1.000	224.000
23:00	4.0	58.1	76.9	0.06402	2085	1.000	224.000
24:00	3.0	62.4	81.1	0.06407	2085	1.000	224.000

The results based on this load and temperature cycle are:

- Maximum Capability: 349.1 MVA.
- Maximum Current: 3249 amps.
- Maximum Hot-Spot Temperature: 139.8 C at 8:00 pm.
- Maximum Top Oil Temperature: 94.3 C at 8:00 pm.
- Cumulative Loss-of-Life for Cycle: 0.06407 %.
- Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 63 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 82 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 82 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	7	3,256	5
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		11 mm Hg		9 mm Hg

Immediately After the Contingency

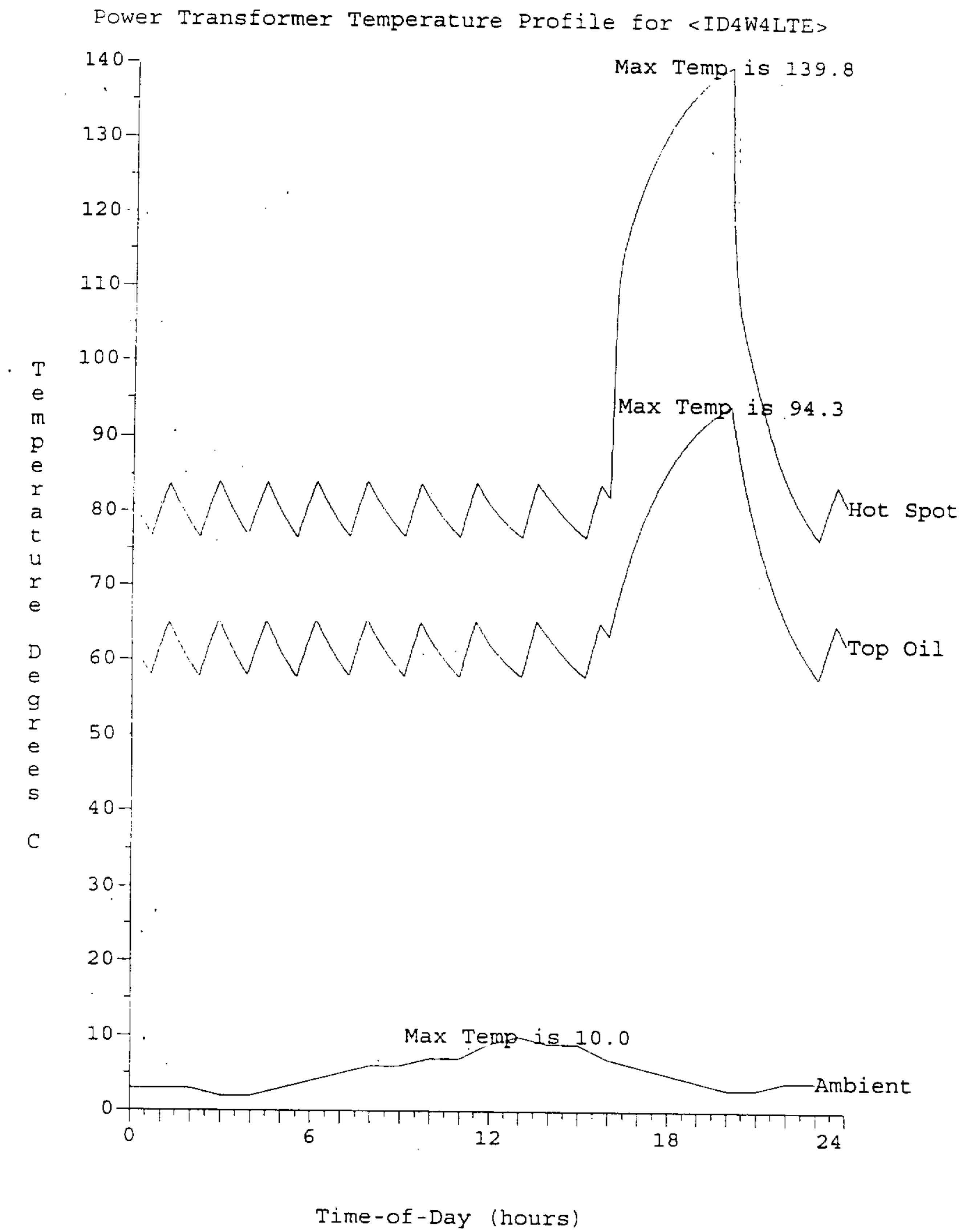
Gas Component	Bulk Oil Region 87 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 132 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 132 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	66,588	79	46,470	54
CO2	0	0	764	1	764	1
O2	0	0	0	0	0	0
CO	0	0	134	1	134	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		83 mm Hg		58 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.



Power Transformer Temperature Profile for <ID4W4LTE>
Max Temp is 139.8
Max Temp is 94.3
Max Temp is 10.0
Hot Spot
Top Oil
Ambient
Temperature Degrees C
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
6
12
18
24
Time-of-Day (hours)

TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
Developed by
Dynamic Systems, Inc. and Berkshire Transformer Consultants, Inc

Station: WINTER 1 t e 8 hour pk staring @ 2 PM
Transformers: Transformer ID #4 224(MVA(65 Deg C) foa-t
Comments: General Electric, 3/1965
126/69 kV

Transformer Operates Under Top Oil Temperature Control.

Id	MVA Nameplate	Type of Cooling Mode	Winding (m)	Oil (n)
9.	224.000	FOA or FOW (Directed Flow)	1.00	1.00

The insulation system is rated for 65 C rise over ambient.

TRANSFORMER CHARACTERISTICS AT RATED LOAD

Parameter	Cooling Id 1. Value	History
Cu/Fe Loss Ratio	7.4	Input
Top Oil Rise Ambient	42.2	Input
Avg Winding Rise Amb.	61.5	Input
Hot Spot Rise Top Oil	15.0	Input
Avg Oil Rise Ambient	40.2	Calc
Winding Time Constant	5	Input
Oil Time Constant	132	Input

SELECTED LOAD AND AMBIENT TEMPERATURE PATTERNS

The selected twenty-four hour load cycle consists of a constant 1.00 P.U. Rated Load for a period of 16.00 hours, followed by a constant higher load for 8.00 hours. The constant higher load is applied at 2 pm.

LOAD PLANNING CONSTRAINT CRITERIA

The output solution selected is to determine the maximum peak load that satisfies the following limiting criteria:

- o Hot Spot Temperature: 140 C
- o Top Oil Temperature: 110 C

INSULATION LIFE

The PROPOSE new Standard uses a different formula for calculating Loss-of-Life of insulation and is discribed in Appendix D. This method was adopted by the Task Force and required a separate calculation of insulation Loss-of-Life. The following page contains the new loss-of-life values. **WHEN THE LIMITING CRITERIA IS 'LOSS-OF-LIFE', THE VALUES GENERATED BY THE PROGRAM ARE EQUIVALENT TO THE NEW METHOD.**

INSULATION LOSS - of - LIFE

FOR

65 deg. C Class

Transformer ID #4

WINTER LTE(8 hour) RATING, starting @ 2 PM

Time	Hot Spot Temperature Deg. C	Aging Acceleration Factor	Cumulative Aging Hours
1	77.2	0.025523	0.025523
2	82	0.045546	0.071069
3	79.1	0.03216	0.103229
4	79.3	0.032947	0.136176
5	83.4	0.053769	0.189945
6	76.9	0.024603	0.214548
7	81.1	0.040908	0.255456
8	80.1	0.036283	0.291739
9	79.2	0:032551	0.32429
10	83.3	0.053138	0.377428
11	78.3	0.029186	0.406615
12	83.7	0.055707	0.462321
13	78.7	0.030639	0.49296
14	82	0.045546	0.538506
15	122.8	3.548634	4.08714
16	131.2	7.800201	11.88734
17	135.8	11.84294	23.73028
18	138.3	14.80198	38.53225
19	139.6	16.6044	55.13665
20	140	17.19946	72.33612
21	139.9	17.04884	89.38496
22	139.8	16.89946	106.2844
23	96.4	0.236479	106.5209
24	84.9	0.064142	106.585

% Loss - of - Life = 0.059214 %

Emergency operation criteria for Loss of Life is .25% per occurence.

BUBBLE EVOLUTION MODEL - MEMBRANE CONSERVATOR

Gas pressure at top oil level is 760 mm Hg.
Static head of oil to hot spot is 72 inches.
Gas pressure at the winding hot spot is 895 mm Hg.

Partial pressure equilibrium is assumed to have occurred between the gases dissolved in the bulk oil and the gasses in the oil at the hot spot location.

The average transformer temperatures for a typical load cycle are: bulk oil at 50.0 C and hot spot at 60.0 C.

Prior to Contingency

Gas Component	Bulk Oil Region 63 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 82 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 82 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	2	3,256	7	3,256	5
CO2	0	0	0	0	0	0
O2	0	0	0	0	0	0
CO	0	0	0	0	0	0
N2	500	4	512	4	512	4
Total Pressure		6 mm Hg		11 mm Hg		8 mm Hg

Immediately After the Contingency

Gas Component	Bulk Oil Region 87 deg C Bulk H2O 1.00% ppm Vol	mm Hg	Hot Spot #1 132 deg C Insul H2O 0.64% ppm Vol	mm Hg	Hot Spot #2 132 deg C Insul H2O 0.50% ppm Vol	mm Hg
H2O	3,742	3	65,190	77	45,477	53
CO2	0	0	734	1	734	1
O2	0	0	0	0	0	0
CO	0	0	129	1	129	1
N2	500	4	512	4	512	4
Eff. Total Pressure		5 mm Hg		81 mm Hg		57 mm Hg

Hot Spot #1

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

Hot Spot #2

Bubble evolution is not likely to occur at the winding hot spot as the result of this contingency.

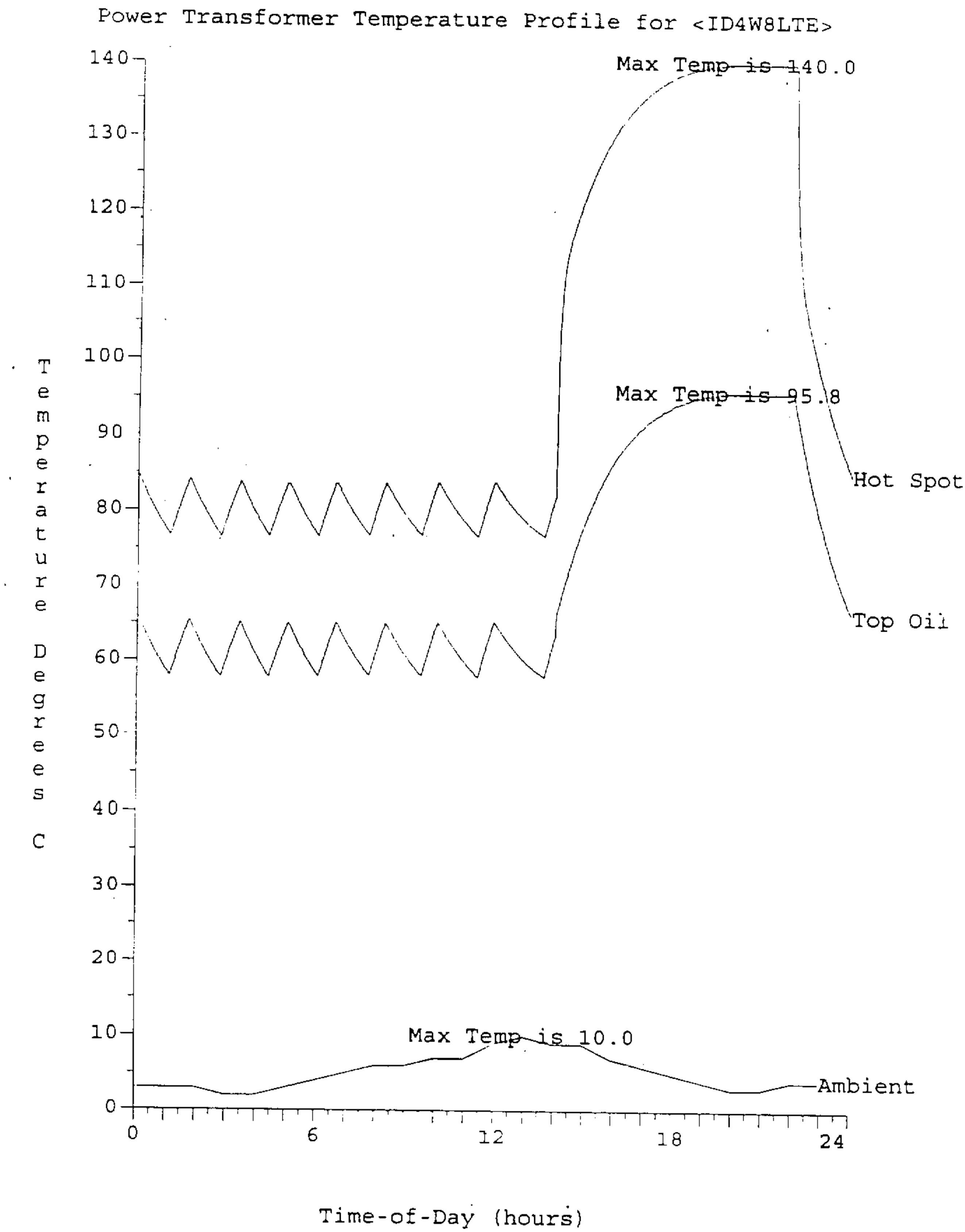
TRANSFORMER LOAD PLANNING PROGRAM (v4.1)
(Continued)

Time	< Temperatures Ambient	(Deg C) Top Oil	> Hot Spot	Cumulative Loss Life (Percent)	Current (amps)	Load (P.U. NP)	Load (MVA)
1:00	3.0	58.5	77.2	0.00005	2085	1.000	224.000
2:00	3.0	63.3	82.0	0.00010	2085	1.000	224.000
3:00	2.0	60.3	79.1	0.00014	2085	1.000	224.000
4:00	2.0	60.5	79.3	0.00019	2085	1.000	224.000
5:00	3.0	64.6	83.4	0.00023	2085	1.000	224.000
6:00	4.0	58.2	76.9	0.00028	2085	1.000	224.000
7:00	5.0	62.4	81.1	0.00033	2085	1.000	224.000
8:00	6.0	61.4	80.1	0.00037	2085	1.000	224.000
9:00	6.0	60.5	79.2	0.00042	2085	1.000	224.000
10:00	7.0	64.6	83.3	0.00046	2085	1.000	224.000
11:00	7.0	59.6	78.3	0.00051	2085	1.000	224.000
12:00	9.0	64.9	83.7	0.00056	2085	1.000	224.000
13:00	10.0	59.9	78.7	0.00061	2085	1.000	224.000
14:00	9.0	63.3	82.0	0.00064	3200	1.535	343.752
15:00	9.0	78.6	122.8	0.00395	3200	1.535	343.752
16:00	7.0	87.0	131.2	0.01382	3200	1.535	343.752
17:00	6.0	91.6	135.8	0.03175	3200	1.535	343.752
18:00	5.0	94.2	138.3	0.05658	3200	1.535	343.752
19:00	4.0	95.4	139.6	0.08606	3200	1.535	343.752
20:00	3.0	95.8	140.0	0.11780	3200	1.535	343.752
21:00	3.0	95.8	139.9	0.14995	3200	1.535	343.752
22:00	4.0	95.7	139.8	0.18188	2085	1.000	224.000
23:00	4.0	77.6	96.4	0.18340	2085	1.000	224.000
24:00	3.0	66.1	84.9	0.18357	2085	1.000	224.000

The results based on this load and temperature cycle are:

- Maximum Capability: 343.8 MVA.
- Maximum Current: 3200 amps.
- Maximum Hot-Spot Temperature: 140.0 C at 8:00 pm.
- Maximum Top Oil Temperature: 95.8 C at 8:00 pm
- Cumulative Loss-of-Life for Cycle: 0.18357 %.
- Limiting Criteria was Hot-Spot

Ambient air temperatures and transformer loads listed at each time apply for the remainder of the one hour time period. An exception to this is the short time emergency (STE) type rating where the load may vary within a one hour time period.



Power Transformer Temperature Profile for <ID4W8LTE>
Max Temp is 140.0
Max Temp is 95.8
Max Temp is 10.0
Hot Spot
Top Oil
Ambient
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
6
12
18
24
Temperature Degrees C
Time-of-Day (hours)

NYPP 1994 Tie-Line Rating Task Force

Appendix E

Excerpts from NEPOOL 1978 Working Group Analysis of Wind-Temperature Data and Current Carrying Capacity

SDTF-19

AN ANALYSIS OF WIND-TEMPERATURE DATA AND THEIR EFFECT ON CURRENT CARRYING CAPACITY OF OVERHEAD CONDUCTORS

By

The Conductor Rating Working Group

Of

The System Design Task Force

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December 20, 1978

ACKNOWLEDGEMENT

The Conductor Rating Working Group acknowledges gratefully the he Air Force Cambridge Research Laboratories scientists Dr. H. Stuar and Mr. Wayne S. Hering, Chief of the Mesoscale Forecasting Branc Meteorology Laboratory, for furnishing us their unique meteorolog data base and for their patience and understanding in answering o questions.

The Conductor Rating Working Group was supported by Mrs. Theresa Murphy and Mrs. Catherine F. Capuano, of the Boston Edison Co. Re and Planning Department, who contributed project critical program and solutions to software problems.

BACKGROUND:

A huge amount of unique raw weather data was acquired by the Conductor Rating Working Group from the Mesoscale Forecasting Experiments conducted by the Meteorology Laboratory, Air Force Cambridge Research Laboratories (AFCRL), Bedford, Massachusetts.

Nearly 16 million meteorological observations from summer 1973, (June, July, and August) collected via 25 weather sensing stations established the baseline data of wind velocities and ambient air temperatures; the foundation of this study. This summer represented the hottest summer in 25 years. These sensor stations composed a dense network of remote surface weather stations that gathered finely structured meteorological data. Weather data was collected every 10 second from each operational sensor station via conditioned telephone lines. Data was archived directly on magnetic tape at the central computar located at AFCRL Hanscom Field, Bedford, Massachusetts.

Certain qualities unique to this sophisticated meteorological experiment made it significantly valuable to power transmission line engineers. These features are discussed later.

INTEREST OF WIND-TEMPERATURE RELATIONSHIP TO POWER ENGINEERS

Design guidelines, cited in Section 23 of the Massachusetts Department of Public Utilities (DPU) Code for the Installation and Maintenance of Electric Transmission Lines, precipitated the New England Planning Committee (NEPC) to authorize the Conductor Rating Working Group (CRWG) to investigate, evaluate, and report, the effect of weather on overhead power line conductors current carrying capacity.

Section 23 addressing vertical clearances of wires above ground, rails, or water, states - "In computing conductor temperature, an ambient air temperature of 100 degrees F (Fahrenheit) and a transverse wind of 2 feet per second should be used".

This research project's major objective, was to ascertain wind-temperature exposure of overhead transmission line conductors in order to better evaluate existing line designs and industry ampere ratings. The interrelated considera[illegible] of conductor size and temperature, conductor sags and clearances of wires above ground level are inseparable constraints, which must also be considered as affecting the current carrying capability assigned to any transmission line.

Although the AFCRL weather station network instrumentation was designed to help predict short-range aviation hazards, such as fog, snow, and severe storms, through the collection of finely structured data, it could prove to be the vehicle to amend or modify the application of the guidelines and operation of lines built under Section 23 of the DPU Code.

Several unique features of the Air Force meteorological experiment made it particularly adaptable to the evaluation of existing engineering practices used in designing power transmission lines. Transmission line design engineers strive to build economically reliable lines. This translates into extracting in a saf fashion, all reasonable thermal capacity from any transmission line conductor size. Total capital costs, operating and maintenance costs, are all directly related to transmission line conductor size.

These unique qualifying features of this AFCRL experiment were:

1. (Geographic density) - The study geographic sector extended a distance of 35 nautical miles from Hanscom Field simulating a potential corridor for power lines greater than 40 miles (64.37 kilometers) in length.
2. (The AFCRL sensors height). The above ground level of 25 feet (7.62 meters) was representative of a transmission line conductor height.

Observed ambient air temperature and wind velocity values, therefore, were more meaningful than those measured at ground level in standard instrument shelters typically used by the National Weather Service.

3. (Sensor sensitivity) - The threshold of sensitivity of the anemometers when non-rotating, was 0.8433 feet per second; and was reduced to a minimum threshold of 0.5276 feet per second with the anemometers rotating

4. (Sensor accuracy) - The accuracy of wind speed measurements was ± 0.84 feet per second in the 0 to 17 feet per second range. The observed temperatures were accurate to ± 1°F.

5. (Frequency of measurements) - The data acquisition system was automated. Each station reported weather every 10 seconds assuring a finely structured history of the geographic sector.

6. (Data period) - The June, July, and August 1973 weather data base, represented the hottest summer in 25 years (according to the U.S. Weather Service). The consumption of electricity and energy, peak at times of sustained high ambient air temperatures and humidity, due to air conditioning system loads being supplied from a power system.

SUMMARY:

The research work performed by the Conductor Rating Working Group was concluded with positive results herein noted:

1. Our major conclusion is that the minimum wind velocity of two feet per second used to calculate ampacity ratings of overhead transmission lines, should be raised to at least three feet per second (FPS). A three feet per second (3 FPS) wind velocity will result in an upgrading of thermal capacity of transmission line conductors, which is an equivalent to an 11% increase for the three ACSR conductor sizes studied (336.4 kcmil, 954 kcmil and 1,113 kcmil). This will result in significant economies. Ambient air temperatures of 100°F were used for each conductor rating calculation.

   This conclusion is based upon processing nearly 16 million meteorological observations recorded by the Air Force Cambridge Research Laboratories (AFCRL), in Summer 1973 (June-August), which indicated that a network random 5-minute mean wind speed of three FPS was exceeded 99.9598% of the time, when network ambient air temperatures in a range of 91°F to 104°F, were measured over a large geographical sector of Massachusetts.

2. It is apparent from this AFCRL network weather model, that a low probability of coincident 5-minute high ambient temperatures and low wind speeds exists in nature.

   The duration of these coincident events are relatively short and transitory. Figure 8 presents conductor transient temperatures during "worst conditions" of weather, when 954 kcmil ACSR (45/7) conductors were subjected to 100% amperage loadings. Wind speeds in excess of 2 FPS were measured for 65 minutes of the 110 minutes (59% of the time) at this <u>single station</u>. Wind speeds below 2 FPS were measured for 45 continuous minutes (about 41% of the time), but were preceded by winds of 2.79 FPS or greater for 35 minutes (about 32% of the time) and followed by a wind speed of 3.47 FPS for 30 minutes (about 27% of the time).

The ambient air temperature declined from 93°F to 84°F during this period. The ambient temperature descent periods are identified below the conductor temperature plots in Figure 8.

The arguments presented in Figure 8 recognized that "sheltered areas" do exist in nature, where low velocity winds coincident with high ambient air temperatures occur. Figure 8 represents actual weather data recorded on August 2, 1975, when actual ground ambient temperatures in excess of 100°F were recorded. An AFCRL scientist estimated this temperature phenomenon occurs about every 100 years.

The probability of coincident low winds/high ambient temperature and 100% amperage load conditions on transmission lines is very remote. Even if these conditions do occur, it will take some time for the conductors to reach maximum temperature as indicated in Figure 8.

This reinforces the conclusion that member companies utilize at least three feet per second wind velocity for rating their transmission lines. This will allow an increased ampacity of approximately 11% which will result in significant economic savings.

3. The AFCRL data base showed a direct correlation between wind speeds and ambient air temperatures. Network correlation studies presented in Tables VIII-X, and an explanation in the Appendix (pages 28 and 29) present our analysis of these variables, which shows network 5-minute mean wind speeds tend to increase with rises in ambient temperatures. The network 5-minute mean wind speeds ranged from 5.30 to 9.15 FPS for network temperatures in excess of 95°F. The greater than 10.0 FPS winds were accounted for, but not included in these mean values. The probability of 5-minute network temperatures exceeding 95°F is:

$$P(\bar{T} > 95^{\circ}F) = \frac{6 \times 30 \times 100}{11,331,583} = 0.00016\% \text{ or about } \frac{1}{62,953}$$

or 30 minutes out of 31,477 hours.

4. An analysis of the AFCRL network 5-minute mean temperatures and wind speeds data to determine "coincident events" (i.e., 0 to ≤3 feet per second, with their attendant ambient air temperatures, greater than 90°F), disclosed these facts:

4.1 The observed network June-August 1973 "coincident events" occurred in a temperature range of 91.00°F to 93.24°F. No "coincident events" were observed, when ambient air temperatures in excess of this temperature range were measured.

5. The calculated probability ($\bar{P}$) of the AFCRL network June-August "coincident events", based upon 152 5-minute observations within the 0 to ≤3 feet per second range of wind velocities, part of 11,331,583 valid measurements recorded every 10 seconds from the sensor stations is:

$$P(\bar{V},\bar{T}) = \frac{152 \times 30 \times 100}{11,331,583} = 0.0402\%, \text{ or about } \frac{1}{2469}, \text{ or about}$$

12.67 hours out of 31,477 hours, a cumulative period when 25 weather sensor stations recorded the total data base. These stations were interrogated by the AFCRL computer once every 10 seconds.

5.1 Thus, for 99.9598% of the time represented by the data base, "coincident events" of temperatures and wind speeds <u>never</u> occurred.

6. The 152 5-minute mean coincident weather data observations described above, represent the natural, random and transient occurrences, of wind speeds measured and collected during June-August 1973 by a dense network of weather sensing stations (25) designed by AFCRL meteorologists. The frequency of these occurrences was derived by computer by selectively counting wind speeds in a class interval against the allied ambient air temperature (class interval) with all frequencies classified by hour of occurrence. A sample, page 1/20 of the month of July 1973 matrix, presents the data grouping resulting from this three-dimensional counting. Page 1/20 is contained in the Appendix for our readers' convenience.

The individual 5-minute wind-velocity-temperature frequency counts, represents a summing of similar data. They do not represent a series of contiguous 5-minute "coincident events" at a single station but represent their natural distribution throughout the network measured over a month.

6.1 The probability ($\overline{P}$) of the network "coincident events" occurring in June 1973, is based upon three (3) 5-minute observations. The probability,

$P(\overline{V},\overline{T}) = \dfrac{3 \times 30 \times 100}{11,331,583} = 0.0008\%$, or an occurrence of about $\dfrac{1}{125,906}$, or 15 minutes out of 31,477 hours. For five (5) minutes of the period the mean wind speed was 1.5 FPS and the other ten (10) minutes the mean wind speed was 2.6 FPS. The attendant network mean ambient air temperature was 91.9°F.

6.2 The probability ($\overline{P}$) of the network "coincident events" occurring in July, based upon 44 5-minute observations is:

$P(\overline{V},\overline{T}) = \dfrac{44 \times 30 \times 100}{11,311,583} = 0.0116\%$, or an occurrence of about $\dfrac{1}{8,585}$, or 220 minutes of 3.67 hours out of 31,477 hours.

Ten (10) observations (50 minutes) of the 44 observations recorded 5-minute mean speeds ranging from 1.6 FPS to 2.52 FPS. There was one (1) observation (5-minutes) when the mean wind speed recorded was 0.70 FPS and 33 observations (165 minutes) when mean wind speeds of 0.22 FPS were recorded. The attendant network mean ambient air temperature was 93.23°F.

6.3 The probability ($\overline{P}$) of the network "coincident events" occurring in August is based upon 105 observations, a cumulative period of 525 minutes, or an occurrence of 8.75 hours of the total data base, representing 31,477 hours:

$$P(\overline{V},\overline{T}) = \frac{105 \times 30 \times 100}{11,331,583} = 0.0278\%$$, or an occurrence of about $\frac{1}{3,597}$. However, examination of the data base showed that 40 observations (200 minutes) had a 5-minute mean wind speed of 2.54 FPS and 40 additional observations (200 minutes) the 5-minute mean wind speed recorded was 2.02 FPS. The breakdown of the remaining 125 minutes of the "coincident events" recorded; 1.5 FPS for 60 minutes, 1.04 FPS for 40 minutes, and 0.50 FPS for 25 minutes. The attendant network mean ambient temperature was 91.28°F.

6.4 A majority of the network "coincident events", 151 of 152 observations (99+%), occurred during the daytime period between 1200 and 1800 hours. June's network minimum 5-minute mean wind speed of 1.5 FPS (for 5 cumulative minutes) occurred at 1700 hours.

July's network minimum 5-minute mean wind speed of 0.22 FPS (for 165 cumulative minutes) was distributed over a daily four hour period throughout the month. Their breakdown of occurrence by time of day was:

(a.) 1400 hours, (3 observations) 15 minutes

(b.) 1500 hours, (12 observations) 60 minutes

(c.) 1600 hours, (12 observations) 60 minutes

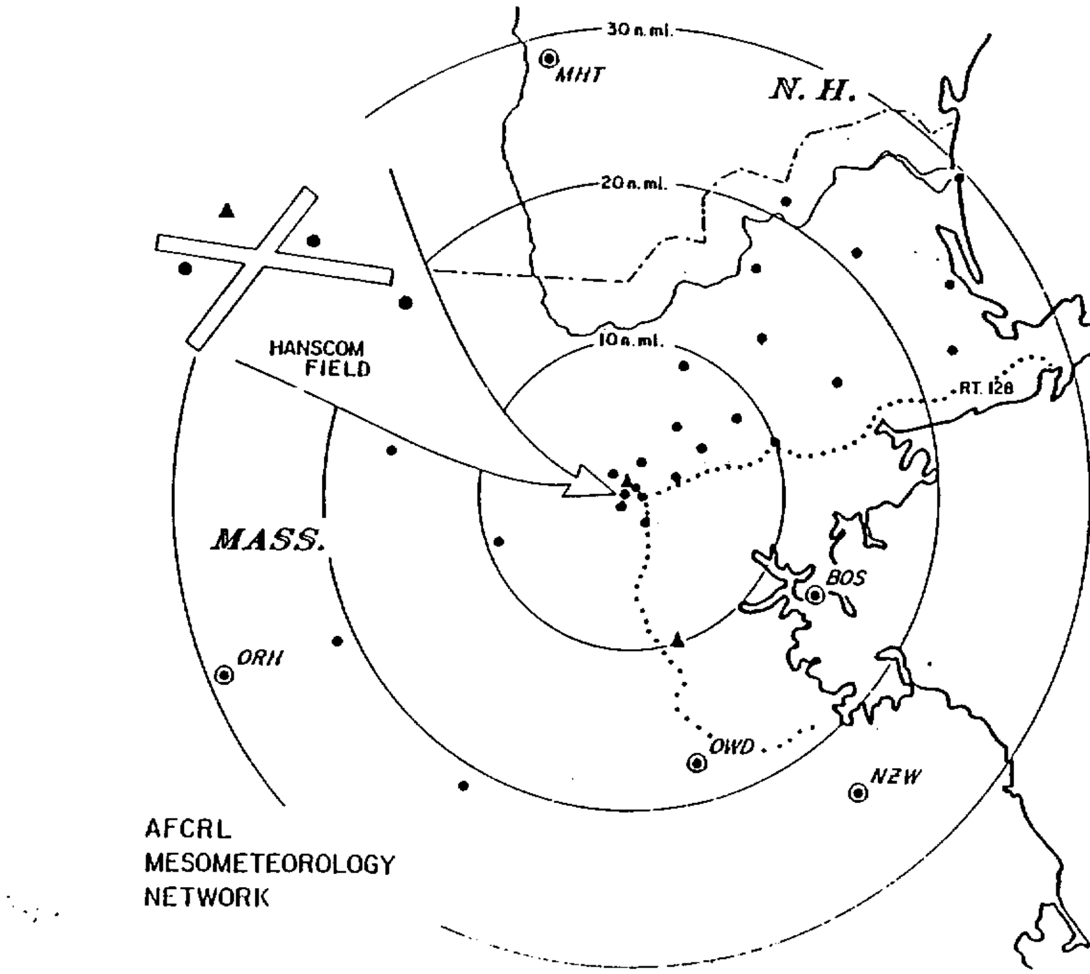
(d.) 1700 hours, (6 observations) 30 minutes

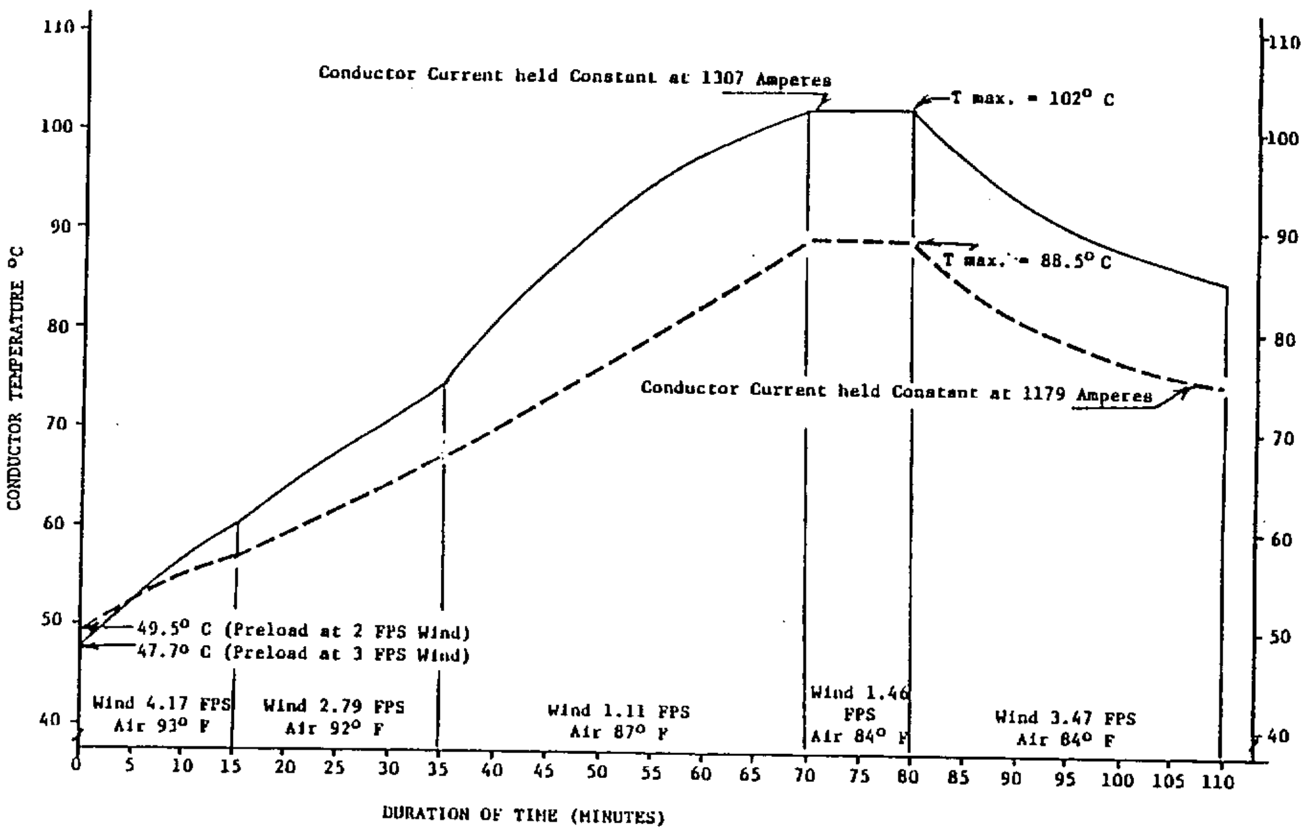
A similar analysis of the August's network "coincident events" showed that the minimum 5-minute mean wind speed of 0.50 FPS (for 25 cumulative minutes) was distributed over a three hour period throughout the month. Their breakdown of occurrence by time of day was:

(a.) 1400 hours, (1 observation) 5 minutes

(b.) 1600 hours, (1 observation) 5 minutes

(c.) 1700 hours, (3 observations) 15 minutes

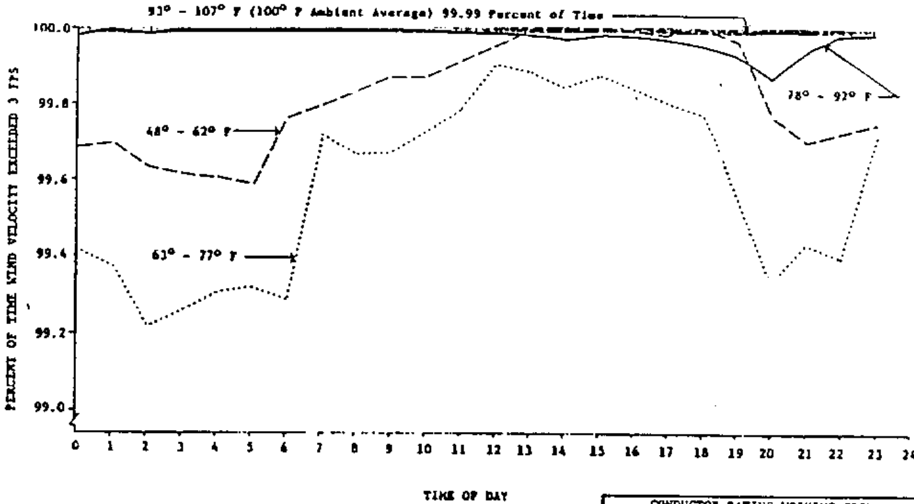




NOTE: 1. Conductor preloaded to 590 amperes (50% of normal) at 100° F (38° C) ambient air temperature.

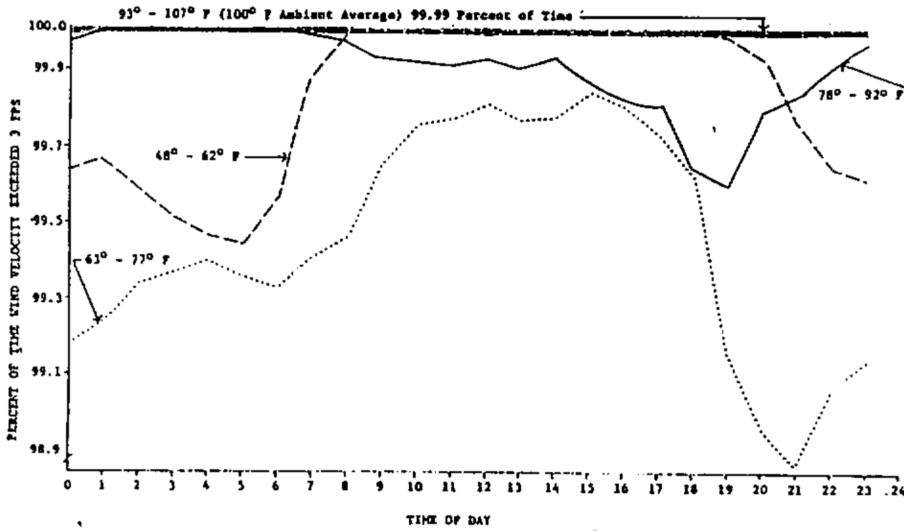
2. Calculations based on the actual weather conditions of August 1, 1975, at Fort Devens Weather Station, which occurred after sunset (therefore no solar effect in calculations).

CONDUCTOR RATING WORKING GROUP
Conductor Temperature Vs. Time
954 kcmil, 45/7, ACSR Conductor
ACTUAL WEATHER CONDITIONS
ASSUMED AMPERE LOADINGS
FIGURE 8



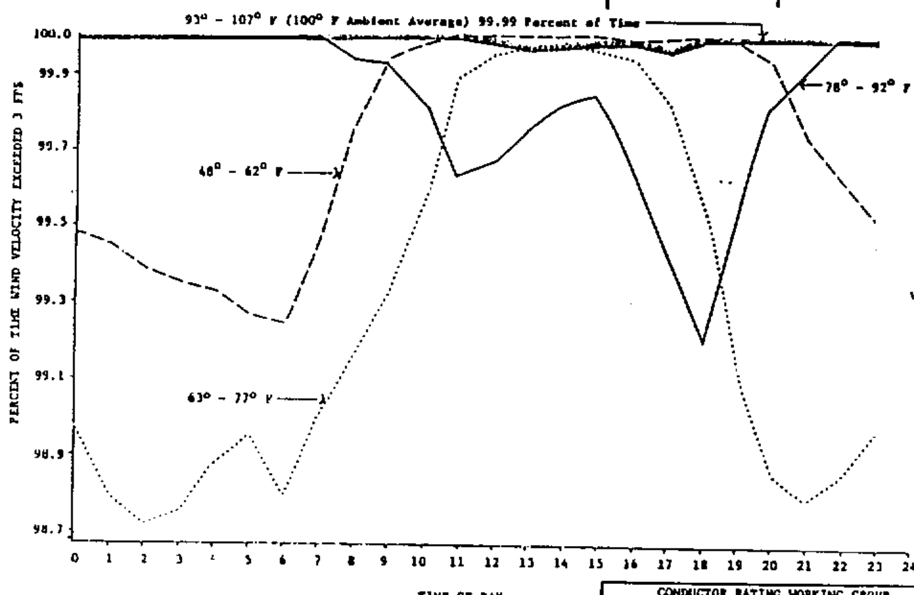
CONDUCTOR RATING WORKING GROUP
ANALYSIS OF AFCRL WEATHER NETWORK DATA

PERCENT OF TIME WIND VELOCITY EXCEEDED 3 FPS
DURING THE MONTH OF JUNE 1973



CONDUCTOR RATING WORKING GROUP
ANALYSIS OF AFCRL WEATHER NETWORK DATA

PERCENT OF TIME WIND VELOCITY EXCEEDED 3 FPS
DURING THE MONTH OF JULY 1973



CONDUCTOR RATING WORKING GROUP
ANALYSIS OF AFCRL WEATHER NETWORK DATA

PERCENT OF TIME WIND VELOCITY EXCEEDED 3 FPS
DURING THE MONTH OF AUGUST 1973

FIGURE 6

Total Number of Valid Observations 3,323,265

SUMMER - TEMPERATURE > 35C

	0-4fps				4-6fps				6-8fps				>8fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A		
Buffalo	0	0	0	0	0	0	0	0	0	1	1	0	0	4	1	0	7	0.008
Rochester	0	0	0	0	0	0	0	0	0	1	1	0	0	23	6	0	31	0.035
Syracuse	0	0	0	0	0	0	0	0	0	2	2	0	0	19	6	0	29	0.033
Binghamton	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	4	0.005
Albany	0	1	0	0	0	0	0	0	0	2	2	0	0	12	9	0	26	0.030
LaGuardia AP	0	0	0	0	0	0	0	0	0	3	3	0	2	69	36	0	113	0.129
Bradford, PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000
Massena	0	0	0	0	0	0	0	0	0	0	0	0	0	7	3	0	10	0.011

	0-4fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A		
Buffalo	0	0	0	0	0	0
Rochester	0	0	0	0	0	0
Syracuse	0	0	0	0	0	0
Binghamton	0	0	0	0	0	0
Albany	0	1	0	0	1	0.001
LaGuardia AP	0	0	0	0	0	0
Bradford, PA	0	0	0	0	0	0
Massena	0	0	0	0	0	0

WINTER - TEMPERATURE > 9C

	0-4fps				4-6fps				6-8fps				>8fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A	8-11A	12-3P	4-7P	8P-7A		
Buffalo	8	18	13	18	15	23	18	22	33	46	40	64	820	1281	1109	1787	5315	6.063
Rochester	21	18	17	62	42	28	28	80	36	43	60	112	747	1293	1096	1541	5224	5.959
Syracuse	16	8	12	85	42	35	49	124	66	75	100	179	742	1293	1059	1369	5254	5.993
Binghamton	10	10	6	17	8	10	17	19	22	32	29	47	684	1196	1042	1506	4655	5.31
Albany	34	40	48	171	8	10	15	24	57	63	81	108	718	1381	1125	1419	5302	6.048
LaGuardia AP	15	15	13	101	40	37	29	97	46	55	23	135	1553	2372	2167	3568	10266	11.71
Bradford, PA	11	10	19	73	4	10	12	30	18	24	29	82	658	1174	1058	1414	4626	5.277
Massena	38	24	42	169	5	3	4	2	7	9	11	21	492	963	823	818	3431	3.914

	0-4fps				ttl hrs	% hrs
	8-11A	12-3P	4-7P	8P-7A		
Buffalo	8	18	13	18	57	0.065
Rochester	21	18	17	62	118	0.135
Syracuse	16	8	12	85	121	0.138
Binghamton	10	10	6	17	43	0.049
Albany	34	40	48	171	293	0.334
LaGuardia AP	15	15	13	101	144	0.164
Bradford, PA	11	10	19	73	113	0.129
Massena	38	24	42	169	273	0.311

Note: " %hrs" is percent of total hours in the 10-yr period or approx. 87760hrs