Jack

# NEPLAN

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August 25, 1983

Members of the System Design Task Force
Members of the Conductor Working Group

Gentlemen:

Enclosed is the latest revision (August 1983) of the SDTF Report #20 entitled "An Analysis of Wind-Temperature Data and Their Effect on Current Carrying Capacity of Overhead Conductors."

This revision has resolved issues raised at the Planning Committee meeting of December 16, 1982. The Planning Committee accepted the three feet per second wind speed for conductor rating but referred the report back to the SDTF for "review and finalization."

Unless I hear from you before September 8, I shall forward this revision to the Planning Committee as the final report.

Very truly yours,

Jack

John E. Hurley, Chairman
System Design Task Force

JEH/lt825
Enclosure

cc: J. M. Schamberger - w/o enc.
R. deR. Stein - w/o enc.
J. R. Smith - w/o enc.

SDTF-20

# 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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August 1983

Abstract: The Conductor Rating Working Group (CRWG) of the System Design Task Force (SDTF) was initially charged with the responsibility of studying weather data for the winter months of September through May to determine if a wind velocity greater than 2 feet per second could be safely used throughout New England to rate transmission line conductors. A previous CRWG was charged with studying the summer data (June through August), Report SDTF-19, and since a different analysis technique was used in this study the charge was then expanded by the SDTF to consider the entire year. This new report therefore supercedes SDTF Report 19.

To study the weather conditions, weather information from 25 weather sensing stations was obtained for the entire year of 1973 from the Air Force Cambridge Research Laboratory.

The new methodology used sophisticated computer modeling techniques and computer programs were written to do analysis and produce various plots. The plots of temperature vs. time, and wind velocity vs. time for each day of the period under study helped the Working Group to pinpoint dates and times when potential thermal overloads might occur. These trouble periods were then modeled in greater detail.

The conclusion of the study in brief is as follows:

> Based on the analysis and findings for the entire year, transmission line conductors in the New England region can be rated with a wind velocity of 3 feet per second. However, each company should weigh the factors affecting the conservatism of the 3 feet per second assumption in the consideration of any particular line being rated.

## BACKGROUND

A large amount of 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.

The year 1973 was chosen because it was the hottest summer in 25 years. A review of the National Weather Service daily temperture logs for the winters of 1968 through 1978 indicated that the winter of 1973 was representative of average winter conditions.

Approximately 63 million meteorological observations recorded for the year 1973 and collected via 25 weather sensing stations established the baseline data of wind velocities and ambient air temperatures for this study. These sensor stations composed a network of remote surface weather stations that gathered finely structured meteorological data which were collected every 10 seconds via conditioned telephone lines. Data were archived on magnetic tape at the central computer located at AFCRL, Hanscom Field, Bedford, Massachusetts.

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.

This project's 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 considerations of conductor size, 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.

Transmission line design engineers strive to build economically reliable lines. This translates into extracting in a safe fashion reasonable thermal capacity from any transmission line conductor size. Total capital costs, operating, maintenance and loss costs, are all directly related to transmission line conductor size.

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 proved to be the vehicle to amend or modify the design guidelines and operation of transmission lines.

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.

The 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 km) in length. Two private weather services confirmed that the weather data received from this geographic sector are representative of the weather data in the New England area.
2. (The AFCRL sensor height) - The above ground level of 25 feet (7.62 m) 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 $\pm$ 0.22 feet per second or 1% of measured wind speed, whichever is greater in the 0 to 17 feet per second range. The observed temperatures were accurate to $\pm$ 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.

## METHODOLOGY AND DISCUSSION

The raw weather data received from the Air Force Cambridge Reasearch Laboratories (AFCRL), Bedford, Massachusetts were recorded on 7-track tapes. In order to use this data on Northeast Utilities Service Companies (NU) IBM 3033 computer, the first step was to have the Air Force tapes translated to 9-track tapes. This translation was made by the Wang Data Center in Burlington, Massachusetts.

The information on the 9-track tapes supplied the input to an assembler program that copied blocks of records to output tapes. A PL/1 (Programming Language One) program was then written to read the records from the tapes. Records were then constructed and contained the following information:

a) date which is in the format year, month and day;

b) time which is in the format hour, minute and second;

c) readings obtained from the twenty-five weather stations;

d) identity number of each station.

The records in this file contained the information relevant to the twenty-five stations polled at ten second intervals.

A second PL/1 program was written to generate two files from the files of the previous PL/1 program. The first file contains records of five-minute averages of wind speed and temperature for twenty-five stations for each month. The second file contains records of daily averages for the twenty-five stations.

The last step in the preparation of the data collected involved the Statistical Analysis System (SAS). Procedures were written utilizing SAS to generate the following reports and plots:

a) A report showing the five-minute averages of wind speed and temperature at all the sensor stations (Sample Shown: Fig. 1);

b) A frequency distribution (Fig. 2);

c) A report of the daily and monthly averages of wind speed and temperature at all sensor stations (Fig. 3);

d) Line graphs displaying the wind speed profile for each day of every month of the year (Fig. 4);

e) Line graphs displaying the temperature profiles for each day of every month of the year (Fig. 5).

Validation of research data was very important because of the relationship to confidence level and subsequent decision making based upon acquired data. Using a conservative approach, if there were two (2) invalid readings per 5-minute interval, the 30 observations were discarded from the "valid category", and were recorded in the "invalid category" summary and were accounted for in total recorded observations. This approach yields a confidence level of about 97% for any single 5-minute interval.

The valid observations are classified as those observations that met our confidence level requirements and were used in our summaries.

The invalid observations are those that were discarded from the 5-minute summaries because of an erroneous recording, a frozen anemometer, a damaged component or telephone line problem.

The observations were unrecorded when no data were available for a particular date or time from a sensor station because of shutdown or problems with the telemetering equipment. There was a total of 16,117,054 unrecorded observations. There was a total of 62,722,946 meteorological observations recorded, of which 50,054,317 fell into the valid category and 12,668,629 into the invalid category.

The graphs displaying the wind speed and the ambient temperature for every hour of every day of the year were first compared to determine where the potential problem areas were that needed further investigation. That is, if the speed was below 3 feet per second and the ambient temperatures were in the upper regions, then high conductor temperatures could be suspect. The five-minute averages of wind perpendicular to the conductor and ambient temperatures for the suspect time were then used to model the actual conductor temperatures for the low-wind and high-ambient temperature period. An example of a worst-condition case is shown in the Case Study section.

## CASE STUDIES

The Conductor Rating Working Group's approach to ambient condition analysis was as follows:

1. Calculate normal circuit ratings for the "standard" ambient temperatures of 50°F winter and 100°F summer and a 3 feet per second wind perpendicular to the conductor.

2. Simulate "actual" conductor temperatures assuming that the circuit loading is constant and equal to the full normal rating and using actual 5-minute average values for perpendicular wind speed and ambient temperatures.

Because the statistical information tabulated by Northeast Utilities' computer programs demonstrated that wind speed rarely drops below 3 feet per second the Conductor Rating Working Group focused its efforts onto suspected trouble times. These periods of time were identified by scanning plots of ambient temperature and wind, and selecting occurrences of low wind and high ambient. (Sample plots. Fig. 4 and 5)

Data to model trouble periods were taken from the 5-minute average wind and temperature tables produced by Northeast Utilities' statistical analysis system and entered into a special version of the Conductor Transient Temperature Program PG108. This program was developed by NEES and is a part of the standard procedure for rating transmission conductors. The output consisted of plots of conductor temperature for full load and actual ambient conditions.

A total of 46 trouble periods were modeled in detail (Fig. 9) During 10 of these periods, we discovered that operating temperature limits were exceeded. Several of these incidences were of short duration and/or very minor degree. However, several others were fairly long (over one hour) with temperatures of as much as 110% of allowable being reached. September 3, 1973, stands out as one of the worst cases and will be described in more detail. Graphs 1, 2 and 3 are plots of conductor temperature, wind speeds and ambient temperature for the entire day. The cases described are for 795 KCMIL 54/7 ACSR (Condor) conductor, with 100°C operating limit. Other conductor sizes behave similarly.

The critical hours during this day were between 5:00 p.m. and 9:00 p.m. A plot of the simulated conductor temperature for this period shows that the 100°C limit for this case was exceeded for 166 minutes, with a maximum temperature of about 115°C. (Graph 4)

A histogram (Figure 6) of the numbers of minutes at each temperature over 100°C, shows that the majority of the minutes were below 110°C.

It is important to note here that several conservative factors in our modeling push simulated temperatures higher than may be expected.

The first of these factors is solar effect. For the preceding analysis, we assume a full summer solar effect of 5.59 watts per foot per inch of conductor diameter even though our modeling period is not that close to the time of year when the sun is highest, and even though the critical time period is relatively late in the day. If we assume that the actual solar effect for September 3 beginning at 5:00 p.m. is 2.8 watts per foot per inch of conductor diameter (still a conservative value), our simulation results in the temperatures shown in Graph 5. Now, conductor temperatures exceed 100°C for 100 minutes. The histogram depicting the time during which 100°C was exceeded, (Fig. 7) shows a dramatic shift downward, with the majority of exceeded minutes at 105°C or below.

Another overly conservative assumption is that the modeled conductor carries 100% of its normal rating <u>continuously</u>. Simulations of conductor temperature with reduced solar effect and under 97.5% and 95% loading are shown in Graphs 6 and 7. At 97.5% loading, temperature limits are exceeded for only 43 minutes, with a maximum of 104°C, and at 95% loading, allowable temperature limits are <u>not</u> exceeded.

The analysis shows that for a 43-minute period for one day out of the year, the conductor temperature exceeded the maximum design temperature by 5° centigrade (C°). The extra 5°C conductor temperature on spans of 800 feet would increase the conductor sag by about five inches for this period of time. For spans less than 800 feet, the sag increase will be less.

On the other hand, the effect of a wind direction at any angle other than perpendicular to the line is an increase in conductor temperature. Because of the wide variations of wind direction relative to the conductors of a transmission line, it is probable that some spans will be subject to a higher temperature than if wind were blowing perfectly perpendicular to the conductor. However, since the direction of the wind is known to be quite variable at any one location along a transmission line, an assumption that the wind is continually blowing parallel to the general direction of the line conductors is unduly restrictive. Furthermore the thermal inertia of the conductor would tend to smooth the effects of the varying wind direction.

Therefore, a 3 feet per second wind blowing perpendicular to the conductor is not an unreasonable assumption, weighting the possible impact of varying wind direction against the very conservative assumptions of solar heat gain, and continuous full loading of the conductor used in calculating line ratings as well as the significant conductor thermal inertia and safety factors used in plotting line clearance.

The preceding analysis was repeated using circuit loadings based on transverse wind speeds of 3.5 and 4.0 feet per second. Under these specific conditions, the modeled conductor temperatures exceeded design limits by greater amounts (up to 27°) and for far longer durations (up to 10 hours) than in the 3 feet per second Case (Graphs 8 & 9, Figures 10 & 11). The Conductor Rating Working Group decided that the risks associated with the use of these higher wind speeds as design guidelines are not justifiable.

## CONCLUSIONS

It has been common practice among New England electric utilities to calculate ampacity ratings of overhead transmission lines utilizing a minimum wind velocity of two feet per second. The basis for deciding to utilize this value has been questioned for some time.

After careful analysis of one year's weather data representing 50,054,317 valid observations, the Conductor Rating Working Group concluded that the minimum wind speed rarely falls below 3 feet per second. During those infrequent times where the wind speed is below 3 feet per second, factors such as the unlikelihood of an attendant high ambient temperature, significant conductor thermal inertia, the improbability of full solar effect, the unlikelihood of continuous full loading, and the safety factors used in plotting line clearances tend to mitigate or, more likely, cancel the effect of being below 3 feet per second for the purpose of rating transmission line conductors. On the other hand, the variation in the angle at which the wind crosses the conductors caused by wind direction can diminish the relative effectiveness of the wind and reduce the conservatism of using a 3 feet per second wind velocity assumption. However, all factors considered, 3 feet per second appears to be a reasonable wind velocity assumption for the rating of transmission lines in New England on a year-round basis. Each company should weight the factors affecting the conservatism of this assumption in consideration of any particular line being rated.

STATION NUMBER 10 135 FT ABOVE SEA LEVEL BILLERICA JULY 4, 1973

| TIME | WIND SPEED KNOTS | WIND SPEED FEET / SECOND | UNDER 3 FT/SEC | AIR TEMPERATURE FAHRENHEIT | AIR TEMPERATURE CELSIUS |
|---|---|---|---|---|---|
| 16:30 | 10.4 | 17.6 | | 80.9 | 27.2 |
| 16:35 | 9.9 | 16.7 | | 80.3 | 26.8 |
| 16:40 | 9.1 | 15.3 | | 79.8 | 26.6 |
| 16:45 | 8.4 | 14.2 | | 79.7 | 26.5 |
| 16:50 | 6.7 | 11.3 | | 79.3 | 26.2 |
| 16:55 | 6.5 | 10.9 | | 79.3 | 26.2 |
| 17:00 | 5.7 | 9.7 | | 79.2 | 26.2 |
| 17:05 | 8.7 | 14.6 | | 79.1 | 26.2 |
| 17:10 | 7.0 | 11.9 | | 79.0 | 26.1 |
| 17:15 | 6.6 | 11.2 | | 79.1 | 26.2 |
| 17:20 | 5.6 | 9.4 | | 79.3 | 26.3 |
| 17:25 | 7.7 | 12.9 | | 79.4 | 26.3 |
| 17:30 | 8.0 | 13.5 | | 79.4 | 26.3 |
| 17:35 | 7.3 | 12.2 | | 79.3 | 26.3 |
| 17:40 | 5.2 | 8.8 | | 79.4 | 26.4 |
| 17:45 | 6.3 | 10.6 | | 79.2 | 26.2 |
| 17:50 | 7.1 | 12.0 | | 79.0 | 26.1 |
| 17:55 | 5.2 | 8.7 | | 78.7 | 25.9 |
| 18:00 | 5.8 | 9.7 | | 78.4 | 25.8 |
| 18:05 | 5.5 | 9.3 | | 78.2 | 25.7 |
| 18:10 | 5.6 | 9.5 | | 78.4 | 25.8 |
| 18:15 | 4.6 | 7.7 | | 78.2 | 25.7 |
| 18:20 | 4.4 | 7.4 | | 78.4 | 25.8 |
| 18:25 | 5.1 | 8.7 | | 78.3 | 25.7 |
| 18:30 | 5.0 | 8.4 | | 78.4 | 25.8 |
| 18:35 | 7.3 | 12.3 | | 78.4 | 25.8 |
| 18:40 | 7.4 | 12.5 | | 78.2 | 25.7 |
| 18:45 | 7.2 | 12.1 | | 77.9 | 25.5 |
| 18:50 | 6.5 | 11.0 | | 77.7 | 25.4 |
| 18:55 | 5.5 | 9.4 | | 77.7 | 25.4 |
| 19:00 | 5.9 | 10.0 | | 77.7 | 25.4 |
| 19:05 | 5.3 | 9.0 | | 77.7 | 25.4 |
| 19:10 | 6.5 | 11.0 | | 77.6 | 25.4 |
| 19:15 | 5.8 | 9.8 | | 77.5 | 25.3 |
| 19:20 | 6.3 | 10.6 | | 77.5 | 25.3 |
| 19:25 | 6.0 | 10.2 | | 77.7 | 25.4 |
| 19:30 | 6.6 | 11.2 | | 77.6 | 25.3 |
| 19:35 | 7.7 | 13.1 | | 77.6 | 25.3 |
| 19:40 | 6.1 | 10.4 | | 77.6 | 25.3 |
| 19:45 | 7.3 | 12.3 | | 77.5 | 25.3 |
| 19:50 | 5.5 | 9.3 | | 77.4 | 25.2 |
| 19:55 | 5.1 | 8.7 | | 77.3 | 25.1 |
| 20:00 | 6.5 | 10.9 | | 77.3 | 25.1 |
| 20:05 | 6.2 | 10.4 | | 77.1 | 25.1 |
| 20:10 | 4.7 | 8.0 | | 77.1 | 25.1 |
| 20:15 | 5.7 | 9.7 | | 77.0 | 25.0 |
| 20:20 | 6.2 | 10.5 | | 76.9 | 24.9 |
| 20:25 | 6.0 | 10.2 | | 76.9 | 24.9 |
| 20:30 | 6.8 | 11.4 | | 77.0 | 25.0 |
| 20:35 | 11.5 | 19.4 | | 77.0 | 25.0 |

| TIME | WIND SPEED KNOTS | WIND SPEED FEET / SECOND | UNDER 3 FT/SEC | AIR TEMPERATURE FAHRENHEIT | AIR TEMPERATURE CELCIUS |
|---|---|---|---|---|---|
| 20:40 | 11.0 | 18.6 | | 77.0 | 25.0 |
| 20:45 | . | . | | . | . |
| 20:50 | 9.9 | 16.7 | | 76.6 | 24.8 |
| 20:55 | 8.2 | 13.8 | | 76.3 | 24.6 |
| 21:00 | 7.8 | 13.2 | | 75.8 | 24.3 |
| 21:05 | 7.8 | 13.2 | | 75.6 | 24.2 |
| 21:10 | 6.8 | 11.4 | | 75.6 | 24.2 |
| 21:15 | 9.3 | 15.7 | | 75.6 | 24.2 |
| 21:20 | 9.0 | 15.1 | | 75.6 | 24.2 |
| 21:25 | 11.0 | 18.5 | | 75.6 | 24.2 |
| 21:30 | 9.9 | 16.7 | | 75.4 | 24.1 |
| 21:35 | 10.1 | 17.1 | | 75.2 | 24.0 |
| 21:40 | 9.8 | 16.5 | | 74.9 | 23.8 |
| 21:45 | 11.4 | 19.3 | | 74.9 | 23.8 |
| 21:50 | 12.0 | 20.2 | | 74.1 | 23.4 |
| 21:55 | 9.5 | 16.0 | | 73.4 | 23.0 |
| 22:00 | 7.0 | 11.9 | | 73.3 | 23.0 |
| 22:05 | 7.3 | 12.4 | | 73.1 | 22.8 |
| 22:10 | 6.8 | 11.5 | | 73.1 | 22.8 |
| 22:15 | 6.1 | 10.3 | | 73.0 | 22.8 |
| 22:20 | 7.0 | 11.9 | | 72.9 | 22.7 |
| 22:25 | 7.0 | 11.9 | | 72.8 | 22.7 |
| 22:30 | 5.5 | 9.2 | | 72.8 | 22.7 |
| 22:35 | 6.1 | 10.3 | | 72.8 | 22.7 |
| 22:40 | 5.6 | 9.4 | | 72.8 | 22.7 |
| 22:45 | 5.2 | 8.8 | | 72.8 | 22.7 |
| 22:50 | 4.8 | 8.2 | | 72.8 | 22.7 |
| 22:55 | 5.2 | 8.7 | | 72.8 | 22.7 |
| 23:00 | 4.7 | 8.0 | | 72.8 | 22.7 |
| 23:05 | 5.5 | 9.4 | | 72.9 | 22.7 |
| 23:10 | 5.8 | 9.9 | | 73.0 | 22.8 |
| 23:15 | 6.9 | 11.7 | | 73.0 | 22.8 |
| 23:20 | 5.8 | 9.7 | | 73.0 | 22.8 |
| 23:25 | 5.5 | 9.3 | | 73.1 | 22.8 |
| 23:30 | 6.8 | 11.4 | | 73.1 | 22.8 |
| 23:35 | 6.3 | 10.6 | | 73.1 | 22.8 |
| 23:40 | 5.8 | 9.8 | | 72.9 | 22.7 |
| 23:45 | 6.7 | 11.2 | | 73.0 | 22.8 |
| 23:50 | 6.2 | 10.4 | | 73.0 | 22.8 |
| 23:55 | 5.1 | 8.6 | | 72.9 | 22.7 |
| 23:55 | . | . | | . | . |
| HIGH | 17.7 | 29.9 | | 81.2 | 27.3 |
| LOW | 0.6 | 1.1 | | 69.3 | 20.7 |
| AVG | 5.2 | 8.7 | | 74.1 | 23.4 |

VALID OBSERVATIONS 8586
INVALID OBSERVATIONS 54
UNRECORDED OBSERVATIONS 0
TOTAL OBSERVATIONS 8640

FIVE MINUTE AVERAGE – WINDSPEED AND TEMPERATURE

Fig. I

5 MINUTE WIND / VELOCITY / TEMPERATURE FREQUENCY DISTRIBUTION
FOR THE MONTH OF SEPTEMBER 1973

VELOCITY RANGE
7.5-8.0 FT/SEC

TEMPERATURE IN DEGREES FAHRENHEIT

| | | <= 25 | <= 30 | <= 35 | <= 40 | <= 45 | <= 50 | <= 55 | <= 60 | <= 65 | <= 70 | <= 75 | <= 80 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 00:00 | 0 | 0 | 0 | 0 | 2 | 24 | 83 | 50 | 27 | 31 | 2 | 0 | 219 |
| | 01:00 | 0 | 0 | 0 | 0 | 1 | 34 | 76 | 50 | 27 | 28 | 1 | 0 | 217 |
| T | 02:00 | 0 | 0 | 0 | 0 | 10 | 34 | 68 | 46 | 17 | 7 | 0 | 0 | 182 |
| I | 03:00 | 0 | 0 | 0 | 1 | 11 | 35 | 54 | 60 | 26 | 21 | 0 | 0 | 208 |
| M | 04:00 | 0 | 0 | 0 | 2 | 15 | 31 | 42 | 57 | 26 | 13 | 0 | 0 | 186 |
| E | 05:00 | 0 | 0 | 0 | 5 | 11 | 26 | 69 | 38 | 20 | 13 | 0 | 0 | 182 |
| | 06:00 | 0 | 0 | 0 | 1 | 21 | 23 | 52 | 37 | 15 | 19 | 0 | 0 | 168 |
| O | 07:00 | 0 | 0 | 0 | 0 | 12 | 32 | 46 | 48 | 22 | 11 | 5 | 0 | 176 |
| F | 08:00 | 0 | 0 | 0 | 0 | 8 | 36 | 96 | 67 | 42 | 18 | 14 | 0 | 281 |
| | 09:00 | 0 | 0 | 0 | 0 | 0 | 19 | 73 | 74 | 53 | 41 | 12 | 1 | 273 |
| D | 10:00 | 0 | 0 | 0 | 0 | 1 | 2 | 46 | 70 | 41 | 51 | 7 | 7 | 225 |
| A | 11:00 | 0 | 0 | 0 | 0 | 0 | 3 | 41 | 92 | 56 | 57 | 23 | 14 | 286 |
| Y | 12:00 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 57 | 62 | 47 | 21 | 4 | 220 |
| | 13:00 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 51 | 55 | 72 | 27 | 7 | 255 |
| | 14:00 | 0 | 0 | 0 | 0 | 0 | 2 | 25 | 39 | 64 | 68 | 28 | 3 | 229 |
| L | 15:00 | 0 | 0 | 0 | 0 | 1 | 1 | 23 | 38 | 58 | 83 | 52 | 10 | 266 |
| O | 16:00 | 0 | 0 | 0 | 0 | 0 | 2 | 21 | 46 | 84 | 129 | 37 | 17 | 336 |
| C | 17:00 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 62 | 59 | 135 | 25 | 9 | 313 |
| A | 18:00 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 56 | 53 | 52 | 12 | 4 | 217 |
| L | 19:00 | 0 | 0 | 0 | 0 | 0 | 6 | 44 | 39 | 53 | 36 | 18 | 8 | 204 |
| | 20:00 | 0 | 0 | 0 | 0 | 0 | 14 | 60 | 51 | 75 | 24 | 6 | 3 | 233 |
| | 21:00 | 0 | 0 | 0 | 0 | 1 | 10 | 44 | 71 | 35 | 27 | 3 | 1 | 192 |
| | 22:00 | 0 | 0 | 0 | 0 | 0 | 14 | 34 | 77 | 19 | 28 | 3 | 2 | 177 |
| | 23:00 | 0 | 0 | 0 | 0 | 1 | 12 | 60 | 71 | 14 | 33 | 4 | 2 | 197 |
| TOTALS | | 0 | 0 | 0 | 9 | 95 | 360 | 1192 | 1347 | 1003 | 1044 | 300 | 92 | 5442 |
| MEAN | | | | | | | | | | | | | | |
| TEMP. | | 0.00 | 0.00 | 0.00 | 39.17 | 43.60 | 47.95 | 52.93 | 57.20 | 62.48 | 67.27 | 72.19 | 76.31 | |
| VEL. | | 0.00 | 0.00 | 0.00 | 7.73 | 7.74 | 7.76 | 7.75 | 7.75 | 7.75 | 7.75 | 7.76 | 7.79 | |
| STD. DEV. | | | | | | | | | | | | | | |
| TEMP. | | 0.000 | 0.000 | 0.000 | 0.546 | 1.188 | 1.388 | 1.348 | 1.430 | 1.511 | 1.398 | 1.411 | 1.298 | |
| VEL. | | 0.000 | 0.000 | 0.000 | 0.147 | 0.140 | 0.140 | 0.139 | 0.143 | 0.141 | 0.144 | 0.138 | 0.137 | |

Fig. 2

| NEWDATE | TEMP | WIND_VEL |
|---|---|---|
| MAY 1, 1973 | 48.2524 | 6.1163 |
| MAY 2, 1973 | 55.5096 | 6.7408 |
| MAY 3, 1973 | 58.7830 | 8.2382 |
| MAY 4, 1973 | 55.7588 | 7.3865 |
| MAY 5, 1973 | 47.6434 | 6.2818 |
| MAY 6, 1973 | 48.5257 | 6.8065 |
| MAY 7, 1973 | 48.7945 | 7.5770 |
| MAY 8, 1973 | 53.4711 | 7.6285 |
| MAY 9, 1973 | 51.4081 | 8.2367 |
| MAY 10, 1973 | 52.7363 | 6.7244 |
| MAY 11, 1973 | 53.8373 | 6.8614 |
| MAY 12, 1973 | 54.9310 | 10.4126 |
| MAY 13, 1973 | 54.6073 | 11.1315 |
| MAY 14, 1973 | 55.0386 | 8.4489 |
| MAY 15, 1973 | 51.6044 | 6.0824 |
| MAY 16, 1973 | 53.5165 | 8.3361 |
| MAY 17, 1973 | 50.9849 | 8.7446 |
| MAY 18, 1973 | 47.6787 | 11.9999 |
| MAY 19, 1973 | 52.1022 | 10.9330 |
| MAY 20, 1973 | 54.9666 | 7.1633 |
| MAY 21, 1973 | 55.5460 | 11.0924 |
| MAY 22, 1973 | 54.9173 | 12.3043 |
| MAY 23, 1973 | 56.5584 | 7.0433 |
| MAY 24, 1973 | 54.0719 | 7.1423 |
| MAY 25, 1973 | 49.2478 | 10.0887 |
| MAY 26, 1973 | 47.7866 | 7.5104 |
| MAY 27, 1973 | 51.2445 | 6.1910 |
| MAY 28, 1973 | 54.4054 | 7.6885 |
| MAY 29, 1973 | 70.1459 | 10.8015 |
| MAY 30, 1973 | 66.2077 | 5.8267 |
| MAY 31, 1973 | 65.2620 | 7.0904 |

Fig. 3

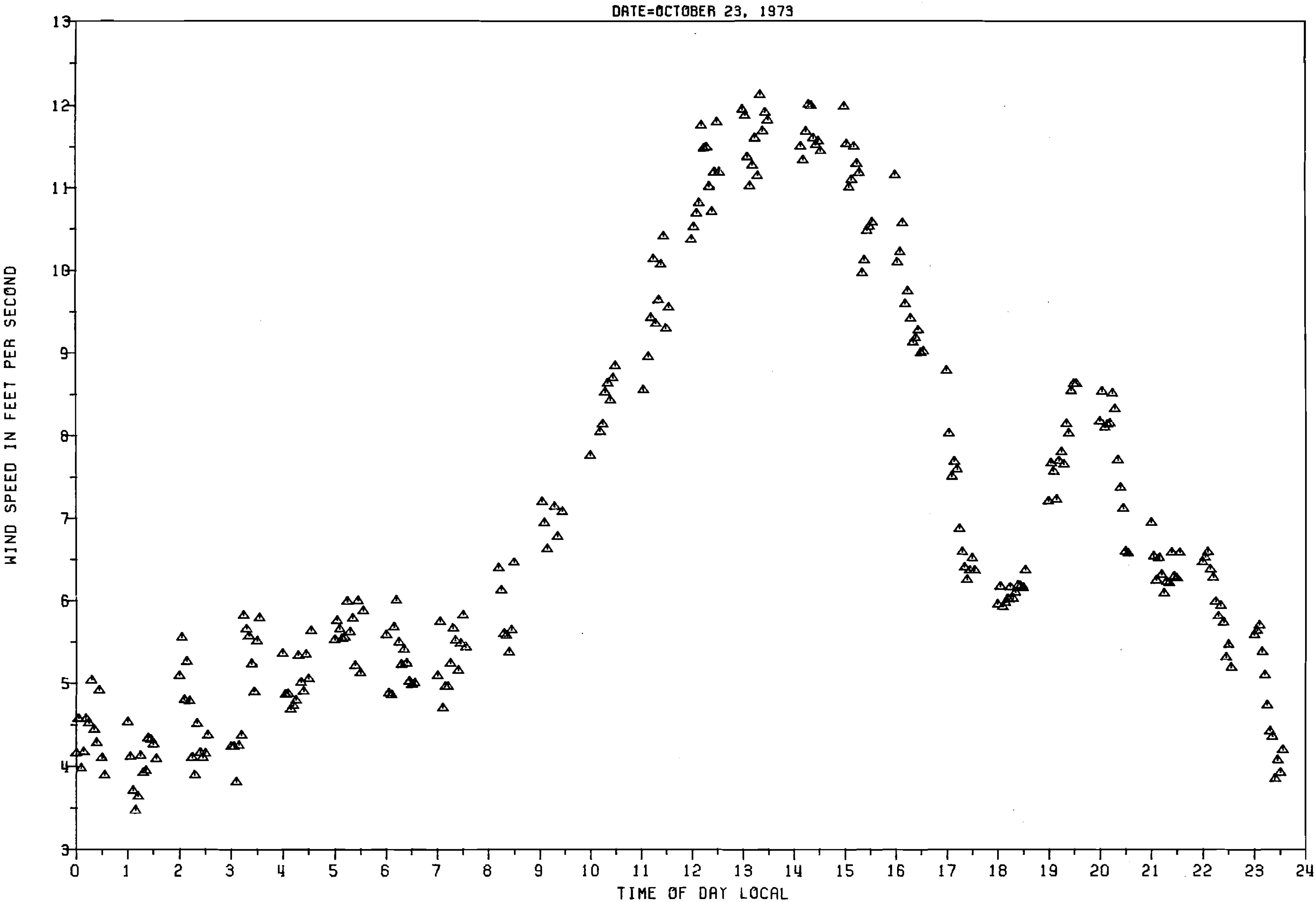

DATE=OCTOBER 23, 1973
WIND SPEED IN FEET PER SECOND
TIME OF DAY LOCAL
3
4
5
6
7
8
9
10
11
12
13
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

Fig. 4

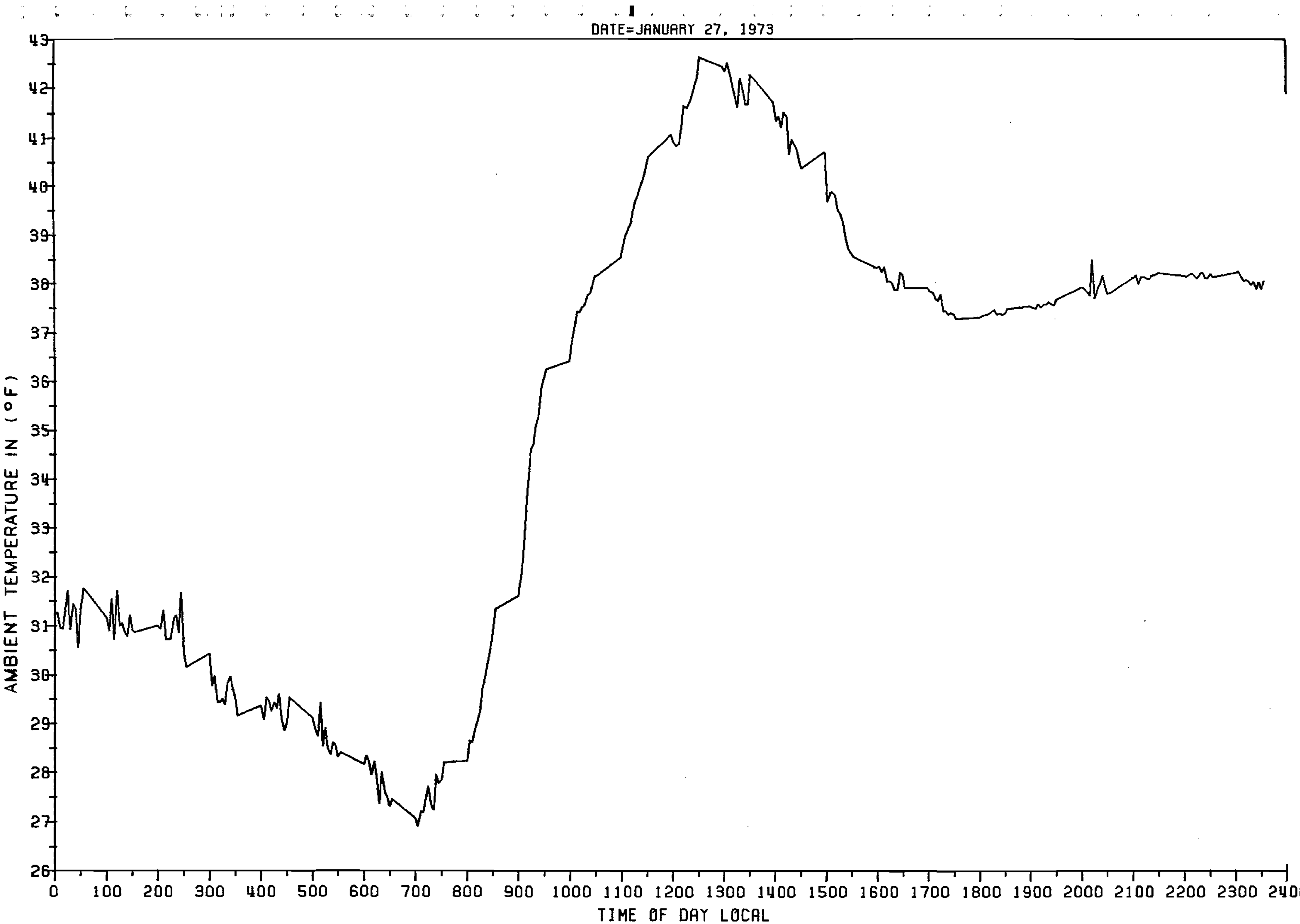
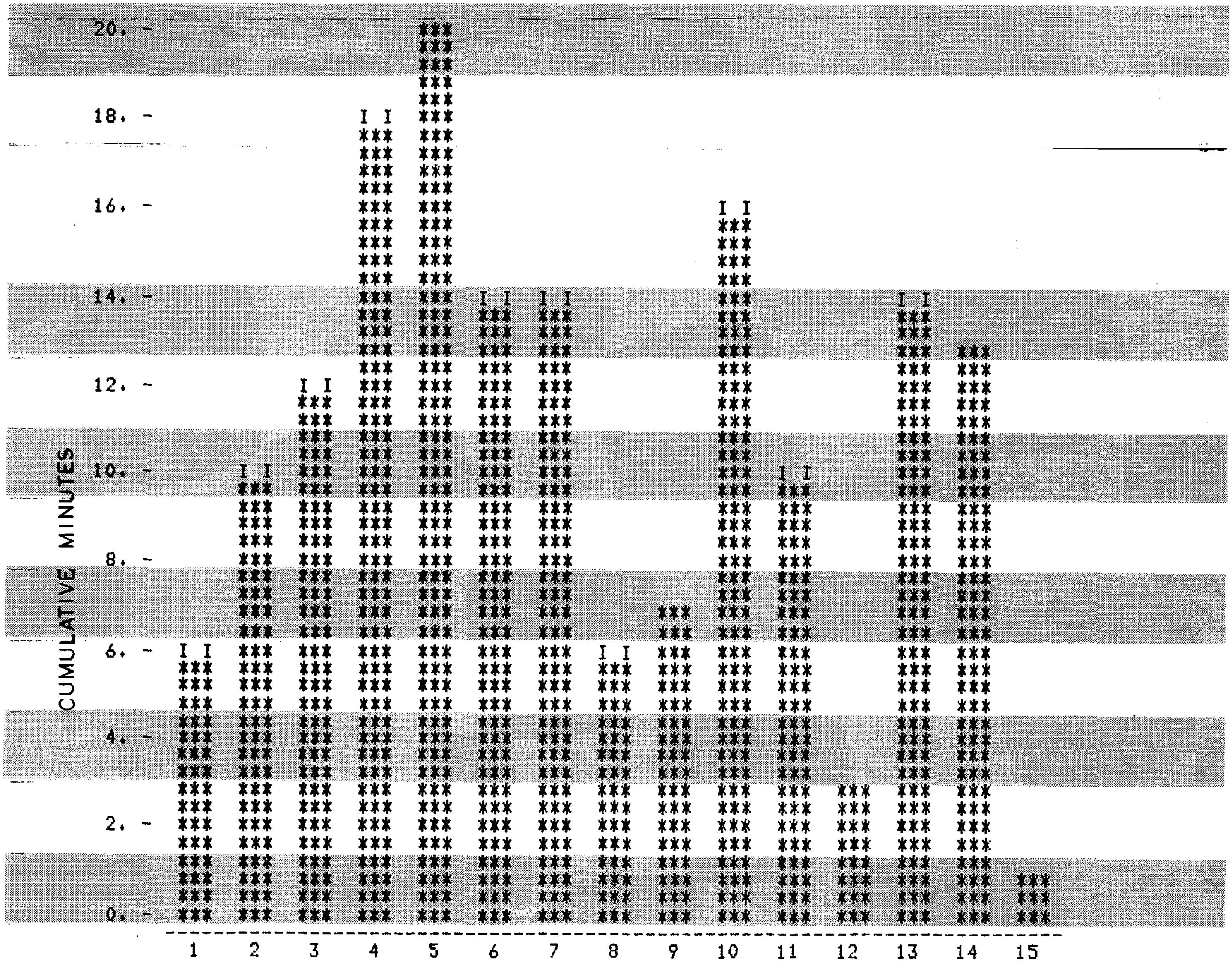
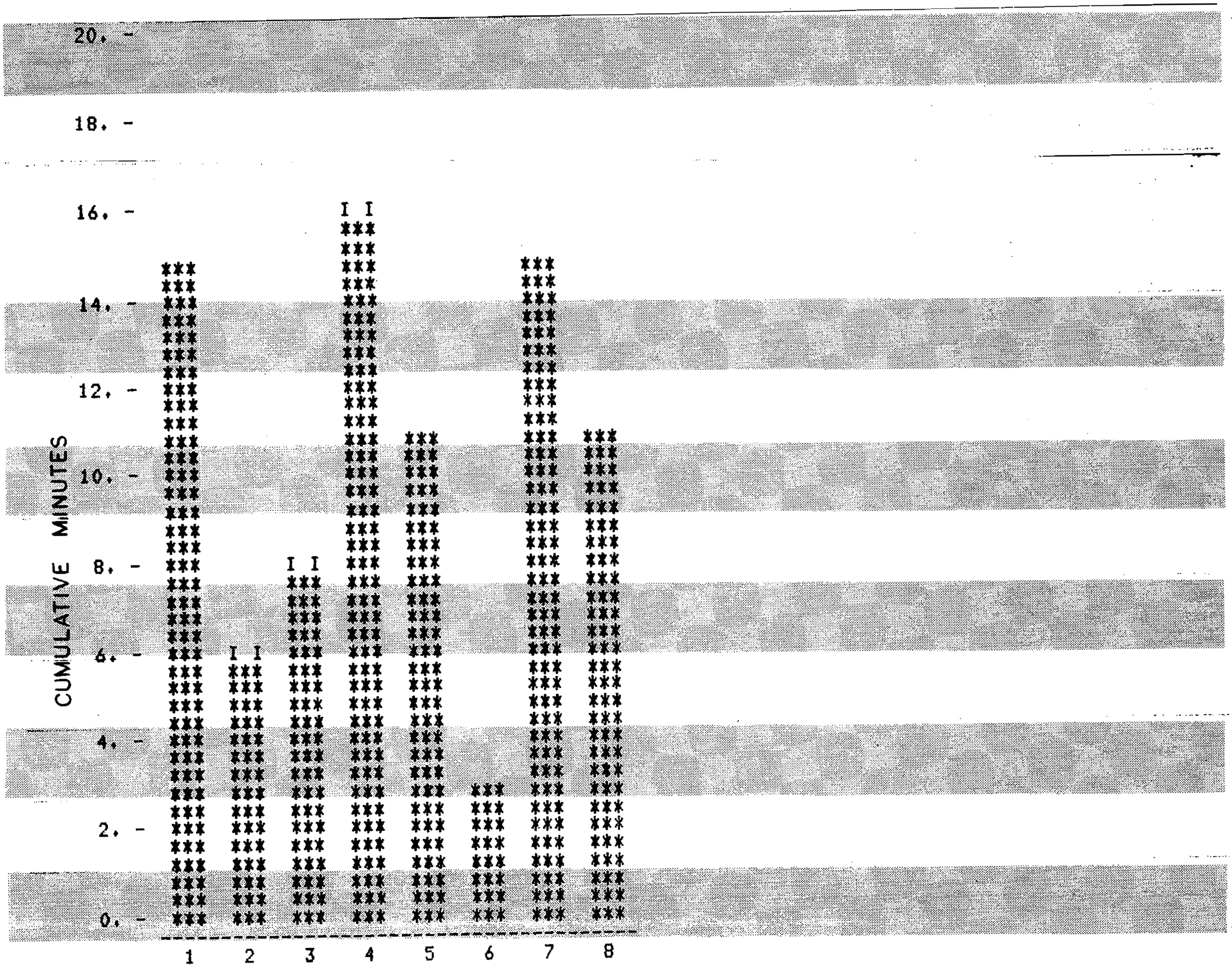

DATE=JANUARY 27, 1973
AMBIENT TEMPERATURE IN (°F)
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
TIME OF DAY LOCAL

Fig. 5



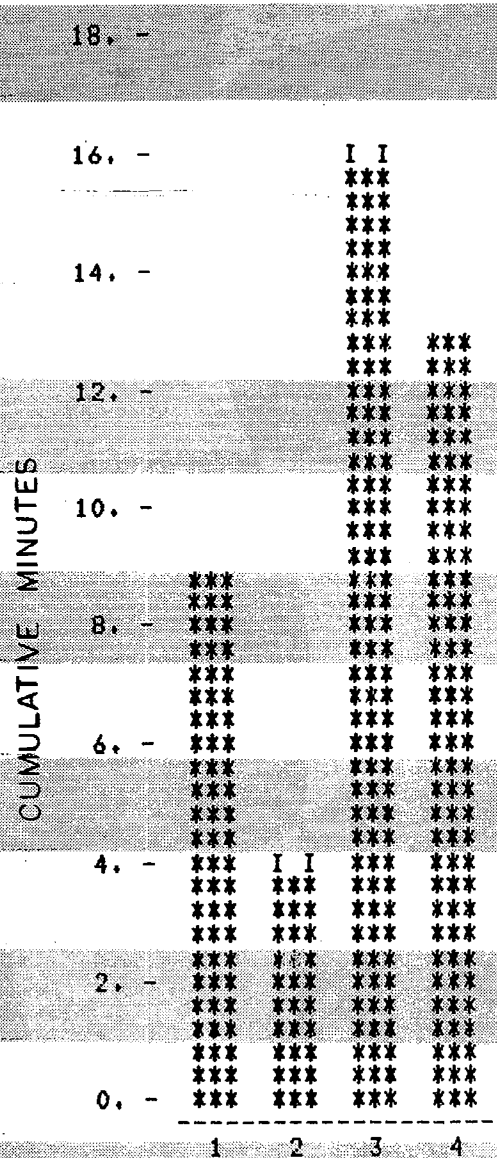

MINUTES VS. EXCESS TEMP., FULL SOLAR, DEGREES OVER 100° C, SEPTEMBER 3, 1973, 3FPS

Fig. 6




MINUTES VS. EXCESS TEMP., HALF SOLAR, DEGREES OVER 100°C, SEPT. 3, 1973, 3FPS

Fig. 7




MINUTES VS. EXCESS TEMP. DEGREES OVER 100°C, 97.5 % LOADING, HALF SOLAR, SEPT. 3, 1973, 3FPS

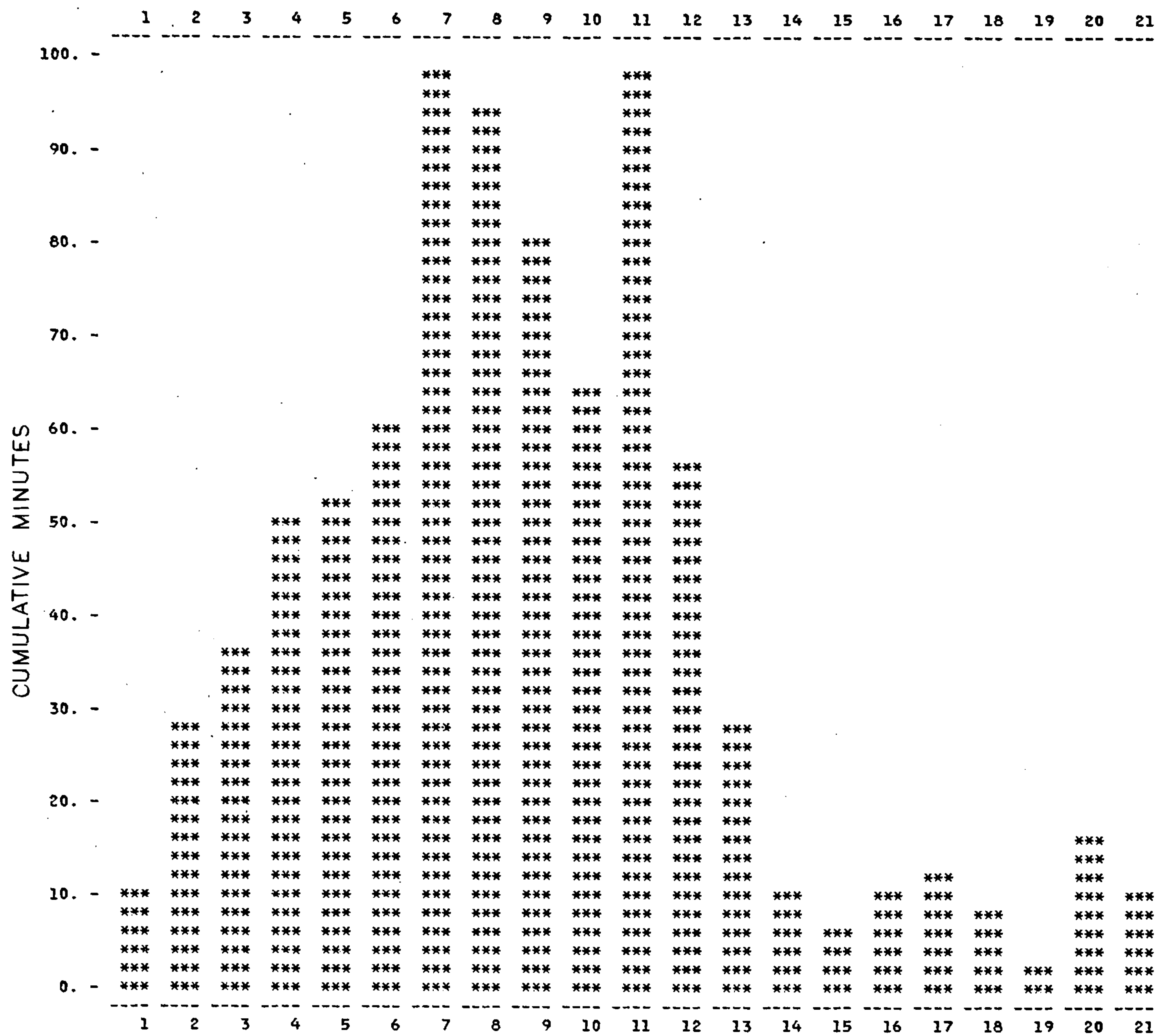
Fig. 8

## Modelled Periods

| Date | Approximate Time |
|---|---|
| Jan. 10 | 22:00 - 23:00 |
| Jan. 13 | 16:00 - 20:00 |
| Jan. 17 | 20:00 - 22:00 |
| Jan. 18 | 18:00 - 20:00 |
| Jan. 21 | 16:00 - 19:00 |
| Feb. 2 | 15:00 - 24:00 |
| Feb. 3 | 0:00 - 5:00 |
| Feb. 26 | 4:00 - 6:00 |
| Mar. 1 | 6:00 - 7:00 |
| Mar. 8 | 1:00 - 6:00 |
| Mar. 8 | 7:00 - 7:30 |
| Mar. 12 | 1:20 - 4:15 |
| May 27 | 4:20 - 8:30 |
| June 26 | 0:00 - 3:40 |
| July 9 | 19:00 - 24:00 |
| July 21 | 5:00 - 11:00 |
| July 21 | 16:00 - 21:00 |
| July 5 | 13:30 - 14:00 |
| July 9 | 22:50 - 24:00 |
| July 10 | 22:30 - 23:30 |

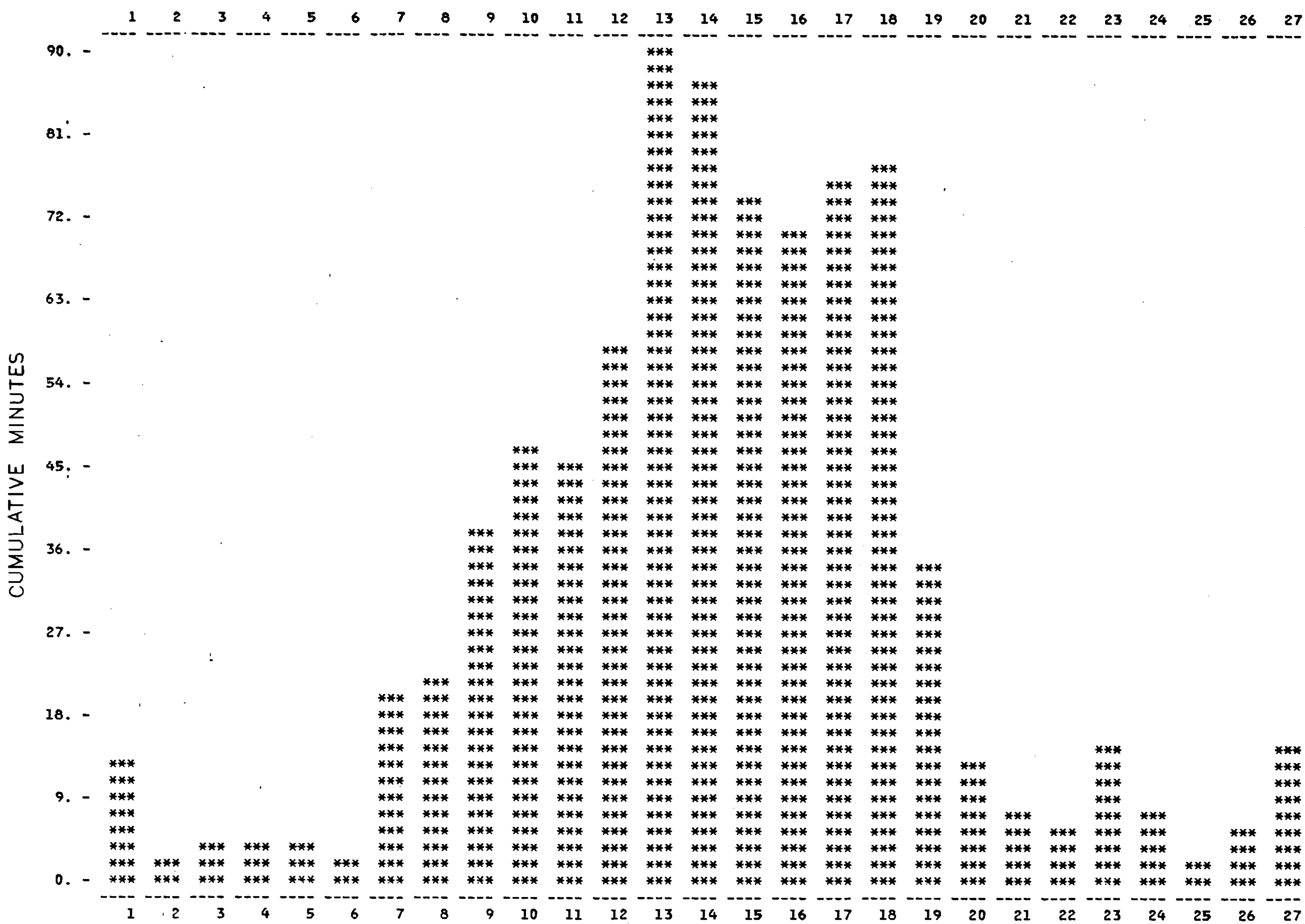
| Date | Approximate Time |
|---|---|
| Aug. 3 | 19:50 - 21:30 |
| Aug. 4 | 4:30 - 8:45 |
| Aug. 6 | 21:50 - 23:30 |
| Aug. 7 | 1:15 - 2:40 |
| Aug. 20 | 21:30 - 24:00 |
| Aug. 21 | 17:30 - 19:30 |
| Aug. 25 | 6:45 - 8:00 |
| Aug. 27 | 8:00 - 9:15 |
| Aug. 30 | 14:30 - 15:40 |
| Sept. 1 | 14:00 - 18:00 |
| Sept. 1 | 21:00 - 24:00 |
| Sept. 2 | 0:00 - 7:00 |
| Sept. 3 | 3:00 - 8:00 |
| Sept. 4 | 0:00 - 7:00 |
| Sept. 5 | 3:00 - 6:00 |
| Oct. 30 | 8:00 - 10:00 |
| Nov. 11 | 19:30 - 24:00 |
| Nov. 12 | 4:00 - 10:00 |
| Nov. 16 | 8:00 - 8:30 |
| Nov. 18 | 18:00 - 19:00 |
| Nov. 18 | 21:50 - 24:00 |
| Nov. 22 | 5:00 - 7:00 |
| Nov. 22 | 9:30 - 10:15 |
| Dec. 4 | 18:00 - 21:00 |
| Dec. 13 | 7:50 - 9:00 |
| Dec. 17 | 7:00 - 11:00 |

Fig. 9




MINUTES VS. EXCESS TEMP., FULL SOLAR, 10C % LCAD, DEGREES OVER 100°C, SEPT. 3, 1973, 3.5 FPS

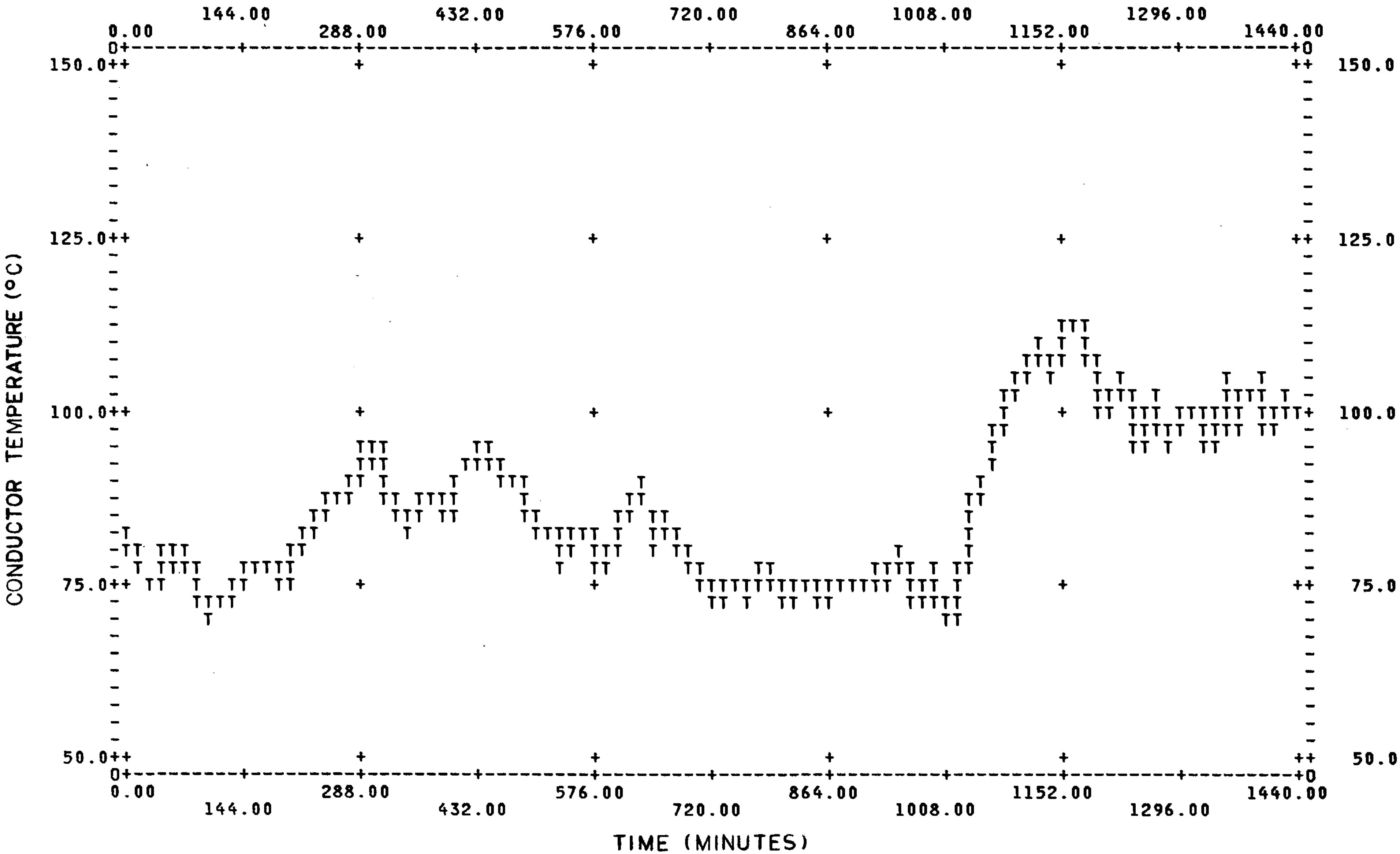
Fig. 10




MINUTES VS. EXCESS TEMP., FULL SOLAR, 100 % LOAD, DEGREES OVER 100°C, SEPT. 3, 1973, 4.0 FPS

Fig. 11

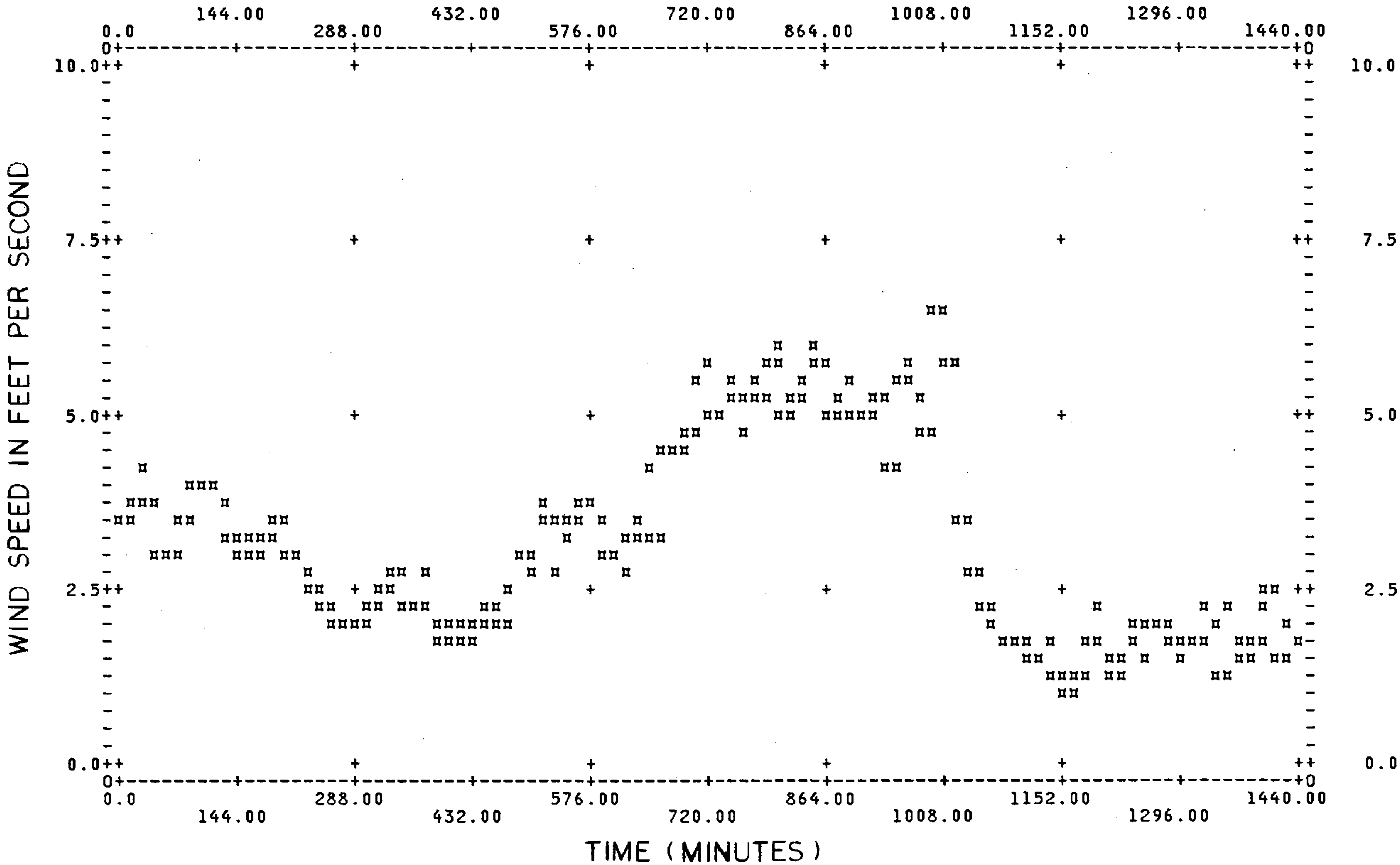
RESISTANCE= 0.1190 OHM/MI    DIAMETER= 1.0930 IN    AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT    EMISSIVITY=0.75    NUMBER OF CONDUCTORS= 1




SDTF CONDUCTOR RATING WORKING GROUP
CONDUCTOR TEMPERATURE VS. TIME, 795 ACSR 54/7 CONDOR
SEPTEMBER 3, 1973: 100% LOAD,3 FPS RATING, FULL SOLAR

Graph I.

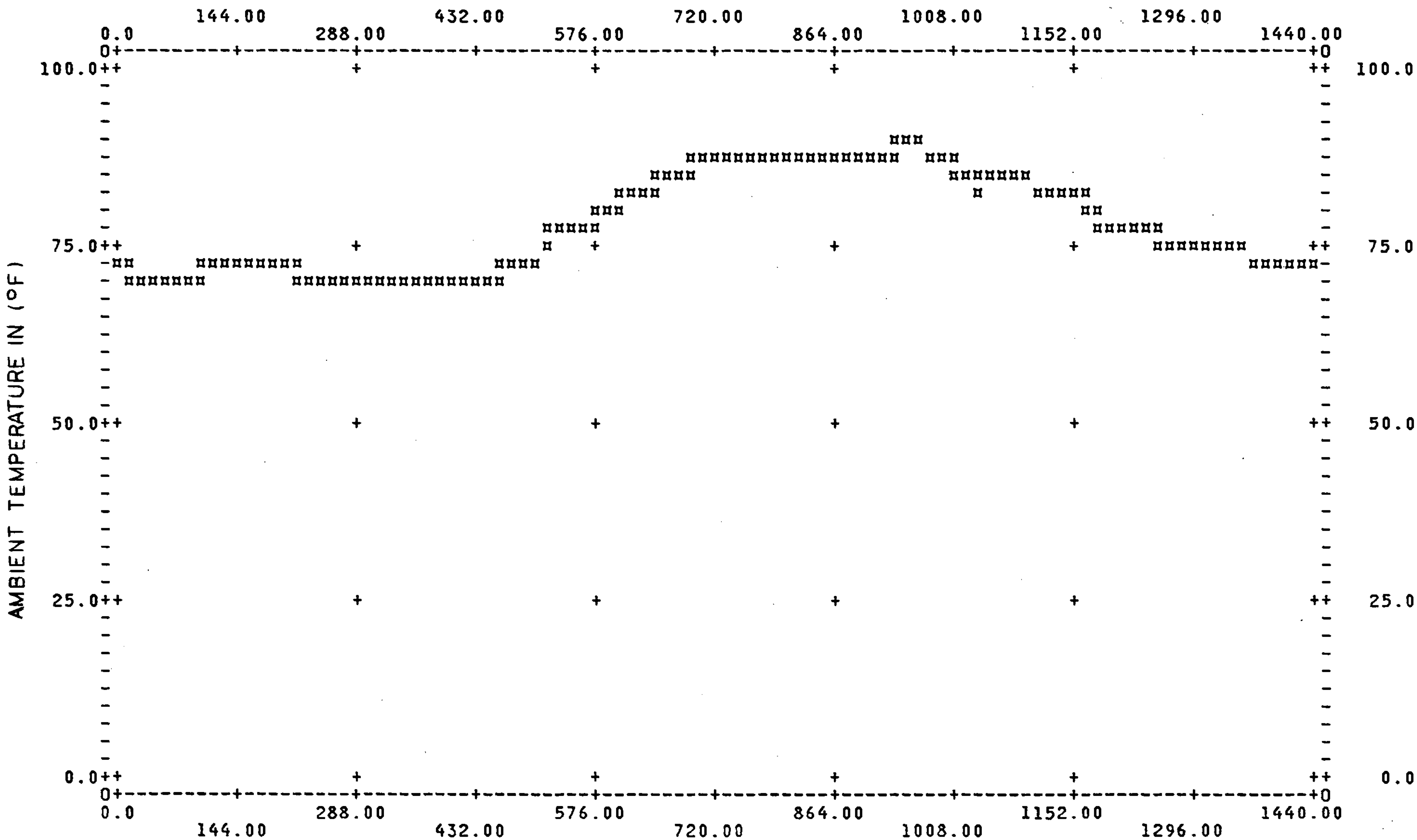
RESISTANCE= 0.1190 OHM/MI DIAMETER= 1.0930 IN AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT EMISSIVITY=0.75 NUMBER OF CONDUCTORS= 1




SEPTEMBER 3, 1973
WIND VELOCITY VS. TIME

Graph 2.

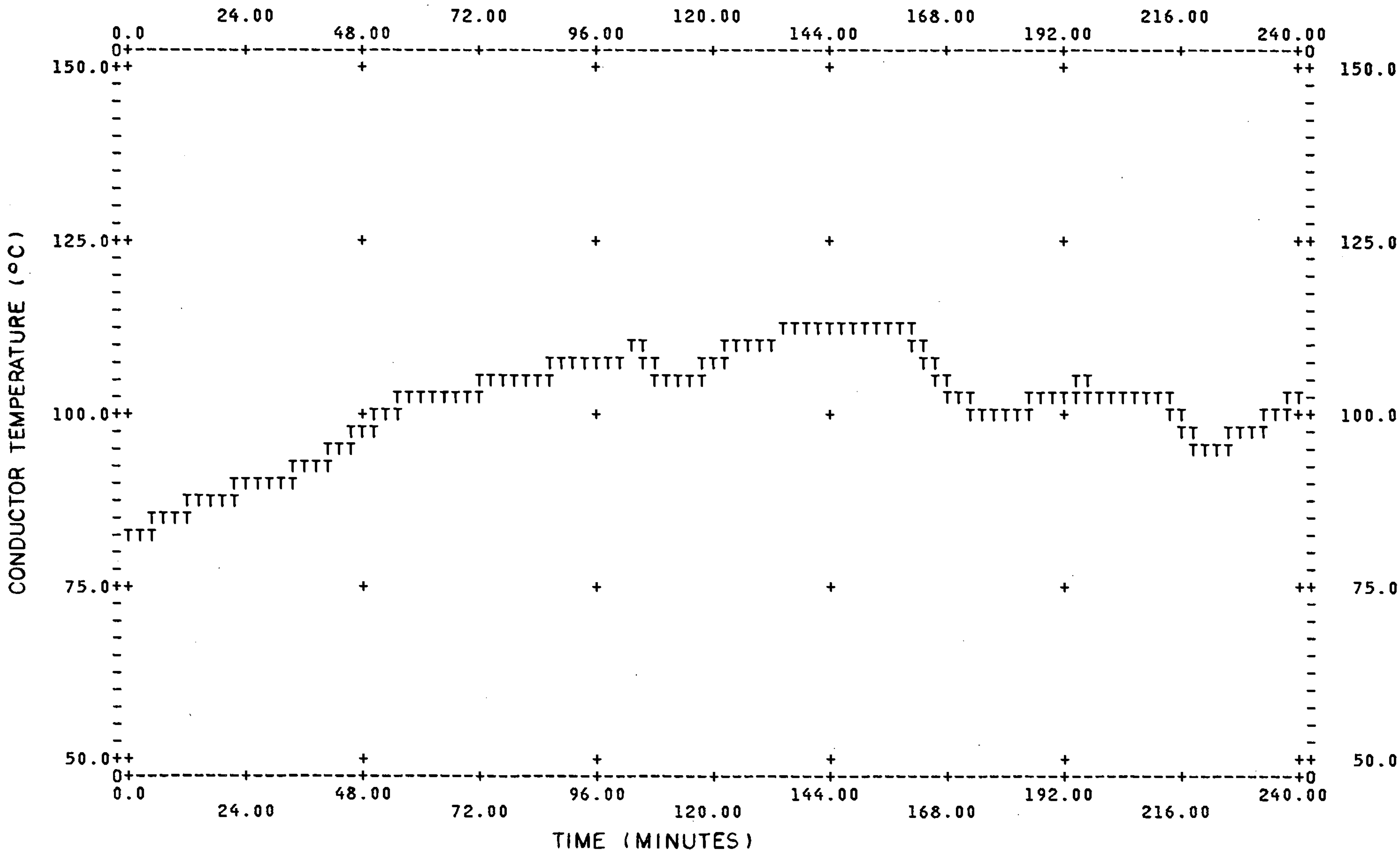
RESISTANCE= 0.1190 OHM/MI　DIAMETER= 1.0930 IN　AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT　EMISSIVITY=0.75　NUMBER OF CONDUCTORS= 1




SEPTEMBER 3, 1973
AMBIENT TEMPERATURE VS. TIME

Graph 3.

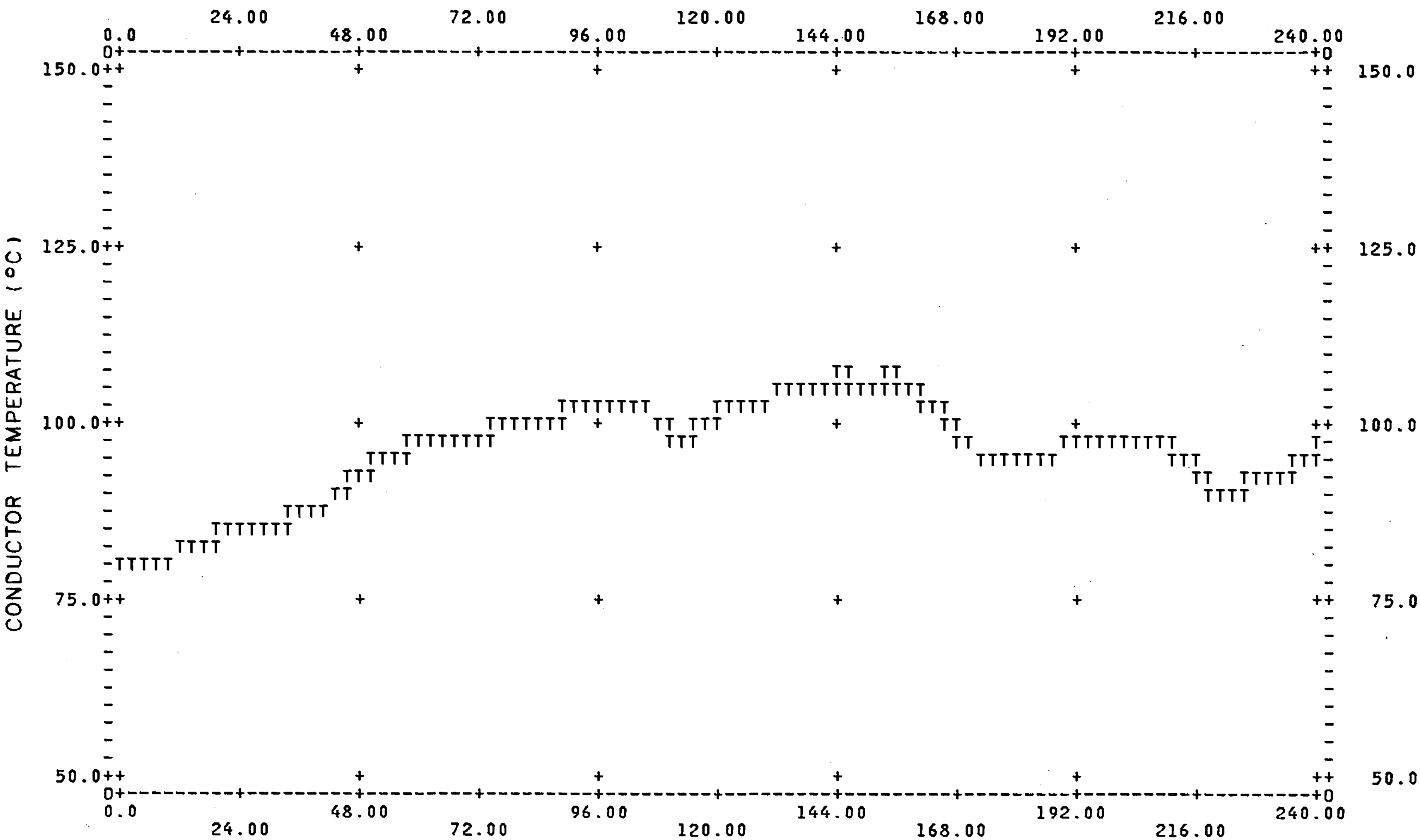
RESISTANCE= 0.1190 OHM/MI    DIAMETER= 1.0930 IN    AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT    EMISSIVITY=0.75    NUMBER OF CONDUCTORS= 1




SDTF CONDUCTOR RATING WORKING GROUP
CONDUCTOR TEMPERATURE VS. TIME, 795 ACSR 54/7 CONDOR
SEPT 3,1973 1700 TO 2100 , 100% LOAD, FULL SOLAR

Graph 4.

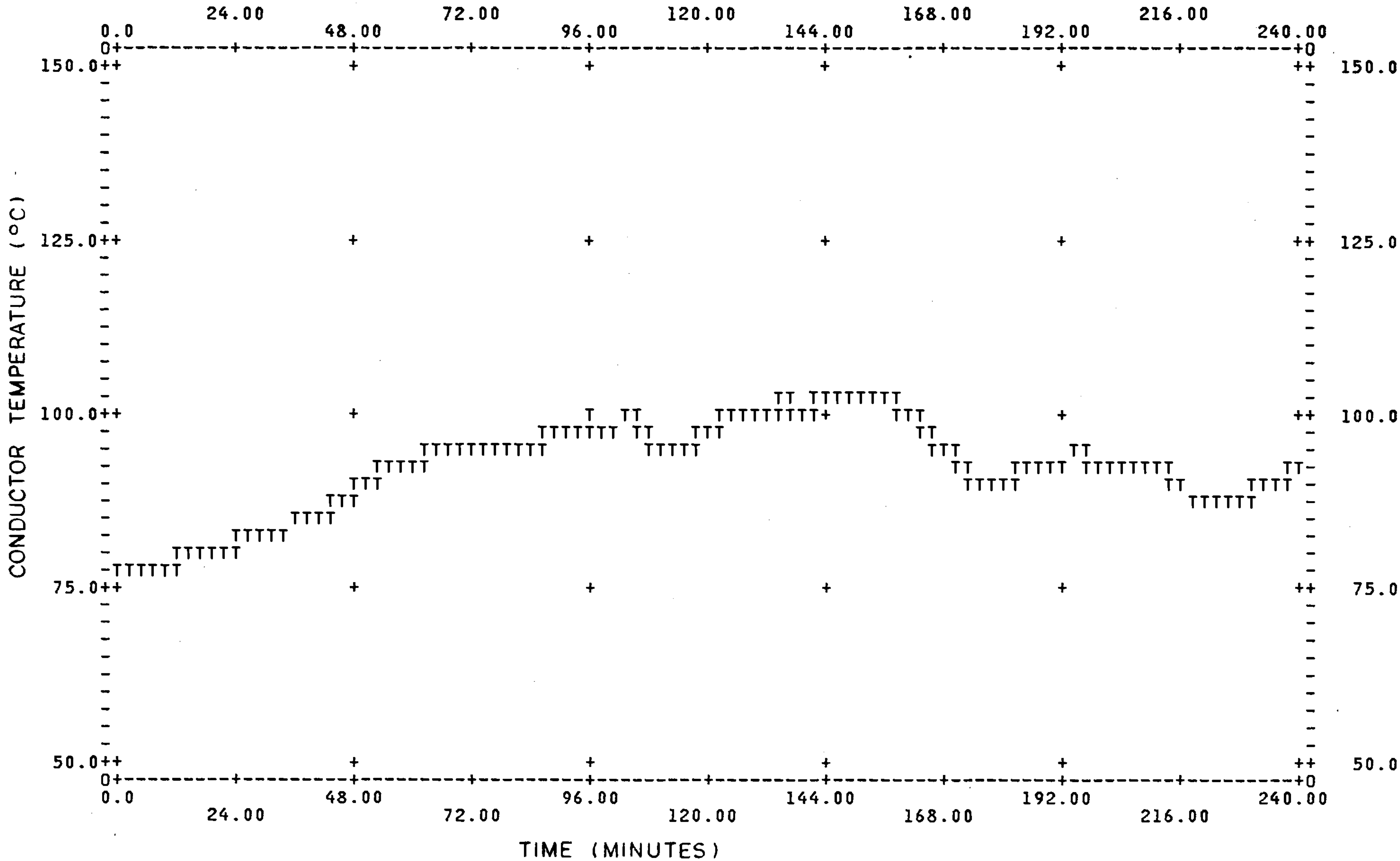
RESISTANCE= 0.1190 OHM/MI    DIAMETER= 1.0930 IN    AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT    EMISSIVITY=0.75    NUMBER OF CONDUCTORS= 1




SDTF CONDUCTOR RATING WORKING GROUP
CONDUCTOR TEMPERATURE VS. TIME, 795 ACSR 54/7 CONDOR
SEPT 3,1973 1700 TO 2100 , 100% LOAD, HALF SOLAR

Graph 5.

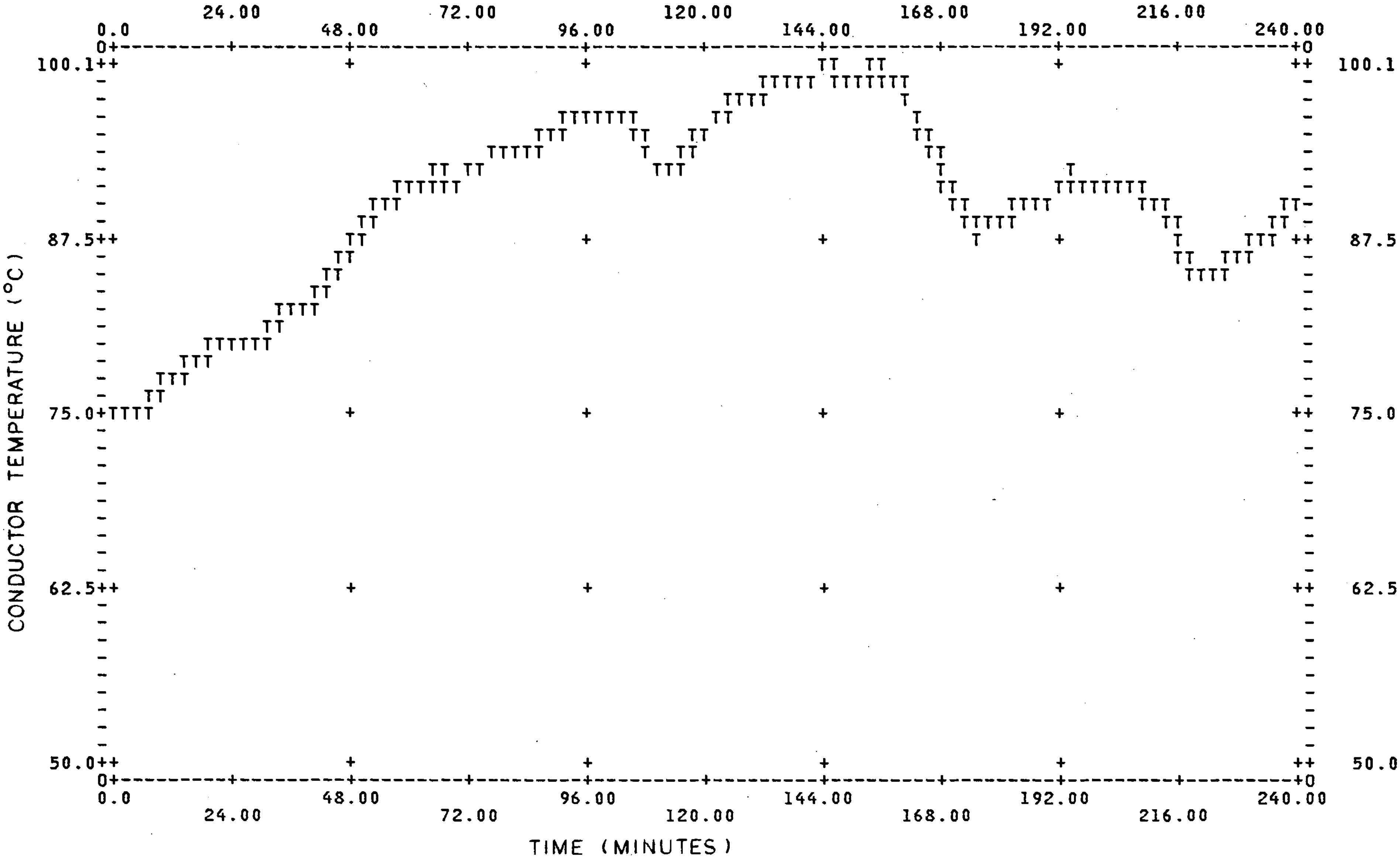
RESISTANCE= 0.1190 OHM/MI    DIAMETER= 1.0930 IN    AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT    EMISSIVITY=0.75    NUMBER OF CONDUCTORS= 1




SDTF CONDUCTOR RATING WORKING GROUP
CONDUCTOR TEMPERATURE VS. TIME, 795 ACSR 54/7 CONDOR
SEPT 3,1973 1700 TO 2100 , 97.5% LOAD, HALF SOLAR

Graph 6.

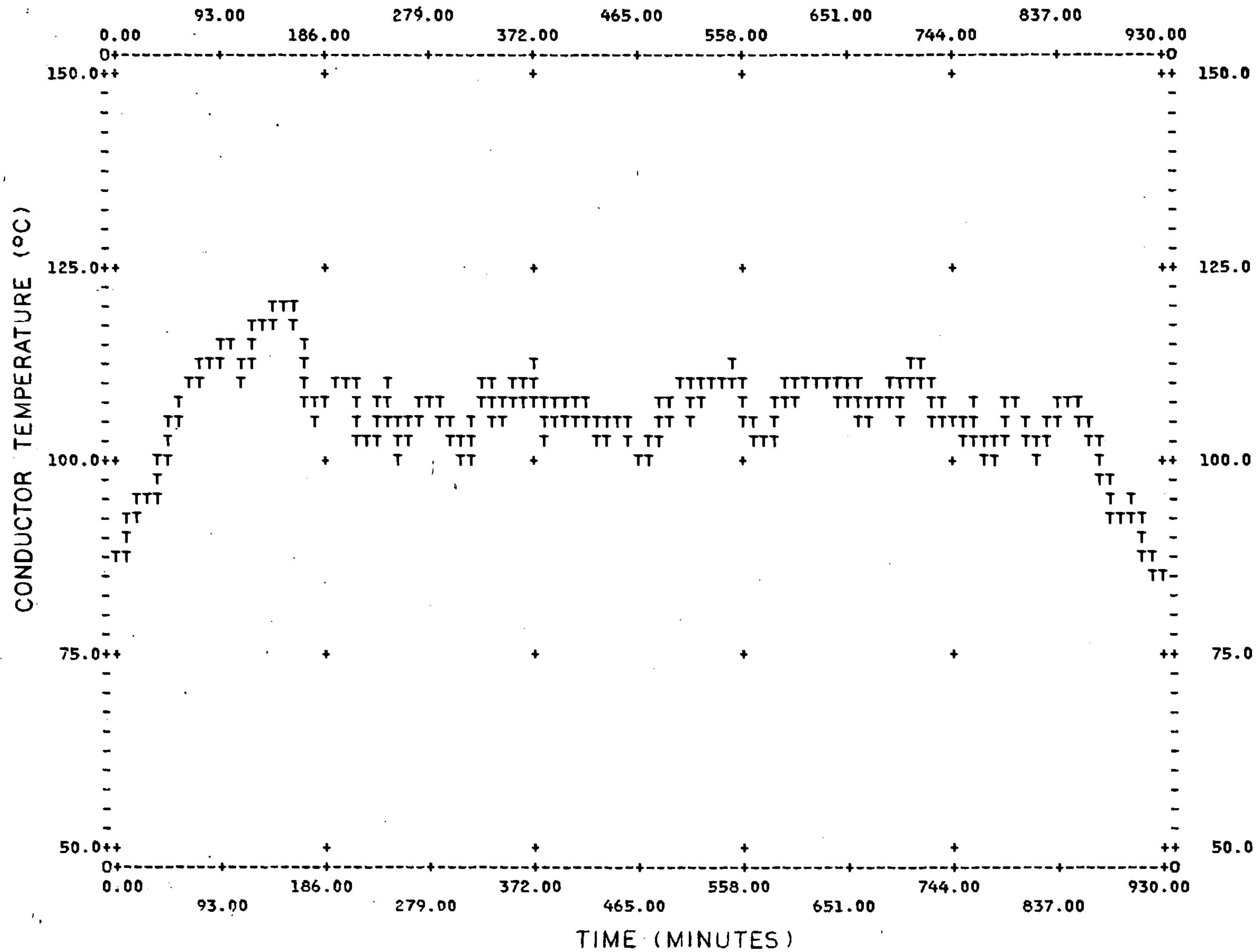
RESISTANCE= 0.1190 OHM/MI    DIAMETER= 1.0930 IN    AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT    EMISSIVITY=0.75    NUMBER OF CONDUCTORS= 1




SDTF CONDUCTOR RATING WORKING GROUP
CONDUCTOR TEMPERATURE VS. TIME, 795 ACSR 54/7 CONDOR
SEPT 3,1973 1700 TO 2100 , 95.0% LOAD, HALF SOLAR

Graph 7.

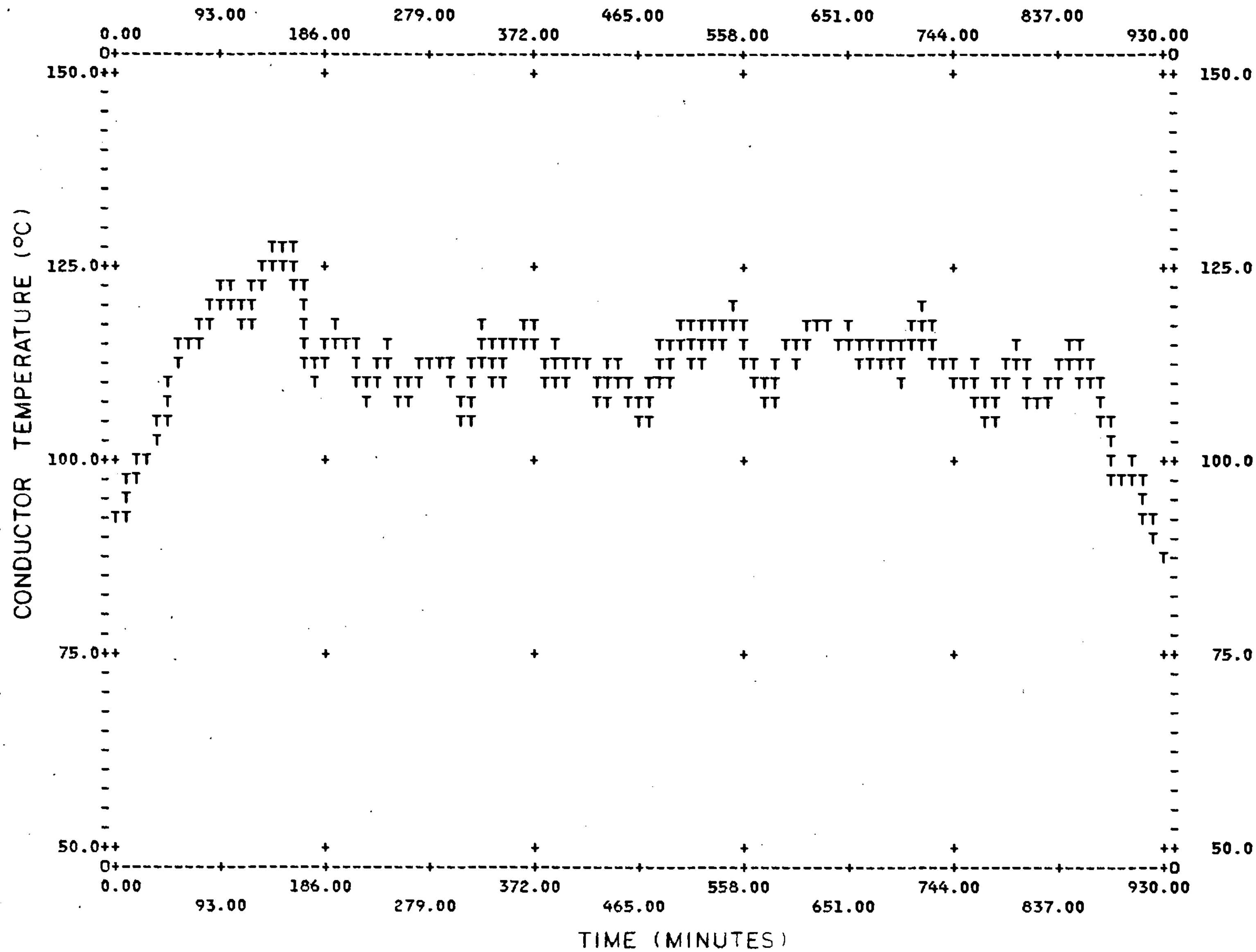
RESISTANCE= 0.1190 OHM/MI    DIAMETER= 1.0930 IN    AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT    EMISSIVITY=0.75    NUMBER OF CONDUCTORS= 1




SDTF CONDUCTOR RATING WORKING GROUP
CONDUCTOR TEMPERATURE VS. TIME, 795 ACSR 54/7 CONDOR
SEPT 3 TO SEPT 4,1973:1700 TO 835,100% LOAD, 3.5 FPS RATING, FULL SOLAR

Graph 8.

RESISTANCE= 0.1199 OHM/MI DIAMETER= 1.0930 IN AL/CU WEIGHT= 0.750 LB/FT
STEEL WEIGHT= 0.274 LB/FT EMISSIVITY=0.75 NUMBER OF CONDUCTORS= 1




SDTF CONDUCTOR RATING WORKING GROUP
CONDUCTOR TEMPERATURE VS. TIME, 795 ACSR 54/7 CONDOR
SEPT 3 TO SEPT 4,1973:1700 TO 835, 100% LOAD, 4 FPS RATING, FULL SOLAR

Graph 9.