# FORECASTING METEOROLOGICAL PARAMETERS

# IMPORTANT IN DAILY LOAD PREDICTION

by

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## Introduction

Temperature, relative humidity and natural illumination are probably the most important meteorological factors in determining electric power loads. As part of its continuing research into objective prediction of meteorological parameters, the Travelers Research Center has developed a computer technique for the prediction of hourly values of these elements. The results of four months of daily forecasts for Hartford, Connecticut by this technique and a three month correlation of observed data with peak load values of the Hartford Electric Light Company, are summarized in this paper.

## Development and Procedure for Predicting Hourly Values of Temperature, Relative Humidity and Natural Illumination

This technique for predicting hourly temperatures is based on diurnal temperature regimes contained in ten years of observational data from a specific weather station. Using the concept first outlined by the Travelers Research Center climatological statistician Joseph Bryan, [3] coeficients defining each hour's temperature rise or fall from the hour preceding were derived. Separate sets of monthly coeficients were computed from observational data associated with the following categories relating to the sky condition. Category 1 - a clear sky or just scattered clouds; Category 2 - a cloud ceiling greater than or equal to 5,000 ft.; Category 3 - a cloud ceiling less than 5,000 ft.

A humidity prediction technique was adapted from Pandolfo, et.al. [4] and is based on a constructed daytime humidity sounding for the lower levels of the atmosphere and a forecast for the occurrence or non-occurrence of precipitation.

Finally a procedure was adapted to compute incoming solar radiation and illumination for various times of the year for Hartford, Connecticut after considering a forecast for sky conditions in the specific categories described in the first paragraph.

Mr. James MacMonegle of TRC then programmed the three techniques for operational use on the Center's IBM 1620 computer.

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The program for the prediction of temperature, relative humidity and natural illumination was then tested on an operational basis by forecasters at the Travelers Weather Service in Hartford for a four month period, September through December 1965. The procedure for making a prediction requires the gathering of the following data:

1. First an initial or starting time is selected, which can be any hour of the day or night.

2. The temperature at this specified time and latest available mid-afternoon dew point temperature are recorded.

3. The temperature and dew point temperature at 5,000 and 2,000 feet respectively are recorded over the station from radiosonde observations at the nearest time available to Step (2).

4. The dew point temperatures or humidity sound for the lower levels of the atmosphere at the same time as (3) are recorded.

5. A categorical sky condition forecast for a forty-eight hour extended period is prepared by a forecaster. (Category 1, 2, or 3 as previously described)

6. Next a "yes" or "no" forecast for precipitation is required for each hour in the first twenty-four hour period.

7. Then a forecast for upper air temperatures at the levels specified in Step (3) is prepared for six, twenty-four and forty-eight hour intervals after the time of the observation in Step (3).

8. The above data is then punched on IBM cards and prepared for the computer calculations.

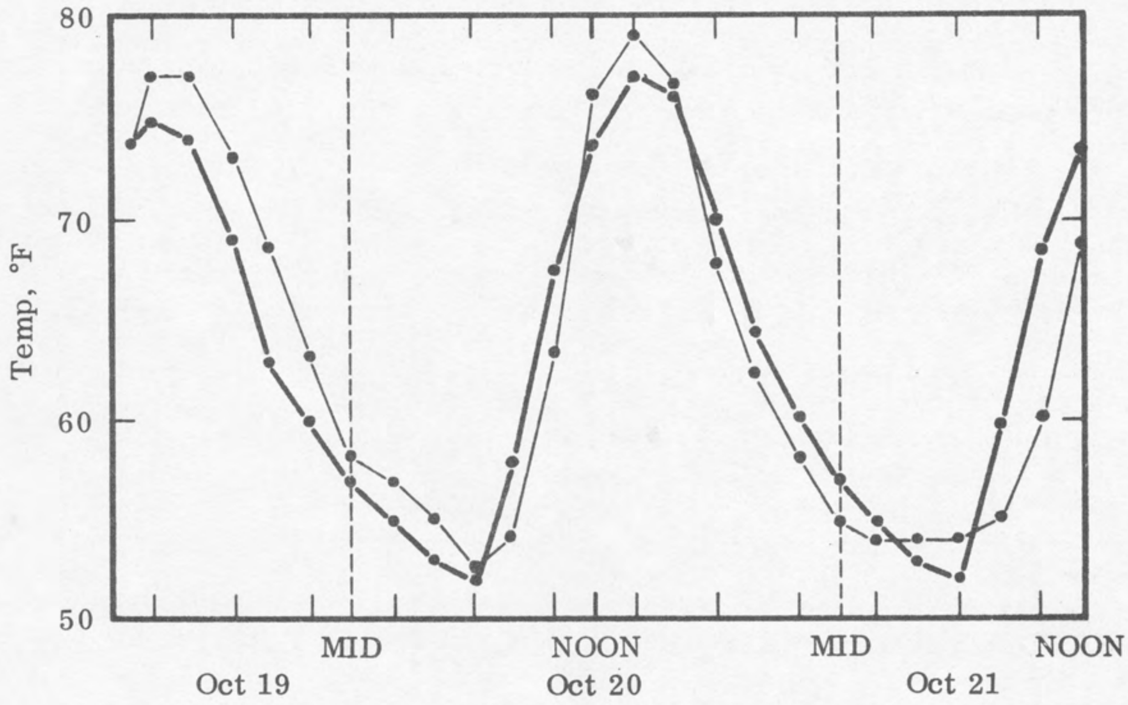
9. The result is a print out giving an hour-by-hour temperature forecast for forty-eight hours, and hourly predictions of humidity, natural illumination in foot candles, and radiation values in ly/sec for the daylight hours.

Two forecasts for Hartford of temperature and humidity serve as examples on Graphs I, II, and III, for December 2 - 4, and October 19 - 21, 1965.

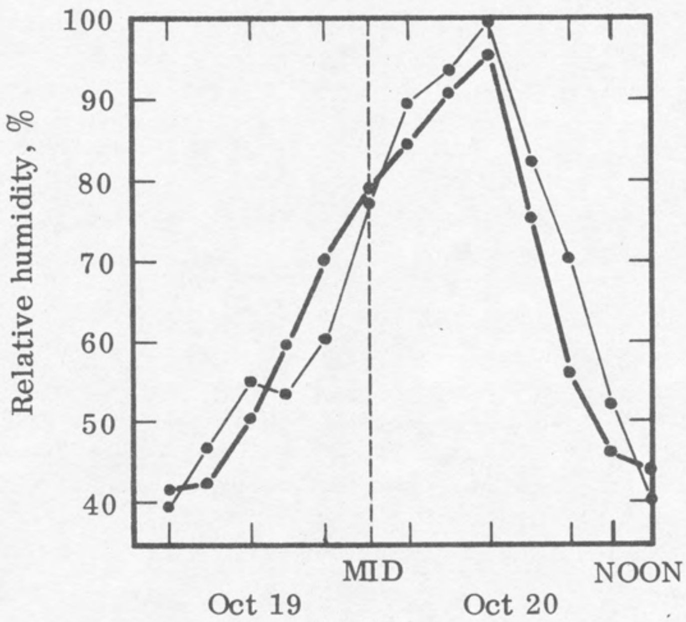
Graph I compares the actual temperature profile with the predicted. The heavy bold lines on all graphs represent the forecast, the lighter lines observed values. In Graph I the two compared quite closely, the amplitude of the curves from daytime maximum temperatures to the night time minimum for the forty-eight hour period shows only a few degrees departure.

On Graph II the humidity prediction for a twenty-four hour period on the same date follows very closely with the actual humidity. Much of the departure of the predicted humidity from actual is due to the departure of

Graph I




Graph II



the actual temperature from predicted. The forecast temperature at any particular time is directly related to the forecast humidity value. For example on the morning of October the 20th, the predicted temperature was higher than actual until just before Noon, and the corresponding humidity values forecast were lower than observed. Shortly before Noon the observed and forecast temperature was identical and the humidity prediction was also perfect.

On Graph III the temperature prediction held very close until about midnight after which a rather large error is noted. This error resulted from a poor cloud forecast through the early morning hours of December 3rd. The clouds which weren't expected to clear did so shortly after midnight, therefore allowing a greater temperature drop to take place. The categorical sky cover prediction worked out well during the daylight hours of December 3rd, and the resulting amplitude of the temperature curve was almost perfect. A predicted six degree temperature rise between the early morning low and daytime high, and an actual range of seven degrees. Shortly before midnight on the second day, an abnormal night time temperature rise is noted. This was due to southerly winds and milder air being advected into the area. The predicted and normal night time temperature drop didn't occur. This particular case along with a few other similar cases, would suggest a need for a wind term in the prediction equation.

The Electric Power Business by Vennard, 1962, points out the fact that electric heating and air conditioning are increasing at a steady rate and are expected to continue to do so. The Electric Heating Association presently estimates two million homes are heated electrically in the United States today, and predictions for 1980 indicate a possible expansion to about ten times this amount. So based on this prediction and the work done by Gillies, et.al. (1956) we assume that temperature, humidity, illumination, and wind will become more and more important meteorological factors for electric power load forecasting. Hot, humid summer days creating abnormally high peak loads because of the increased use of electric air conditioners and de-humidifiers, and a similar effect on cold, windy days in the winter where a greater amount of electric power would be required to keep electrically heated homes warm and comfortable.

## Meteorological Factors in Weekday Peak Load Forecasting

A preliminary investigation of the applicability of the types of meteorological forecasts described above to the specific problem of forecasting weekday peak loads was carried out. The study made use of three months of hourly load data, October 1 through December 31, 1965, provided by The Hartford Electric Light Company. This data is plotted for the three month period in Figure 4. A smooth "base load" curve, as described by Gillies, [1] et.al. (1956) was then drawn by eye, and is also shown in the Figure. The departures of individual weekday peak loads from the base curve provided a "predictand", when categorized in the following way. Departures having values between ±1% of the base load were placed in Category 0, departures in the range +1% to +2% (-1% to -2%) were placed in Category 1, etc. The full sample amounted to about fifty cases, with holidays omitted.

The meteorological "predictors" deemed most suitable were the observed illumination conditions and a temperature index based on the observed temperature, at the hour of peak load. The illumination conditions were represented by the three sky condition categories defined previously, plus an additional category for cases in which precipitation occurred with plus or minus one hour of the hour of peak load. The temperature index is defined by

$$I = (T - Tn)\, w$$

where T is the observed temperature, Tn a climatological normal temperature, and w a weighting factor whose value depends on Tn. The factor w is 0 for Tn greater than 55° F. and increases by one for every five degree decrease in Tn below this value.

Figure 5 shows the distribution of peak load departures among encountered joint predictor categories. Bold face numbers in the table each denote individual cases for which the departure category was negative, each 0 in the table denotes a case in which the departure was smaller in magnitude than 1%, and each light face number represents a case for which load departures were positive.

The hoped for increase in the frequency and magnitude of positive departures toward the left and bottom of the table is borne out. This result, along with the preliminary verification results of the meteorological forecasts presented, appears sufficiently encouraging to warrant further effort in the development of a routinely applicable peak load prediction procedure. Final development of such a procedure will require:

1. A much larger data sample, including data for all seasons.

2. Further improvement in the meteorological prediction procedures.

3. Consideration of the operational uses to which the peak load forecasts are to be put.

The end result would provide a rapid and accurate method for the prediction of daily peak loads. Later extension would be possible to the prediction of hourly load.

Graph III

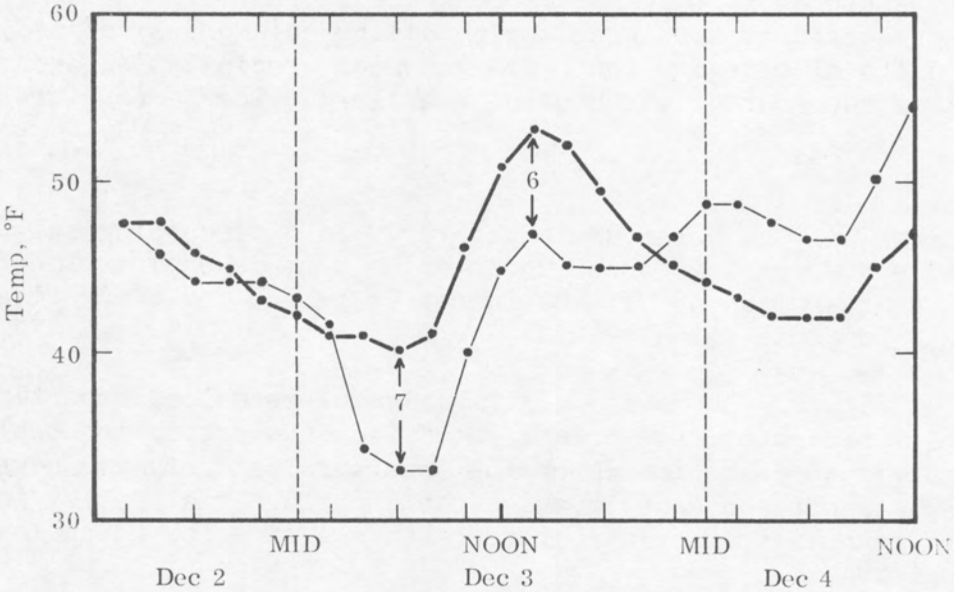
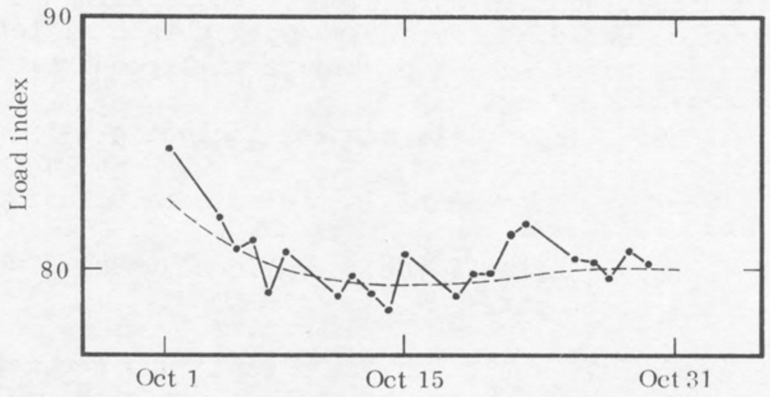



Figure 4



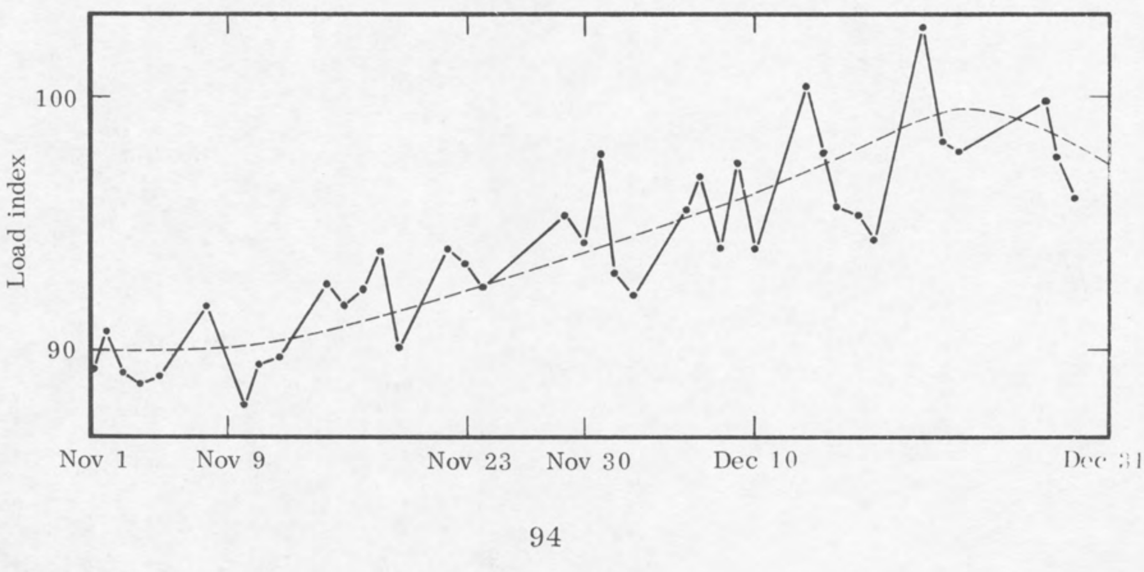



Figure 5

| Temp index | Cloud and precip category: 1 | 2 | 3 | 2-3 R |
|---|---|---|---|---|
| 9 to 18 | **2**,**1**,**2** | **2**,**4** | 0,**2** | 0 |
| 1 to 8 | | **1**,**3** | | 0,1 |
| 0 | 0,0,**1**,0,0,0,0,0,0,0,0,**1**<br>**1**,**2**,1,0 | 0,**2**,0,0,0,0 | 0,0,0,**1**,**2** | **2**,0,**2**,**1** |
| -1 to -8 | 0,**1**,5,**1** | **2**,1 | 0 | 2,3 |
| -9 to -18 | 3,1,0,1<br>5 | 2 | | |

## References

1. "A New Approach to Forecasting Daily Peak Loads", by Gillies, Bernholtz and Sandiford, June 1956.

2. The Electric Power Business, by Vennard, 1962.

3. J. Bryan, 1964: Short Range Hour by Hour Prediction of Temperature by Projecting the Characteristic Curve with Constants Fitted by Immediately Preceding Data. Unpublished, The Travelers Research Center, Inc.

4. J. Pandolfo, D. Cooley and M. Atwater, 1965. "The Development of a Numerical Prediction Model for the Planetary Boundary Layer". Fin. Report Cwb 10960, TRC 7465-174.