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A SET OF RULES FOR FORECASTING MINIMUM TEMPERATURES IN NAPA AND SONOMA COUNTIES

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EDITOR'S NOTE

The author's transmittal letter accompanying this paper contained the following remarks which I thought would be of interest to the reader.

L. W. Snellman, Chief
Scientific Services Division

"This is the only paper that I know of that explains to meteorologists outside of agricultural work how a good hygrometric formula is used when forecasting minimum temperatures. It is not, as you suggest, a matter of modifying the formula to come up with a minimum temperature forecast. The formula depends heavily upon the dew point. And, for all practical purposes, forecasting minima above or below critical in Napa and Sonoma Counties can be made by the methods discussed in the paper, excluding the use of the formula. The value of the formula is to determine what temperature to forecast AFTER it has been decided whether it will be clear and calm.

"There is indeed no new forecast methods used in the paper. In fact, the methods are kept as simple as possible. Yet, as far as I can determine, this paper is the first of its kind in the Frost Service! The use of the word approach in the original title related to the method of organizing pertinent data so as to easily recognize the forecast problem on a given night. No similar approach appears to have been developed in any other districts of the Frost Service. Therefore, this paper could be used as an example of a method that makes it easier on forecasters new to the Frost Service or to a district, and that makes more time available at forecast time by eliminating the need to analyze every piece of information that is available in order to recognize what the forecast problem is.

/s/ Wesley L. Tuft"

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ABSTRACT

If it is assumed that dew points are conserved and that above 850 mbs the only concern is the presence or absence of clouds, then a few parameters can be used to forecast with reasonable accuracy whether or not overnight minimum temperatures in the agricultural areas of Napa and Sonoma Counties will be above critical.

I. INTRODUCTION

From mid-March until mid-May, agricultural forecasts for the two counties are oriented toward minimum temperatures for the following morning. Minima above 34°F are considered "warm" temperatures since crop protection usually begins at 34°F. This Technical Memorandum concerns the use of forecast rules to determine whether minima will be above or below 34°F.

Data used in this Technical Memorandum are part of the data collected for a research study to develop objective methods of forecasting minimum temperatures throughout Napa and Sonoma Counties. Data collection and research were begun in 1969 by Ron Hamilton, Meteorologist in Charge, Riverside Weather Service Office, and was continued by the author beginning in 1973. In addition to the collection of daily observational data, surface and upper-air charts were plotted. Charts for the 1972 and 1973 seasons are lost and there has been no apparent reason to retrieve the chart data or to replot the charts.

II. DISCUSSION

The Napa hygrometric formula estimate [1] can be used as the "first guess" for forecasting the overnight minimum temperature. Of 28 nights studied when the formula estimate was above 34°F, clear and calm conditions occurred on only 8 nights. Of those 8 nights, I had a minimum of 34°F at the Napa Key Temperature Station while the 7 other nights had minima above 34°F. Thus warm nights are to be expected whenever the hygrometric formula estimate is above 34°F. A discussion of the Napa formula is given in the appendix.

Since temperatures forecast above 34°F are grouped together, many forecasts can be based upon dew point alone. It has long been known that even with clear skies and calm winds, minima seldom fall to 34°F unless the 4 p.m. dew point on the previous day is less than 45°F (Table I). This is due to the heat of condensation effectively counteracting radiative cooling. In addition, fog or stratus often forms to further reduce cooling.

With dew points less than 45°F, overnight minima depend upon sky cover and wind. The formula estimate is accurate when skies are clear and calm; all other conditions keep the observed minimum above the formula estimate.

Clouds or winds of any duration will usually keep minima above 34°F since minima seldom drop below 30°F even under ideal radiative conditions. Of 31 clear and windy nights studied, only three had minima below 32°F, and only one had a temperature below 30°F.

Since Napa and Sonoma Counties are located along the California coast, weather conditions there often are dependent upon either an onshore flow or an offshore flow. A good indicator of the type of flow is the 4 p.m. sea-level pressure difference between San Francisco and Medford:

$$(P_{sfo} - P_{mfr} = \Delta P).$$

Observational data, given in Table 2, can be summarized into the following three categories:

> A strong onshore flow, i.e., ΔP greater than 4 mbs: This condition is often associated with a low-pressure area north of California and a nearby surface front giving cloudy conditions.
>
> A strong offshore flow, i.e., ΔP less than -2 mbs: This usually means high pressure lies to the north resulting in either clear and calm or clear and windy conditions.
>
> If ΔP is between 4 and -2 mbs, high pressure generally lies offshore, resulting in either clear and calm or cloudy conditions.

When delta P is between 4 and -2 mbs, overnight conditions sometimes can be made more specific by taking into account any fronts over western United States and eastern Pacific Ocean on the 4 p.m. surface chart for the preceding day. The following rule applies:

> If no front is present between 112° and 130°W longitude, clear and calm conditions can be expected overnight. If a front is present, then either clear and calm or cloudy conditions can be expected (Table 3).

Whenever delta P is less than -2 mbs, the probability of clear and windy conditions increases as low-level wind speeds increase and low-level stability decreases. Low-level wind speeds change, of course, when the surface pressure-gradient changes and also whenever the vertical temperature structure changes, with or without changes in delta P. Delta P can change without changes in low-level wind speeds when the pressure field configuration changes over the Pacific Northwest. For example, clockwise rotation of the field changes the flow from a stable marine flow toward an unstable continental flow dropping down the west slopes of the Sierra Mountains. Therefore, clear and windy conditions are more likely when low-level winds are:

(1) strong due to a strong pressure gradient, (2) strong due to the vertical temperature structure, or (3) from the east. The complex interaction can be represented by an assumed linear relationship between delta P, the 4 p.m. OAK 850-mb wind speed, and the occurrence of clear and windy conditions. The probability of a clear and windy night for these parameters are given in Figure 1.

Daily surface charts show promise as type maps for determining windy conditions since overnight winds appear to be dependent upon the low-level air trajectory. For example, Figure 2 is a case when even with a strong pressure gradient, calm conditions occurred because the flow was cool and stable. Surface charts are of particular interest as type maps when the probability from Figure 1 is near 50 percent. As an example, note the low-level flow in Figure 3 as compared to that in Figure 4. Data from Figure 3 give a 47% probability of a clear, windy night, yet winds were calm. As was the case in Figure 2, these calm conditions were associated with a cool, stable flow. Data from Figure 4 give only a 41% probability of a clear, windy night. Yet, despite an 850-mb wind speed of only 10 knots, it was windy overnight. In this latter case an unstable easterly flow existed. Hopefully, further cataloguing of surface charts will determine more accurately which map types are associated with windy conditions.

The above generalizations can be summarized as a set of forecast rules:

1. Whenever the 4 p.m. dew point is 45°F or higher or the hygrometric formula estimate is 35°F or higher, forecast minima above 34°F.

2. If ΔP is more than 4 mbs, forecast cloudy with minima above 34°F.

3. When the 4 p.m. dew point is less than 45°F and the formula estimate is less than 35°F, then:

   a. If ΔP is less than -2 mbs, obtain the probability percentage of a clear and windy night from Figure 1.

   b. If ΔP is between -2 and 4 mbs, and:

      (1) no front is present between 112° and 130°W, forecast clear and calm.

      (2) a front is present, the forecast is indeterminate: it can be either clear and calm or cloudy.

   c. If the forecast is for clear and calm, forecast minimum temperatures by use of the hygrometric formula estimate; otherwise, forecast minima above 34°F.

The forecast rules serve only as a guide and individual situations may dictate deviation from them. For example, the rules may be invalid when conditions are determined primarily by upper-level phenomena, such as a closed-low aloft producing cloudy conditions or a strong baroclinic field producing windy conditions.

The rules are generally very useful and will provide a high percentage of correct forecasts as to warm or cold nights. Application of the rules on independent data for the 1975 season resulted in the correct forecast on 36 to 41 nights, 88 percent accuracy. (Clear and windy forecasts were based upon a probability of 50 percent or higher.) Of the 5 incorrect forecasts, 2 resulted from a closed-low aloft producing cloudy conditions. On 6 nights, rule 3.b.2 was in effect and no verification was made. When this rule is in effect, reliance must be placed upon satellite and other information received from WSFOs.

III. SUMMARY

During springtime, a high percentage of minimum temperature forecasts for Napa and Sonoma Counties can be based upon dew point, the hygrometric formula estimate, sea-level pressure difference from San Francisco to Medford, and the presence or absence of a surface front, all at 4 p.m. the day before. More qualifications could possibly be developed to reduce the risk of using rules inappropriately.

IV. ACKNOWLEDGMENTS

Appreciation is expressed to Mr. Ronald S. Hamilton, Meteorologist in Charge, Weather Service Office, Riverside, California, who collected much of the data used in this memorandum and to Scientific Services Division, Western Region Headquarters, for their reviews and helpful suggestions.

V. REFERENCE

[1] ELLISON, E. S. *A Critique On the Use of Minimum-Temperature Formulas*. Monthly Weather Review, Vol. 56, No. 12, pp. 485 - 495, December 1928.

4 p.m. dew point for previous day	Number of Nights	
	Minimum 34°F or Less	Minimum Above 34°F
45°F or Above	3	3*
Less than 45°F	61	3

Table I. Distribution of minimum temperatures with respect to 4 p.m. dew point when the hygrometric formula estimate was below 35°F, and observed nighttime conditions at the Napa Key Temperature Station were clear and calm (1969-1974).

*The formula estimate is seldom below 34°F when the dew point is 45°F or above.

Observed Condition	Delta P, 4 p.m., SFO-MFR (mbs)			
	<-6	-6 to -1	-2 to 4	>4
*Cloudy	0	0	19	17
Fog or Stratus	0	1	6	2
Clear and Calm	2	20	40	2
Clear and Windy	15	10	2	0

Table 2. Distribution of minimum temperatures with respect to observed nighttime weather conditions and sea-level pressure difference between San Francisco and Medford (SFO-MFR) when the 4 p.m. dew point was below 45°F and the hygrometric formula estimate for the Napa Key Temperature Station was below 35°F (1969-1974).

*Exclusive of fog or stratus.

Observed Condition	No Front	Front*
+Cloudy	2	6
Fog or Stratus	2	0
Clear and Calm	25	7

Table 3. Distribution of minimum temperatures with respect to observed nighttime weather and the existence of a surface front for cases when the 4 p.m. dew point was below 45°F, the hygrometric formula estimate was below 35°F, and delta P was between -2 and 4 mbs (1969-1971 and 1974).

*See text for criteria as to the presence or absence of a front.
+Exclusive of fog or stratus.

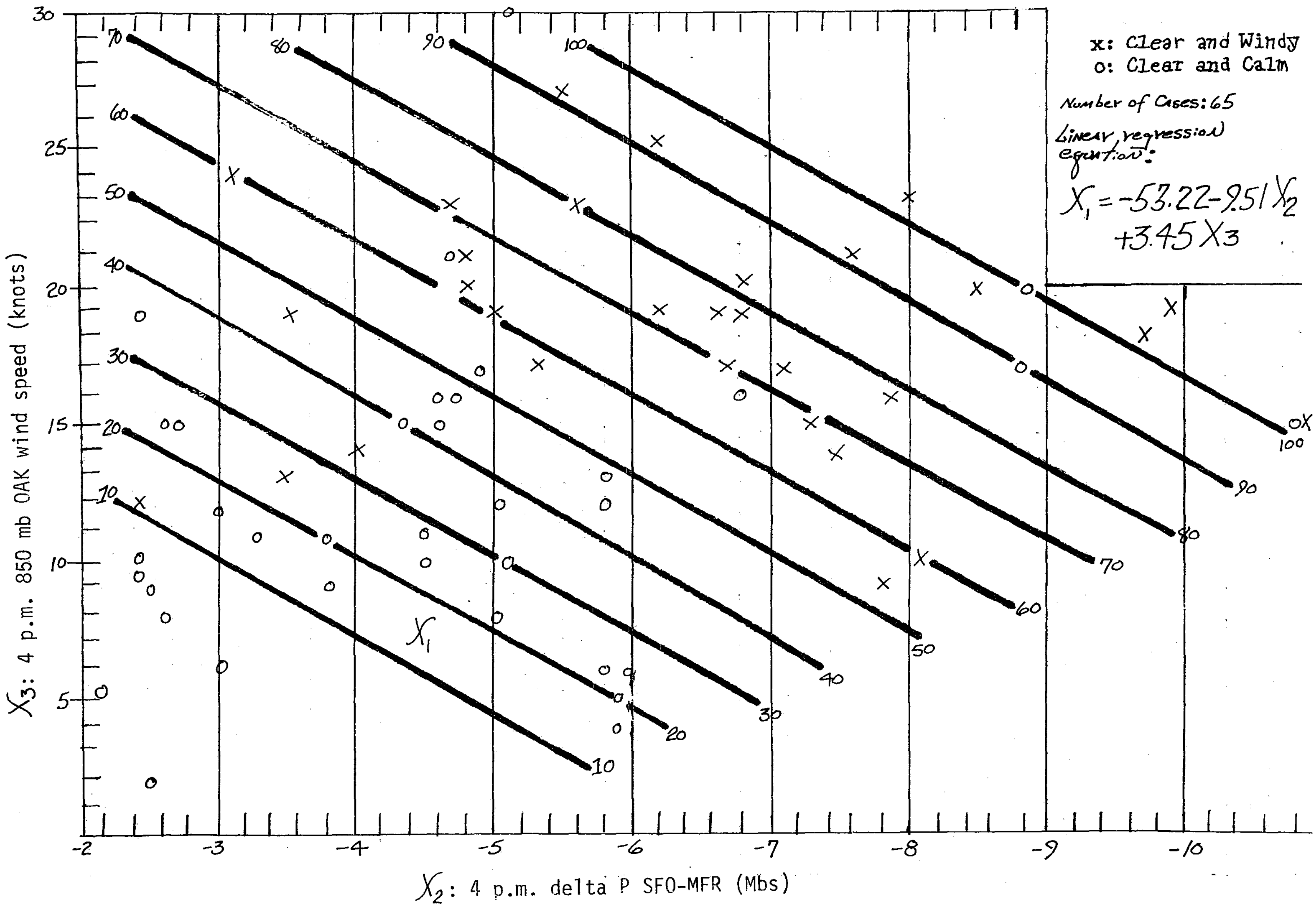

Figure 1. X_1: Probability Percentage of Clear and Windy Conditions Overnight as Function of 4 P.M. 850 mb Oakland Wind Speed and Surface Pressure Difference Between San Francisco and Medford.

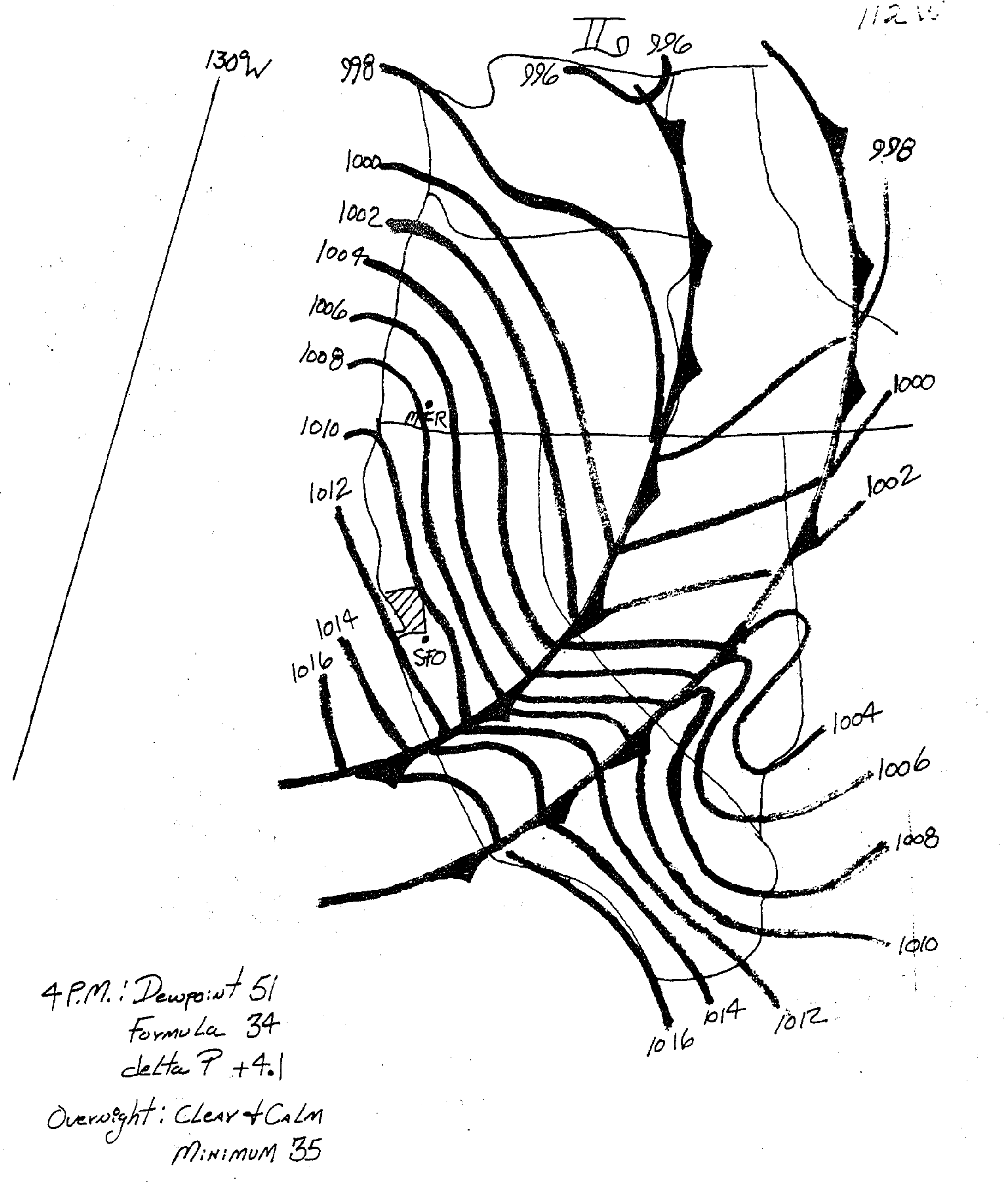

Figure 2. Four p.m. Surface Chart, April 1, 1974. Shaded area is Napa and Sonoma Counties.

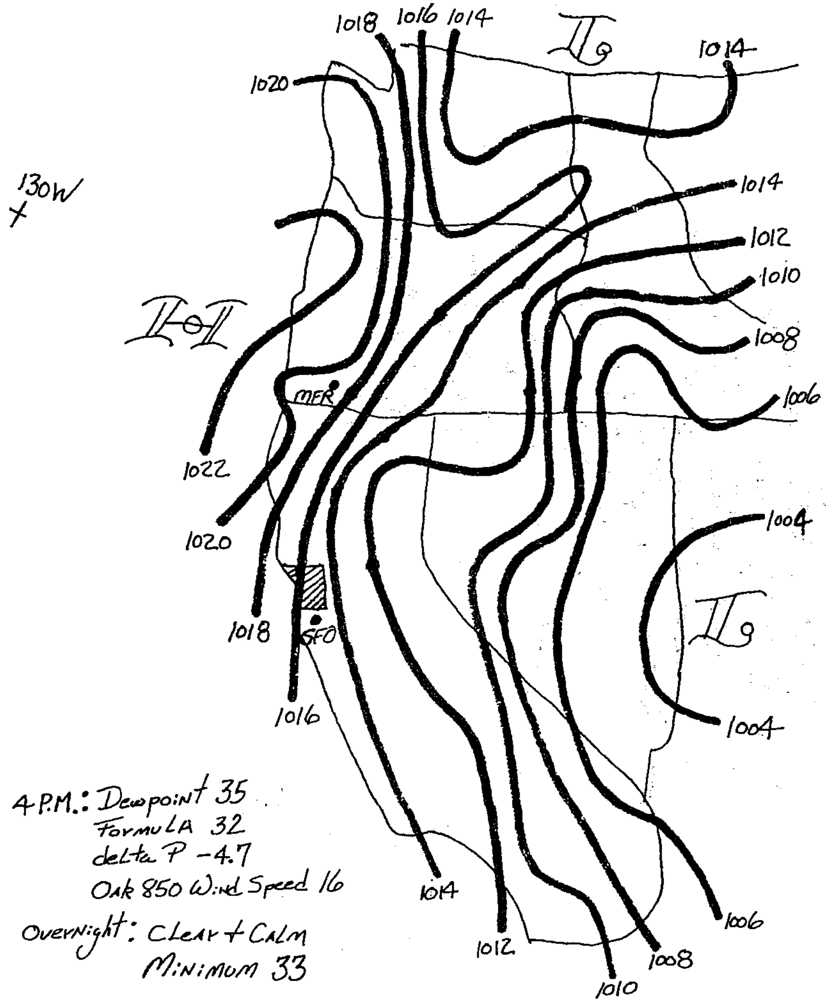

Figure 3. Four p.m. Surface Chart, April 18, 1971.
Shaded area is Napa and Sonoma Counties.

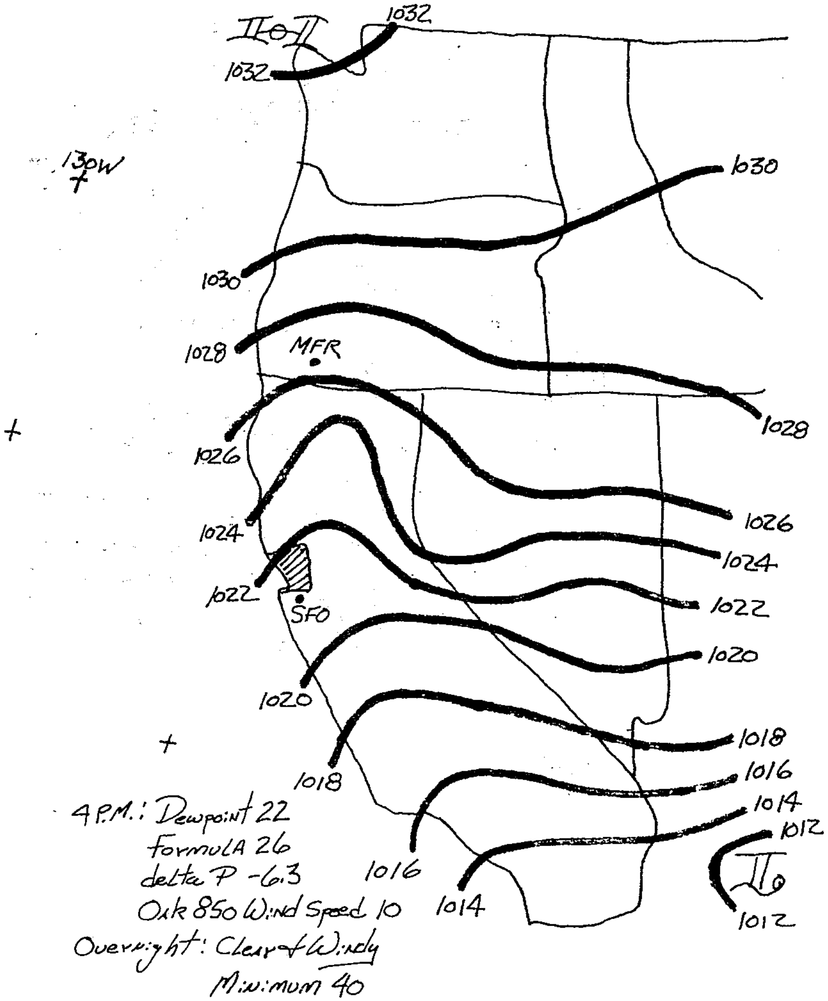

Figure 4. Four p.m. Surface Chart, March 28, 1975.
(On the morning of the 29th, frost damage was reported in many agricultural areas of California, but no known damage occurred in either Napa or Sonoma Counties.)

APPENDIX

The hygrometric formula estimate now used for Napa and Sonoma Counties was developed by Jack Janofsky. It is assumed that the formula was developed by the methods described by E. S. Ellison [1]. The original formula, developed in 1938 and modified in 1944, is still in use today.

Originally, temperature and relative humidity readings were taken at 4:30 p.m. at the key temperature station in the city of Napa. In subsequent years, readings have been taken at 4 p.m. at various locations throughout the Napa Valley. No appreciable change in accuracy was noticed by change of either time or location. This suggests that dew points are fairly uniform throughout the valley at 4 p.m.; dew points are usually conserved overnight, and, consequently, very little advection occurs after 4 p.m. Observations at various locations have confirmed that the dew point is usually both uniform and conserved.

The following tables were abstracted from the 1944 report for Napa County:

Hygrometric Formula Used at Napa

For clear or partly cloudy nights: $T = (D+V) + (V^{\prime}-H+25)$.

T represents the expected minimum temperature in Fahrenheit degrees.
D represents the 4:30 p.m. dew point in Fahrenheit degrees.
H represents the 4:30 p.m. relative humidity in percent.
V and $V^{\prime}$ are variables depending upon the value of the dew point and relative humidity.

Values of (D+V)

Dew Point (°F)	(D+V)
60-59	50
58-57	49
56-55	48
54-53	47
52-51	46
50-48	45
47-45	44
44-43	43
42-41	42
40-39	41
38-37	40
36-35	39
34-33	38
32-31	37
30-29	36
28-27	35
26-25	34
24-20	33
19-14	32

Values of $(V^{\prime} - H + 25)$

R.H. (%)	$(V^{\prime} - H + 25)$
64 and Higher	-12
63-47	-11
46-40	-10
39-34	-9
33-32	-8
31-30	-7
Cold Types	
29-15	-7
Warm Types (includes wind)	
29-15	0
All Types	
15-10	0

With clear skies in prospect, the dew point temperature is often a reliable clue to the probability of frost and freezing temperature, i.e., such conditions usually follow dew points of 46° and lower... During normal seasons, the formula is considered very accurate, but in unusually dry, cold seasons it will average 2° or 3° too high.

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