NOAA Technical Memorandum NWS WR-94

CONDITIONAL PROBABILITY OF VISIBILITY LESS THAN ONE-HALF MILE IN RADIATION FOG AT FRESNO, CALIFORNIA

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Fresno, California
August 1974

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U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

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WESTERN REGION
TECHNICAL MEMORANDUM NO. 94

SALT LAKE CITY, UTAH
AUGUST 1974

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CONDITIONAL PROBABILITY OF VISIBILITY LESS THAN ONE-HALF MILE IN RADIATION FOG AT FRESNO, CALIFORNIA

I. INTRODUCTION

Radiation fog is very common in the San Joaquin valley of California in late fall and winter. Conditions are frequently ideal in this valley for formation of radiation fog[1] during these months, namely:

a) Air of maritime origin that has become relatively stagnant over a cool land area.

b) Light winds.

c) Clear skies.

d) Adequate condensation nuclei.

When these conditions are expected to prevail during the coming night, afternoon weather parameters most strongly associated with the formation of fog by the following morning are the dry-bulb and dew-point temperatures. The relationship of these parameters to fog formation could be expected to be dependent upon the number of hours of cooling, i.e., the length of the night.

It is the purpose of this study to determine the probability of fog at Fresno, California, during nighttime hours based upon afternoon dry-bulb and dew-point temperatures under "radiation" conditions listed above.

The Fresno airport is closed for landing of commercial passenger aircraft when the runway visual range drops below 2400 feet, so for the purposes of this study, "fog" at Fresno airport is defined as visibility less than one-half mile.

II. DEVELOPMENT OF PROBABILITY CHARTS

Data: Dates of clear nights with surface winds of five knots or less were extracted from the winter months (November through March) from November 1958 through March 1973. The 1400 PST dry-bulb and dew-point temperatures and whether or not the visibility was reduced to less than one-half mile during the ensuing night were then recorded on these dates. (The hour 1400 PST was selected to meet the forecast time frame.) The data were segregated by month in order to at least partially take into account the varying duration of darkness. Data from the years 1964 and 1969 were reserved for test purposes.

Procedures: Scatter diagrams using Fresno 1400 PST temperature and dew point as coordinates were plotted for each month with the subsequent occurrence of fog (i.e., visibility $<1/2$ mile) plotted as X, and nonoccurrence of fog plotted as a dot. (See Figures 1 - 5.) Linear regression equations of the form $Y = AX_1 + BX_2 + C$ were computed for each month relating the 1400 temperature and dew point to the occurrence or nonoccurrence of fog. These equations are shown on Figures 1 - 5 with the graphical solution of each equation being the set of parallel, equally spaced lines on each figure.

Estimates of Y from these equations (or from interpolation between the sets of lines) were obtained for each case. All estimates from all months were combined and the frequency of occurrence of fog determined for categories of estimated Y, as shown in Table 1 and plotted in Figure 6 as dots connected by dashed lines.

The relationship between the Y estimates and the per cent frequency of occurrence of fog is obviously not linear, and, in fact, strongly suggests a parabolic relationship. A parabola of the form $P = A + BY + CY^2$ was, therefore, fitted to the plotted point, as shown by the solid curve in Figure 6. The equation for this parabola is:

$$P = 1.7513 + .4674Y + .008527Y^2$$

This equation, or the curve in Figure 6, gives the final conditional probability of visibility $<1/2$ mile based upon the afternoon temperature and dew point.

Values of P for each case of the developmental data were computed and the frequency of occurrence of fog determined for categories of the forecast probability, as shown in Table 2 and plotted in Figure 7. Figure 7 depicts the "reliability" of the probabilities. The average deviation from the "perfect reliability" line is 3.7%.

III. TEST ON INDEPENDENT DATA

Exactly the same procedures were followed in testing the equations (or charts) on the two winters of independent data as were used in developing them. Only those dates were selected from the test months on which skies were clear during the night and winds were less than or equal to five knots. The 1400 PST dry bulb temperature and dew point temperature were recorded and the probability of the visibility dropping to below one-half mile computed using the appropriate equation (or graph) for the month (Figures 1 - 5) and the parabola (Figure 6).

A number of scores were computed both on the developmental and test data samples and are compared in Table 3. Categorical forecasts were obtained by using 45% probability as the "yes" or "no" discriminate value. Note that these scores are based on only the "clear, light-wind nights" samples of data and are for the five winter months combined. All scores from the test data are remarkably close to the scores from the developmental data, indicating the equations should be quite stable.

IV. OPERATIONAL USE OF EQUATIONS OR CHARTS

The use of these equations or charts operationally depends upon a forecast of cloud cover and wind for the ensuing night, so results from operational use cannot be expected to be quite as good as indicated in the previous section.

Although restricting the study to "good radiation" nights (which have to be forecast!) simplifies this study considerably, there still are several factors affecting the formation of radiation fog that are not included. For example: 1) Even though the sky is clear during the nighttime hours, there could be a deep enough layer of moisture aloft to slow down the radiational cooling at the surface. 2) Even though the winds might be light, there could be a gradual change in the air mass during the night which would make the afternoon dry bulb and dew point temperatures poor predictors of fog in such a situation. 3) Even though the surface temperature often drops many degrees lower than the previous afternoon's dew point, winds might be so nearly calm that the relative humidity hovers near 100% for many hours without significant fog formation.

These factors obviously prevent a definitive forecast of fog or no fog on many nights at Fresno, but the equations or charts developed do provide a highly reliable conditional probability which should be very useful in briefing pilots and airline personnel.

V. ACKNOWLEDGMENTS

The encouragement of Mr. Thomas Crossan, MIC, WSO, Fresno, California, and the assistance of Mr. Woodrow Dickey of SSD, WRH, in the analysis and statistical computations are gratefully acknowledged.

VI. REFERENCE

[1] Hewson, E. Wendell, and Longley, R. W.; Meteorology Theoretical and Applied, Chapter 19, John Wiley & Sons, Inc., N. Y.

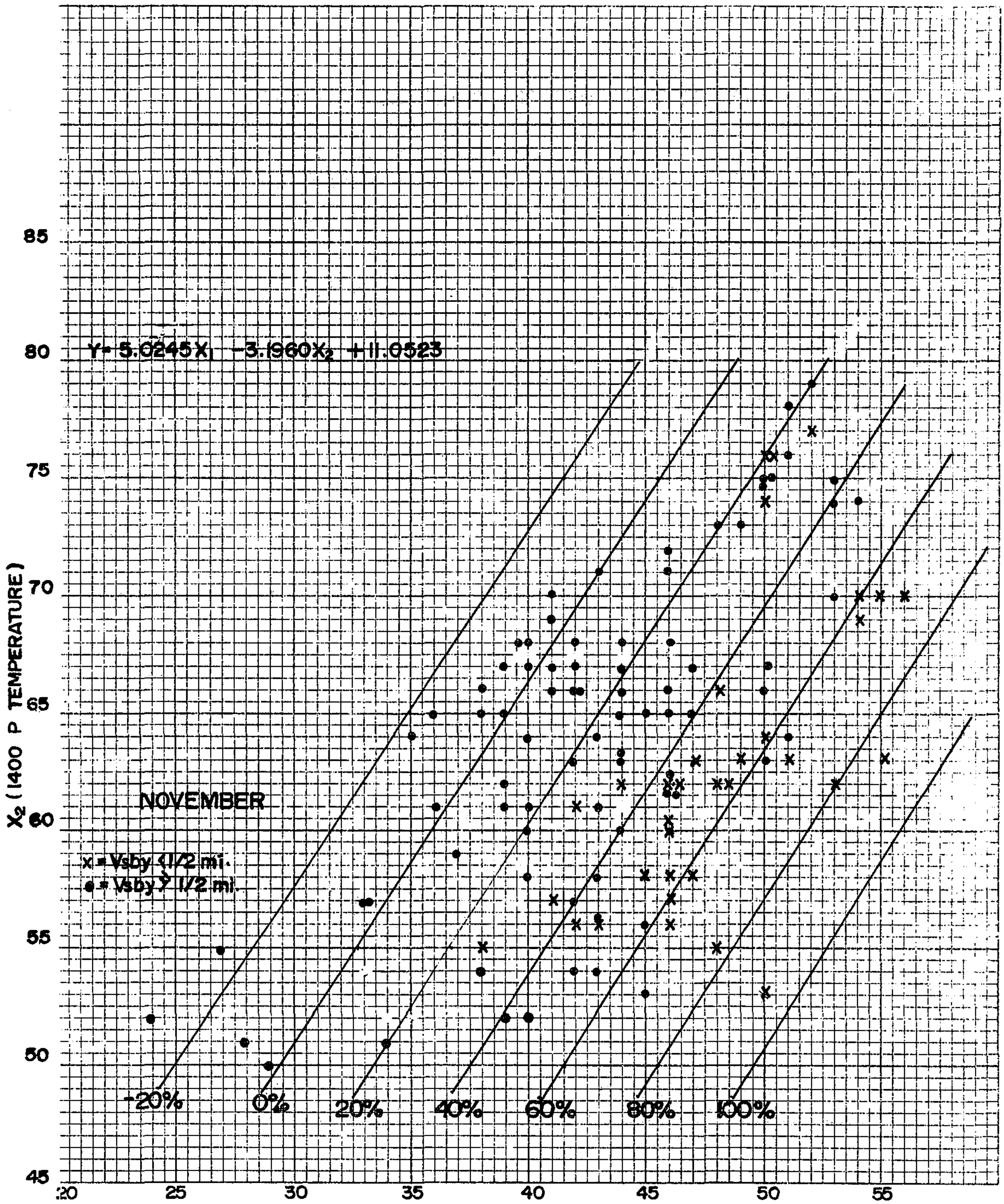


FIGURE 1. RELATIONSHIP BETWEEN 1400 PST DRY BULB AND DEW POINT TEMPERATURE AND THE OCCURRENCE OF VISIBILITY LESS THAN ONE-HALF MILE IN RADIATION FOG ON CLEAR, LIGHT-WIND NIGHTS AT FRESNO, CALIFORNIA, FOR MONTH OF NOVEMBER. LINES ARE GRAPHICAL SOLUTION OF EQUATION SHOWN ON CHART.

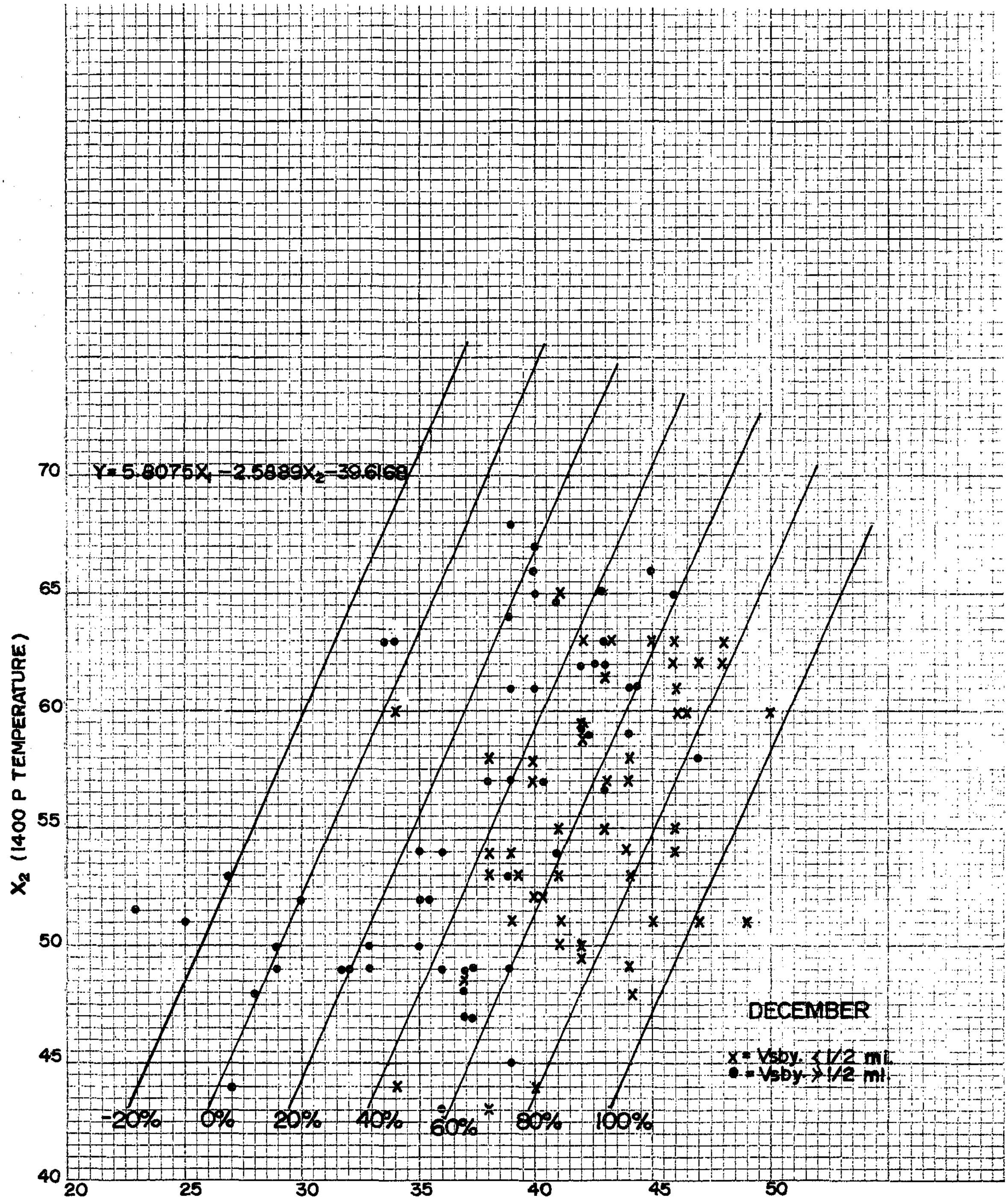
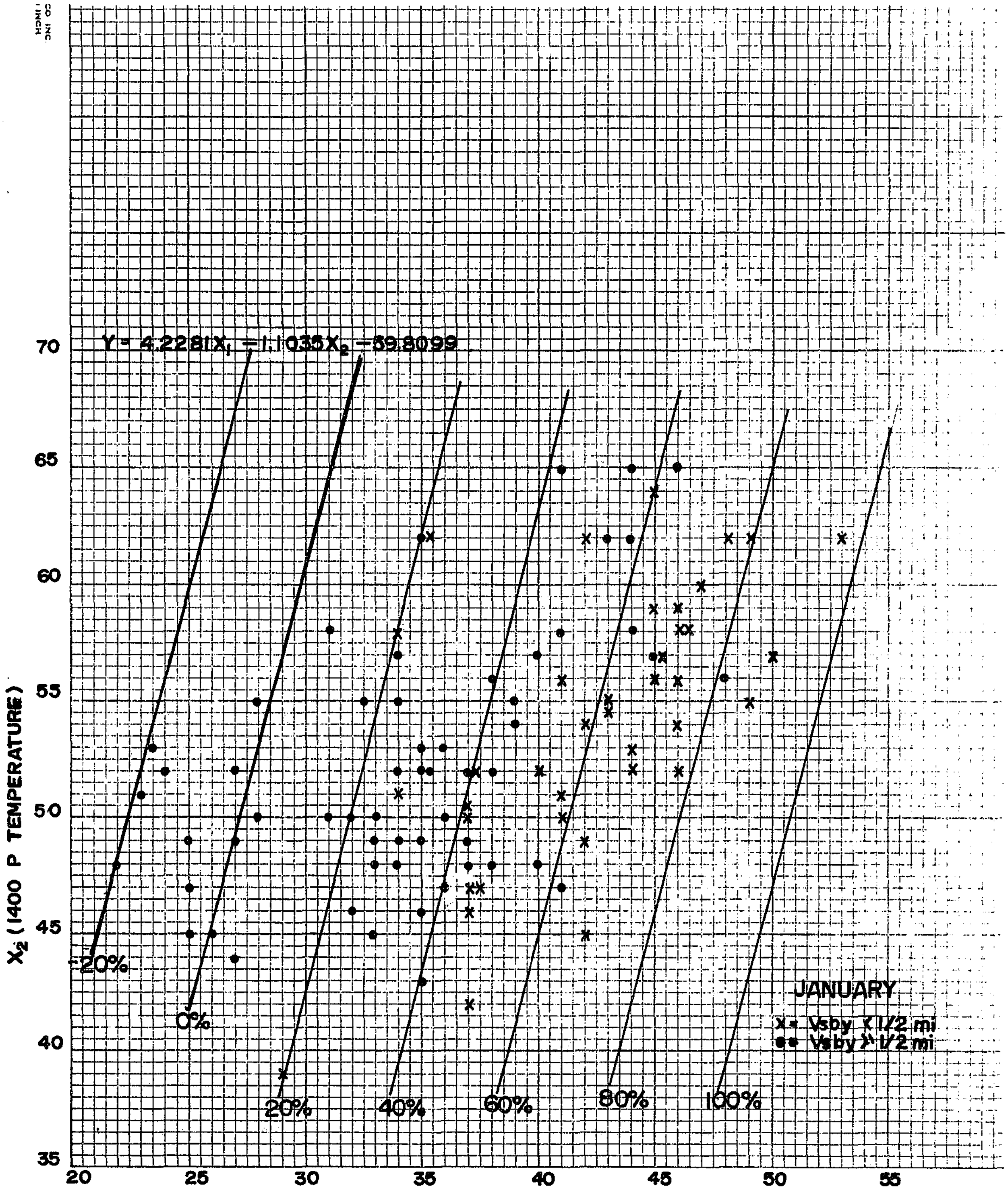


FIGURE 2. RELATIONSHIP BETWEEN 1400 PST DRY BULB AND DEW POINT TEMPERATURES AND THE OCCURRENCE OF VISIBILITY LESS THAN ONE-HALF MILE IN RADIATION FOG ON CLEAR, LIGHT-WIND NIGHTS AT FRESNO FOR MONTH OF DECEMBER.



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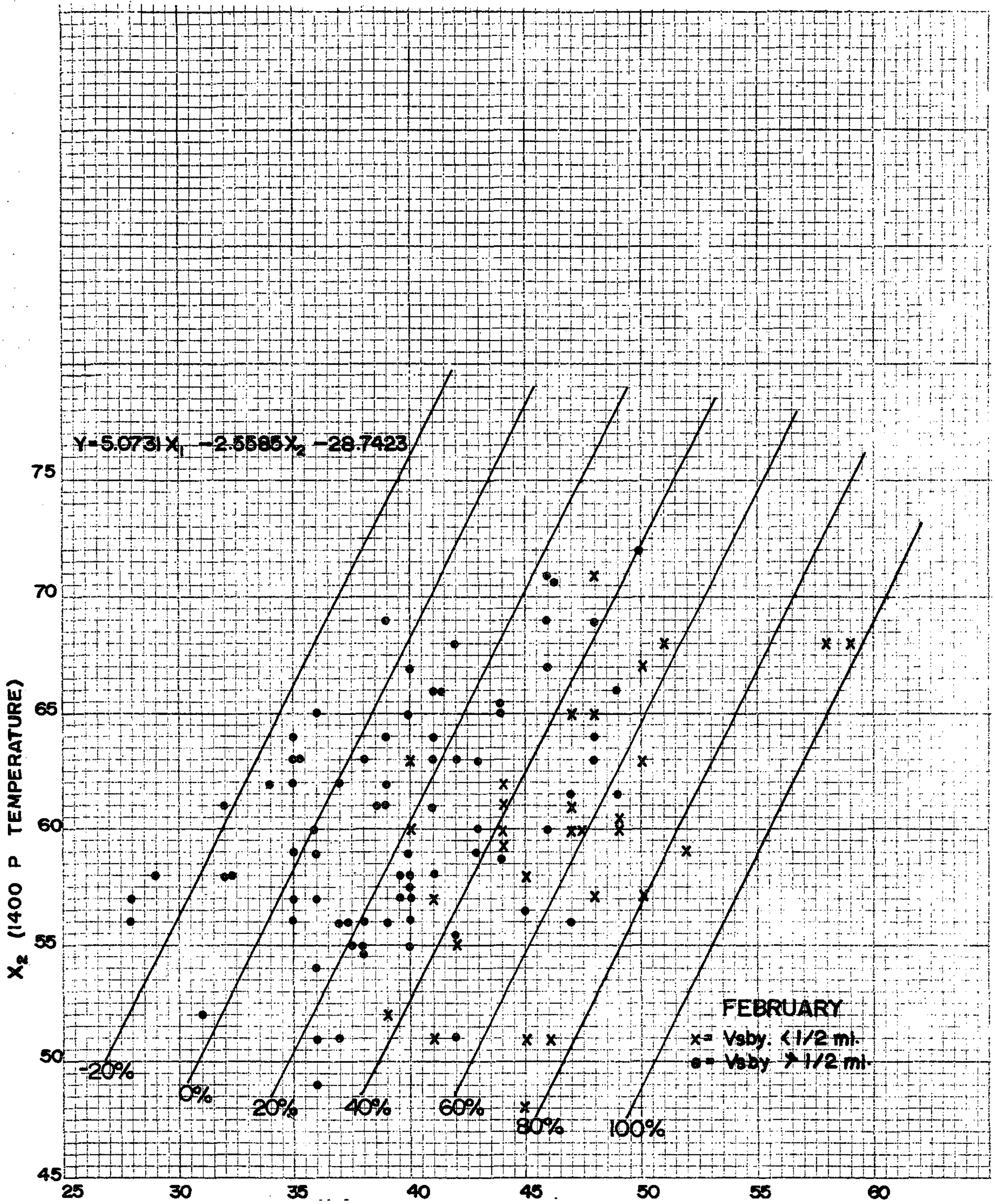
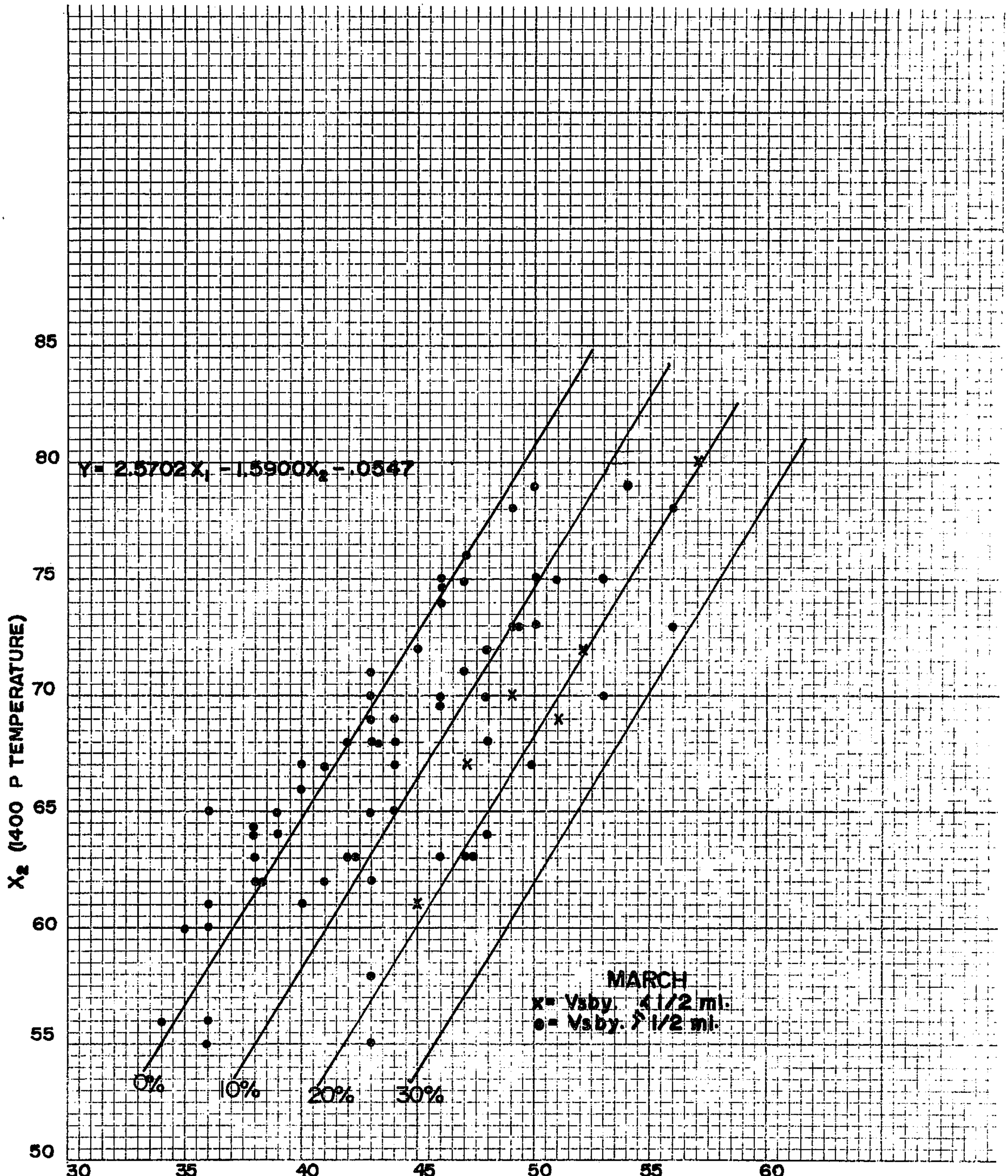


FIGURE 4. RELATIONSHIP BETWEEN 1400 PST DRY BULB AND DEW POINT TEMPERATURES AND THE OCCURRENCE OF VISIBILITY LESS THAN ONE-HALF MILE IN RADIATION FOG ON CLEAR, LIGHT-WIND NIGHTS AT FRESNO FOR THE MONTH OF FEBRUARY.



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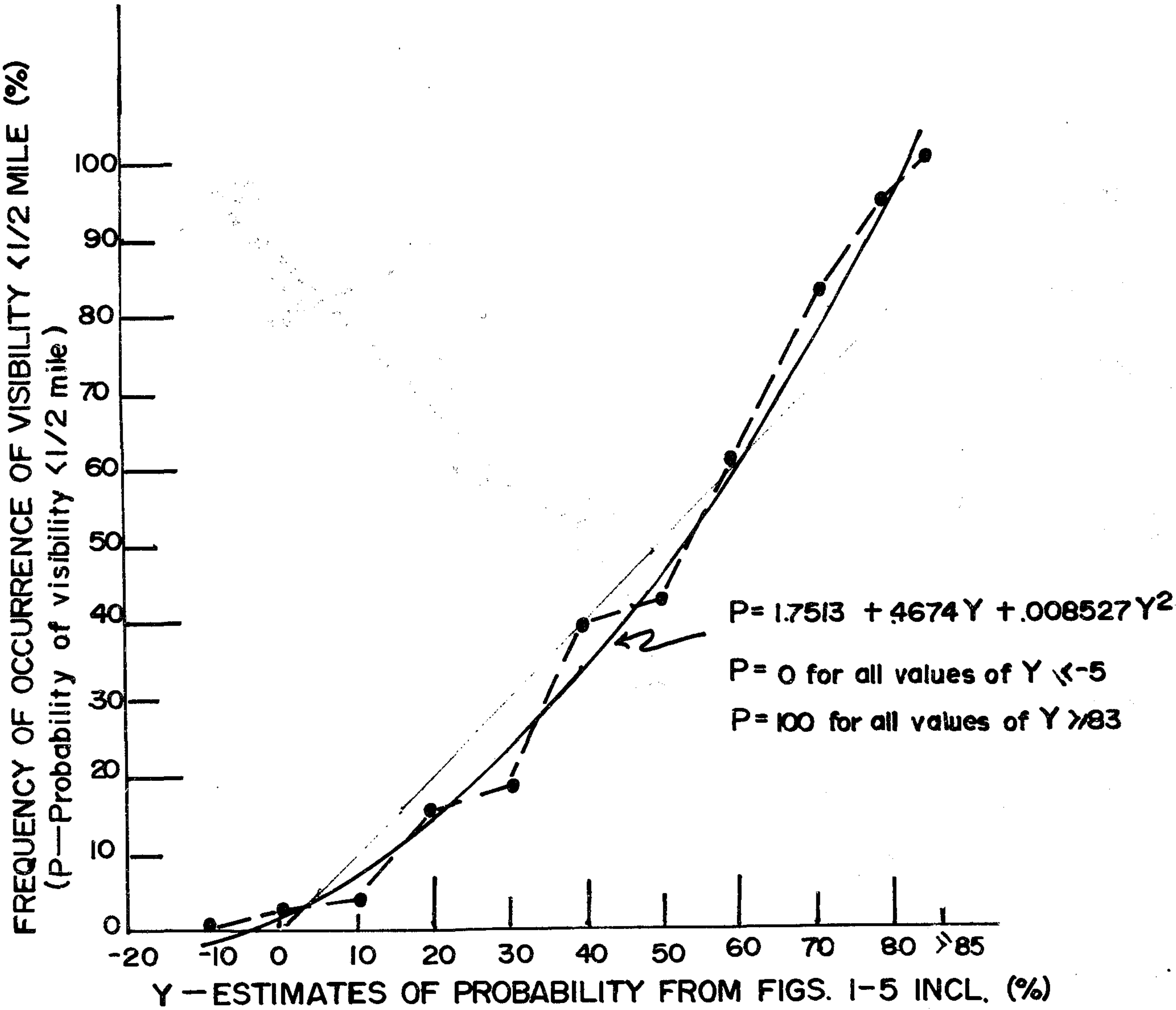

FIGURE 6. RELATIONSHIP OF ESTIMATES OF Y FROM FIGURES 1 - 5 AND THE PER CENT FREQUENCY OF OCCURRENCE OF VISIBILITY LESS THAN ONE-HALF MILE. DOTS CONNECTED BY DASHED LINES REPRESENT OBSERVED FREQUENCIES IN CATEGORIES OF Y-ESTIMATES CENTERED AT 0, 10, 20%, ETC., VALUES. SOLID CURVE REPRESENTS PARABOLA FITTED TO THE DOTS.

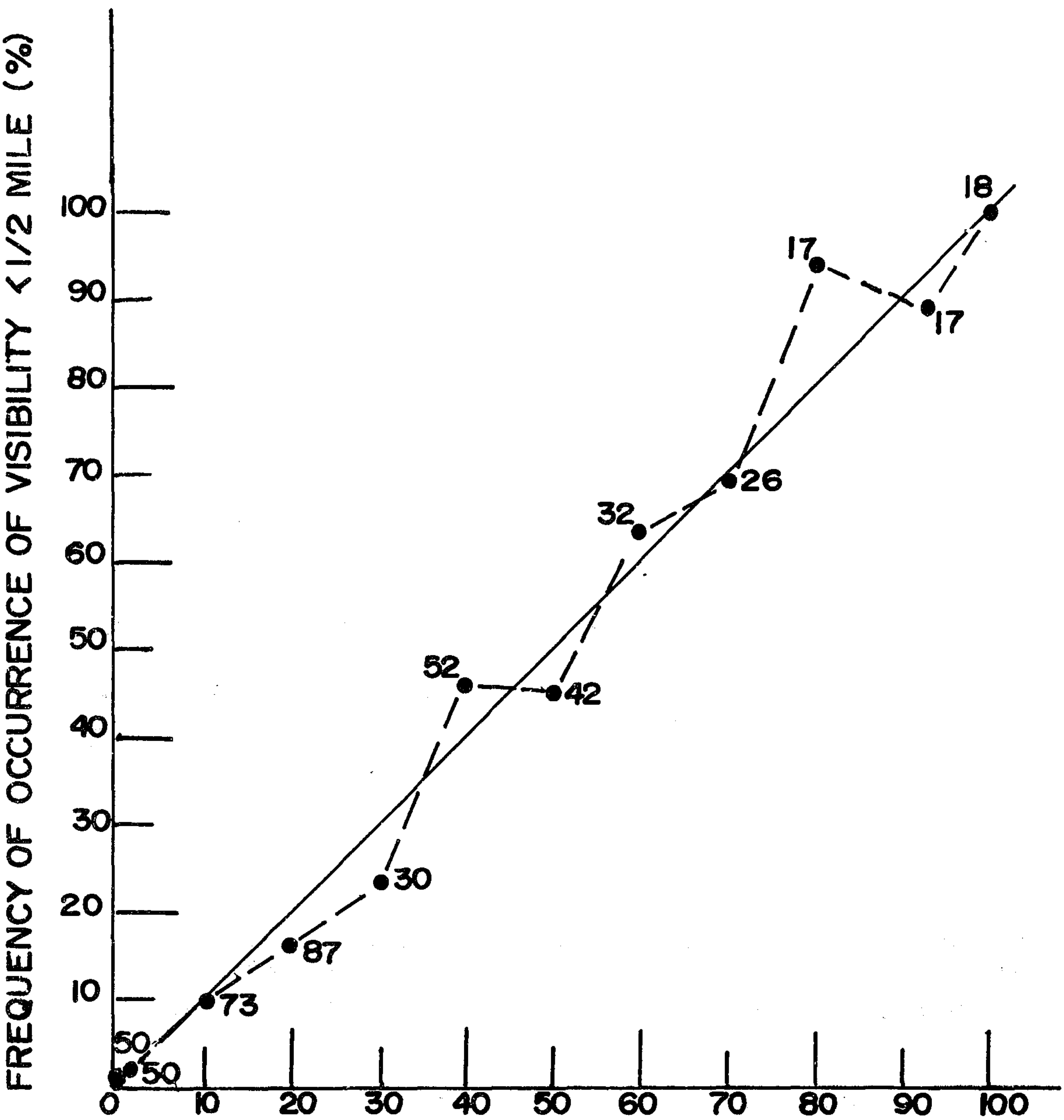

FIGURE 7. RELIABILITY GRAPH OF PROBABILITY "FORECAST" FROM FIGURE 6, DEPENDENT DATA. AVERAGE DEVIATION 3.7%.

TABLE 1

Frequency distribution of Y-estimates from Figures 1 - 5 for all cases and "fog" cases, and computed per cent frequency of occurrence of visibility less than one-half mile for categories of Y-estimates. Dependent or developmental data.

Categories of Y-Estimates	Midpoint of Category	Total Cases	No. of Fogs	% Occurrence
≤-5	≤-5	50	0	0
-4 to +4	0	58	1	2
+5 to +14	+10	48	2	4
+15 to +24	+20	67	10	15
+25 to +34	+30	58	11	19
+35 to +44	+40	53	21	40
+45 to +54	+50	58	25	43
+55 to +64	+60	46	28	61
+65 to +74	+70	38	31	82
+75 to +84	+80	14	13	93
≥85	≥85	17	17	100

TABLE 2

Frequency distribution of P-estimates from Figure 6 for all cases and "fog" cases, and computed per cent frequency of occurrence of visibility less than one-half mile for categories of P Developmental data.

% Probability	Midpoint	Total Cases	No. of Fogs	% Occurrence
0	0	50	0	0
1 - 4	2.5	50	1	2
5 - 14	10	73	7	10
15 - 24	20	87	14	16
25 - 34	30	30	7	23
35 - 44	40	52	24	46
45 - 54	50	42	19	45
55 - 64	60	32	20	63
65 - 74	70	26	18	69
75 - 84	80	17	16	94
85 - 99	92	17	15	88
100	100	18	18	100

TABLE 3

Comparison of various verification scores of "forecasts" of visibility of less than one-half mile in radiation fog at Fresno, California, from test and developmental data.

	PROBABILITY FORECASTS							CATEGORICAL FORECASTS				
	N	R	Bf	Bc	I(%)	Po	Pn	PF	PA	TS	%	Bias
Developmental	494	.32	.13	.22	39.88	59	20	.67	.70	.52	80	.96
Test	78	.26	.12	.19	39.91	59	18	.65	.68	.50	83	.95

N = Number of dates with clear nights and winds ≤5 kt.

R = Frequency of occurrence of visibility <1/2 mile in sample N.

Bf = Brier score of "forecasts" from Figures 1 - 6.

Bc = Climatological Brier Score based upon conditional climatology of vsby <1/2 mile on clear, light-wind nights.

I = Per cent improvement of Bf over Bc. $I = \frac{Bc - Bf}{Bc}(100)$

Po = Average "forecast" probability for observed occurrences of vsby <1/2 mile.

Pn = Average "forecast" probability for non-occurrences of vsby <1/2 mile.

PF = Prefigurance (ratio of correct forecasts of occurrences to total number of occurrences).

PA = Post Agreement (ratio of correct forecasts of occurrences to number of forecasts of vsby <1/2 mile).

TS = Threat Score (ratio of correct forecasts of occurrences to number of observed and/or forecast vsbys <1/2 mile).

% = Per cent correct.

Bias = Ratio of number of occurrences to number of forecasts of vsby <1/2 mile.

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