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CAPE KENNEDY PEAK WIND PROFILE PROBABILITIES FOR LEVELS FROM 10 TO 150 METERS

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16. ABSTRACT

Peak wind statistics for levels up to about 150 m for Cape Kennedy are presented for use in establishing design criteria for space vehicles and facilities. From distributions of peak winds at 10 m and a conditional (power-law profile) equation relating winds at levels between 10 and 152.4 m, a bivariate distribution function is integrated to provide: (a) cumulative probability distributions of peak winds for seven different levels and eleven different exposure periods, and (b) cumulative joint probability distributions of peak winds at a reference level and individual peak-wind profiles between 18.3 and 152.4 m. The cumulative distribution curves for all levels (10, 18.3, 20.5, 61.0, 91.4, 121.9 and 152.4 m) and all exposure periods (1 hour and 1, 2, 5, 10, 15, 30, 60. 90, 180 and 365 days) possess the double-exponential shape, characteristic of Fisher-Tippett Type I (FT1) extreme-value distributions. This feature is illustrated and results are summarized in tables of the two FT 1 distribution parameters, computed from each curve. Results indicate that the probability of a wind value not being exceeded decreases both with increasing height and exposure period.

The conditional equation defines a peak-wind profile subject to a random normally distributed variable. Cumulative joint probability distributions of peak winds at 18.3m, and 0σ, 1σ, 2σ, 3σ wind profiles between 18.3 and 152.4 m are computed. These curves, which also possess a double-exponential shape, are illustrated.

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FOREWORD

This report presents the results of work performed by Lockheed's Huntsville Research & Engineering Center while under subcontract to Northrop Nortronics (NSL PO 5-09287) for Marshall Space Flight Center (MSFC), Contract NAS8-20082. This task was conducted in response to the requirement of Appendix A-1, Schedule Order 28.

The NASA technical coordinator for this study is Mr. O. E. Smith of the Aerospace Environment Division of the Aero-Astrodynamics Laboratory.

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CONTENTS

Section 1

INTRODUCTION

Studies of peak winds at the 10-m level observed at Cape Kennedy, Florida, show that such extremals fit the Fisher-Tippett Type I (FT1) distribution. Because of insufficient observational data, however, similar studies have not been attempted for levels above 10 m. This report outlines a method by which power-law profiles based on peak wind observations from the 150-m meterological tower at Cape Kennedy, and FT1 parameters developed for the 10-m level and for various exposure periods can be used to find:

- Cumulative distributions of peak winds for levels up to about 150 m and for exposure periods ranging from one hour to one year, and
- Joint distributions of peak winds at a reference level (18.3 m) and peak wind profiles (0σ, 1σ, 2σ and 3σ profiles) extending to about 150 m, and for exposure periods ranging from one hour to one year.

Section 2

THEORETICAL DEVELOPMENT

The Fisher-Tippett Type 1 (FT1) density function* for a wind speed variate u, with parameters α and μ (determined from the mean and variance of the wind sample) can be written

$$f(u) = \alpha \exp \left[-e^{-\alpha(u-\mu)} - \alpha(u-\mu) \right]. \tag{1}$$

Figure 1, based on work by Pope (Ref. 1), shows a distribution of 10-m extreme winds. In the figure, the asterisks represent observed extremals, the curves are control bands (Refs. 1 and 2), and the straight line is the integral of the FT1 function (Eq. 1). Experience with extreme winds indicates that they often fit a Fisher-Tippett distribution (c.f., Ref. 3).

Fichtl (Daniels, Ref. 4) established an empirical relationship

$$u_h = u_{18.3} \left(\frac{h}{18.3} \right)^{c\, u_{18.3}^{-3/4}} \tag{2}$$

between u_h, the peak wind speed (m/sec) at level h(m) and $u_{18.3}$, the peak wind speed at the reference level, 18.3 m. The quantity c is a random variable with a mean of 0.52 and a standard deviation of 0.36. Equation (2) represents a power-law profile with parameters c and 3/4 derived by statistical analysis of Cape Kennedy wind records for a specific exposure period.

With this much as background, cumulative distributions of peak winds can be developed for various levels by combining Eq. (1) and Eq. (2). For some level h,

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*In this report, probability density functions are represented by f(u) where u is a random variable.

$$f(u_h, c) = f(u_h | c)\, f(c) \tag{3}$$

where $f(u_h|c)$ is a probability density function with random variable u_h subject to a given value of c; i.e., a conditional probability, which may be expressed in terms of Eq. (1) by

$$f(u_h|c) = \alpha \exp\left[-e^{-\alpha(u_h - \mu)} - \alpha(u_h - \mu)\right], \tag{4}$$

where u_h is a function of c. For some other level h′, the corresponding probability $f(u_{h'}|c)$, is related to $f(u_h|c)$ by the transformation

$$f(u_{h'}|c) = f(u_h|c)\left|\frac{\partial u_h}{\partial u_{h'}}\right|. \tag{5}$$

Then, from Eq. (5) and Eq. (3),

$$f(u_{h'}, c) = f(u_h|c)\, f(c)\left|\frac{\partial u_h}{\partial u_{h'}}\right|. \tag{6}$$

It is convenient to choose h = 10 m, since the 10-m FT1 parameters α and μ required to determine $f(u_h|c)$ by Eq. (4) have been tabulated (Ref. 4, also see Section 3), and to choose h′ = 18.3, since 18.3 appears explicitly in Eq. (2). Subject to these choices, and the fact that c is normally distributed*, i.e.,

$$f(c) = \frac{1}{\sqrt{2\pi}\,\sigma}\, e^{-(c-\bar{c})^2/2\sigma^2},$$

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*Fichtl, private communication.

then Eq. (6) can be integrated to give the probability density function

$$f(u_{18.3}) = \int_{-\infty}^{\infty} f(u_{18.3}, c)\, dc . \tag{7}$$

To summarize, from the distribution $f(u_{10})$ given by Eq. (1) with α and μ specified in Table 1, and a relationship between $u_{18.3}$ and u_{10} given by Eq. (2), the function $f(u_{18.3})$ can be determined. Next the distribution $f(u_h)$ for any level, h, is found.

A bivariate distribution can be formed relating the wind speed at level h to that at 18.3 m by writing an expression similar to Eq. (3)

$$f(u_h, u_{18.3}) = f(u_h | u_{18.3})\, f(u_{18.3}) \tag{8}$$

where $f(u_h | u_{18.3})$ is a conditional probability that can be expressed in terms of the normal deviate c by the transformation

$$f(u_h | u_{18.3}) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-(c-\bar{c})^2/2\sigma^2} \left| \frac{\partial c}{\partial u_h} \right| , \tag{9}$$

and where the explicit dependence among c, u_h and $u_{18.3}$, viz.,

$$c = \frac{\ln u_h - \ln u_{18.3}}{u_{18.3}^{-3/4} \ln (h/18.3)} \tag{10}$$

follows from Eq. (2). The Jacobian in Eq. (9) can be obtained by differentiating Eq. (10)

$$\frac{\partial c}{\partial u_h} = \frac{1/u_h}{u_{18.3}^{-3/4} \ln (h/18.3)} . \tag{11}$$

Substituting Eqs. (7), (9), (10) and (11) into Eq. (8), and integrating gives the probability density function for any level

$$f(u_h) = \int_{-\infty}^{\infty} f(u_h, u_{18.3})\, du_{18.3} \, . \tag{12}$$

The cumulative distribution, or the probability that a peak wind speed will not exceed some value V, is obtained by integrating Eq. (12)

$$F(V) = \int_{-\infty}^{V} f(u_h)\, du_h \tag{13}$$

Consider now peak wind profiles. The profile of winds from 18.3 m to 152.4 m for a given value of $u_{18.3}$ is determined by only one parameter — the normal deviate c. Furthermore, the probability that a profile will not be exceeded is equal to the probability the c will not be exceeded. Then, for a fixed value $c = C$, $f(u_h, u_{18.3})$ in Eq. (8) is the probability that both $u_{18.3}$ and the "C" profile," given by Eq. (2) will occur. For example, the "3σ" profile is obtained by setting $C = \bar{c} + 3\sigma$ in Eq. (2). The cumulative distribution or the probability that neither $u_{18.3}$ nor the C profile will be exceeded is obtained by integrating Eq. (8)

$$F(W, V) = \int_{-\infty}^{W(C,\,V)} \int_{-\infty}^{V} f(u_h, u_{18.3})\, du_{18.3}\, du_h \, . \tag{14}$$

To evaluate Eq. (14), the arbitrary choice is made that $h = 152.4$ and $C = \bar{c}$, $\bar{c} + \sigma$, $\bar{c} + 2\sigma$, and $\bar{c} + 3\sigma$.

Equations (13) and (14) were integrated numerically by Simpson's rule. The application of Simpson's rule to Eq. (7), summing over the limits $\bar{c} + 4\sigma$, was straightforward. Equation (8) was solved in blocks over a windspeed range of from 6 to 154 kts, each block having sides of 2 kts. For the integration of Eqs. (12), (13) and (14) only the blocks with probability greater than 0.00001 were included, and the, total probability was generally about 0.9993. Figures 2 and 3 illustrate the double integration. The general results of this study are presented in Figs. 4 through 47, and are discussed in Section 3.

Figure 2 is an example (Cape Kennedy, 30-day exposure period) of a plot of the probability contained in the individual blocks. Rather than a density function, the ordinate is the probability that an 18.3-m wind value lies between $u_{18.3}$ and $u_{18.3} + 2$ (kts) on the horizontal axis, while a 152.4-m wind value lies between $u_{152.4}$ and $u_{152.4} + 2$ (kts) on the diagonal axis (unlabeled, but on which the lines are spaced at two-knot intervals, beginning at six knots).

Figure 3 illustrates the same results in two-dimensional blocks. The solid blocks represent probability greater than 0.0001, the shaded blocks probability between 0.0001 and 0.00001, and the clear blocks probability less than 0.00001.

Section 3
RESULTS

Results of Eq. (13) are shown in Figs. 4 through 25 for eleven different exposure periods. The curves are almost straight. Since a straight line on this graph represents an FT1 distribution, all curves are interpreted as representing such distributions. The dashed curves on the one-hour exposure period figures (Figs. 4 and 15) are linear extensions of the solid curves; this is discussed below.

The 10-m α and μ values for Cape Kennedy, given in Table 1, vary with the exposure period t according to

$$\alpha = (a + b \ln t)^{-1}$$

$$\mu = (c + d \ln t)$$

with coefficients given below.

	annual reference values		"env" values	
	1 ℓn $\leq$ t $\leq$ 24 hrs	1 day $\leq$ t $\leq$ 365 days	1 ℓn $\leq$ t $\leq$ 24 hrs	1 day $\leq$ t $\leq$ 365 days
a	4.6782	4.7668	5.3487	5.4579
b	0.0279	0.3687	0.0343	0.9170
c	9.3997	16.8799	14.9100	19.8496
d	2.3537	4.7451	1.5535	4.3462

The coefficients designated by "env," result from the interpolation of an envelope of maximum-monthly, bimonthly, and yearly (including hurricane data) means and standard deviations of one- and 30-, 60-, and 365-day peak winds, respectively. The corresponding α's and μ's represent conservative distributions for design and operational purposes. They may be thought of as limiting cases of peak-wind distributions that could be expected to occur (see Ref. 4).

Values of α and μ for the other levels (18.3, 30.5, 61.0, 91.4, 121.9 and 152.4 m) were determined from the linear expression

$$y = \alpha (u - \mu)$$

by substituting values of u and y (the reduced variate) from two points on each curve; they appear in Table 1 also.

Before proceeding further, several comments about exposure period should be made. In the present context, exposure period is the interval of time chosen for which the largest or peak wind is extracted from a given wind record. This period may be 10 minutes* (Ref. 4) which was the case in establishing Eq. (2), or it may be an hour, a day, a month, etc. The importance of exposure period is manifested in the α and μ parameters which vary with the logarithm of exposure period, and which determines the shape of the FT1 distributions.

Figures 26 through 47 result from Eq. (14). The curves represent the joint probability (ordinate value) that $u_{18.3}$ (abscissa value) and the profile indicated in the legend will not be exceeded. These figures show clearly that there is little difference between the cumulative distributions of 0σ and 3σ profiles.

Before proceeding with examples of how the results of this report can be used (Section 4), several points should be made.

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*The peak wind observed at each level h = 18.3, 30.5, 61.0, 91.4, 121.9 and 152.4 m during an exposure period of 10 minutes was tabulated. The peak winds were assumed to have occurred simultaneously at all levels (Fichtl, private communication).

Difficulty arises from trying to integrate Eqs. (12) and (14) for small values of u_h. In the present study, only the one-hour and one-day exposure period cases were affected (Figs. 4, 5, 15, 16, 26, 27, 37 and 38). The center of difficulty is the empirical expression (Eq. (2)) which enters into the integrated $f(u_h, u_{18.3})$. Equation (2) possesses a minimum u_h for some small value[*] of $u_{18.3}$. Such a minimum (call it u_h') is not ordinarily observed, so the empirical relation is not meant to hold for $u_h < u_h'$. Therefore, the contribution to Eqs. (12) and (14) from the range $(-\infty, u_h')$ is lost. Because, theoretically, the integrals must approach unity as their upper limits tend to ∞, it is reasonable to assume that any computed deficit results from this loss. Accordingly, the distributions were adjusted by assigning the deficit value as the cumulative distribution for u_h', and by shifting the values for $u_h > u_h'$ upward. The curves were then completed by linear extrapolation downward to the 0.001 ordinate value (dashed lines in figures).

Secondly, it should be mentioned that no special significance is implied by the use of FT1 graphs for plotting Figs. 26 through 47. The graphs were used simply as a matter of convenience. On the other hand, it might be advantageous for some purposes (e.g., computer applications) to have joint distributions in a form other than graphical. Therefore, each curve was fit by the linear expression $Y(c,t) = \beta(c,t) \left[u_{18.3} - \gamma(c,t)\right]$; the constants β and γ appear in Table 2. Approximate joint distributions $F(u_{18.3}, c)$, for a specific 18.3-m wind and profile, may be computed from

$$F(u_{18.3}, c) = \exp\left[-e^{-Y(c,t)}\right]. \tag{15}$$

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[*] Below this small value of $u_{18.3}$, u_h tends toward ∞ as $u_{18.3}$ tends toward zero.

Section 4

USE OF THE GRAPHS

Figures 26 through 47 represent joint probability statements derived from two conditions, viz., the 18.3-m wind is equal to a given wind A, and the profile of the winds from 18.3 to 152.4 m is equal to a given profile B when the 18.3-m wind is A. The product of these probabilities $P(A \cap B)$, is the probability that both conditions exist simultaneously.

Consider three statements of joint probability to determine how the figures and the table can be used.

Case I The probability that the 18.3-m wind A is less than a given value A', and the profile B is less than a given profile B', in other words, neither A nor B are exceeded, is given symbolically by $P(A \leq A' \cap B \leq B')$

Case II The probability that at least one of the conditions in Case I is violated, i.e., either the 18.3-m wind is exceeded or the profile is exceeded or both are exceeded is given by $P(A > A' \cup B > B') = 1 - P(A \leq A' \cap B \leq B')$

Case III The probability that both the 18.3-m wind and the profile are exceeded is given by $P(A > A' \cap B > B') = 1 - P(A \leq A') - P(B \leq B') + P(A \leq A' \cap B \leq B')$.

To determine the probabilities in Cases I and II, choose the graph from Figs. 26 through 47 for the desired exposure period and the profile of interest. Using the 18.3-m wind value on the abscissa, read the corresponding probability from the ordinate or, use Eq. (15) with β and γ from Table 2.

Example of Case I Suppose that a vehicle must remain on the pad for a period of three months and that its design limits will be exceeded if the 18.3-m wind exceeds 55 kts and the profile of winds exceeds the 3σ peak-wind profile. What is the probability that these conditions will not be exceeded? According to Eq. (2) with $c = \bar{c} + 3\sigma = 1.60$ the profile includes

$$
\begin{aligned}
u_{18.3} &\leq 55.0 \text{ kts} \\
u_{30.5} &\leq 58.78 \\
u_{61.0} &\leq 64.32 \\
u_{91.4} &\leq 67.80 \\
u_{121.9} &\leq 70.39 \\
u_{152.4} &\leq 72.46 \, .
\end{aligned}
$$

Figure 34 gives joint probabilities for the 90-day exposure period. Fifty-five kts on the abscissa corresponds to $P = 0.92$ on the ordinate for the 3σ envelope or profile.

Example of Case II What is the probability that one or both conditions will be exceeded? By subtracting 0.92 from 1.0, 0.08 is obtained for the probability that at least one of the conditions $u_{18.3} \leq 55$ kts and $u_h \leq u_h(3\sigma)$ is violated.

Turning now to Case III, it is suggested that the simplest way to evaluate $P(A > A' \cap B > B')$ is term by term, according to the formula above. Figure 48 is used to find the value of $u_{152.4}$ that corresponds to the profile of interest and the particular $u_{18.3}$ value, or, it may be computed directly from Eq. (2). The terms $P(A \leq A') = F(u_{18.3})$ and $P(B \leq B') = F(u_{152.4})$ are obtained from the appropriate graphs (Figs. 4-25)*. $P(A \leq A' \cap B \leq B')$ is read from Figs. 26 through 47 or computed from Eq. (15).

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*Alternatively, Eq. (1) could be integrated

$$F(u_{18.3}) = \int_{-\infty}^{u_{18.3}} f(u)\, du = \exp\left(-e^{-\alpha(u_{18.3} - \mu)}\right) \tag{16}$$

and $P(A \leq A') = F(u_{18.3})$ solved, using μ and α from Table 1. A similar expression for 152.4 m would lead to $P(B \leq B') = F(u_{152.4})$.

Example of Case III Suppose that for an exposure period of 90 days, the probability is needed that the 18.3-m peak wind is greater than 40 kts and the profile is greater than the 0σ profile. Accordingly

$$P(u_{18.3} \leq 40) = F(u_{18.3} = 40) = 0.40 \quad \text{(Fig. 12)},$$

or

$$\alpha = 0.1509, \quad \mu = 39.3919, \quad F(40) = 0.40 \quad \text{(Table 1, Eq. (16))},$$

$$u_{152.4} = 44.83 \text{ kts} \quad \text{(Fig. 48 or Eq. (2))},$$

$$P(u_{152.4} \leq 44.83) = F(u_{152.4} = 44.83) = 0.37 \quad \text{(Fig. 12)},$$

or

$$\alpha \doteq 0.1463, \quad \mu = 44.9120, \quad F(44.83) = 0.37 \quad \text{(Table 1, Eq. (16))},$$

$$P(u_{18.3} \leq 40 \cap u_{152.4} \leq 44.83) = 0.32 \quad \text{(Fig. 34)},$$

and finally

$$P(u_{18.3} > 40 \cap u_h > 0\sigma \text{ profile}) = 1 - 0.40 - 0.37 + 0.32 = 0.55.$$

Section 5

SUMMARY AND CONCLUSIONS

Integral equations were developed that describe the cumulative distribution of peak winds for several levels viz., 10.0, 18.3, 30.5, 61.0, 91.4, 121.9 and 152.4 m, and several exposure periods viz., 1 hr, 1, 2, 5, 10, 15, 30, 60, 90, 180 and 365 days. The equations are applicable to intermediate levels and time periods. The results are presented in graphical form for each exposure period. The curves in each figure were fitted by a linear expression whose coefficients are tabulated.

Equations describing the joint probability that a wind value at the reference level 18.3 m, and a given profile (0σ, 1σ, 2σ, 3σ) will not be exceeded are also derived. Results are presented in both graphical and tabular form.

The cumulative distribution,presented in this report, of peak winds for levels between 10 and 150 m and for exposure periods between one hour and one year, possess the double exponential shape characteristic of FT1 distributions. As one might expect, the probability that the wind will not exceed a given value, decreases with increasing height above ground (for all exposure periods), and decreases with increasing exposure period (at all levels).

From a physical viewpoint, to the extent that wind gusts associated with individual small scale eddies can be envisioned as simultaneously influencing the entire planetary boundary layer at a given station and within a given exposure period, peak winds at levels above 10 m could be expected to be distributed according to a FT1 distribution with parameters given by Table 1. However, to interpret the results obtained as proof that peak winds above 10-m fit such a distribution would be speculative.

With the reference wind $u_{18.3}$ and the exposure period t fixed, joint distributions for 0σ, 1σ, 2σ and 3σ profiles are practically the same. The probability that $u_{18.3}$ will not exceed a given value and none of the four profiles will be exceeded decreases with exposure period.

Section 6

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Table 1

LEVEL (METERS)	CAPE KENNEDY E T 1 HR		CAPE KENNEDY E T 1 DAY		CAPE KENNEDY E T 2 DAYS		CAPE KENNEDY E T 5 DAYS		CAPE KENNEDY E T 10 DAYS		CAPE KENNEDY E T 15 DAYS	
	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU
10.0	0.2138	9.4000	0.2098	16.8800	0.1991	20.1700	0.1866	24.5200	0.1781	27.8100	0.1735	29.7300
18.3	0.2099	10.3255	0.2067	17.9449	0.1965	21.2847	0.1843	25.6858	0.1760	29.0140	0.1715	30.9535
30.5	0.2055	11.1477	0.2031	18.8697	0.1945	22.2784	0.1827	26.7329	0.1747	30.0894	0.1702	32.0428
61.0	0.2015	12.5395	0.1991	20.3718	0.1908	23.8160	0.1797	28.3292	0.1719	31.7186	0.1676	33.6874
91.4	0.1990	13.5233	0.1964	21.3869	0.1883	24.8471	0.1767	29.3189	0.1692	32.7280	0.1650	34.7026
121.9	0.1960	14.2528	0.1932	22.1142	0.1852	25.5738	0.1752	30.1422	0.1678	33.5550	0.1637	35.5319
152.4	0.1949	14.9637	0.1920	22.8098	0.1842	26.2767	0.1727	30.7279	0.1656	34.1506	0.1616	36.1280

LEVEL (METERS)	CAPE KENNEDY E T 30 DAYS		CAPE KENNEDY E T 60 DAYS		CAPE KENNEDY E T 90 DAYS		CAPE KENNEDY E T 180 DAYS		CAPE KENNEDY E T 365 DAYS	
	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU
10.0	0.1661	33.0200	0.1593	36.3100	0.1556	38.2300	0.1497	41.5200	0.1441	44.8800
18.3	0.1644	34.2768	0.1578	37.5975	0.1541	39.5335	0.1483	42.8512	0.1428	46.2374
30.5	0.1632	35.3913	0.1567	38.7342	0.1531	40.6827	0.1473	44.0191	0.1418	47.4172
61.0	0.1608	37.0634	0.1545	40.4349	0.1510	42.3956	0.1454	45.7588	0.1398	49.1614
91.4	0.1585	38.0976	0.1524	41.4863	0.1488	43.4448	0.1436	46.8313	0.1385	50.2744
121.9	0.1573	38.9329	0.1513	42.3291	0.1479	44.2944	0.1426	47.6842	0.1376	51.1331
152.4	0.1554	39.5382	0.1496	42.9441	0.1463	44.9120	0.1412	48.3090	0.1363	51.7682

Table 1 (continued)

LEVEL (METERS)	CAPE KENNEDY E T 1 HR (ENV)		CAPE KENNEDY E T 1 DAY (ENV)		CAPE KENNEDY E T 2 DAYS (ENV)		CAPE KENNEDY E T 5 DAYS (ENV)		CAPE KENNEDY E T 10 DAYS (ENV)		CAPE KENNEDY E T 15 DAYS (ENV)	
	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU
10.0	0.1870	14.9100	0.1832	19.8500	0.1641	22.8500	0.1442	26.8400	0.1321	29.8600	0.1259	31.6200
18.3	0.1843	15.9468	0.1808	20.9576	0.1622	23.9958	0.1427	28.0332	0.1308	31.0841	0.1247	32.8602
30.5	0.1810	16.8461	0.1792	21.9584	0.1609	25.0270	0.1416	29.0877	0.1299	32.1620	0.1239	33.9599
61.0	0.1780	18.3185	0.1757	23.4627	0.1585	26.5921	0.1396	30.6696	0.1281	33.7666	0.1223	35.5658
91.4	0.1755	19.2721	0.1736	24.4751	0.1563	27.5710	0.1382	31.6918	0.1270	34.7962	0.1212	36.5958
121.9	0.1741	20.0619	0.1710	25.1942	0.1552	28.3732	0.1368	32.4326	0.1258	35.5422	0.1200	37.3389
152.4	0.1720	20.6504	0.1701	25.8766	0.1536	28.9647	0.1361	33.0930	0.1253	36.1975	0.1195	37.9895

LEVEL (METERS)	CAPE KENNEDY E T 30 DAYS (ENV)		CAPE KENNEDY E T 60 DAYS (ENV)		CAPE KENNEDY E T 90 DAYS (ENV)		CAPE KENNEDY E T 180 DAYS (ENV)		CAPE KENNEDY E T 365 DAYS (ENV)	
	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU	ALPHA	MU
10.0	0.1166	34.6300	0.1086	37.6400	0.1043	39.4100	0.0978	42.4200	0.0920	45.9200
18.3	0.1156	35.8978	0.1076	38.9337	0.1035	40.7175	0.0971	43.7512	0.0913	47.2764
30.5	0.1149	37.0179	0.1070	40.0721	0.1029	41.8666	0.0965	44.9171	0.0908	48.4608
61.0	0.1134	38.6462	0.1057	41.7224	0.1018	43.5436	0.0956	46.6128	0.0899	50.1752
91.4	0.1125	39.6827	0.1049	42.7666	0.1009	44.5741	0.0948	47.6523	0.0893	51.2444
121.9	0.1116	40.4376	0.1042	43.5295	0.1004	45.3729	0.0944	48.4596	0.0889	52.0354
152.4	0.1111	41.0852	0.1037	44.1736	0.0998	45.9807	0.0938	49.0663	0.0883	52.6423

Table 2

	CAPE KENNEDY E T 1 HR		CAPE KENNEDY E T 1 DAY		CAPE KENNEDY E T 2 DAYS		CAPE KENNEDY E T 5 DAYS		CAPE KENNEDY E T 10 DAYS		CAPE KENNEDY E T 15 DAYS	
SIGMA ENVELOPE	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA
0.0	0.2035	11.8299	0.1998	19.4326	0.1913	22.8114	0.1793	27.1961	0.1716	30.5452	0.1673	32.4879
1.0	0.2079	10.6864	0.2043	18.2677	0.1952	21.6247	0.1832	26.0345	0.1749	29.3467	0.1706	31.2995
2.0	0.2088	10.3505	0.2055	17.9567	0.1962	21.3183	0.1840	25.7181	0.1758	29.0450	0.1713	30.9840
3.0	0.2087	10.2993	0.2055	17.9159	0.1963	21.2788	0.1841	25.6803	0.1759	29.0082	0.1713	30.9473

	CAPE KENNEDY E T 30 DAYS		CAPE KENNEDY E T 60 DAYS		CAPE KENNEDY E T 90 DAYS		CAPE KENNEDY E T 180 DAYS		CAPE KENNEDY E T 365 DAYS	
SIGMA ENVELOPE	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA
0.0	0.1606	35.8318	0.1543	39.1701	0.1508	41.1104	0.1453	44.4482	0.1401	47.8516
1.0	0.1634	34.6107	0.1568	37.9316	0.1532	39.8678	0.1475	43.1884	0.1420	46.5767
2.0	0.1641	34.3056	0.1575	37.6226	0.1538	39.5585	0.1480	42.8757	0.1425	46.2608
3.0	0.1642	34.2686	0.1575	37.5866	0.1539	39.5226	0.1481	42.8396	0.1426	46.2246

Table 2 (continued)

SIGMA ENVELOPE	CAPE KENNEDY E T 1 HR (ENV)		CAPE KENNEDY E T 1 DAY (ENV)		CAPE KENNEDY E T 2 DAYS (ENV)		CAPE KENNEDY E T 5 DAYS (ENV)		CAPE KENNEDY E T 10 DAYS (ENV)		CAPE KENNEDY E T 15 DAYS (ENV)	
	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA
0.0	0.1790	17.3922	0.1764	22.4556	0.1588	25.4955	0.1402	29.5450	0.1287	32.6000	0.1228	34.3740
1.0	0.1826	16.2699	0.1797	21.2903	0.1613	24.3273	0.1420	28.3614	0.1303	31.4108	0.1242	33.1847
2.0	0.1832	15.9513	0.1805	20.9877	0.1620	24.0275	0.1425	28.0596	0.1306	31.1093	0.1245	32.8839
3.0	0.1832	15.9082	0.1806	20.9489	0.1620	23.9894	0.1425	28.0212	0.1306	31.0706	0.1245	32.8473

SIGMA ENVELOPE	CAPE KENNEDY E T 30 DAYS (ENV)		CAPE KENNEDY E T 60 DAYS (ENV)		CAPE KENNEDY E T 90 DAYS (ENV)		CAPE KENNEDY E T 180 DAYS (ENV)		CAPE KENNEDY E T 365 DAYS (ENV)	
	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA	BETA	GAMMA
0.0	0.1139	37.4190	0.1062	40.4625	0.1021	42.2480	0.0959	45.2900	0.0902	48.8239
1.0	0.1151	36.2217	0.1072	39.2569	0.1031	41.0400	0.0967	44.0729	0.0910	47.5962
2.0	0.1154	35.9202	0.1075	38.9542	0.1033	40.7373	0.0969	43.7685	0.0911	47.2930
3.0	0.1154	35.8833	0.1075	38.9193	0.1033	40.7024	0.0969	43.7336	0.0912	47.2581

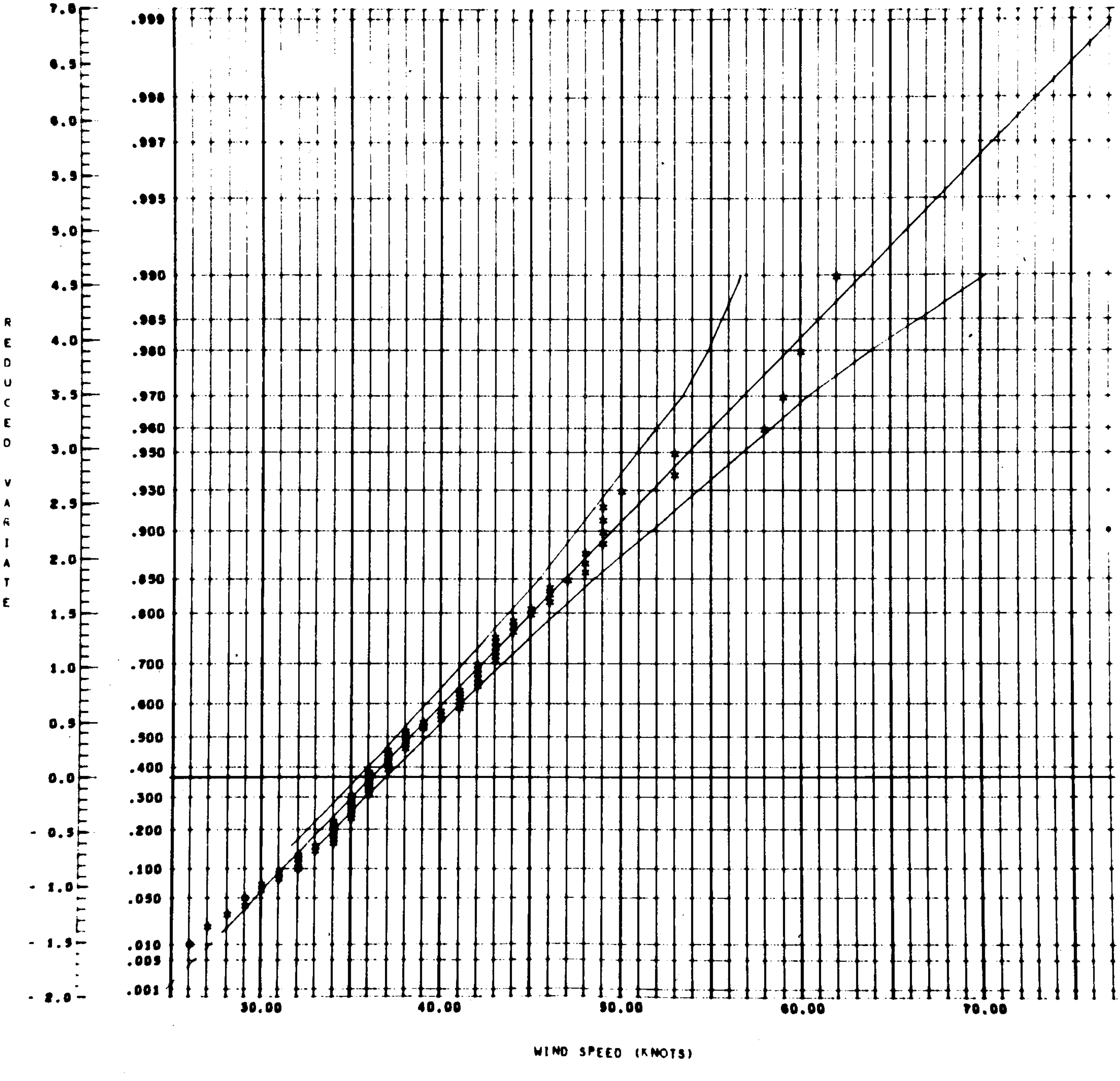

Fig. 1 - FT1 Fit of 30-Day Peak Wind Data for Cape Kennedy

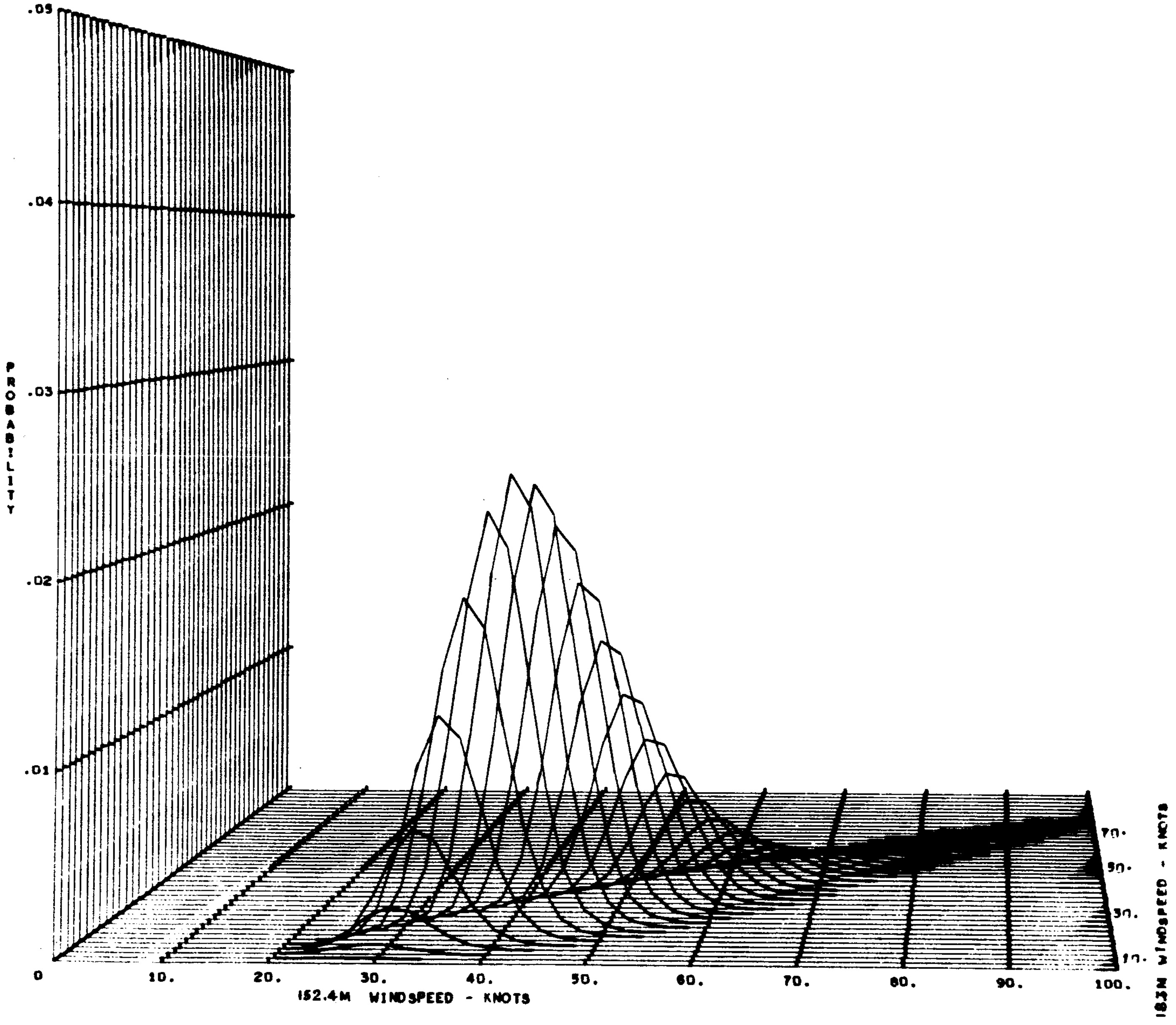

Fig. 2 - Joint Probability Curve for Cape Kennedy (30-Day, Annual Reference Period)

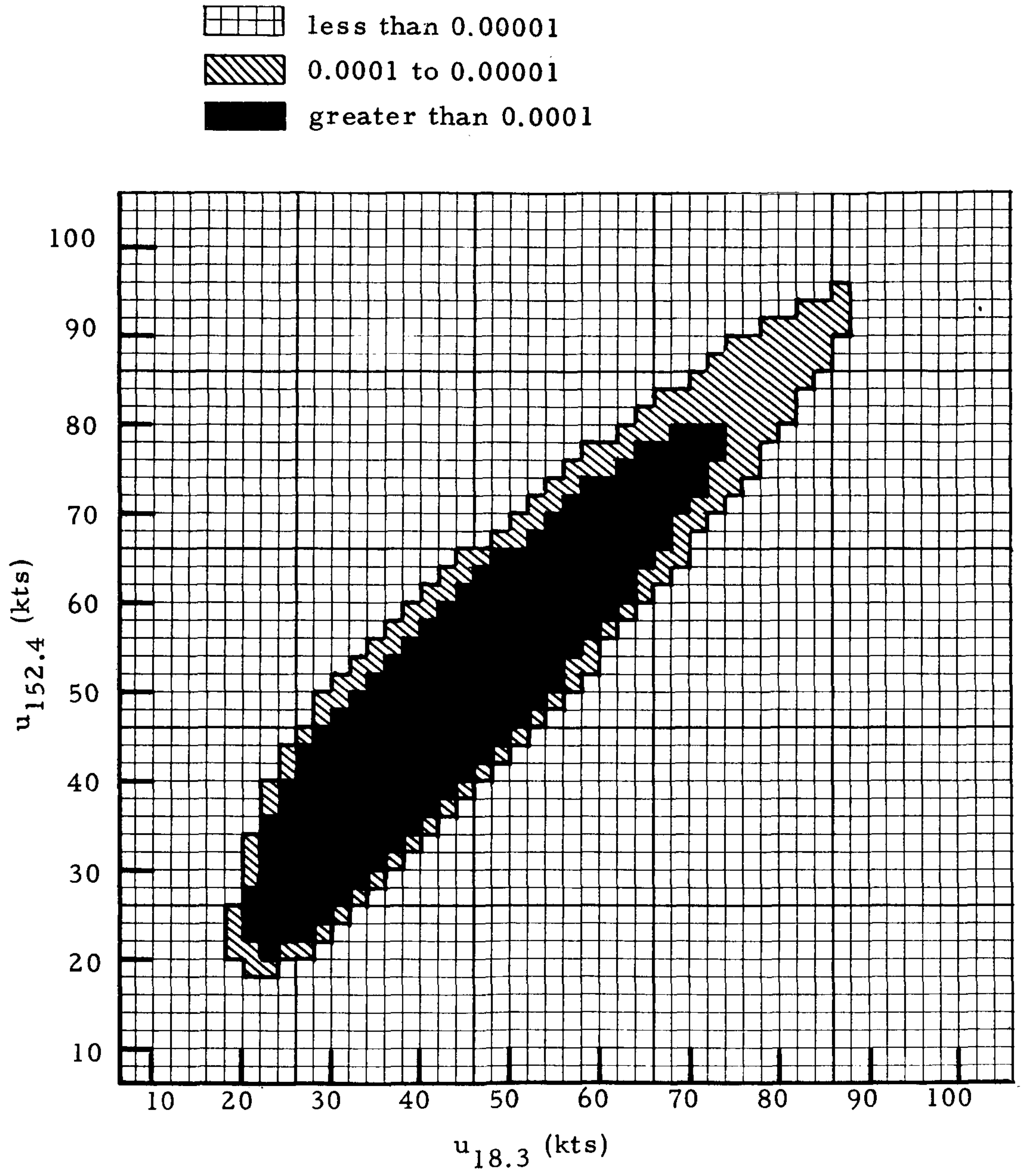

Fig. 3 - Joint Probability Plot for Cape Kennedy (30-Day, Annual Reference Period)

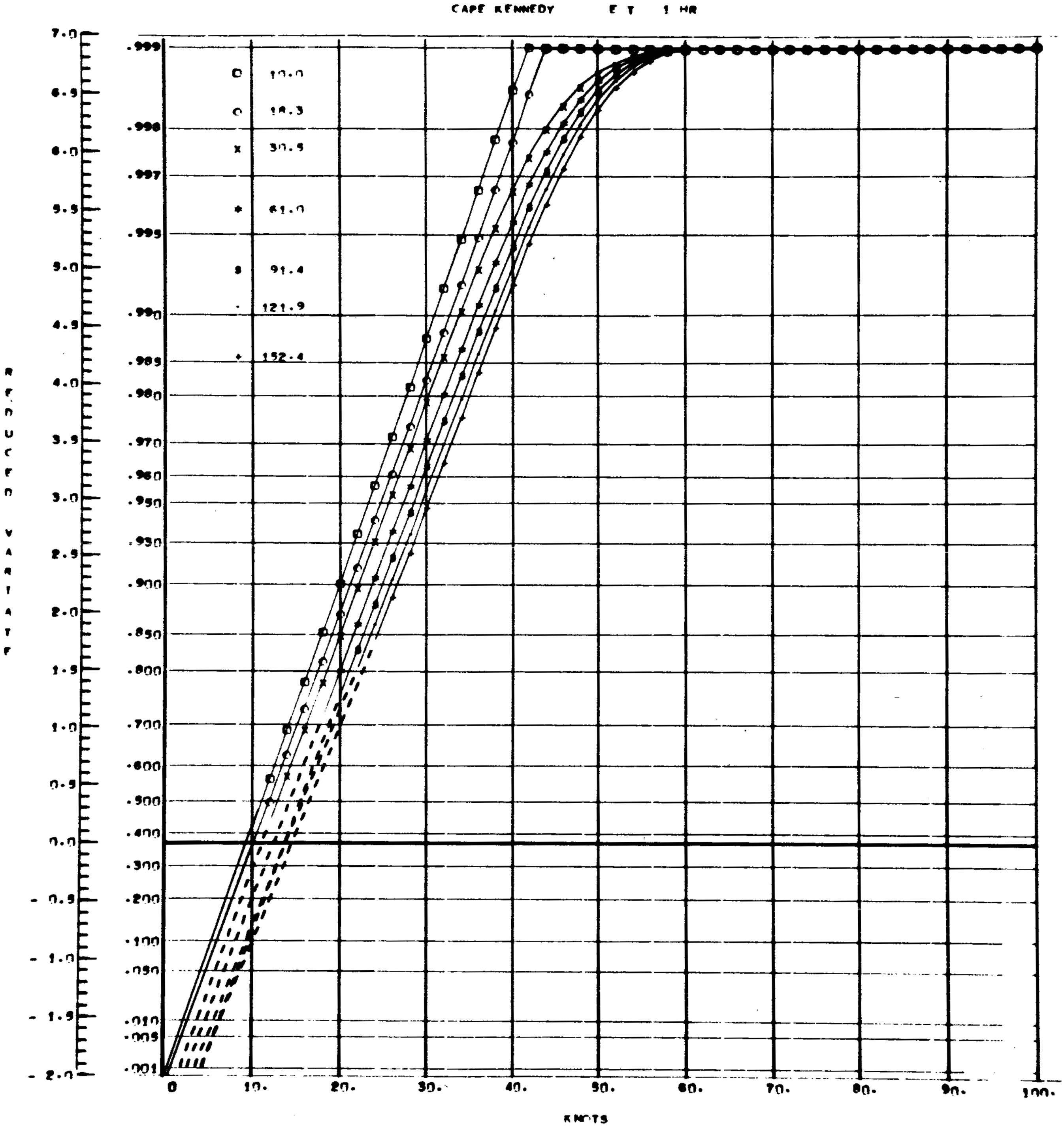

Fig. 4 - Surface Wind Cumulative Distributions

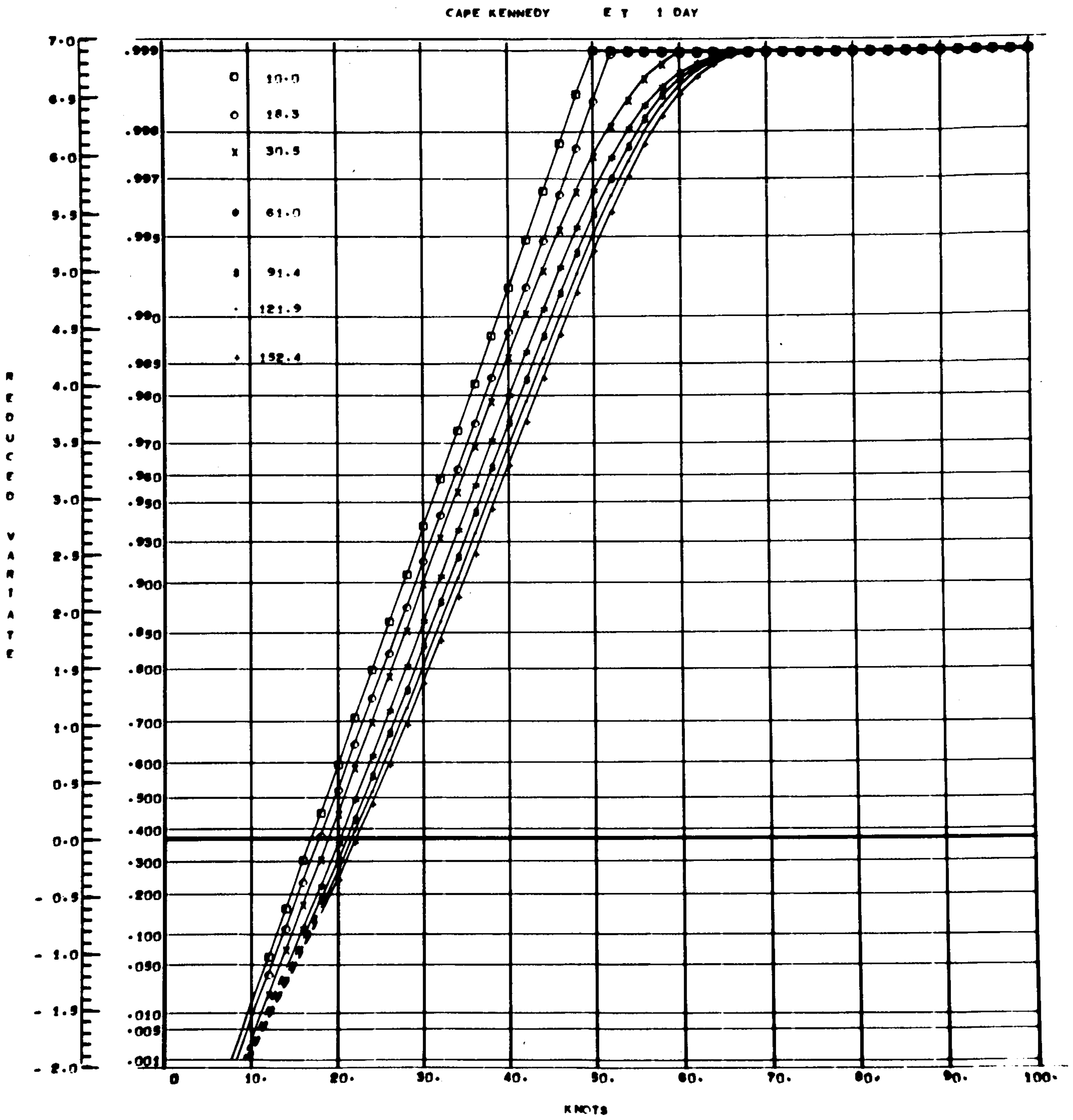

Fig. 5 - Surface Wind Cumulative Distributions

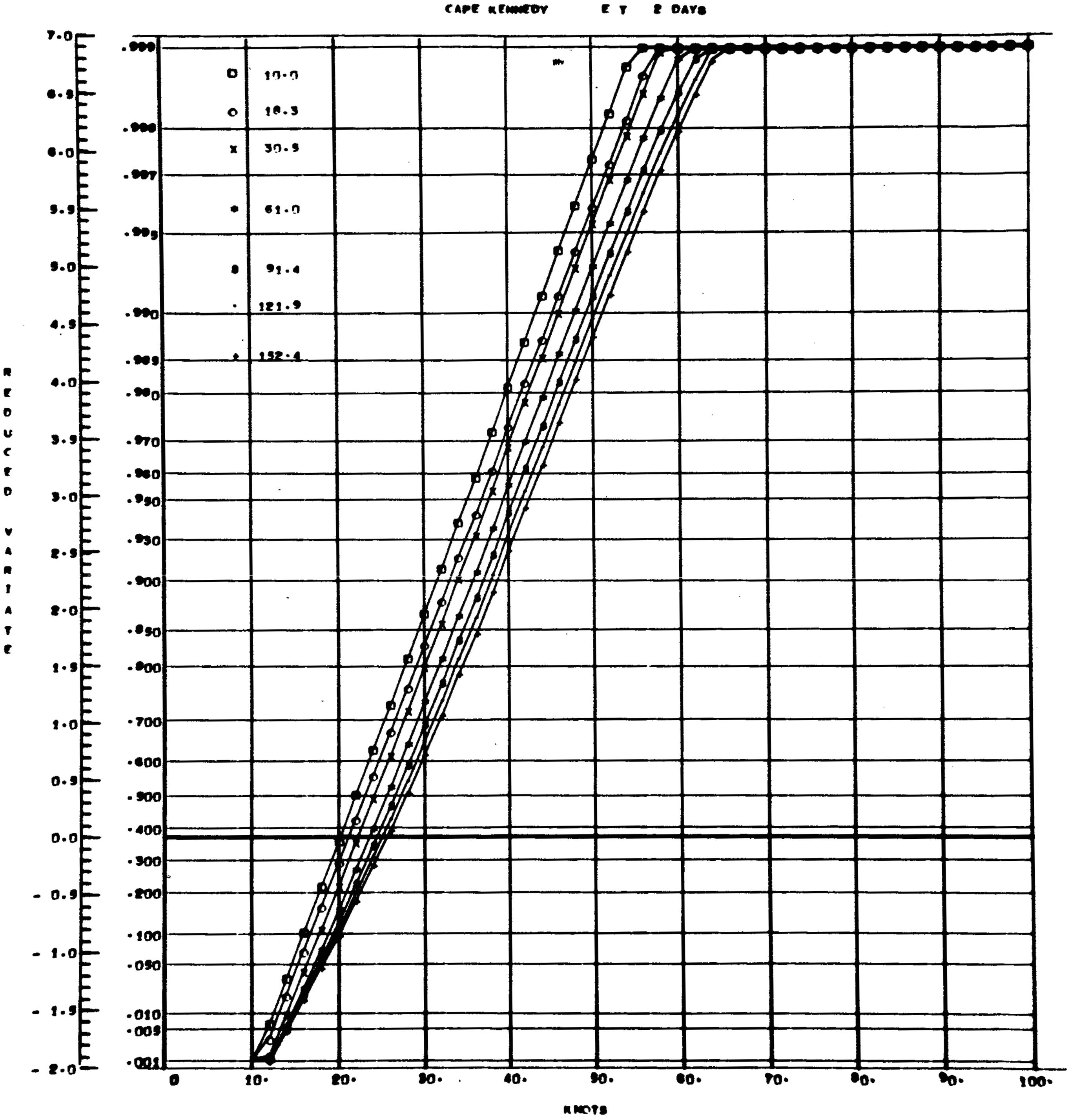

Fig. 6 - Surface Wind Cumulative Distributions

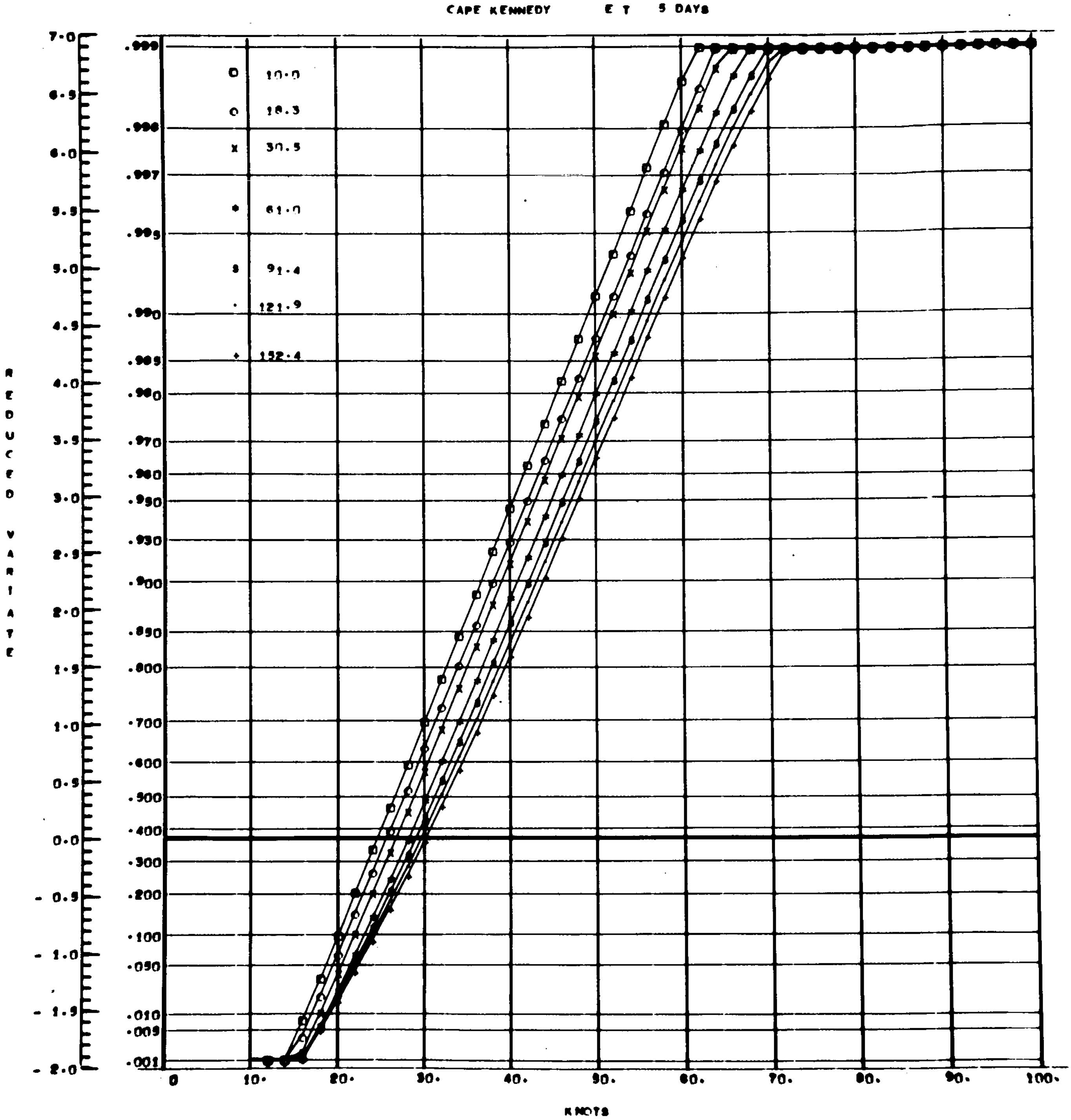

Fig. 7 - Surface Wind Cumulative Distributions

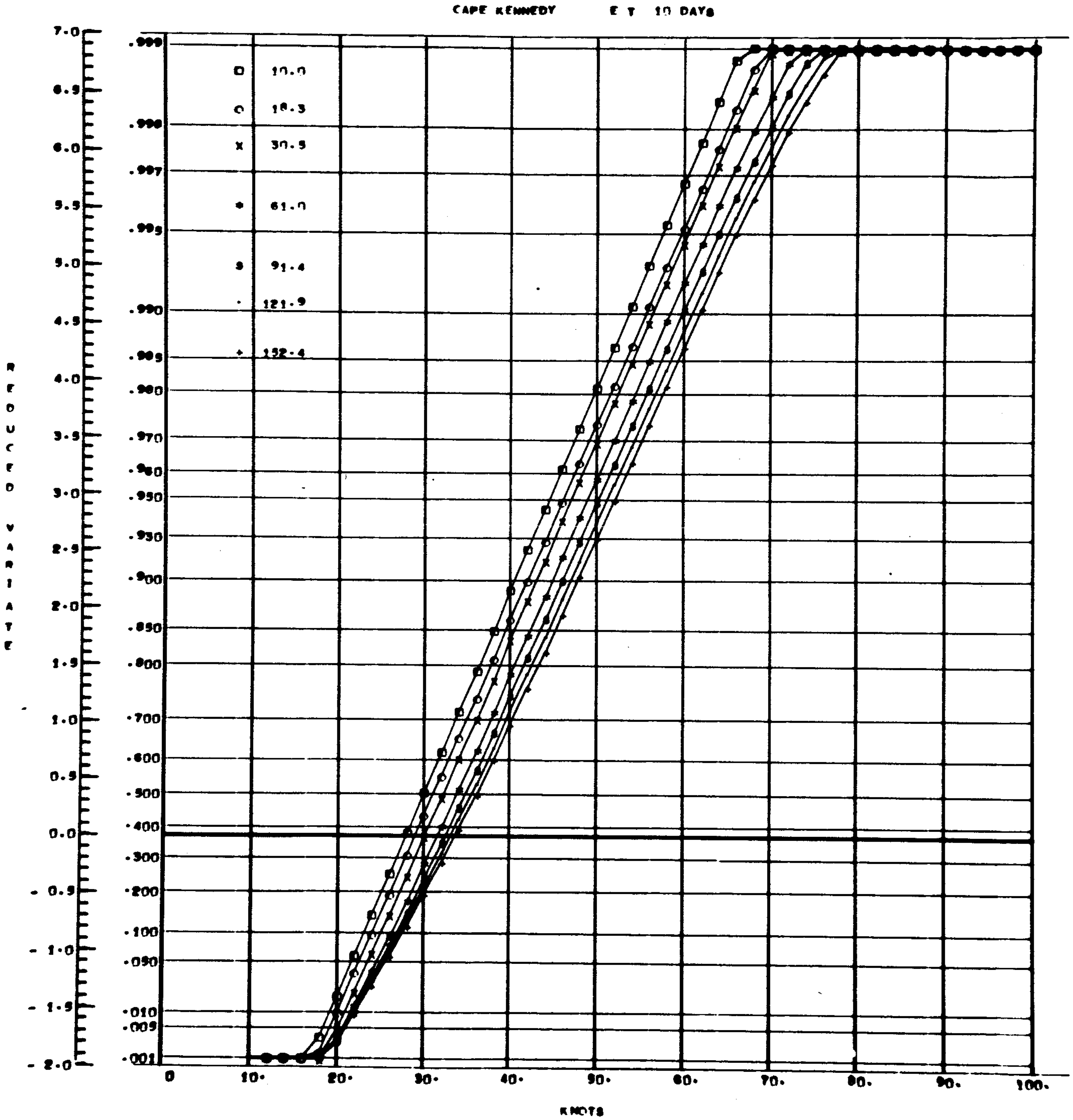

Fig. 8 - Surface Wind Cumulative Distributions

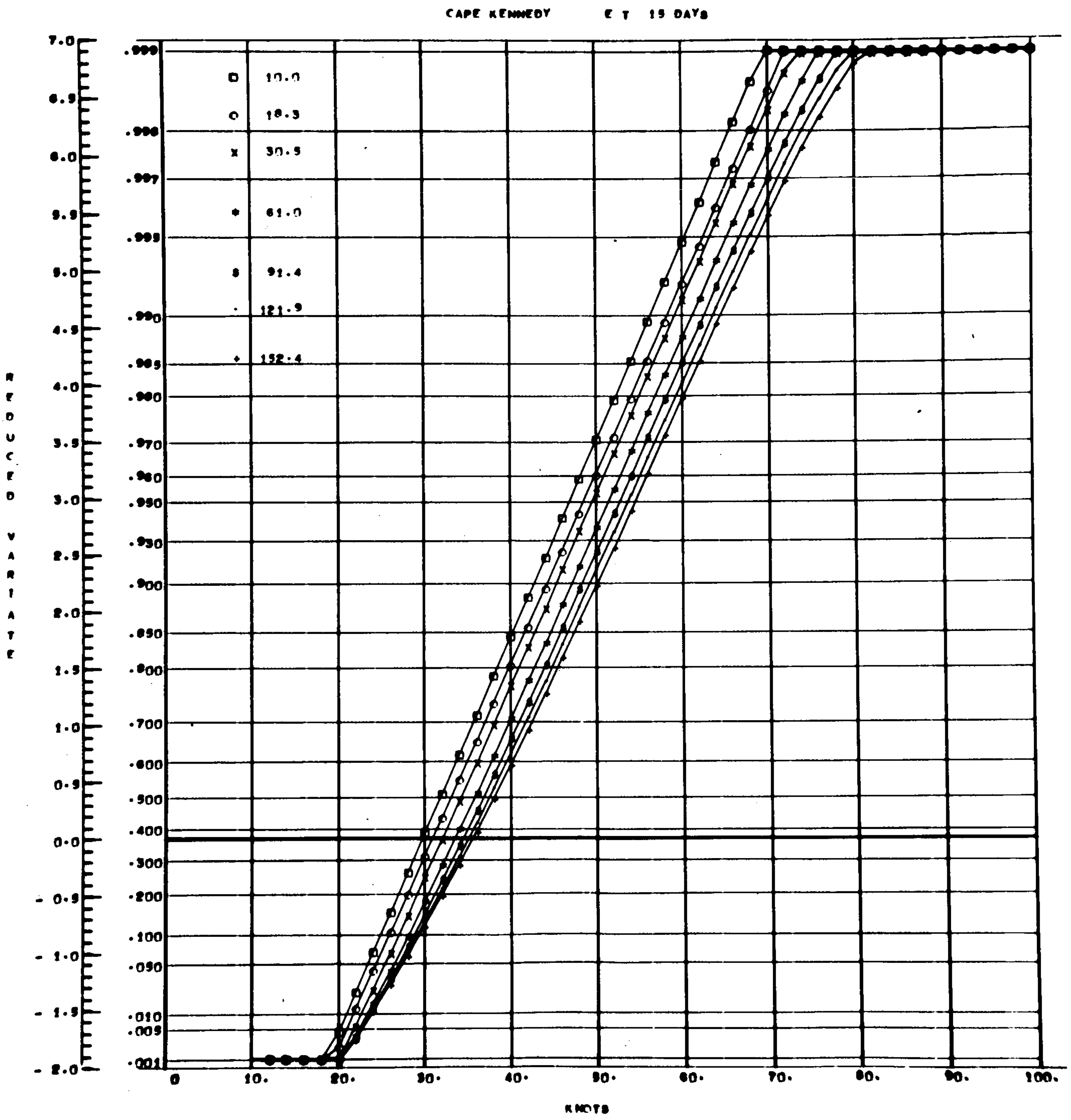

Fig. 9 - Surface Wind Cumulative Distributions

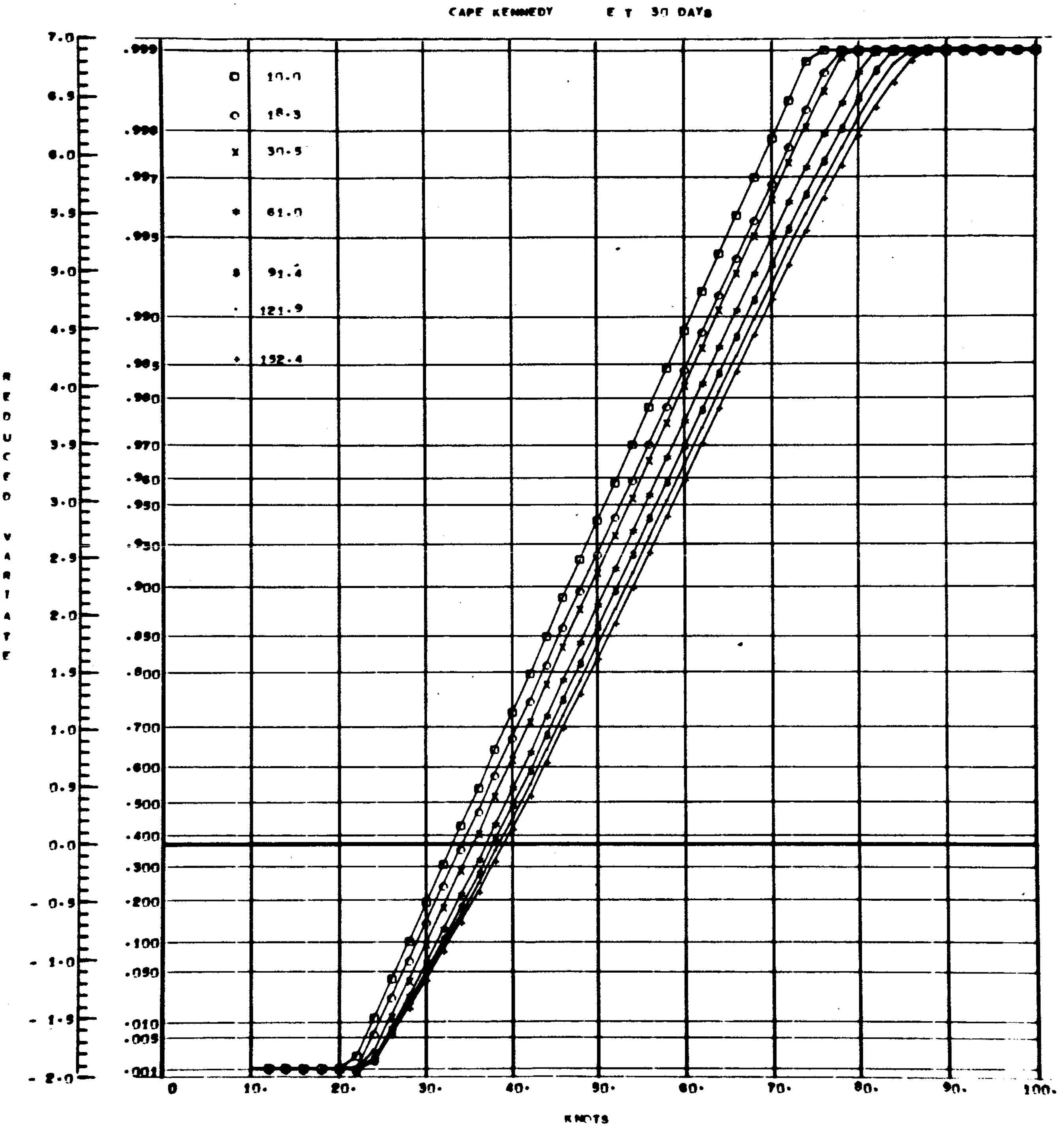

Fig. 10 - Surface Wind Cumulative Distributions

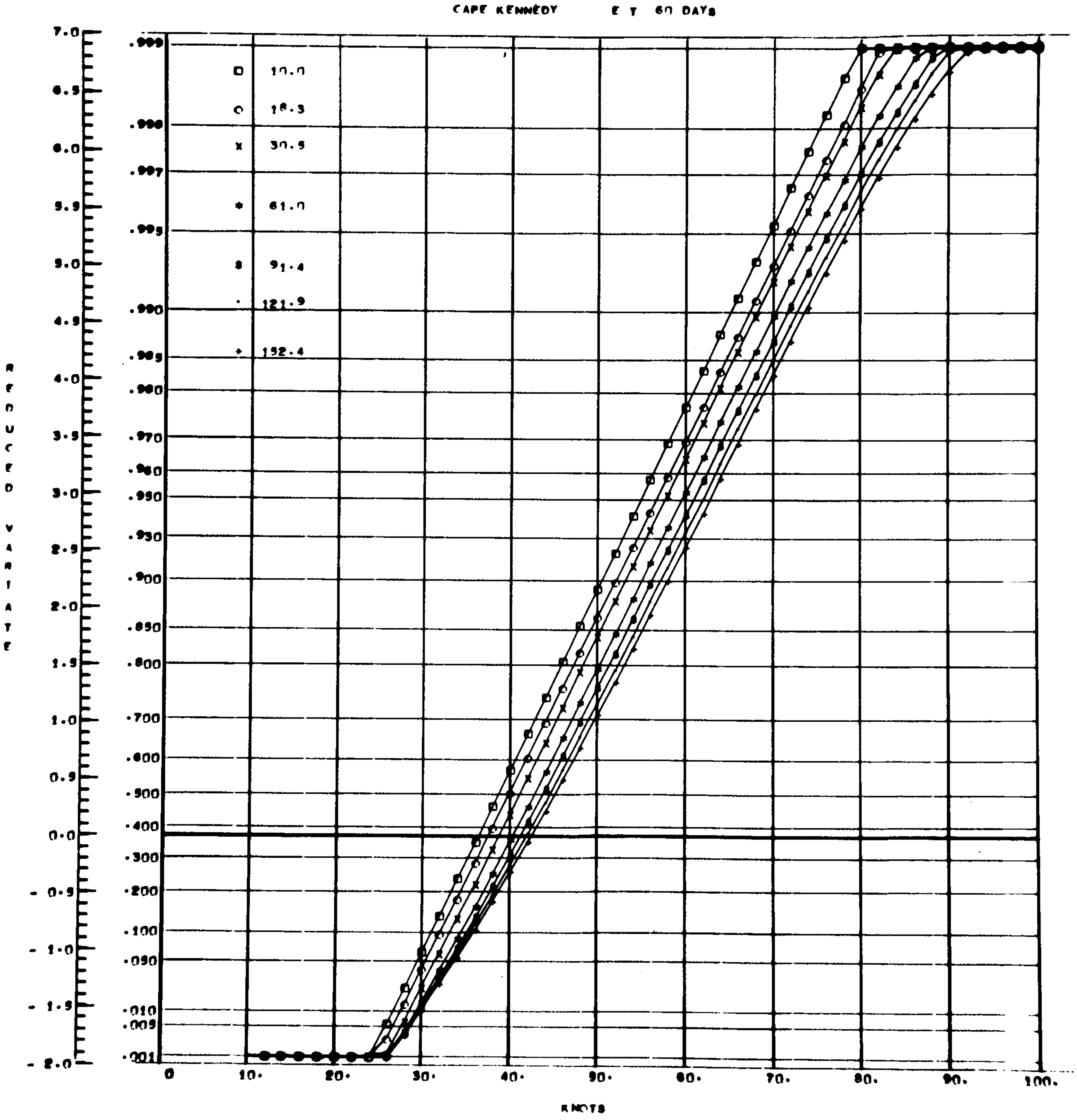

Fig. 11 - Surface Wind Cumulative Distributions

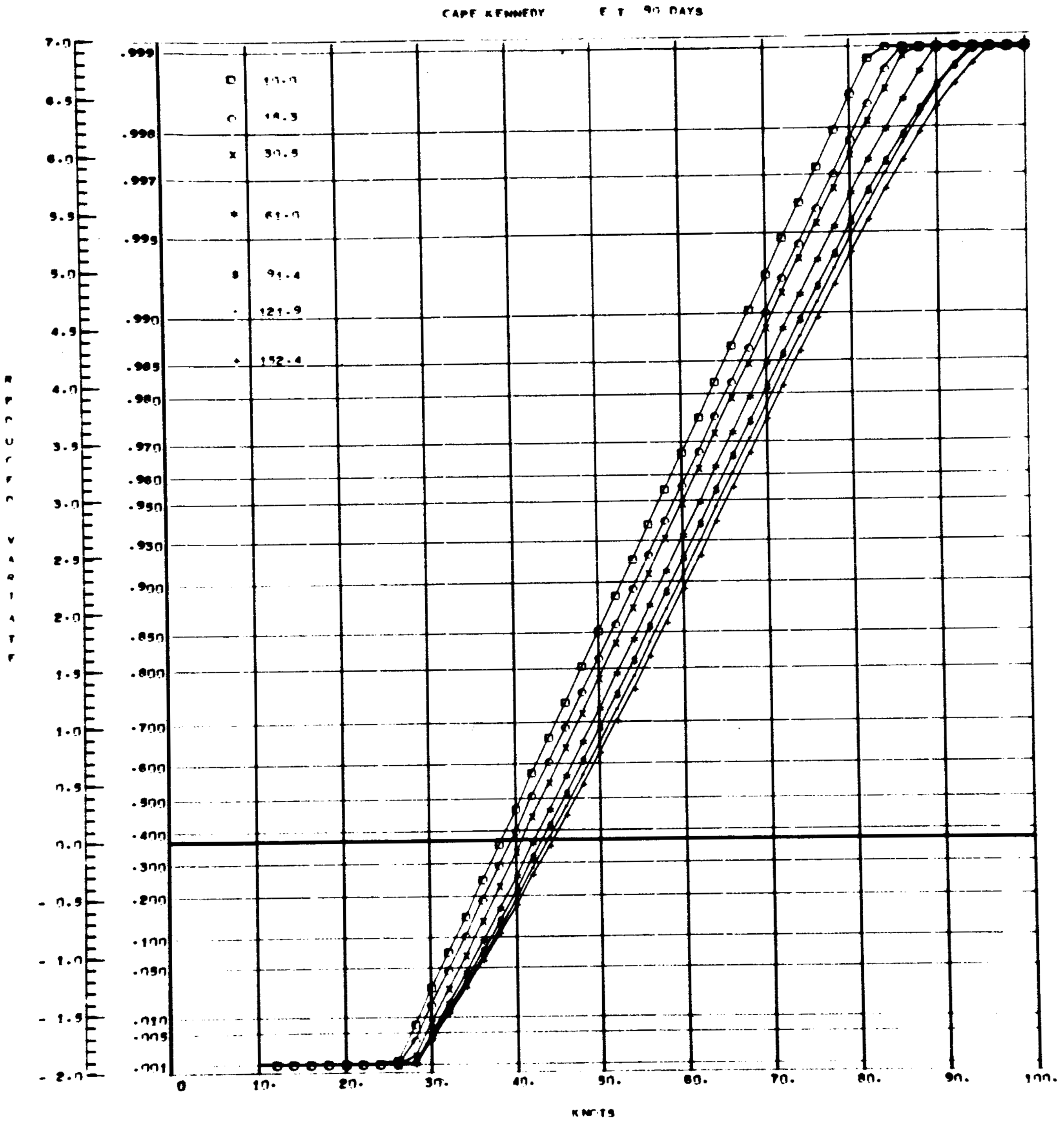

Fig. 12 - Surface Wind Cumulative Distributions

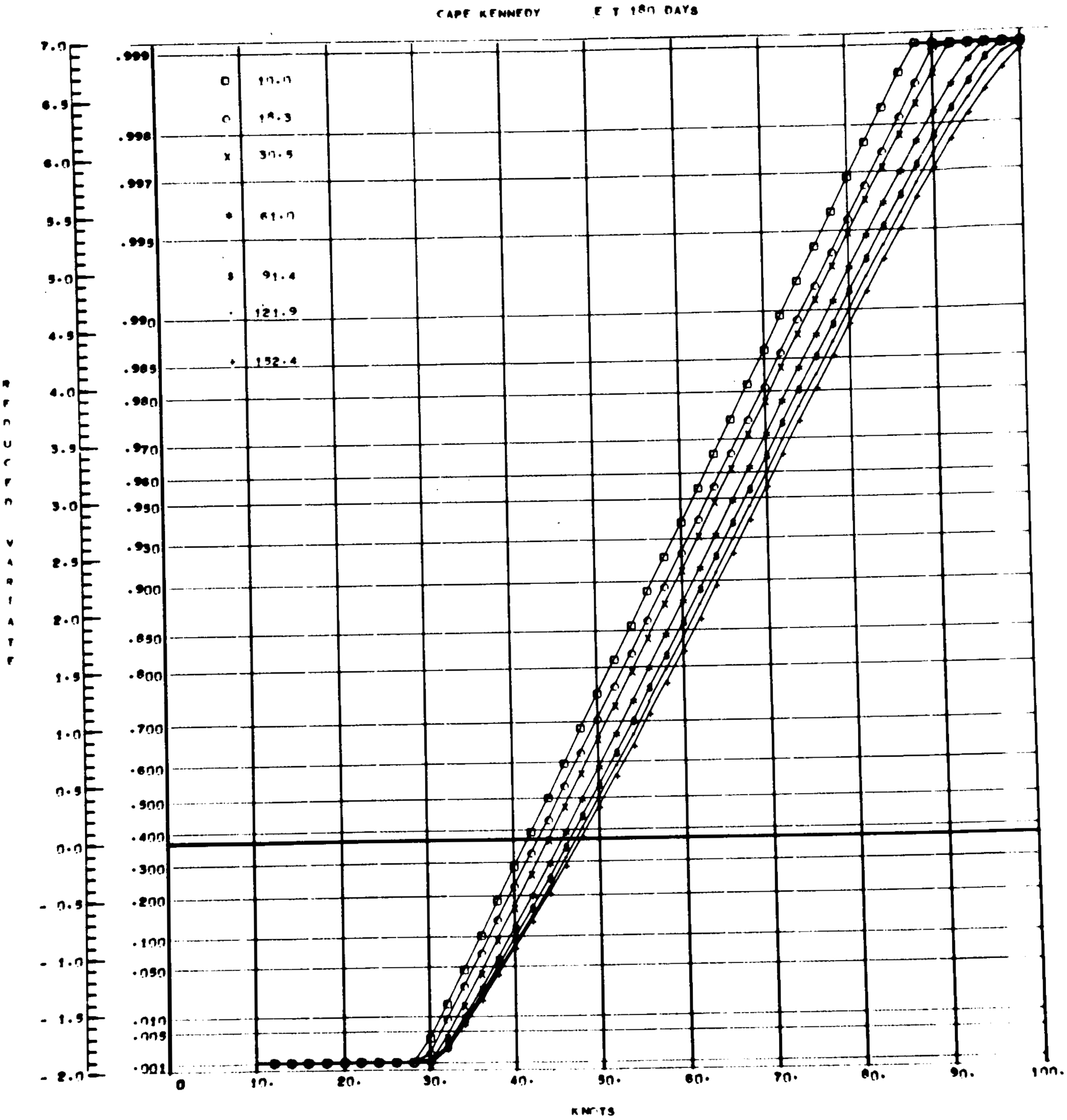

Fig. 13 - Surface Wind Cumulative Distributions

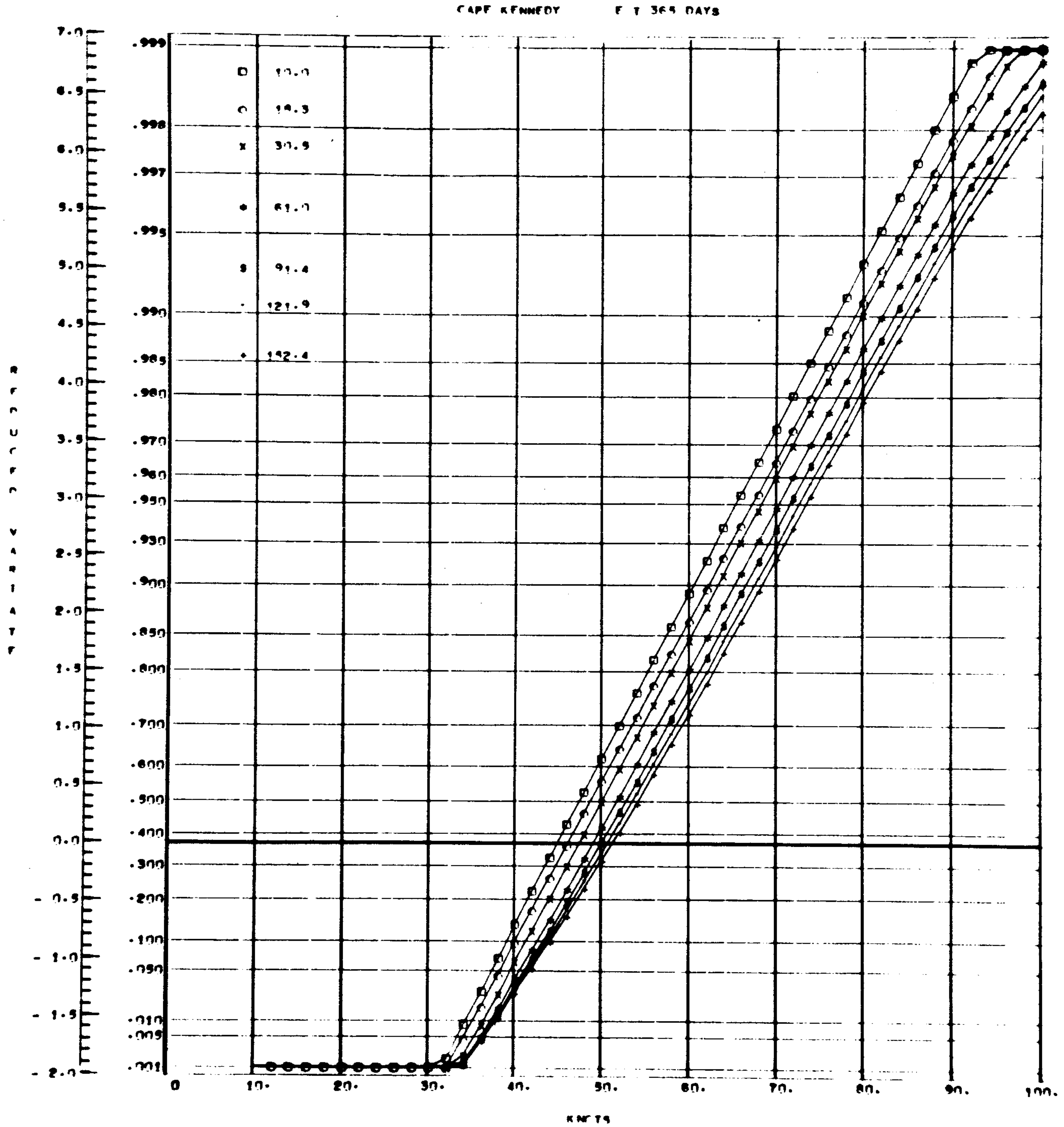

Fig. 14.- Surface Wind Cumulative Distributions

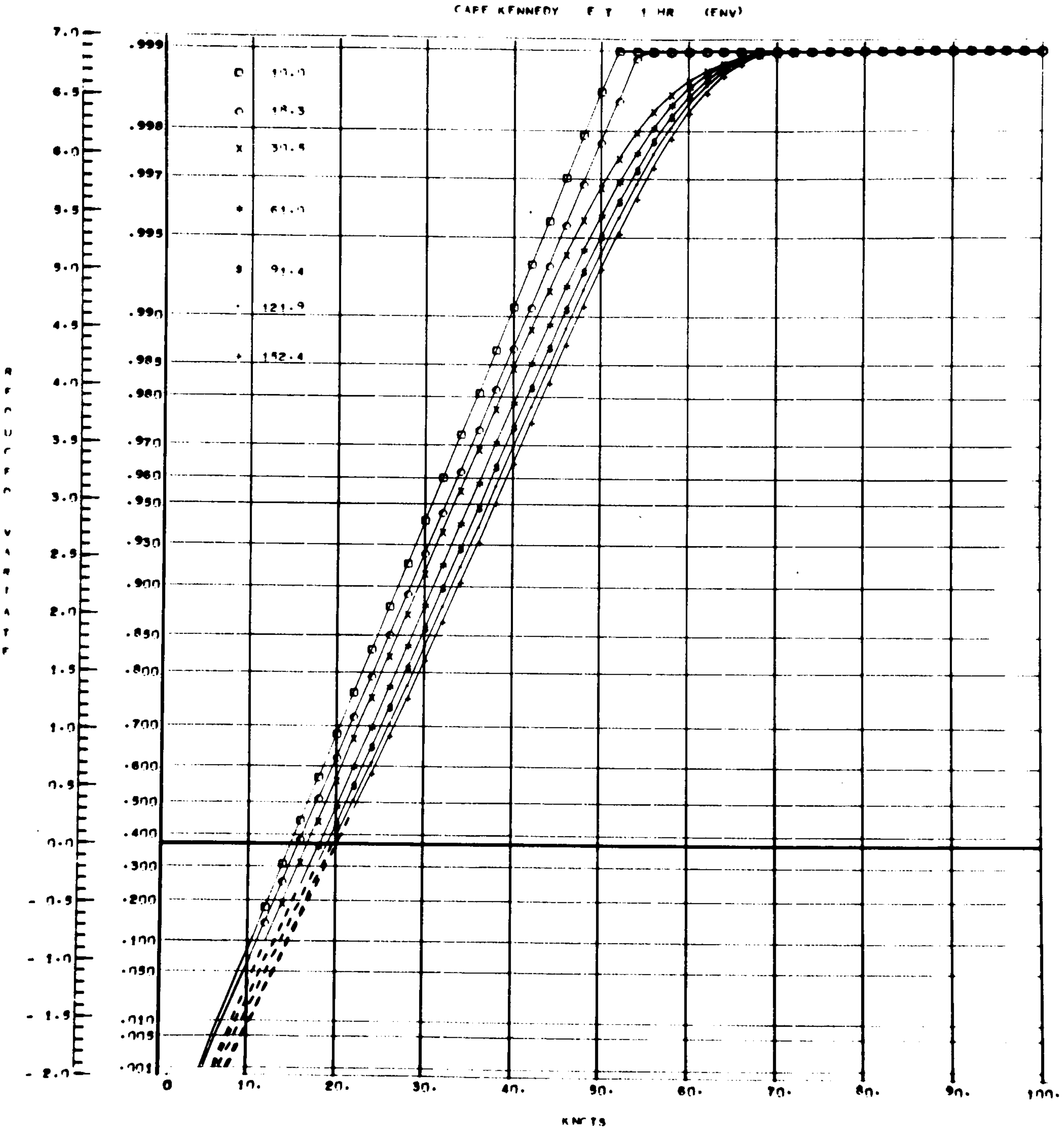

Fig. 15 - Surface Wind Cumulative Distributions

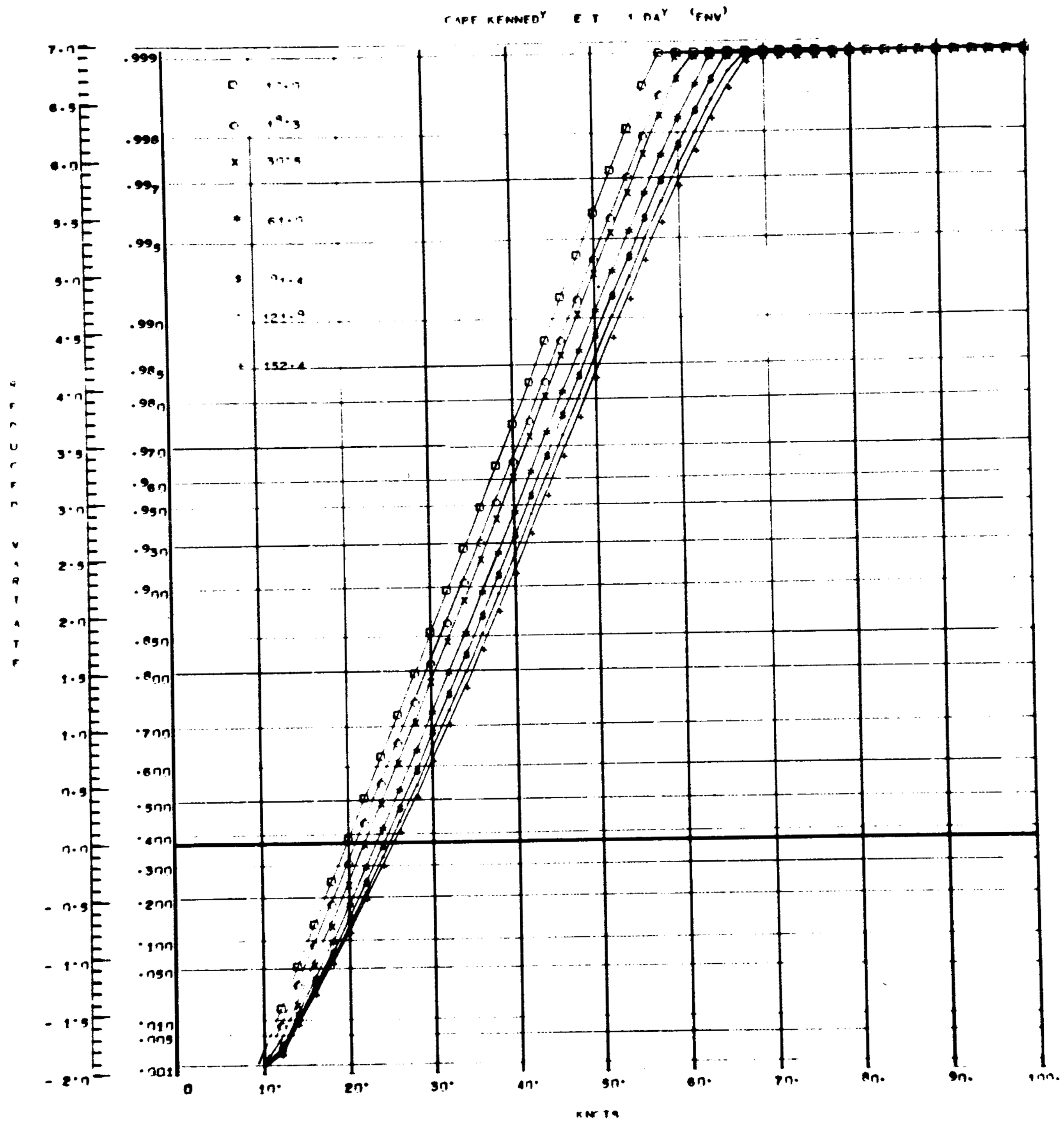

Fig. 16 - Surface Wind Cumulative Distributions

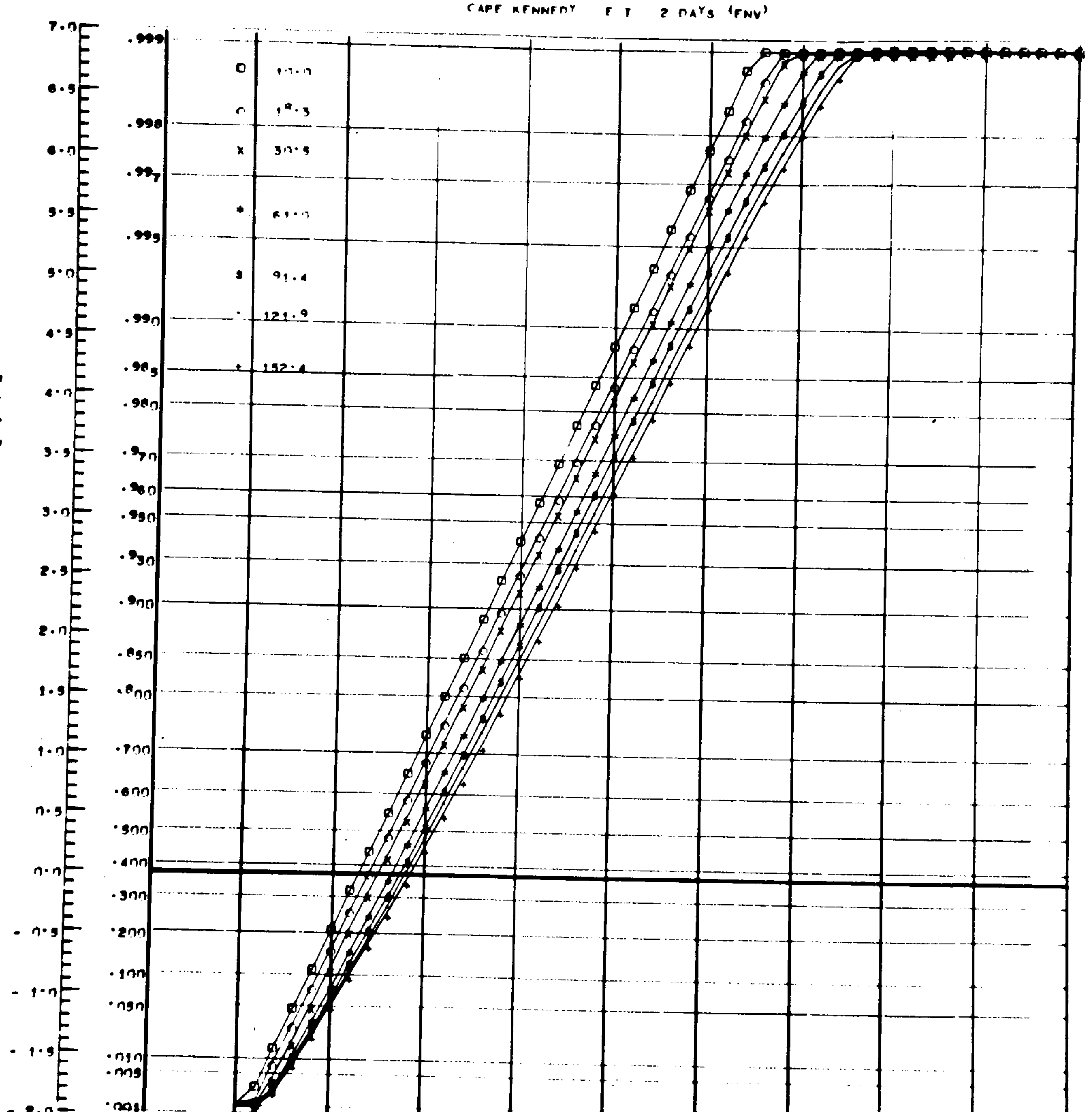

Fig. 17 - Surface Wind Cumulative Distributions

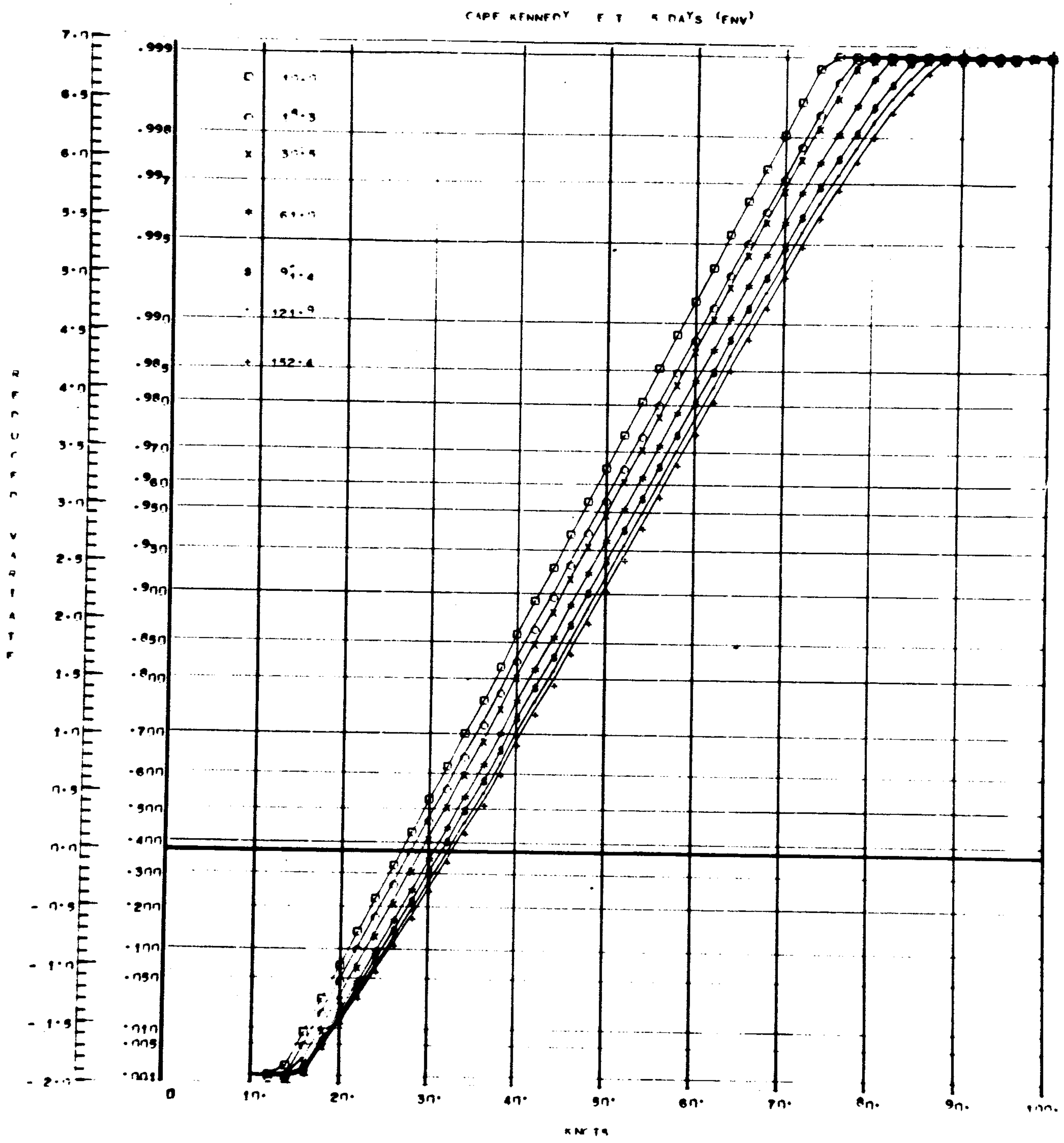

Fig. 18 - Surface Wind Cumulative Distributions

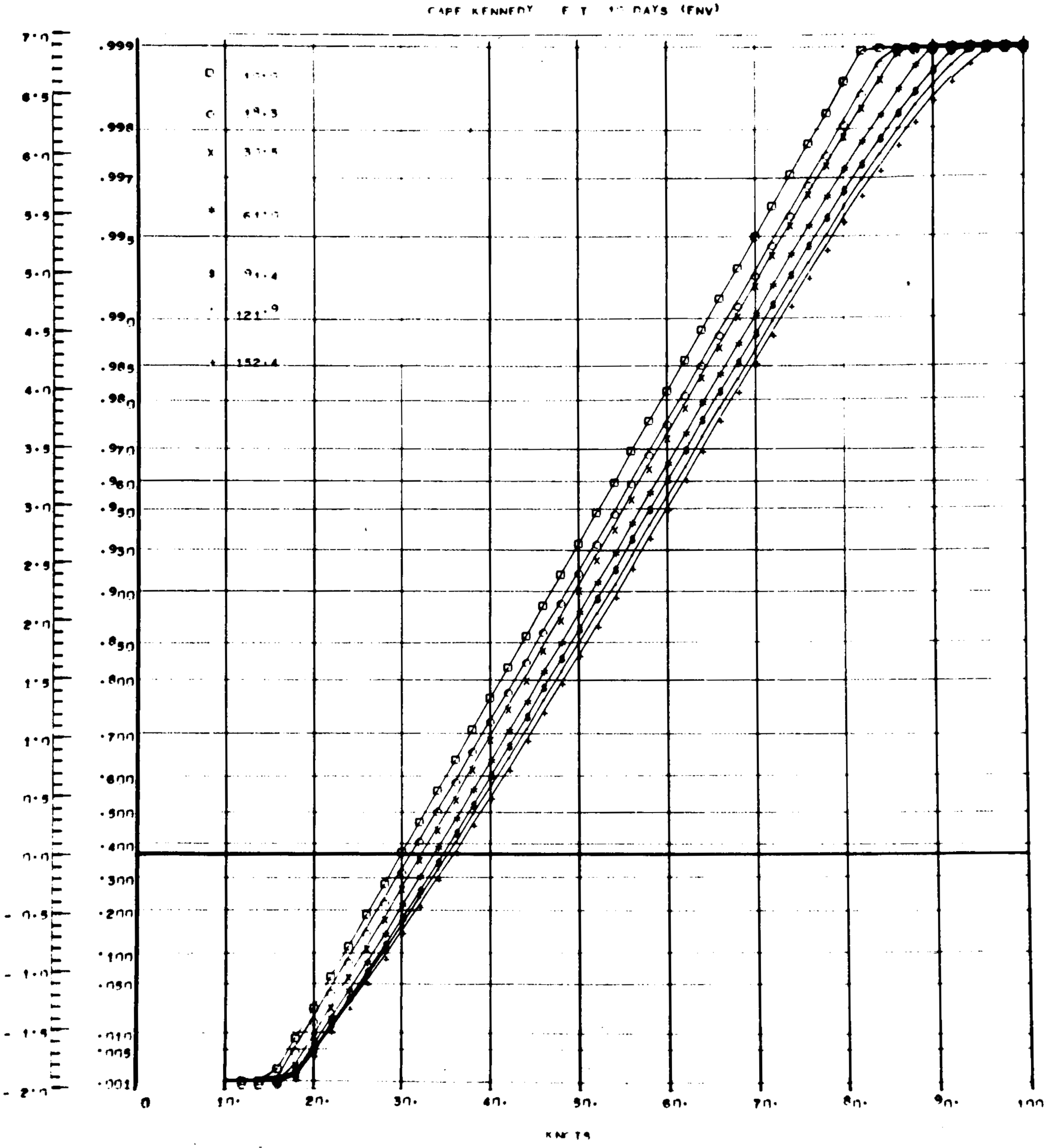

Fig. 19 - Surface Wind Cumulative Distributions

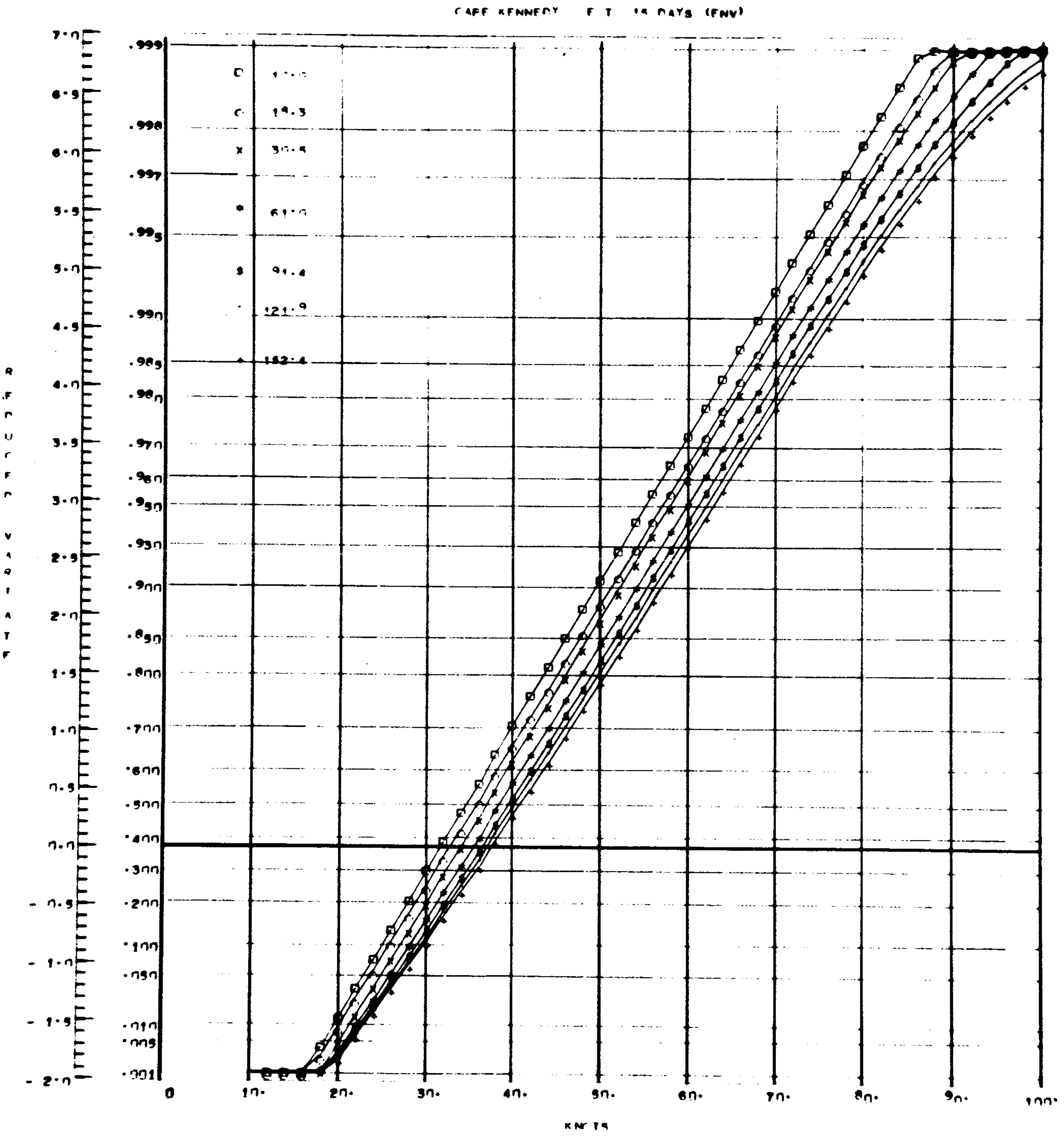

Fig. 20 - Surface Wind Cumulative Distributions

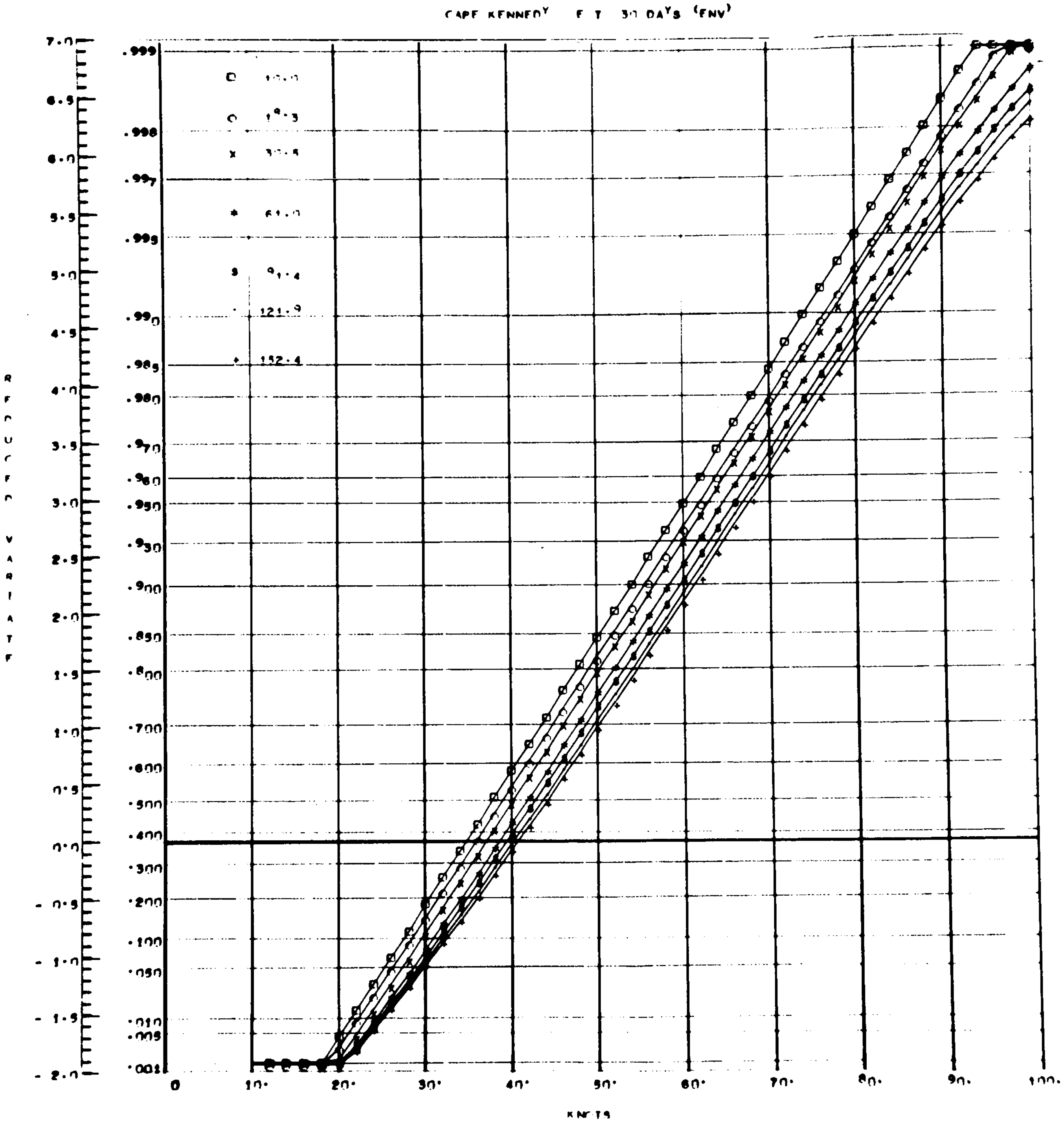

Fig. 21 - Surface Wind Cumulative Distributions

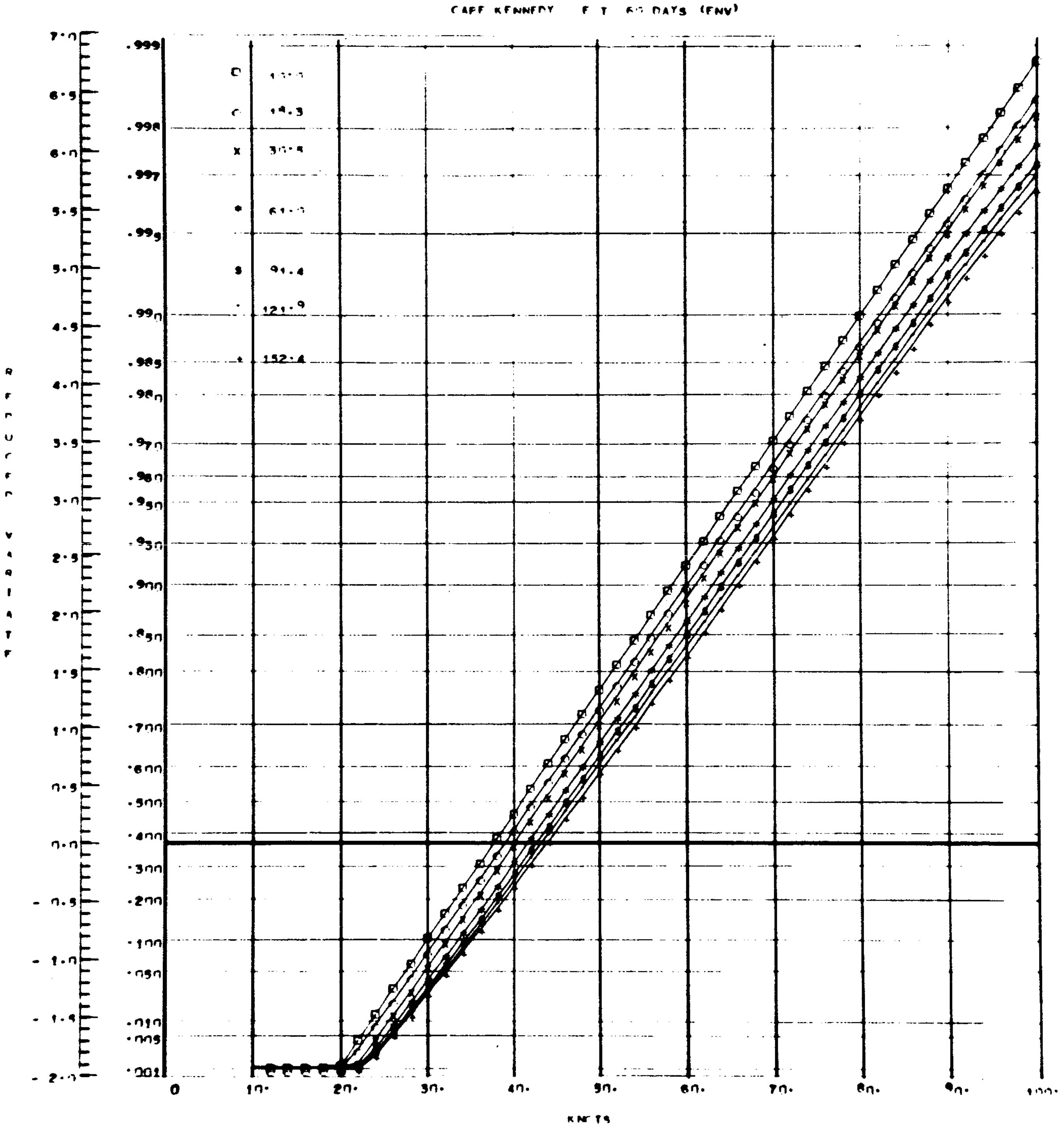

Fig. 22 - Surface Wind Cumulative Distributions

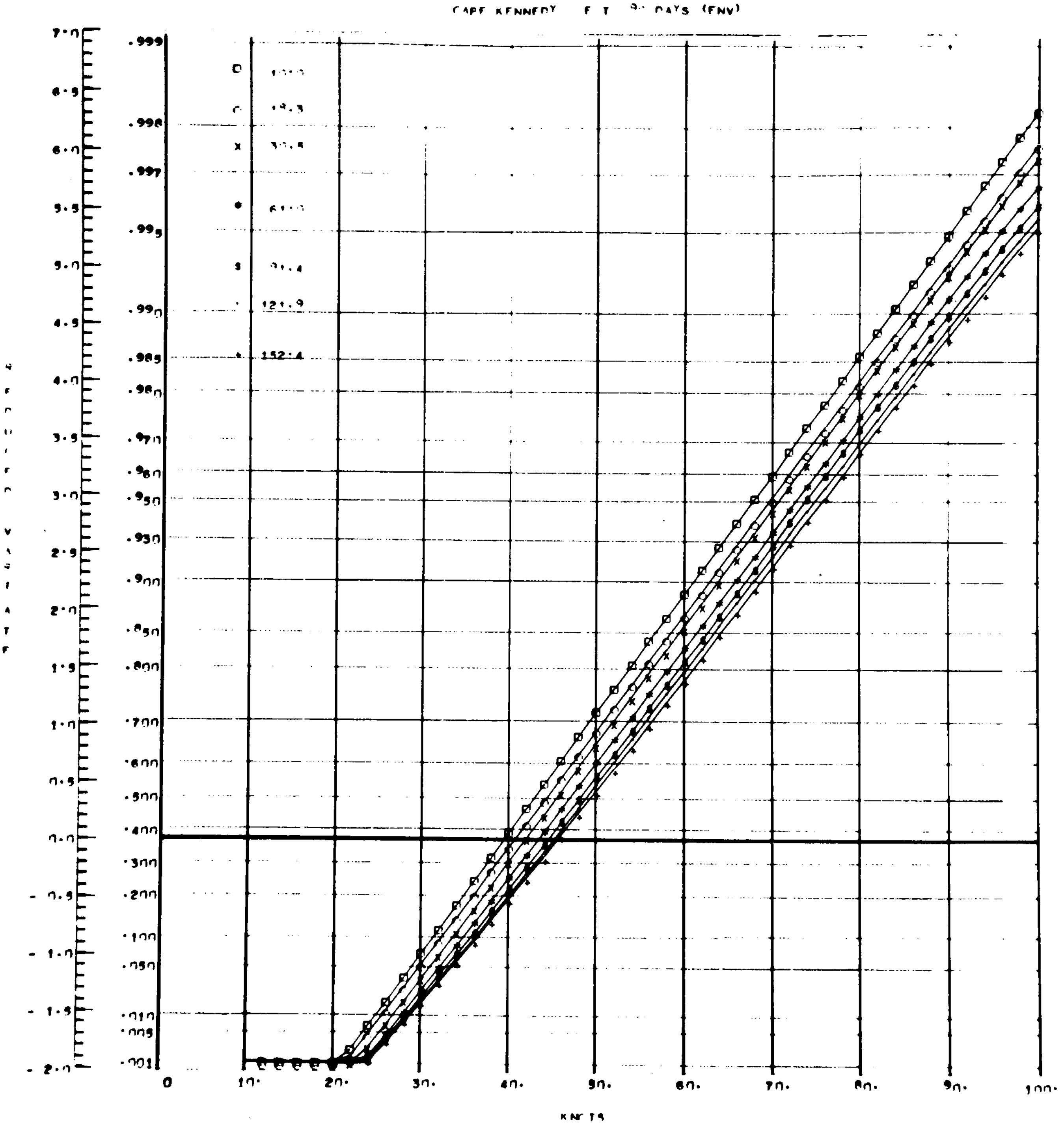

Fig. 23 - Surface Wind Cumulative Distributions

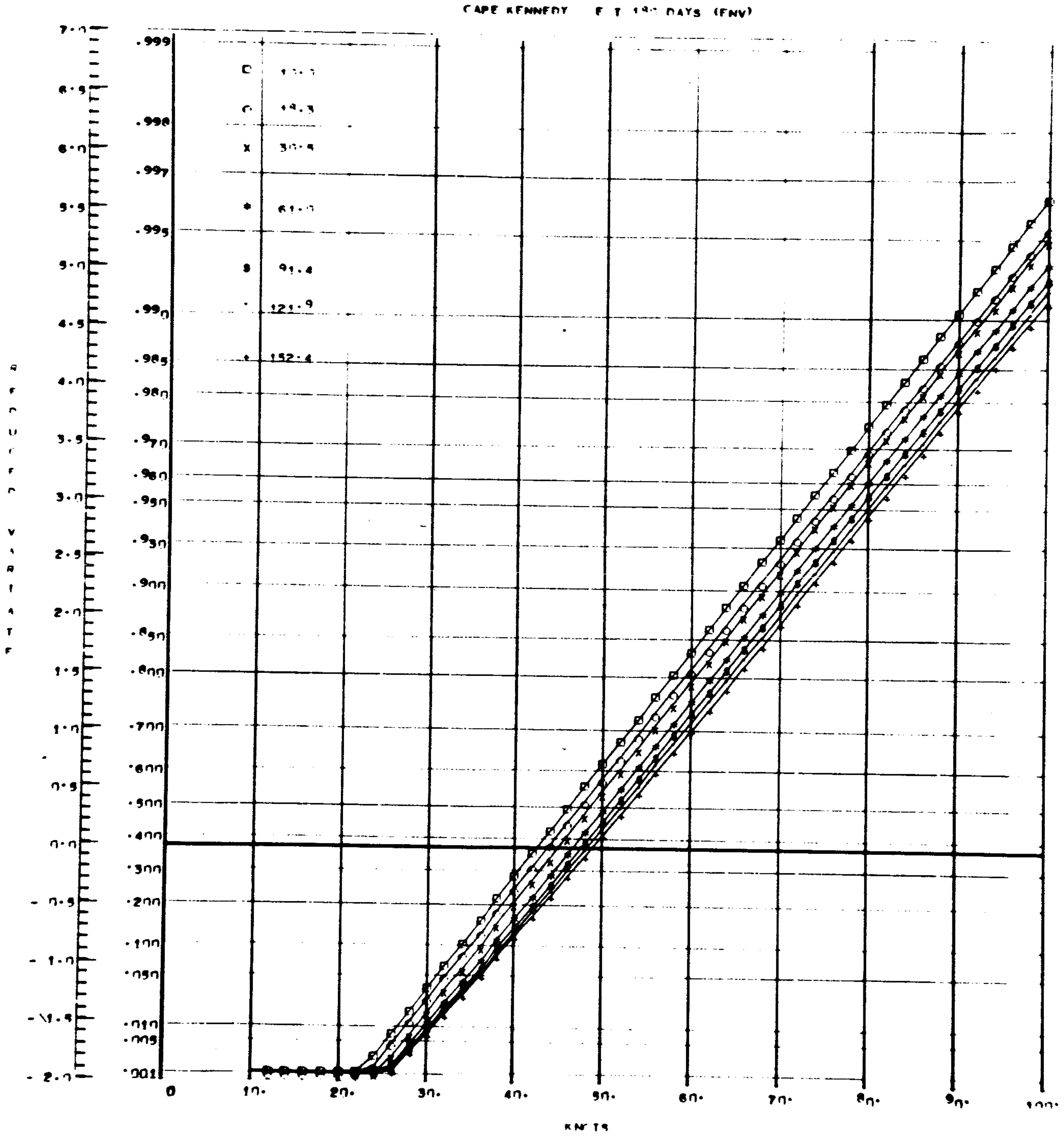

Fig. 24 - Surface Wind Cumulative Distributions

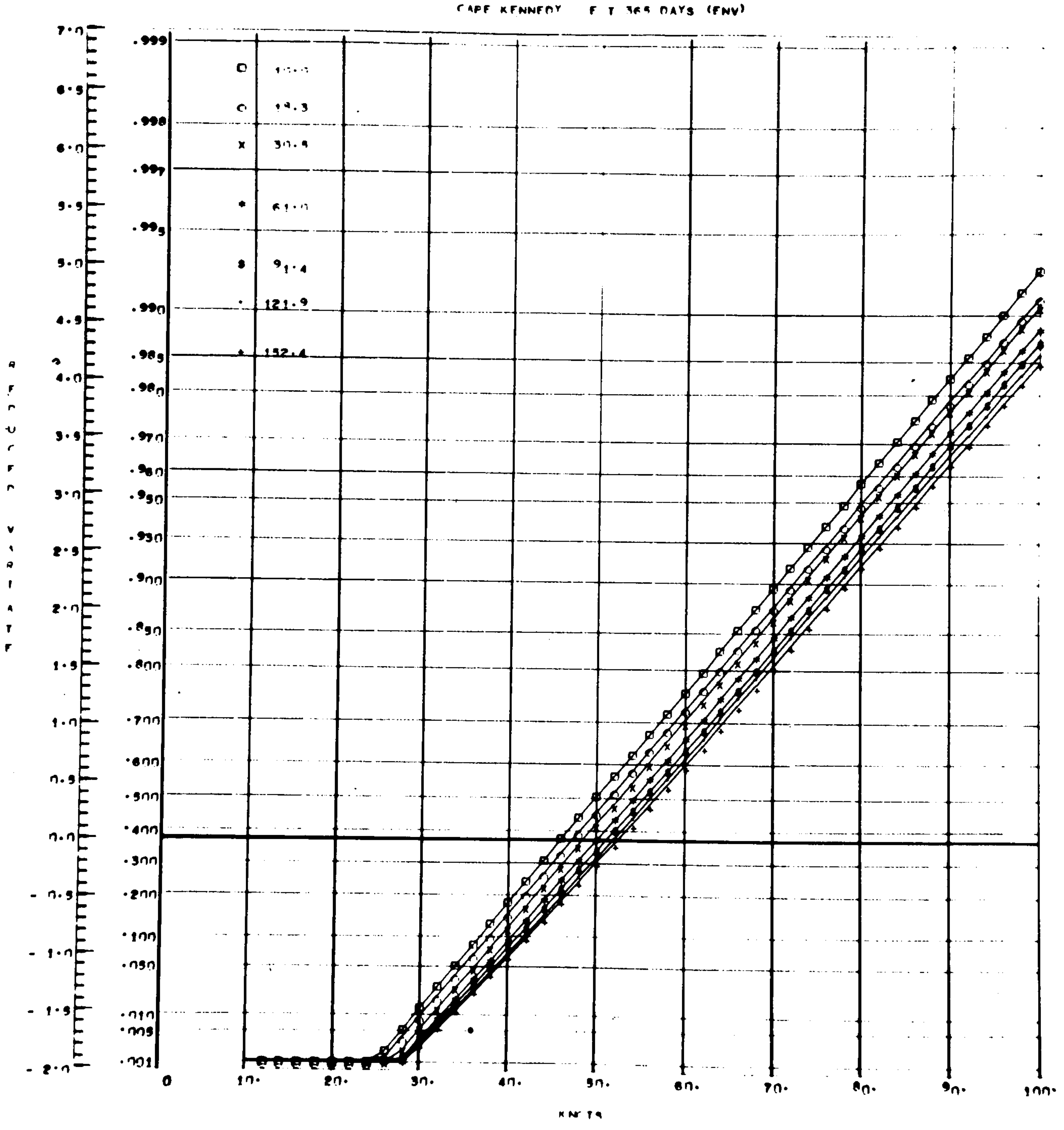

Fig. 25 - Surface Wind Cumulative Distributions

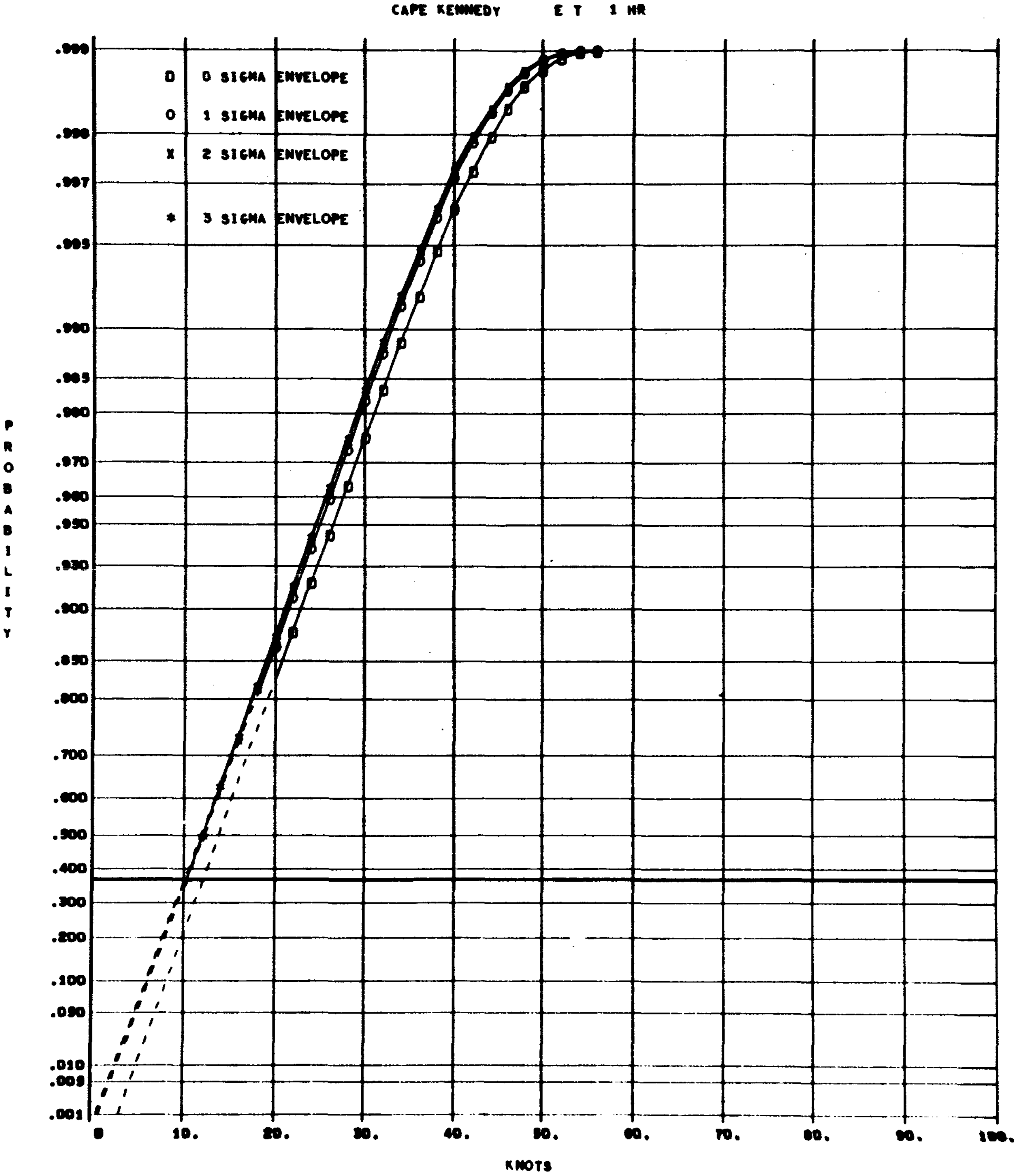

Fig. 26 - Surface Wind Profile Cumulative Distributions

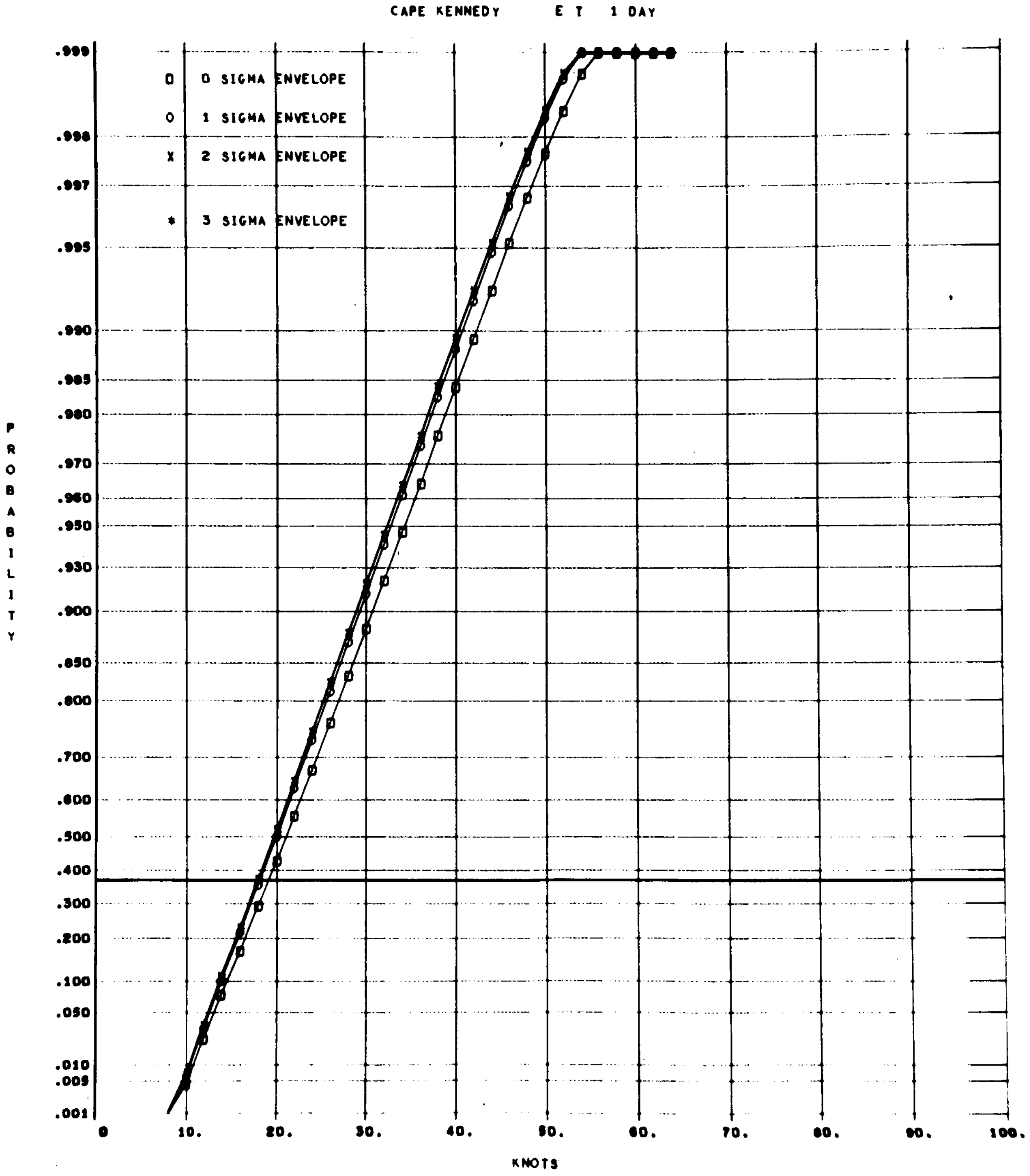

Fig. 27 - Surface Wind Profile Cumulative Distributions

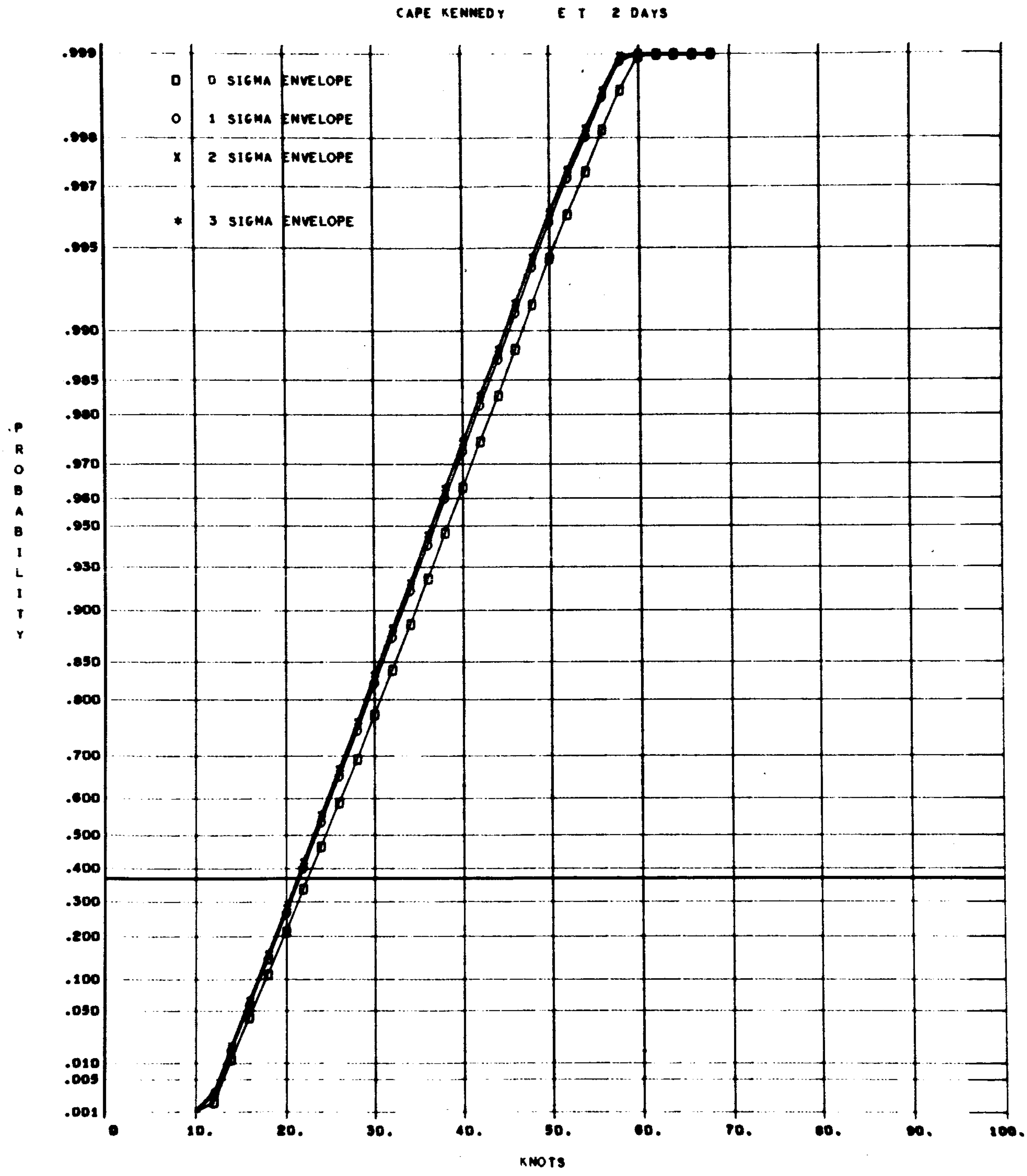

Fig. 28 - Surface Wind Profile Cumulative Distributions

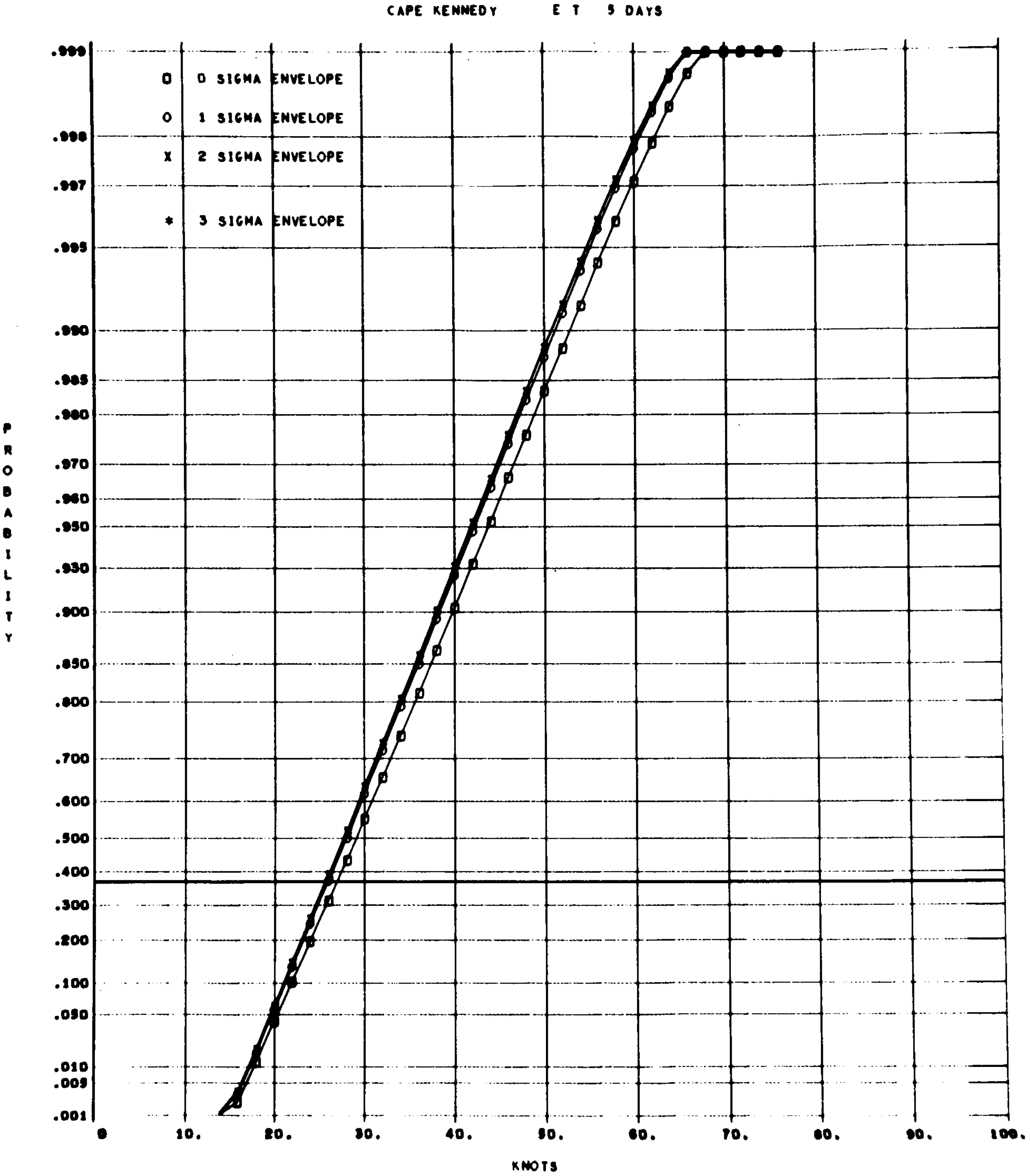

Fig. 29 - Surface Wind Profile Cumulative Distributions

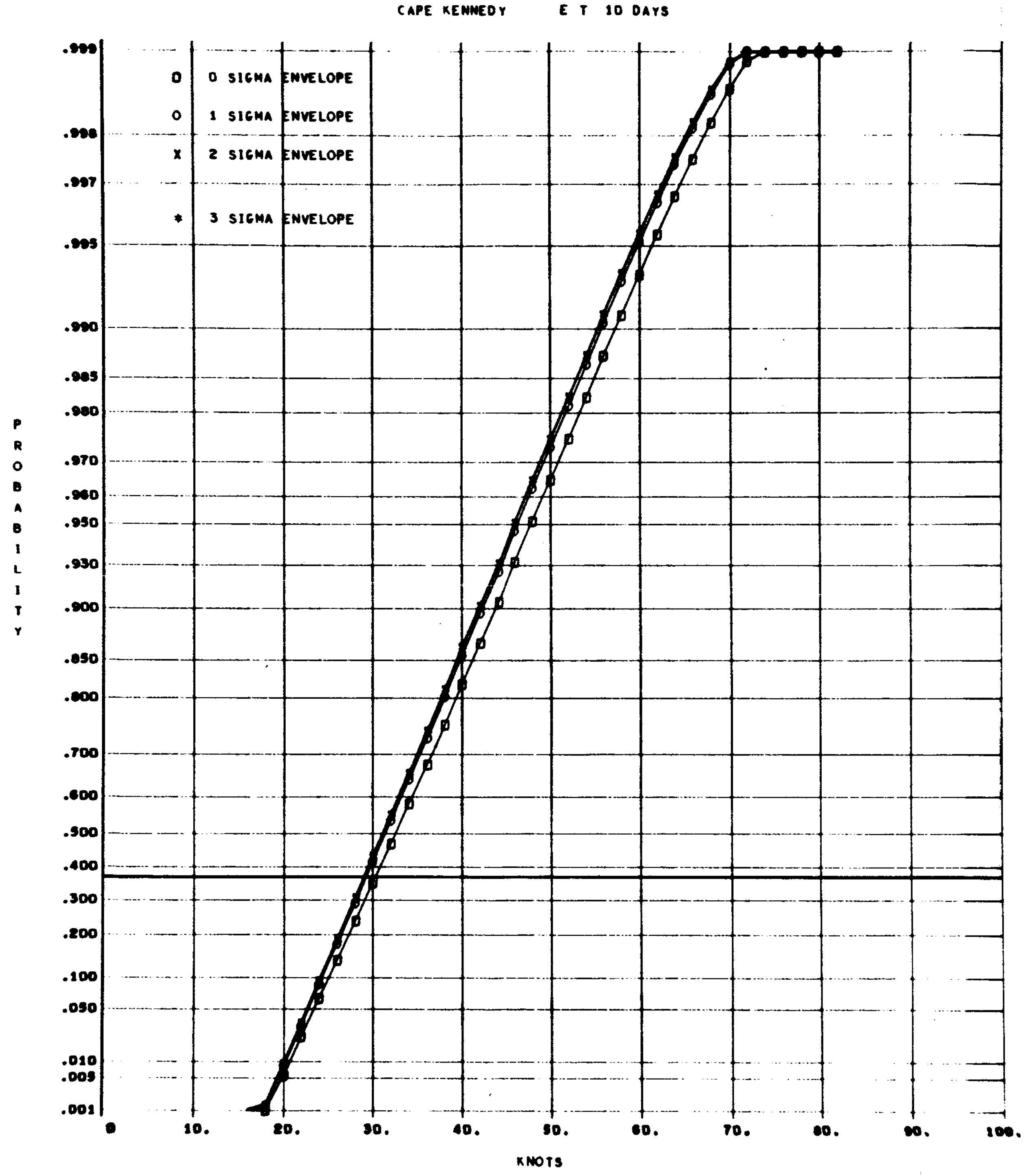

Fig. 30 - Surface Wind Profile Cumulative Distributions

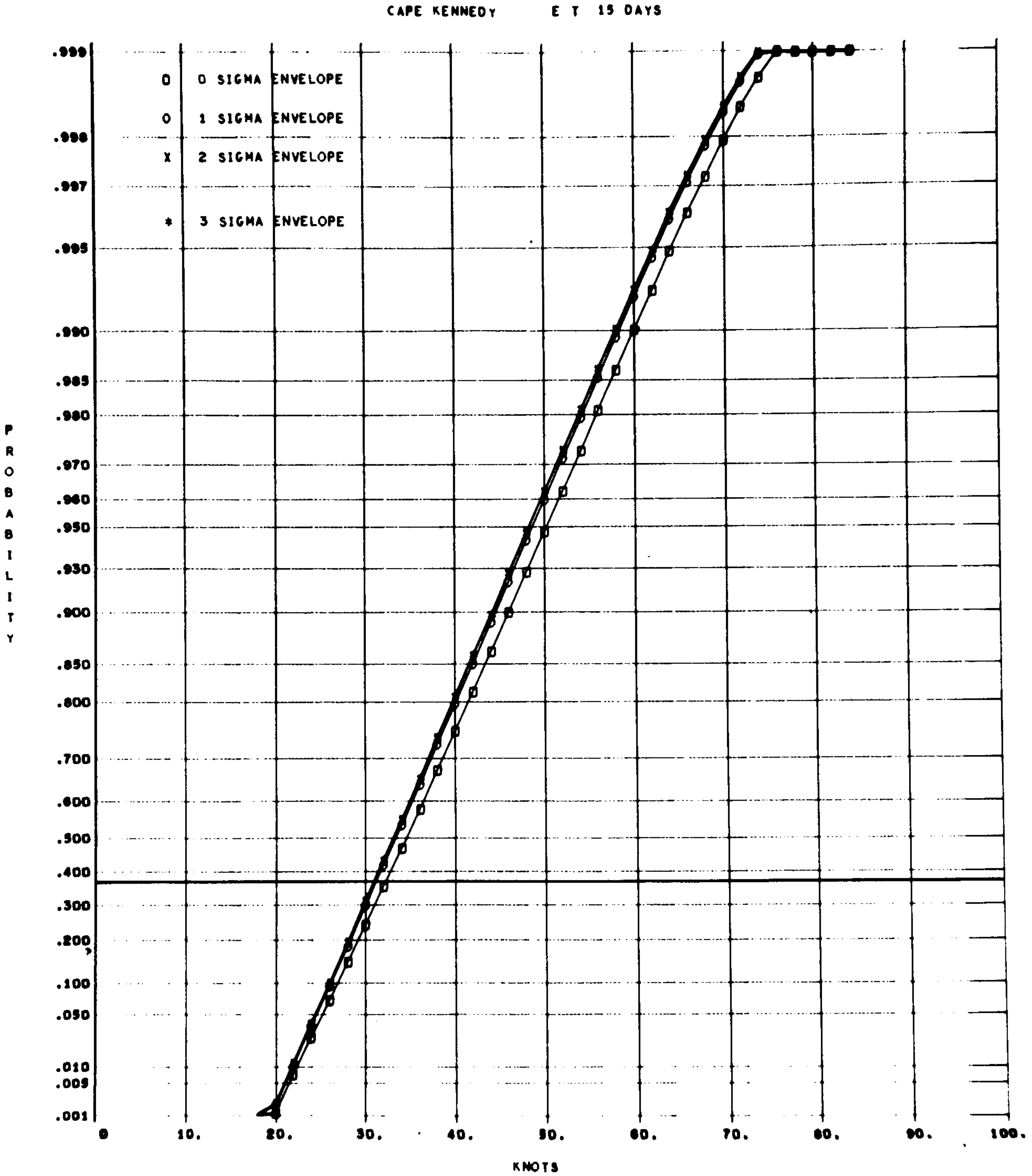

Fig. 31 - Surface Wind Profile Cumulative Distributions

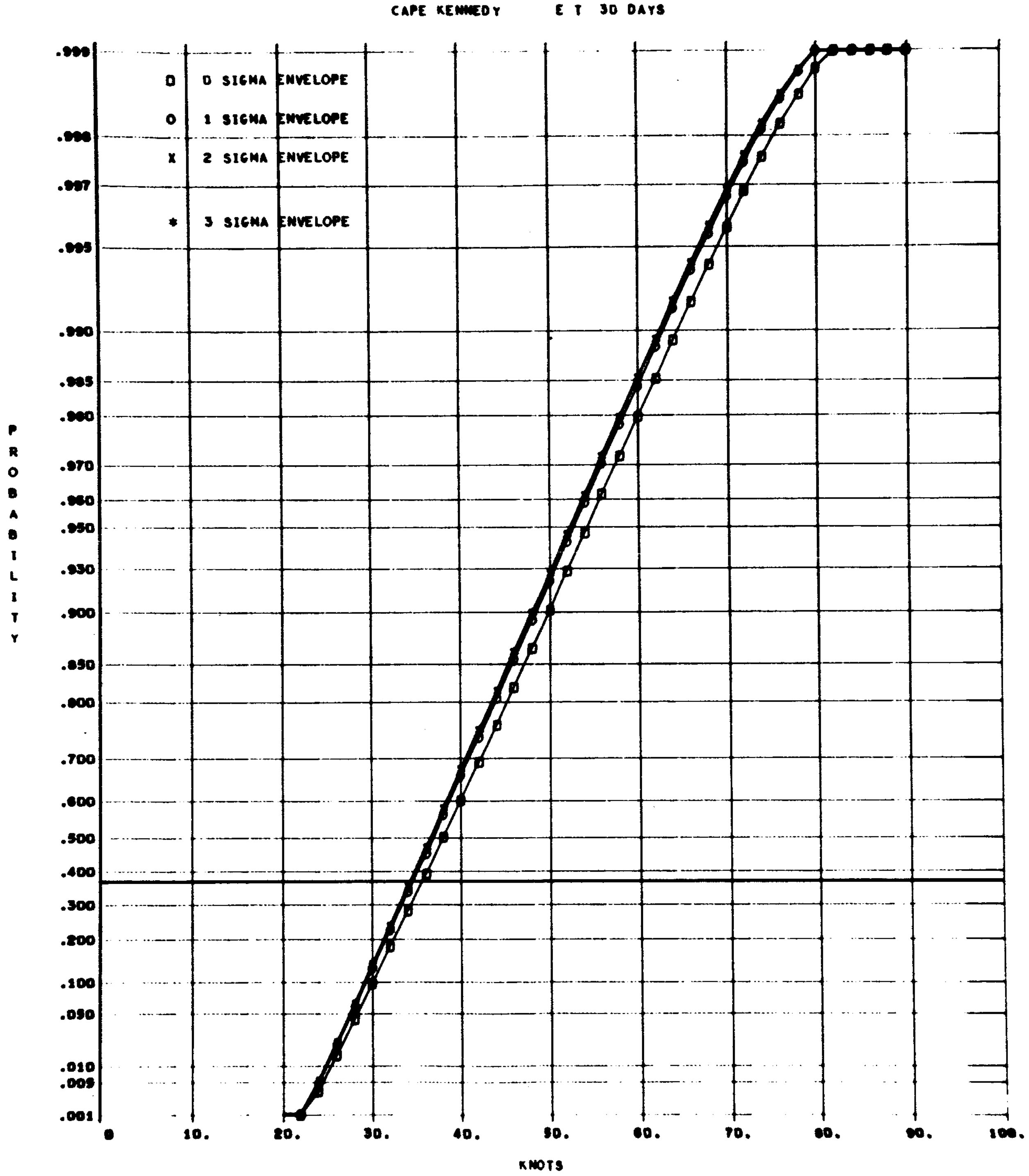

Fig. 32 - Surface Wind Profile Cumulative Distributions

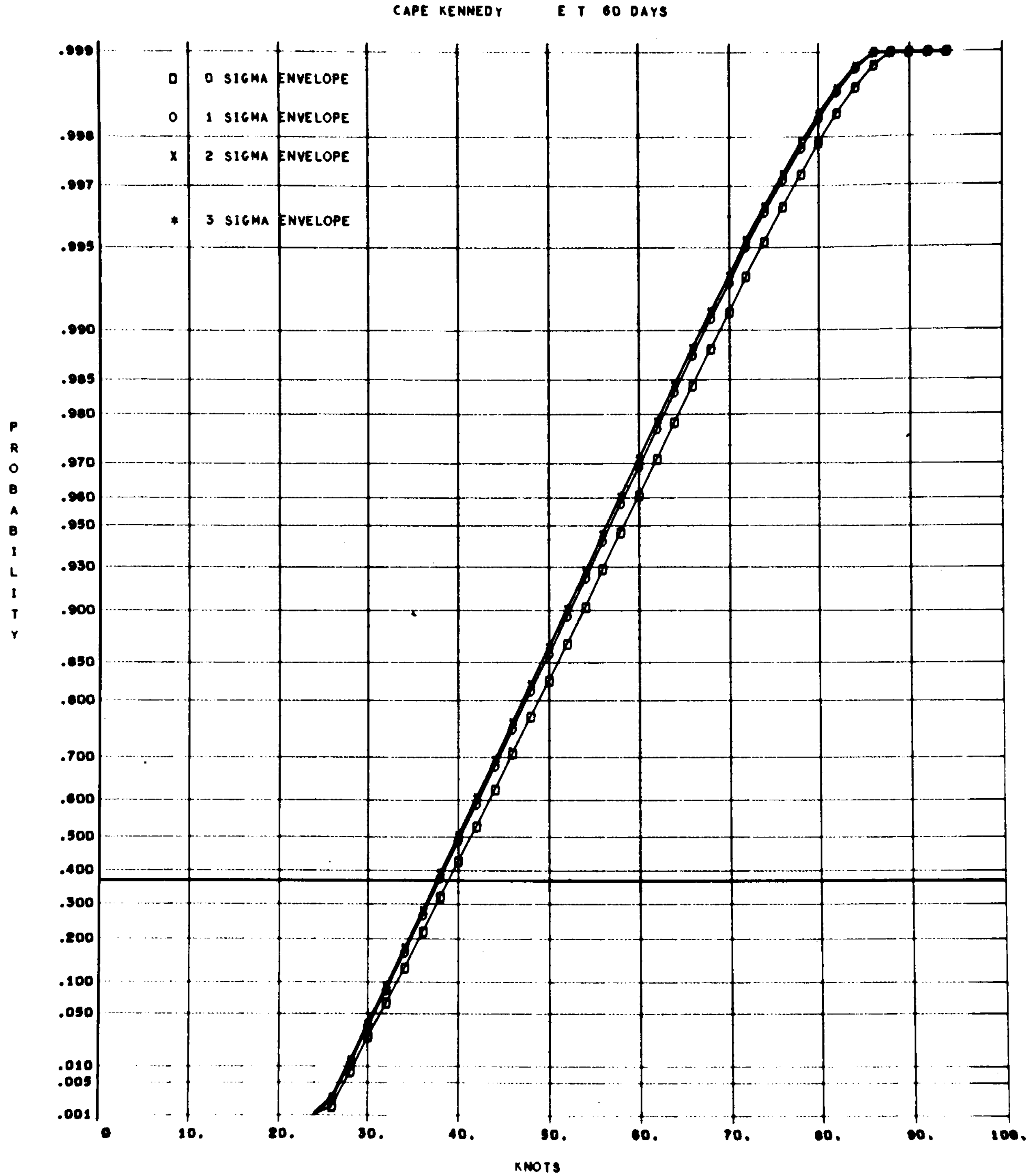

Fig. 33 - Surface Wind Profile Cumulative Distributions

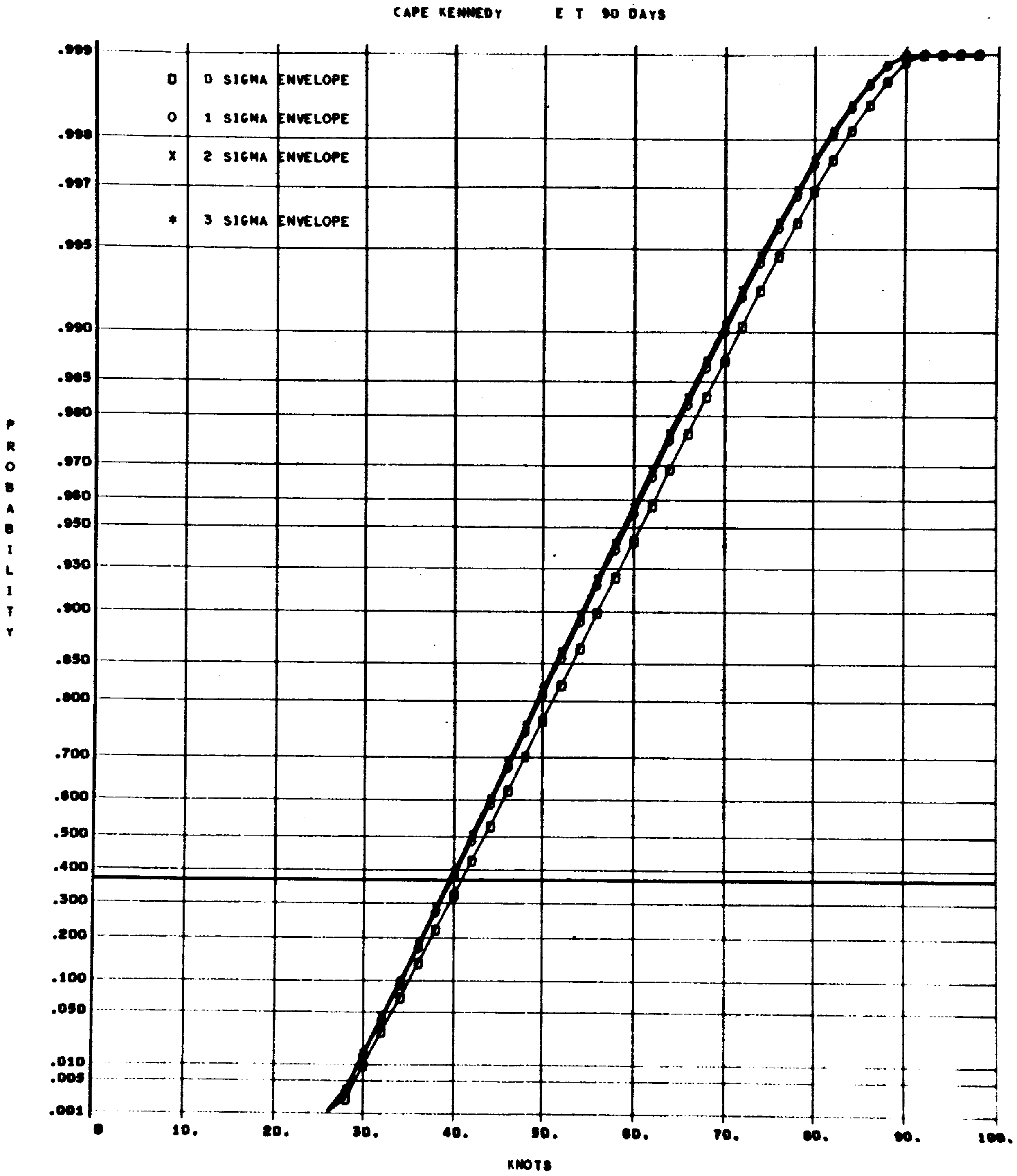

Fig. 34 - Surface Wind Profile Cumulative Distributions

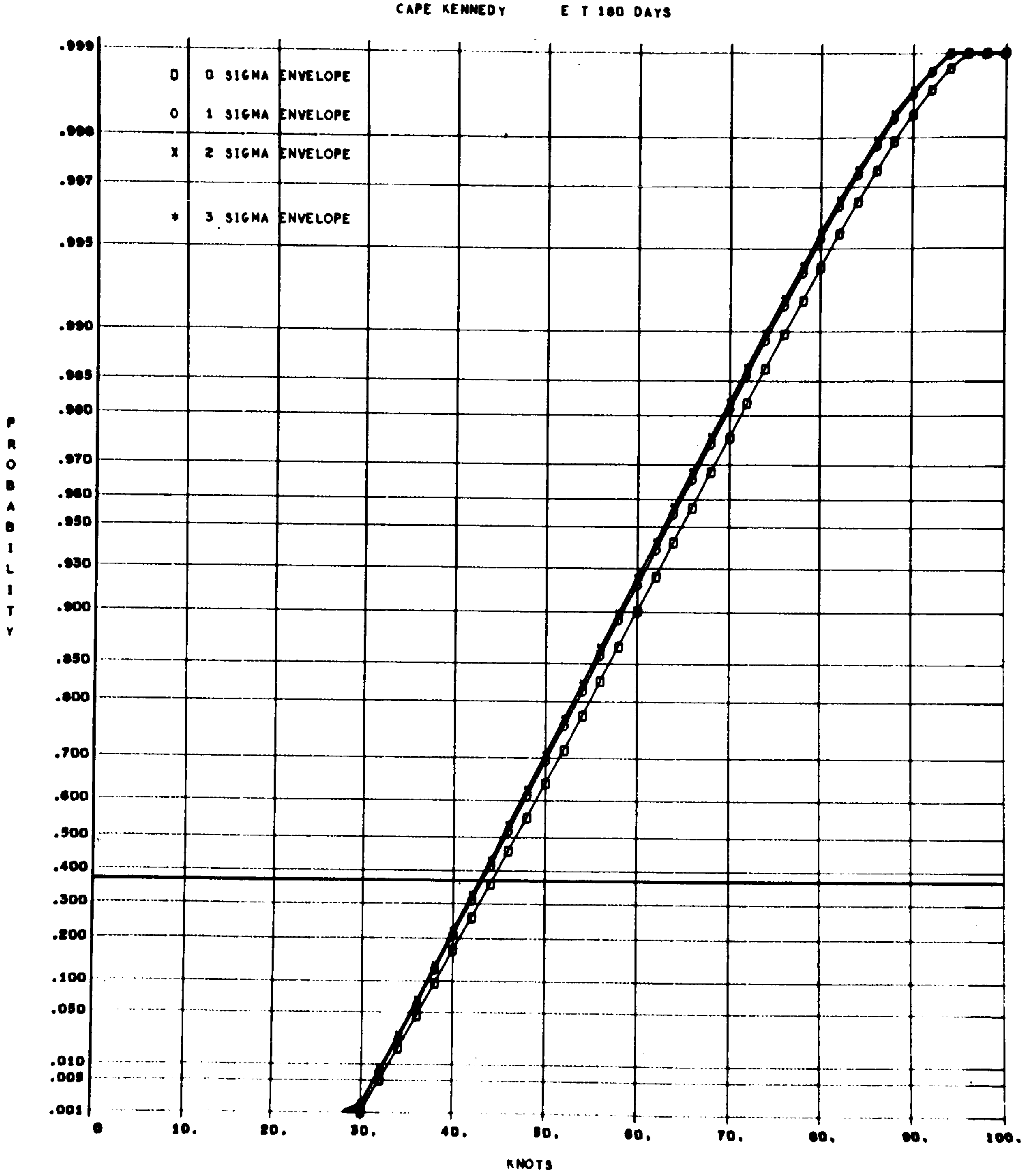

Fig. 35 - Surface Wind Profile Cumulative Distributions

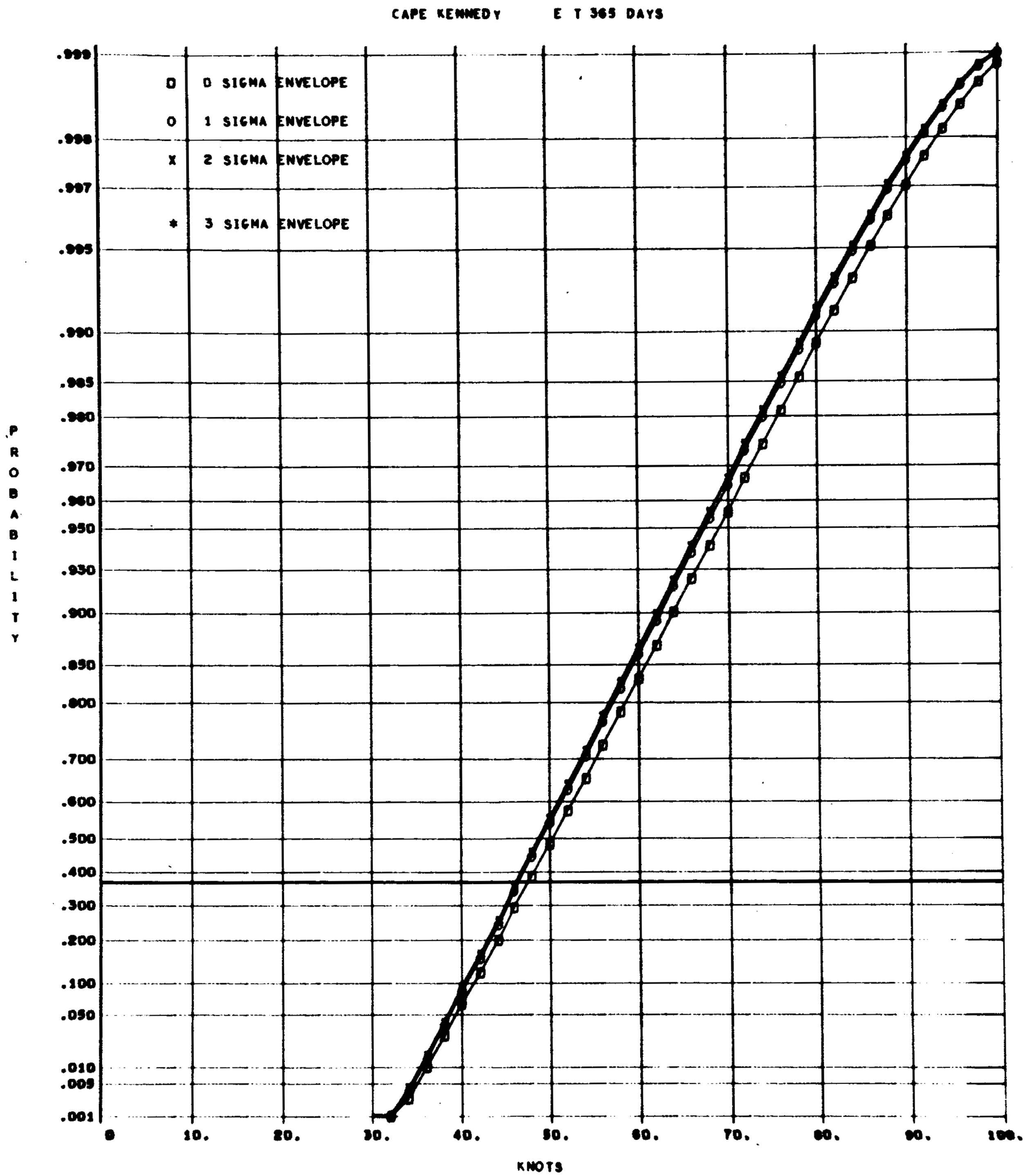

Fig. 36 - Surface Wind Profile Cumulative Distributions

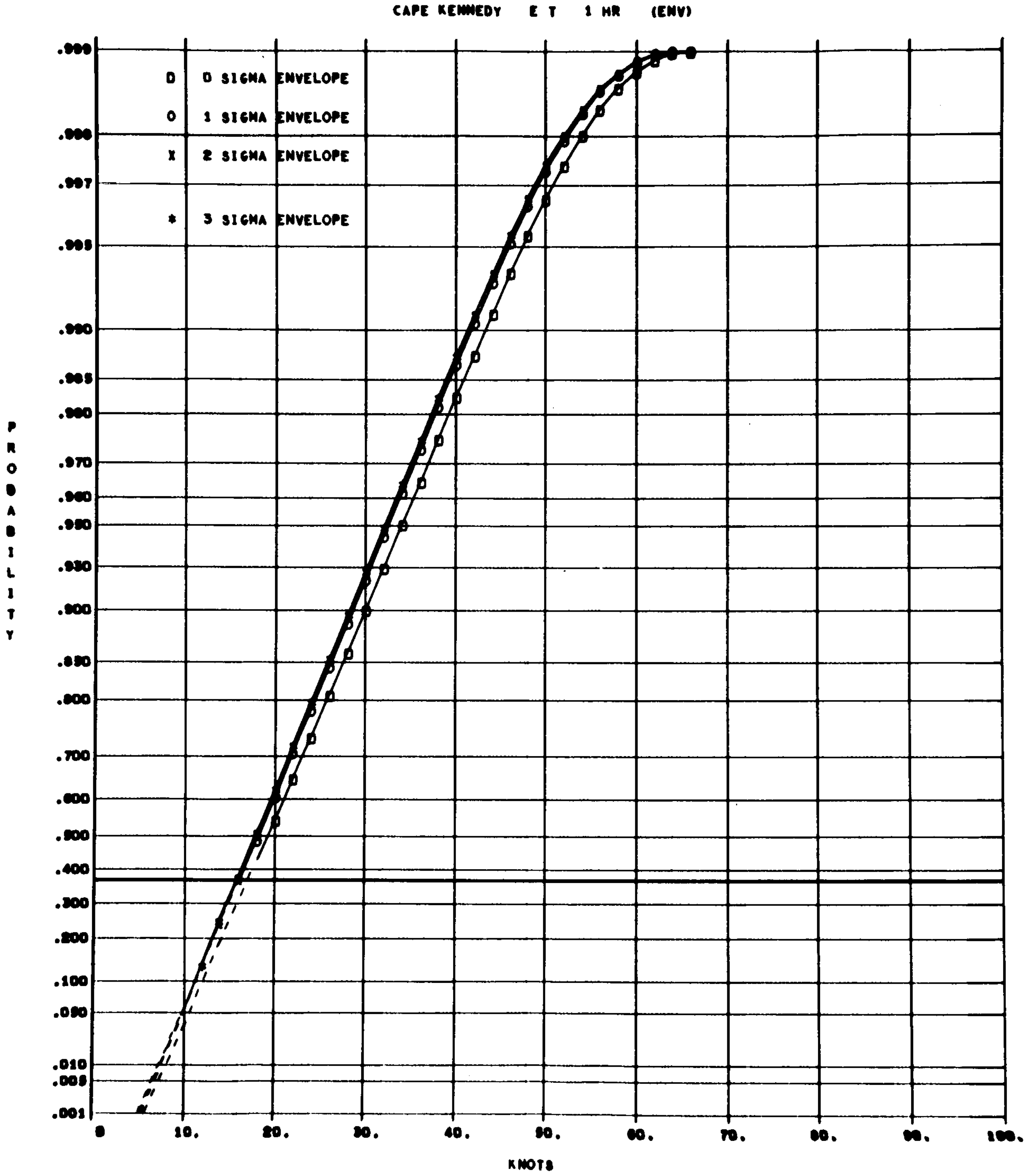

Fig. 37 - Surface Wind Profile Cumulative Distributions

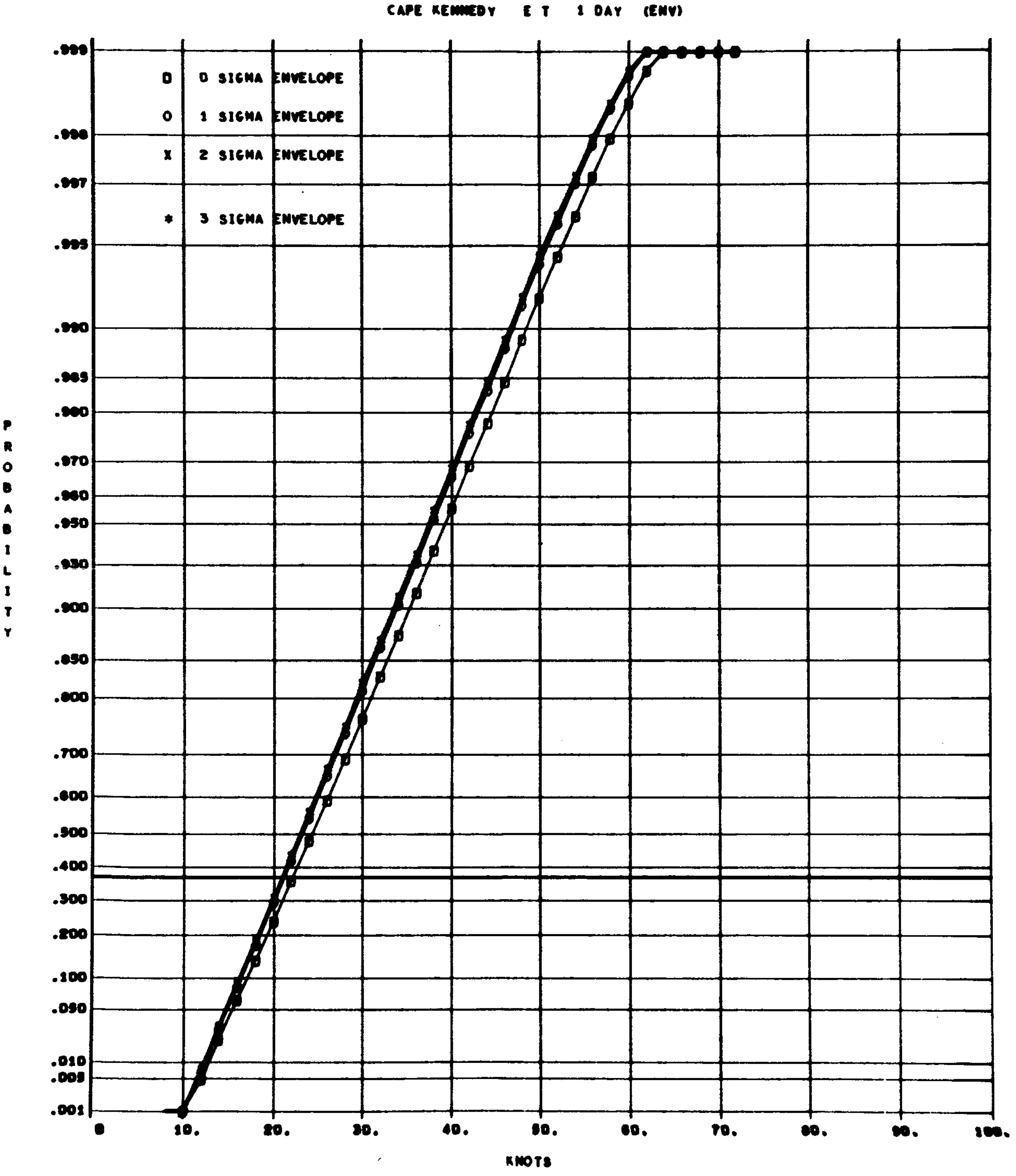

Fig. 38 - Surface Wind Profile Cumulative Distributions

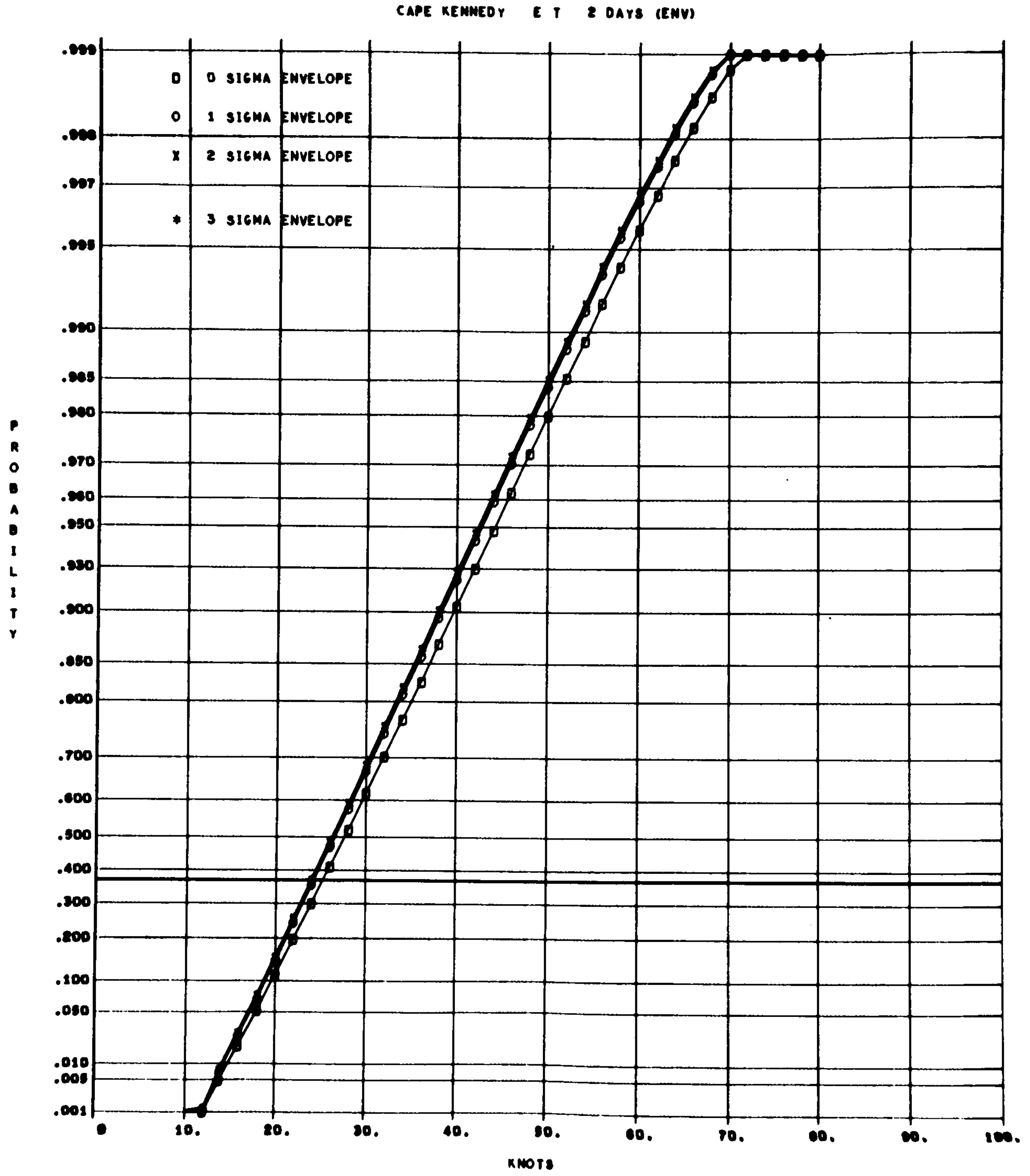

Fig. 39 - Surface Wind Profile Cumulative Distributions

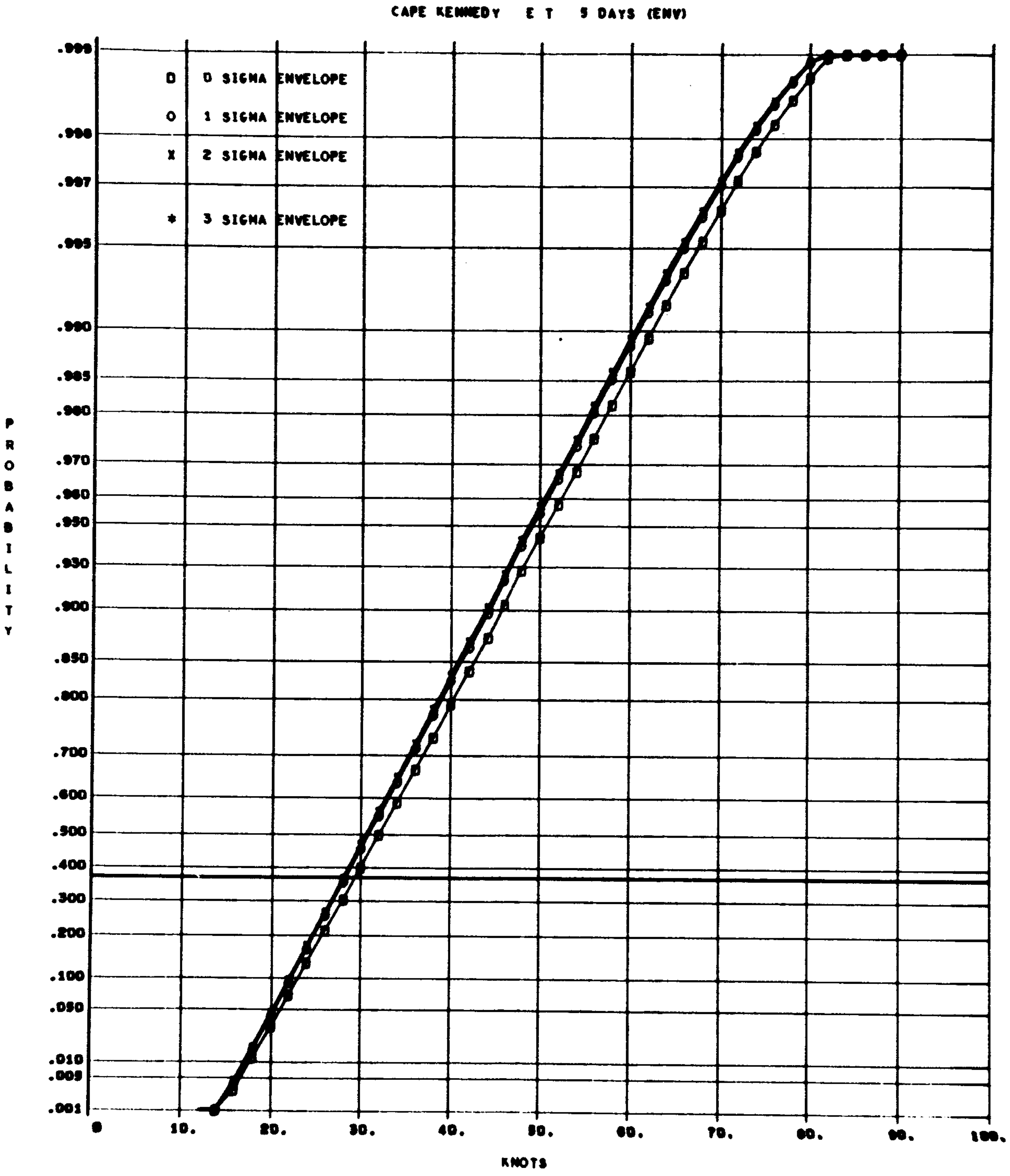

Fig. 40 - Surface Wind Profile Cumulative Distributions

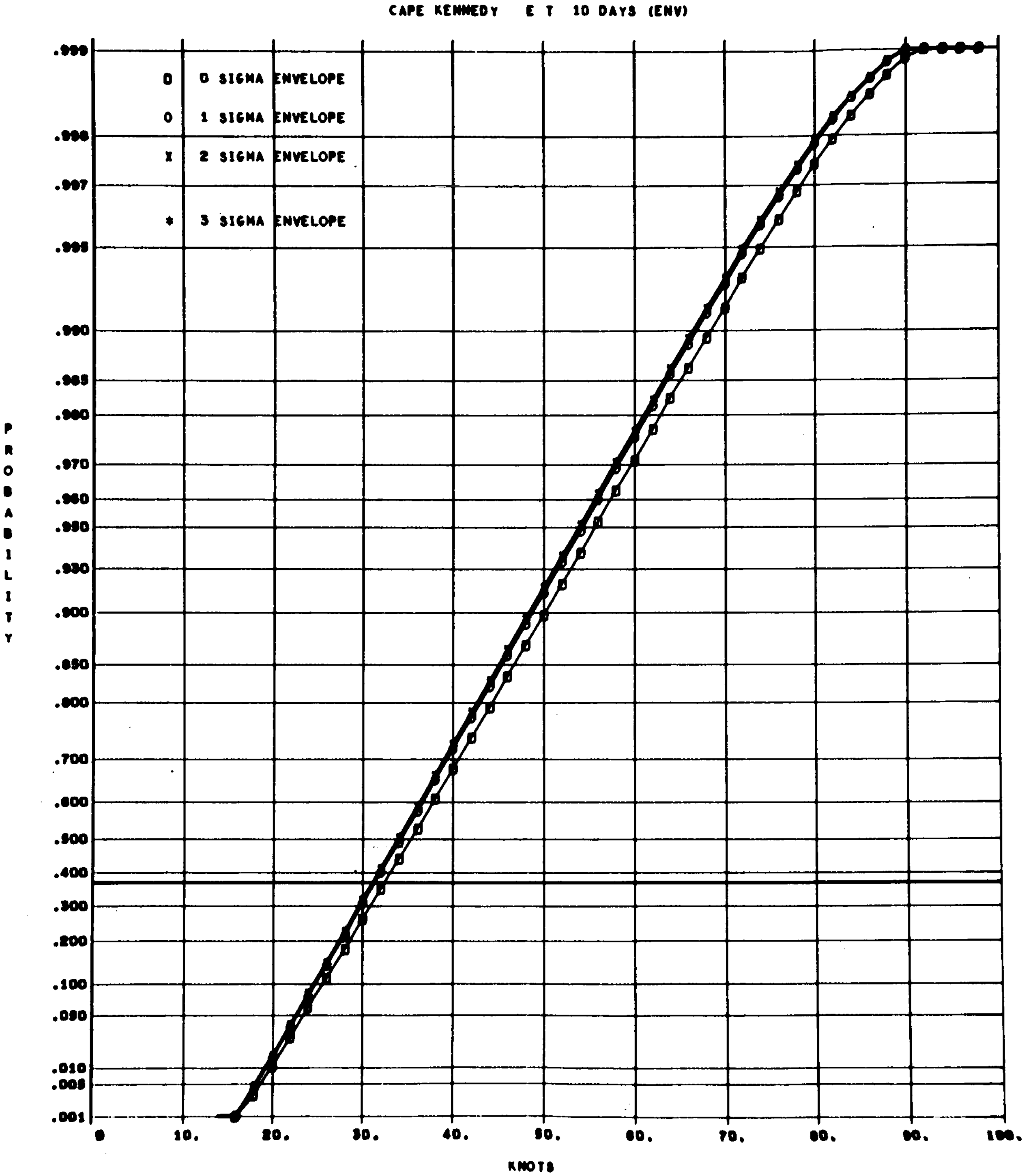

Fig. 41 - Surface Wind Profile Cumulative Distributions

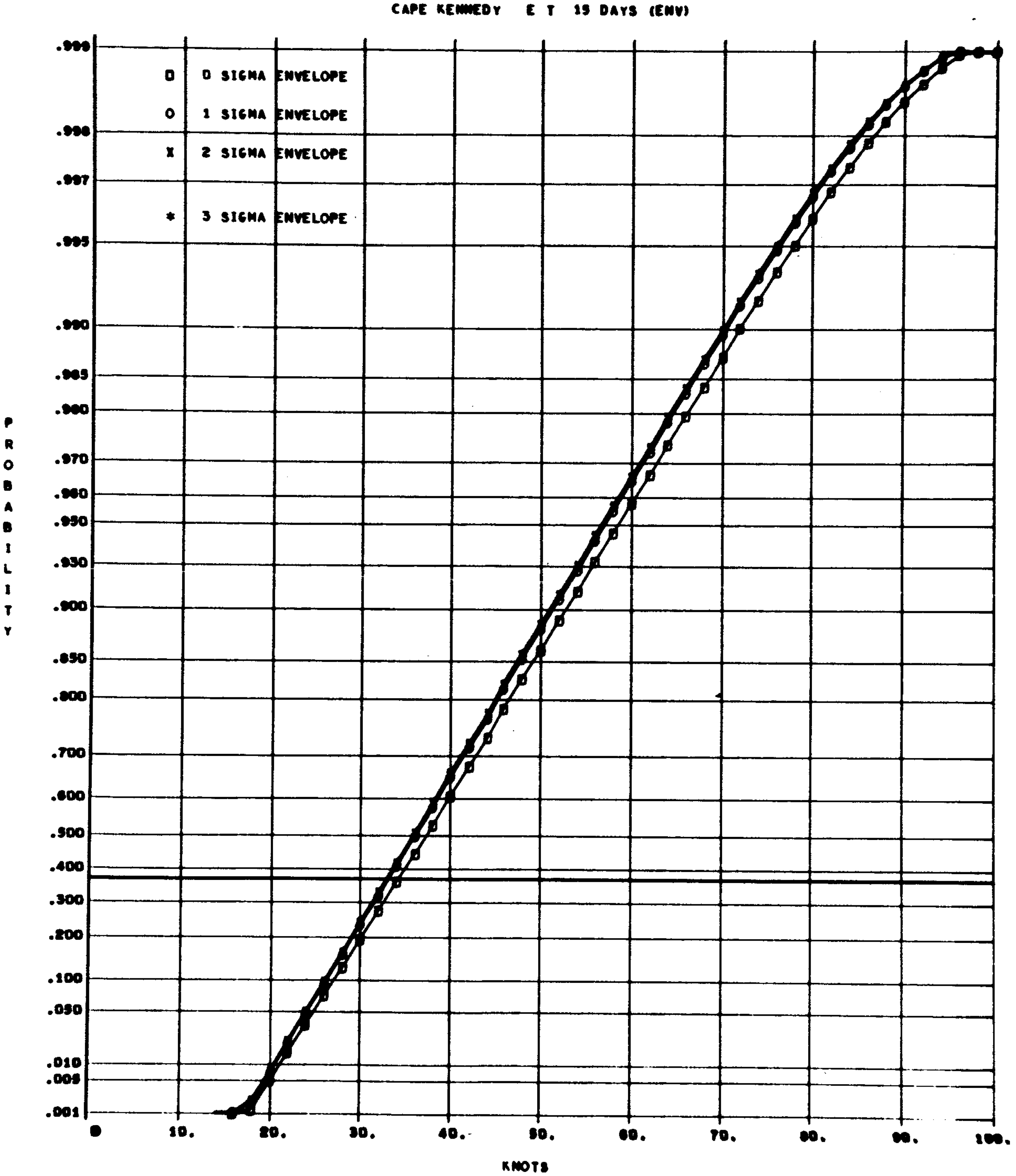

Fig. 42 - Surface Wind Profile Cumulative Distributions

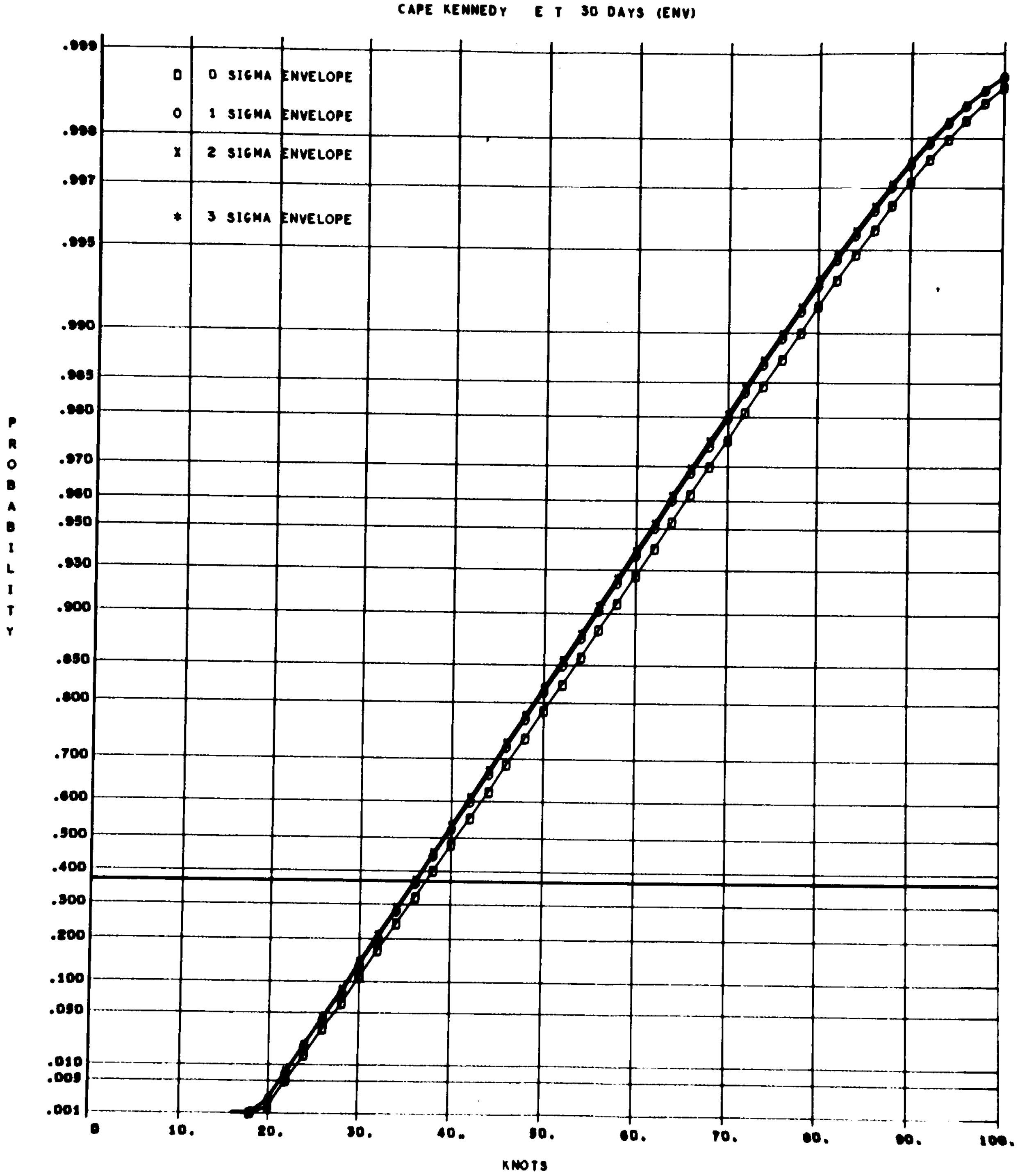

Fig. 43 - Surface Wind Profile Cumulative Distributions

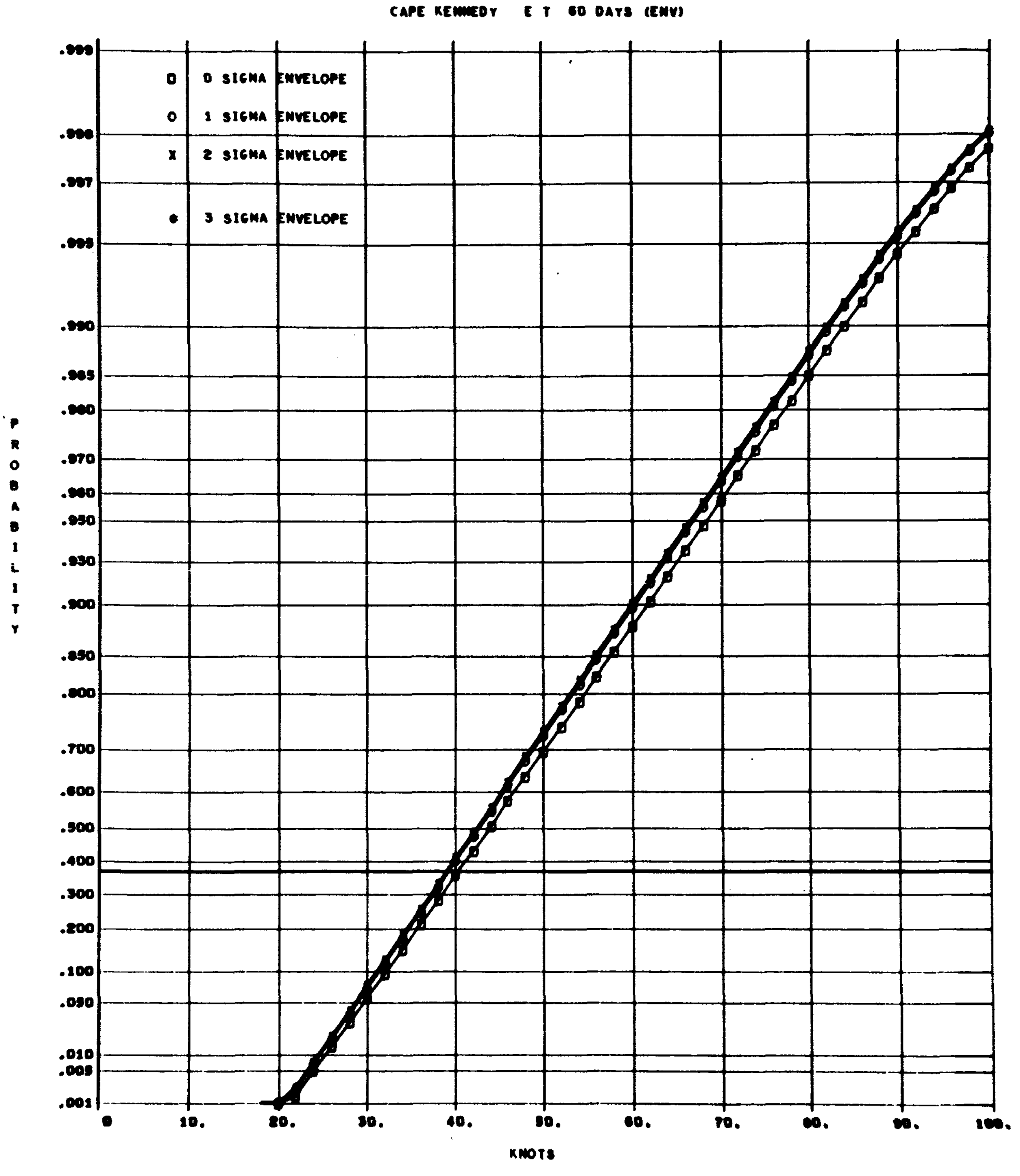

Fig. 44 - Surface Wind Profile Cumulative Distributions

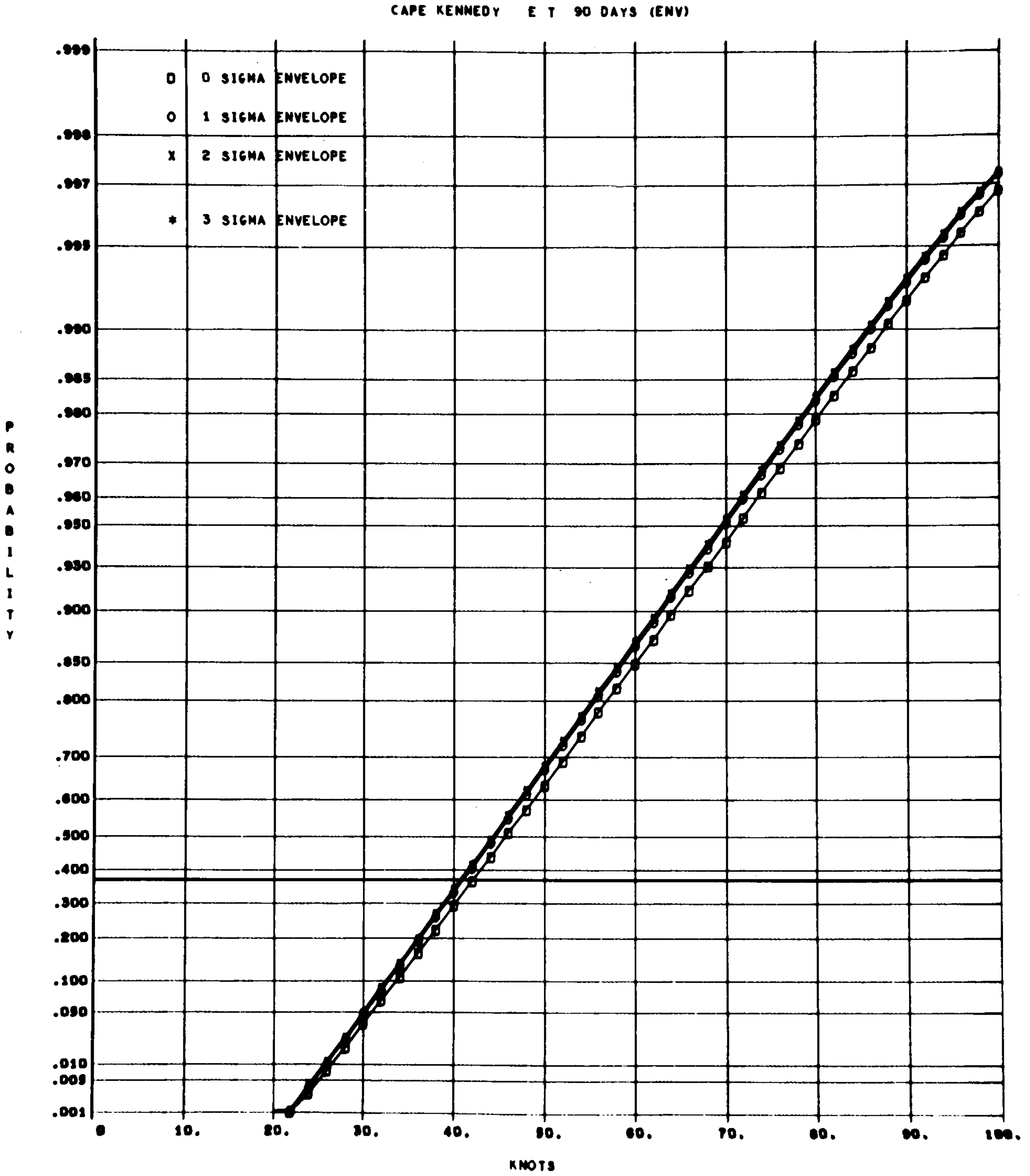

Fig. 45 - Surface Wind Profile Cumulative Distributions

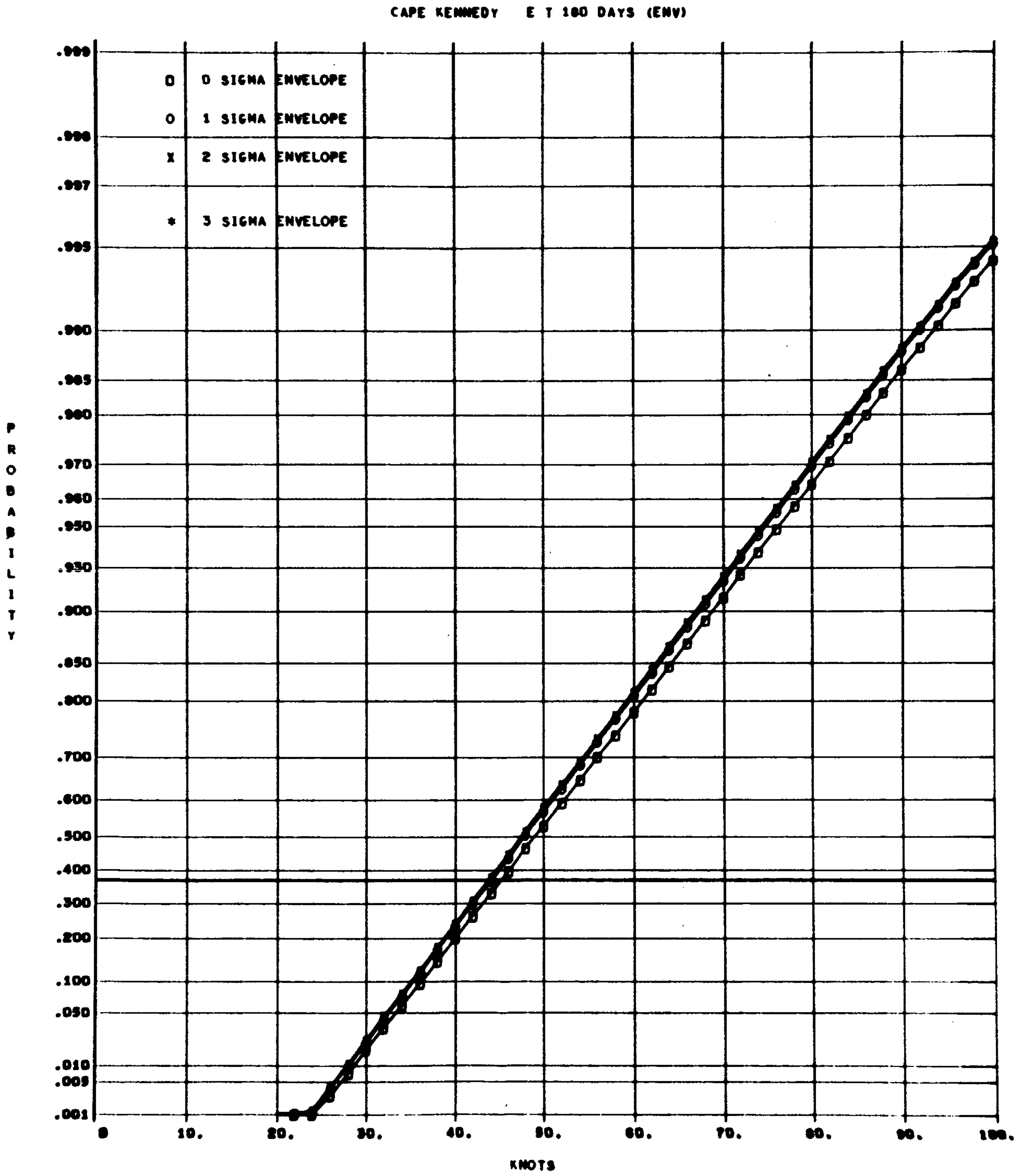

Fig. 46 - Surface Wind Profile Cumulative Distributions

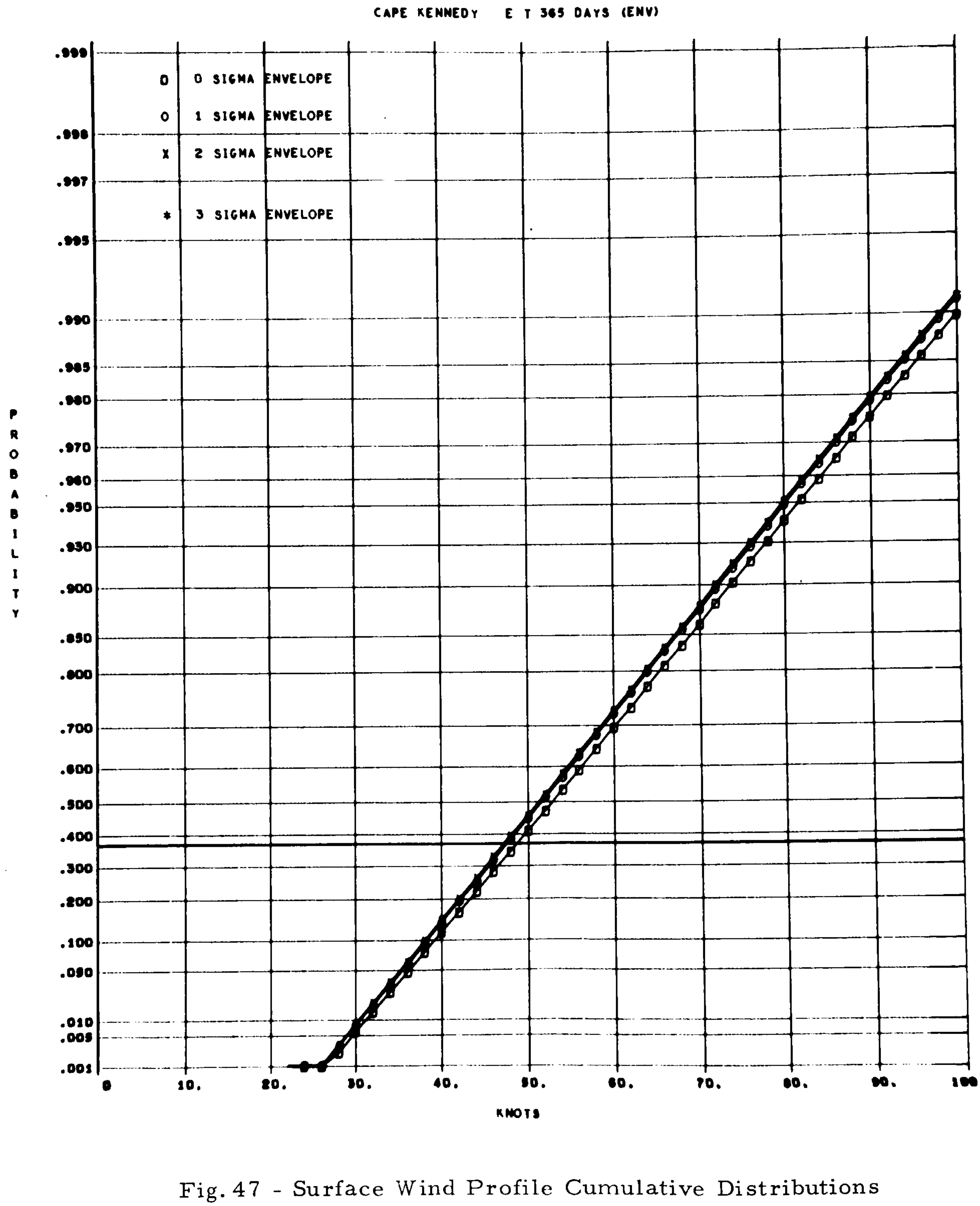

Fig. 47 - Surface Wind Profile Cumulative Distributions

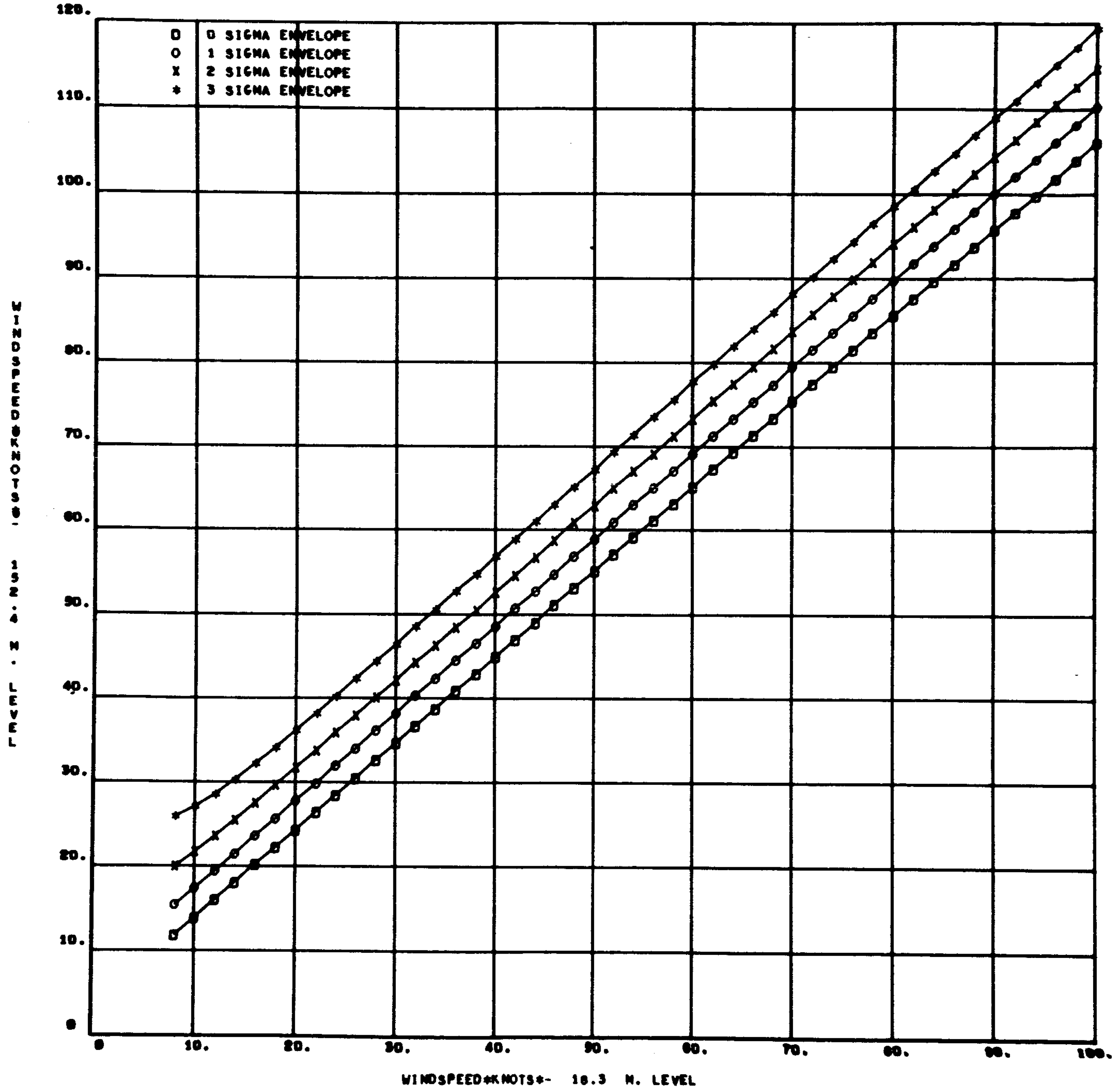

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Fig.48 - Wind Profile Plots