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CAPE KENNEDY LOW LEVEL WIND STUDY FOR SEPTEMBER 23-25, 1963

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NASA

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Huntsville, Alabama

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By

Carroll Hasseltine

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ABSTRACT

This report compares the high winds recorded at Cape Kennedy, September 23 - 25, 1963, with the previously computed 95, 99, and 99.9 percentile wind speeds used for design criteria at Cape Kennedy and vicinity. Methods used in computing the wind speeds at Cape Kennedy are explained. Data are presented for the length of time that these percentile wind values were exceeded. A comparison of the constants describing the wind speed profiles for different wind speeds and a comparison of gust factors are also presented. Some of the computed constants which best describe the characteristics of high surface winds are shown to differ from the constants which best describe the entire spectrum of wind speeds.

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ENVIRONMENTAL APPLICATIONS GROUP
AERO-ASTROPHYSICS OFFICE
AERO-ASTRODYNAMICS LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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CAPE KENNEDY LOW LEVEL WIND STUDY FOR SEPTEMBER 23 - 25, 1963

SUMMARY

The duration of time that the wind speeds at Cape Kennedy between 1600Z, September 23, 1963, to 2200Z, September 25, 1963, exceeded the Marshall Space Flight Center design peak wind speeds for the 95, 99, and 99.9 percentiles is tabulated for each of the three anemometer levels (19.5, 58.5, and 96.3 meters). It is shown that the wind speed measured at the lowest level (19.5 meters) exceeded the design values a greater percentage of the time than at the higher levels.

The value of the constant p in the power law wind profile equation is found to be smaller for these data than the one used in computing the design data. A smaller value of p is justified for use in wind profiles when wind speeds are similar to those encountered during this period.

Gust factors are computed from September 20, 1963 to October 1, 1963. The factors show a large range of values and a trend to decrease with increasing height and steady-state speed.

I. INTRODUCTION

Wind speed profiles have been established for Cape Kennedy for the 95, 99, and 99.9 percentiles* from the wind speed frequency distribution measured at a single height. The wind speed profile was obtained using the power law:

$$\frac{V_2}{V_1} = \left(\frac{Z_2}{Z_1}\right)^p ,$$

* Percentile is used in this report as defined in Reference 6; i.e., the value of the wind speed below which lie k% of the observed wind speeds is called the kth percentile.

where V is the wind speed, Z the height, p a constant for a given set of conditions, 1 refers to a reference height, and 2 to a height greater than the reference height. This formula is considered valid from about 1 meter to 200 meters above the surface. The value of p varies with the wind speed and the temperature distribution within the atmospheric layer concerned. At relatively high mean wind speeds, the change in temperature with height in the planetary layer approaches a constant (usually determined by the dry adiabatic lapse rate), so that the value of p then becomes dependent on wind speed only. The value of p decreases with high wind speeds (Ref. 2) encountered in the 95, 99, and 99.9 percentile wind speeds which, in turn, follows the observed small increase in wind speed with height in the planetary layer.

The surface winds at Cape Kennedy reached a recorded speed of approximately 26 m/sec during the period of September 23 - 25, 1963, at 96.3 meters height. These unusually high surface winds afford an opportunity to evaluate the representativeness of the power law. The conclusions are not conclusive due to possible interference of the structure on the wind flow. The winds were from the northeast during the period of observation which is believed to be a good exposure for Launch Complex 34.

This study presents an analysis of wind data as recorded at the 19.5 meter (64 feet), 58.5 meter (192 feet), and 96.3 meter (316 feet) levels at Launch Complex 34 (Figure 1) during the period 1600Z, September 23, 1963, to 2000Z, September 25, 1963, and compares the results with current design criteria. Heavy rain showers occurred throughout the period.

Mrs. Margaret B. Alexander compiled much of the data used in this report and made many helpful suggestions while it was being prepared.

II. SYNOPTIC SITUATION

The synoptic pattern, which caused the high winds at Cape Kennedy during the period of interest, evolved from a cold front that stagnated in mid-Florida, as shown in Figures 2, 3, and 4. A weak wave developed east of Florida with an associated center of low pressure. The pressure gradient associated with the center of low pressure gave exceedingly high surface winds from the northeast. While cold fronts more frequently stagnate farther north at this time of year, it is not a rare instance for them to advance this far south. Likewise, the center of low pressure more frequently develops farther west, but again, it is not too unusual to have a low pressure area centered east of Florida. Winds of 26 m/sec at Cape Kennedy, however, are unusual. This, in turn, indicates that low pressures of this type in the vicinity of Cape Kennedy are normally farther east or less intense than the one occurring during the period of interest.

Wind direction recorded by the anemometers during the period of interest, was from the northeast at all levels except the 19.5-meter level during the last half of the period. An inspection of the 19.5-meter level anemometer after this period indicated the anemometer had rotated, so that this wind direction was unreliable. It is, therefore, assumed that the true wind was from the northeast at all times.

III. EQUIPMENT

Wind measuring equipment at Launch Complex 34, Cape Kennedy, consists of Bendix-Friez aerovanes located at 19.5 meters, 58.5 meters, and 96.3 meters (Figure 1) with strip chart recorders. Since wind measurements consist of simple readings of the speed from the strip chart, a comment on the accuracy of the measurements is in order.

It is assumed for a steady-state wind that the recorded wind is the best estimate of the actual wind obtainable; i.e., the equipment responds to the wind speed in accordance to the calibration. Unfortunately, all equipment has a lag in reaching a steady-state value. The lag encountered by a step function input is best described by the time constant of the instrument. The Bureau of Standards has determined the time constant for the aerovane to be about 0.5 seconds for the speeds used in this study. This means that if the equipment is subjected to a step function wind input, approximately 63 percent of the correct value would be recorded in 0.5 seconds, 87 percent of the correct value in 1.0 second, and 95 percent of the correct value in 1.5 seconds, etc. Wind gusts do not fulfill the definition of a step function; therefore, most errors will be less than those indicated above. The point that is apparent, however, is that the amplitude of a short period gust depends, to a large extent, on the time constant of the equipment used to measure it. Gusts recorded by the equipment at Cape Kennedy, which have a period of less than three seconds, are attenuated a significant amount by the equipment used. However, gust speed data recorded at Cape Kennedy have been accepted as exact data for this report. For operational purposes the recorded winds are probably sufficiently accurate, although the philosophy of what is satisfactory accuracy is a study in itself.

The surface wind of interest in vehicle design is that which will influence a missile and/or associated facilities significantly and, therefore, the wind data should be representative of the wind which exerts forces on the complex structure. This is the wind direction and speed before it is modified by the launch complex itself, but includes all changes in speed and direction caused by other structures. Since structures are necessary to hold the anemometers, the measured wind from some directions may not represent the true wind. For a northeast wind at Launch Complex 34, the 58.5-meter wind measurement is more likely to be influenced by obstructions to the free flow than the other two elevations. Since this cannot be verified, however, the measured air speeds have been accepted as being correct. This illustrates the desirability to have anemometers located at many locations on the service structure, and the necessity for a careful analysis of the resulting records prior to making decisions on the recorded data.

IV. DESIGN CRITERIA WINDS

For vehicle design and launch operations, high speed surface winds are of great significance. Vehicles must resist structural damage from wind speeds up to a certain value, and this value should be a maximum limit that could reasonably be expected at the launch pad. It, therefore, behooves the designer to obtain some type of a frequency distribution of high speed winds. The Aero-Astrophysics Office (R-AERO-Y), Marshall Space Flight Center, has provided these data based upon ten years of wind data taken at Patrick Air Force Base and Cape Kennedy. These data have been analyzed to produce the design ground wind speed values of the 95, 99, and 99.9 percentiles. These values (Table I) are considered applicable to the NASA launch complexes and facilities at Cape Kennedy and the Merritt Island Launch Area (Reference 5).

It is considered appropriate here to emphasize that values in Table I were obtained from statistical data, and reflect the occurrence of past events. An increase in the extreme wind conditions in the vicinity of Cape Kennedy could well increase the frequency of the extreme maximum speeds given by the record. They were, however, the best estimates of these values when the criteria were published.

The extrapolation of the data, to higher (or lower) elevations from the reference level, was made by use of the formula

$$\frac{U_2}{U_1} = \left(\frac{Z_2}{Z_1}\right)^p$$

U_2 is the velocity at height Z_2

U_1 is the velocity at height Z_1

$Z_2 > Z_1$

p is a number determined by the wind speed profile.

This formula has been accepted as valid for the range of heights used in this study. The best overall estimate for p at the time the design criteria were issued was p = 0.20 (Reference 2). A comparison of this value for determining the wind speed profile and that obtained from the wind profiles from 1600Z, September 23, 1963, to 2200Z, September 25, 1963, is one of the purposes of this study.

V. GUST FACTORS

Gust factors are obtained by dividing the maximum gust speed by the average speed for a given period. The maximum gust speed and five-minute average speeds have, for the most part, been used in computing gust factors and are used in this study. A value of 1.4, the design criteria gust factor, multiplied by the maximum one- to five-minute average speed has, in general, been used by the Marshall Space Flight Center to obtain maximum gust speed.

VI. DISCUSSION OF DATA

Design winds provided for Cape Kennedy by the Marshall Space Flight Center are given in Table I. As previously stated, these data were obtained from the wind speed frequency distributions at Patrick Air Force Base and Cape Kennedy, and extrapolated to other heights using Figures 5 and 6. Maximum gust speed is the percentile wind multiplied by the gust factor of 1.4. These extrapolations produced the design wind speed values for given percentiles at specific heights.

Table II gives the length of time during the period of study that the observed speeds exceeded the 95, 99, and 99.9 percentile design values. These time periods include the time that the steady-state and/ or gust speeds exceeded the specified design values. Table III gives the maximum gust speed recorded at each level and the associated wind speed at the other levels.

It is interesting to note in Table II that the wind speed exceeded the 95, 99, and 99.9 percentile value at 19.5 meters more total time than it exceeded these values at 58.5 and 96.3 meters height. This would indicate that the value of $p = .20$ is too large in the formula

$$\frac{U_2}{U_1} = \left(\frac{Z_2}{Z_1}\right)^p$$

It is also noted that the 95-percentile design wind at 58.5 meters was exceeded less than that at 96.3 meters. This is indeed surprising, and the only explanation given without proof, is that the speed was reduced by interference of the tower structure.

Table IV gives the mean value of the hourly five-minute mean wind speeds and 95-, 99-, and 99.9-percentile values of the winds during the study period. These are based on actual observations which were 55 in number. With this small number of observations it is difficult to arrive at a true probability distribution of observations, particularly in the extreme values of the 99 and 99.9 percentiles. These data are the values obtained from the available data by taking all percentiles between the lower bound of the lowest class interval, and the higher bound of the highest class interval in which speeds were observed.

Comparing these data (Table IV) with the 95, 99, and 99.9 percentile wind speeds (Table I), the mean and 50-percentile design winds, for the period of interest, were greater than the 95 percentile for the design winds at all levels and even the 99-percentile value at the 19.5-meter level. The value of the speeds for the 95, 99, and 99.9 percentiles computed for the 19.5 meter level also is greater than the design winds. This is not true at the 58.5- and 97.5-meter levels, however.

The value of p in Table IV was computed using the method of least squares to fit the three points of the profile to the equation. It is indeed unfortunate that data are not available for more heights in the computation of p, since three levels are only one over the absolute minimum to determine a value of p. By assuming the speed correct at one level, and computing the speed at the other two levels using the profile formula and the best fit value of p, it can be shown that this equation for computing the wind profile leaves much to be desired for these cases.

From Table IV it is also obvious that the value of $p = 0.20$ in the wind profile equation, as used in reference 5 to extrapolate from the reference level climatological data, is too large for the period in which we are concerned. This does not preclude the value of 0.20 being the best single value for all cases. The value of the p's given in Table IV also indicates that p probably increases with decreasing wind speed, but the small number of observations does not make it conclusive for all cases. This feature of p is noted in references 2 and 5.

Gust factors have been computed for five-minute average wind speeds taken on the hour from 1400Z, September 20, 1963, to 1500Z, October 1, 1963, (Table V). These values are plotted on Figures 7, 8, and 9. Data for the figures involved were taken for a period greater than the high wind study to illustrate the variation of the gust factor with speed and height. It is evident from these figures that the variation of the gust factor decreases with height, and in the lower levels with speed.

Mean gust factors and variances were computed for the 19.5-, 58.5-, and 96.3-meter levels for two groups of data stratified by wind speeds encountered at the 19.5-meter level. Correlation coefficients of the gust factors were computed between 19.5 and 58.5 meters and 58.5 and 96.3 meters for these stratified data. The mean gust factor and its variance (Table V) for these two groups of data decrease with height. The correlation coefficients of the gust factors between the levels indicated are small enough that the actual correlation is considered purely coincidental. This, in turn, indicates that if we are to correlate wind speed at one level with that of another we must use an average speed rather than an instantaneous speed. This is the equivalent of saying that p will not express a true instantaneous profile with these data when gusts are present, since these gusts are not transmitted to the other levels. The design wind profiles constructed from percentile values, as given in Reference 5, should not be interpreted as representative of any particular instantaneous wind profile, but are representative of the wind speeds for the given percentiles. It is also obvious that there must be a limiting distance through which gust speeds are transferred, since the gust must represent a velocity of a finite mass of air. The physical distance through which gusts are transmitted, however, is smaller than the separation of the anemometers used in this wind study.

VII. CONCLUSIONS

All five-minute mean wind speeds derived for the period 1600Z, September 23, 1963, to 2200Z, September 25, 1963, exceed the ten-year median of 4.8 m/sec at 19.5m, 6.0 m/sec at 58.5m, and 6.6 m/sec at 96.3m. The small duration of these wind speeds (54 hours), compared to ten years or more of climatological data, indicates that the value for the design wind speeds given in Table I would not be changed significantly if at all.

Wind speed profiles for winds over 10 m/sec at the 19.5-meter level indicate that the value of p in the wind profile equation should be less than 0.20. A decrease in p increases the wind speed at the 19.5-meter height, and decreases the values at the higher levels.

A single value gust factor of 1.4, as used in the design values, gives little information as to the expected gust speed for any specified period. More information could be extended to using agencies by expressing the gust factor as a probability function, although such an expression would be more complicated. It is again pointed out that gust factors measured with more responsive equipment may be larger than those measured with the Friez-Aerovane and strip chart recorders; similarly, less responsive equipment will have smaller gust factors.

A final conclusion, well illustrated by this study but seldom mentioned in meteorology, is the application of conditional probability of occurrence of an event rather than independent probability. For example, if the wind speed is 10 m/sec now, the probability that it will have a speed of at least 10 m/sec the next hour is not the same as if a calm existed at the present time. These conditional probabilities are being investigated.

During this period of study, which covered 54 hours (55 hourly observations), all observations were higher than the median wind speed for ten years. The probability for 55 independent consecutive observations being higher than the median is 1 in 3.603×10^{16}. Atmospheric data frequency distributions, however, include several extended periods of abnormal weather conditions and consecutive observations cannot be considered independent of each other. The occurrence of winds for a period of 54 hours with a speed as high as those encountered in this study is indeed a rare event. This is shown by the length of time that it exceeded certain climatological design data. It is not as rare, however, as would be indicated by the probabilities for each observation, which are applicable to independent observations.

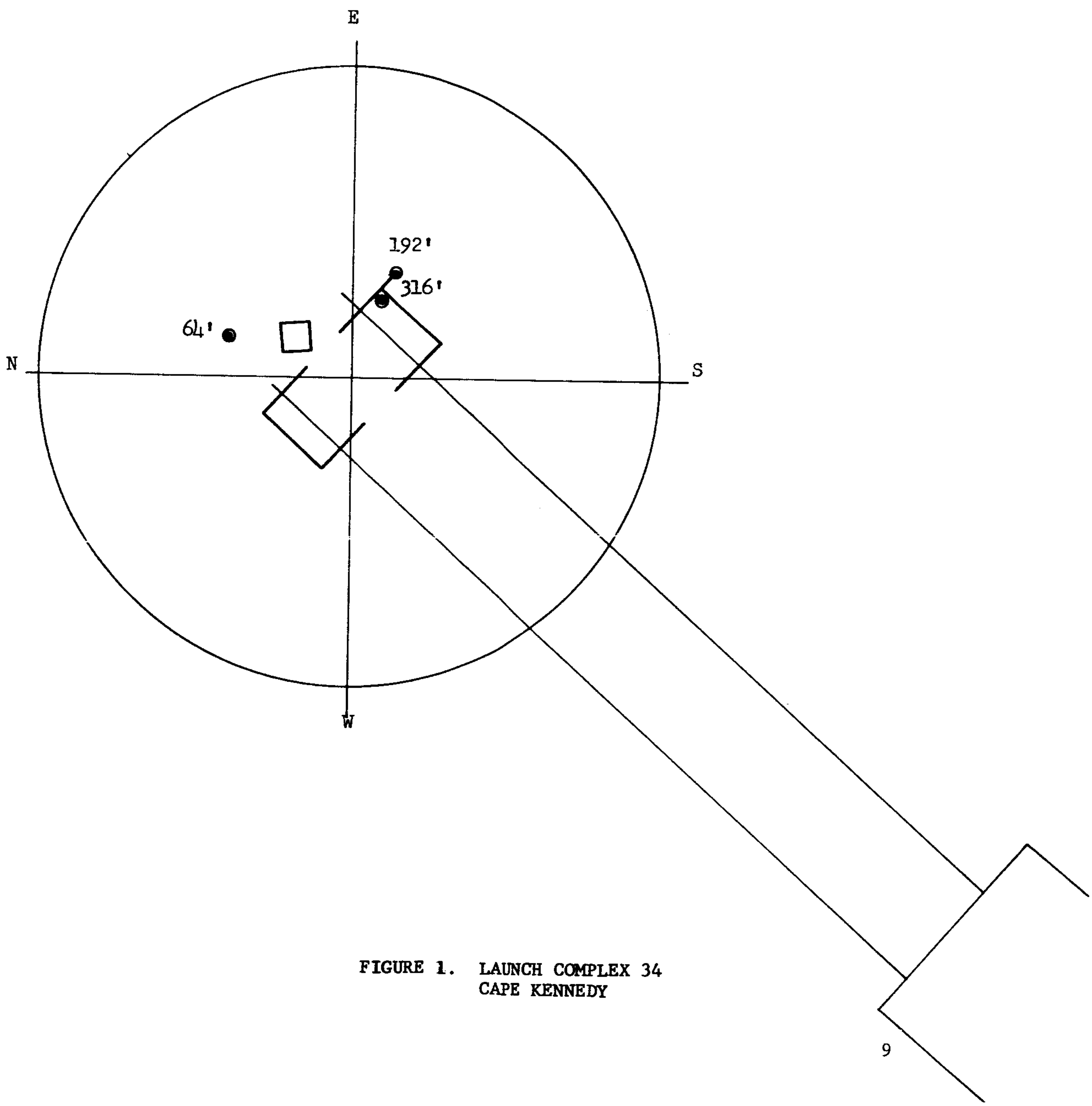

FIGURE 1. LAUNCH COMPLEX 34
CAPE KENNEDY

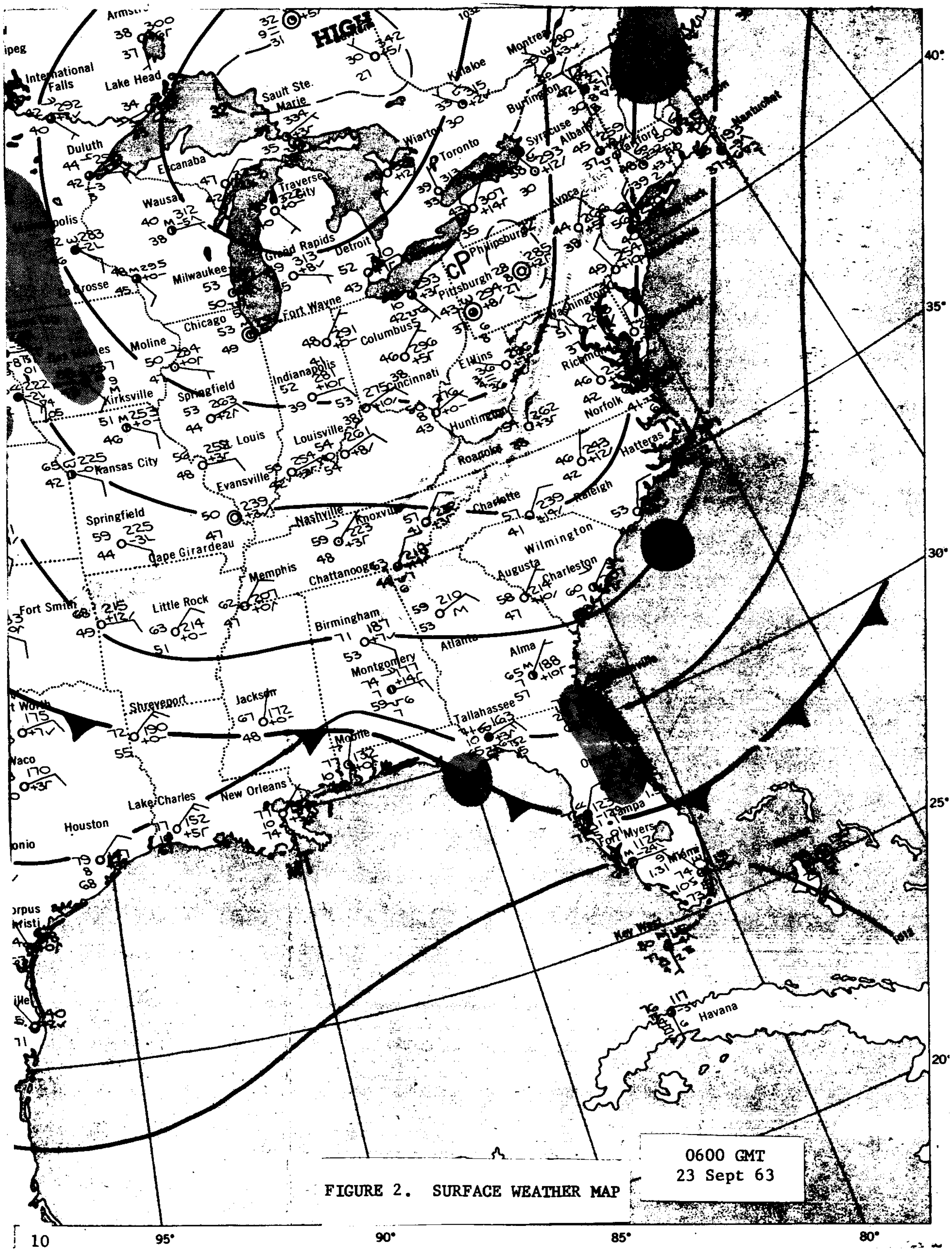

FIGURE 2. SURFACE WEATHER MAP

0600 GMT
23 Sept 63

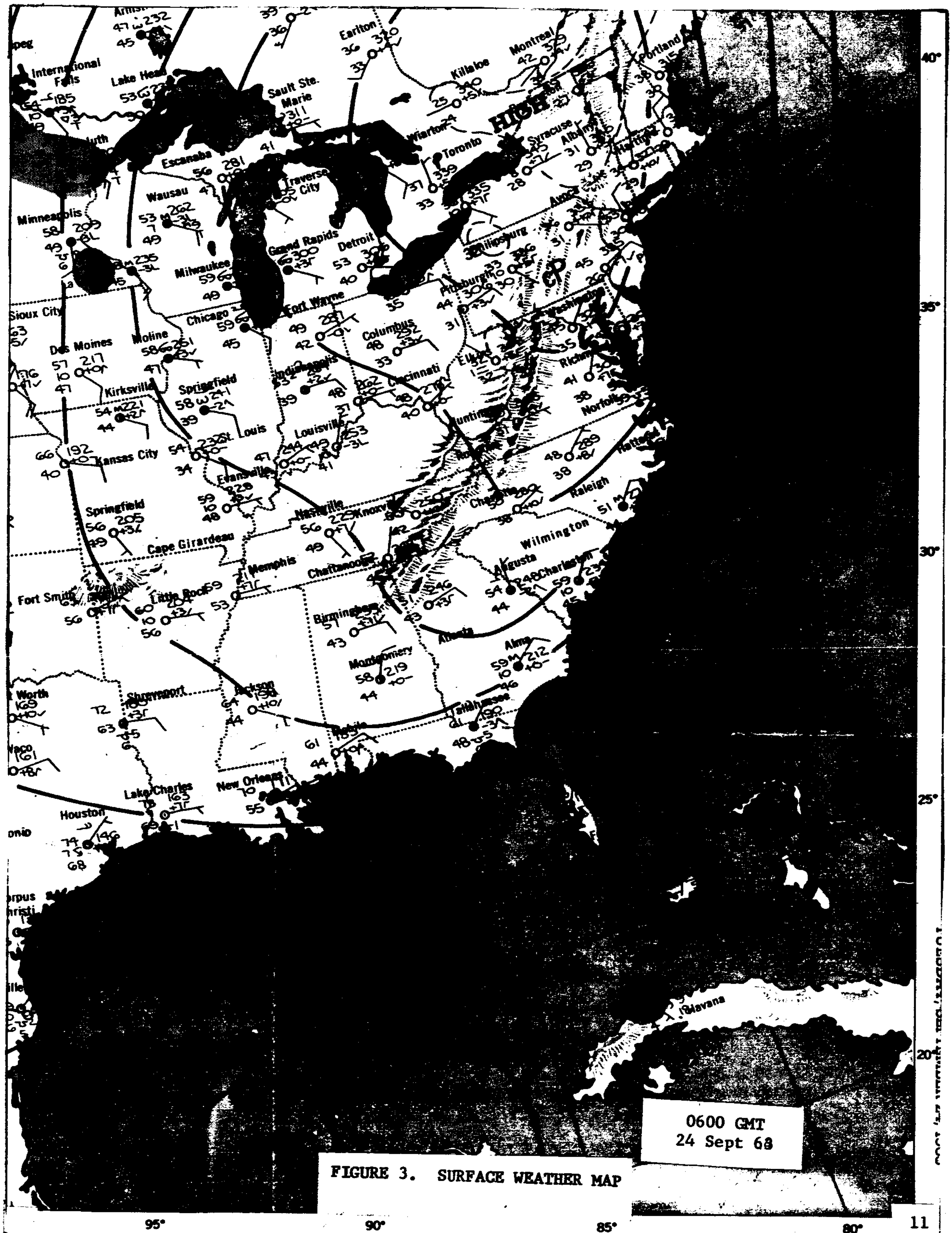

FIGURE 3. SURFACE WEATHER MAP

FIGURE 4. SURFACE WEATHER MAP

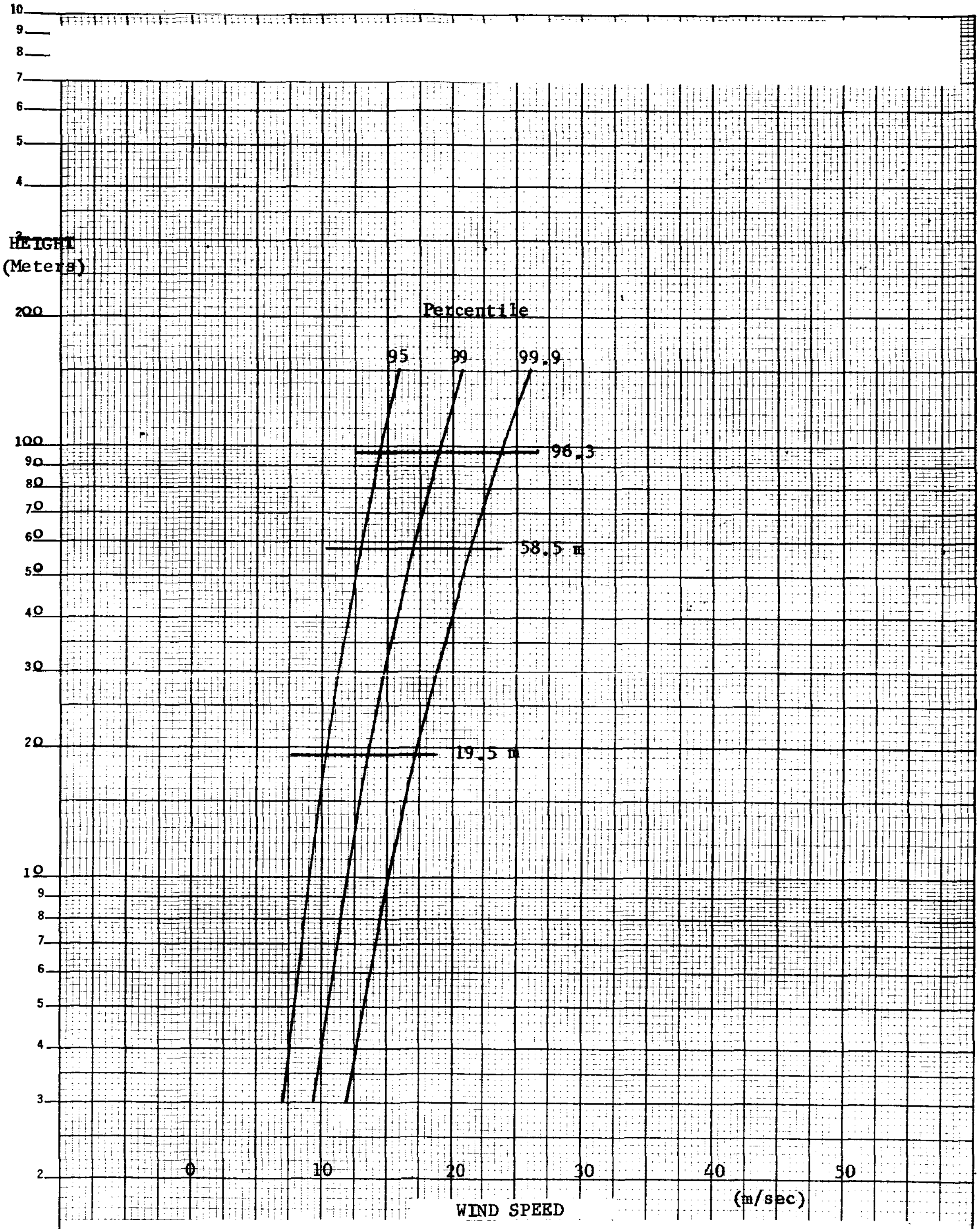

FIGURE 5. DESIGN GROUND WIND PROFILE QUASI-STEADY STATE SPEED VS HEIGHT FOR CAPE KENNEDY, FLORIDA

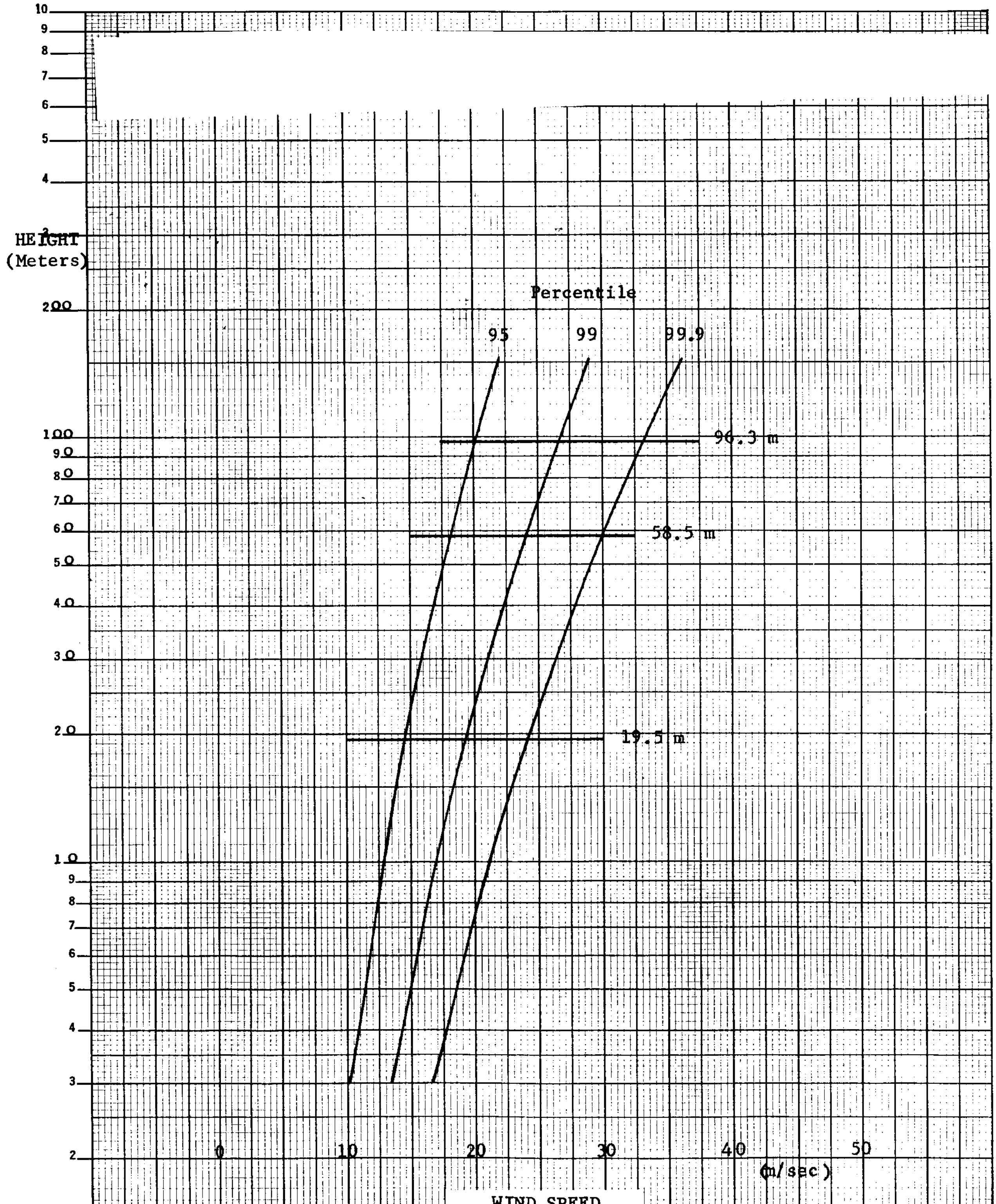

FIGURE 6. DESIGN GROUND WIND PROFILE MAXIMUM GUST OR PEAK WIND SPEED ASSOCIATED WITH PERCENTILE STEADY STATE VS HEIGHT - CAPE KENNEDY, FLORIDA

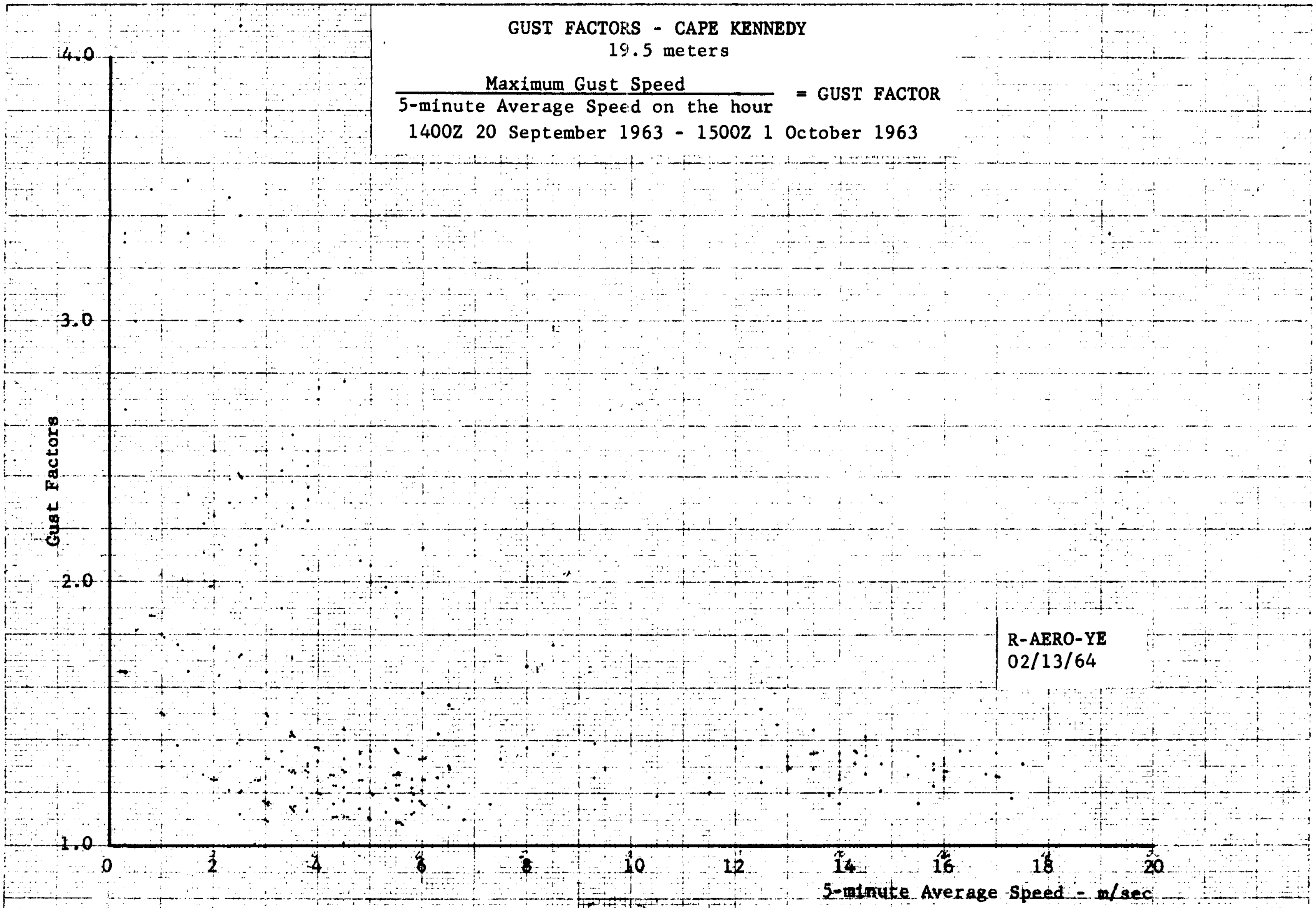

FIGURE 7. GUST FACTORS - CAPE KENNEDY
19.5 METERS

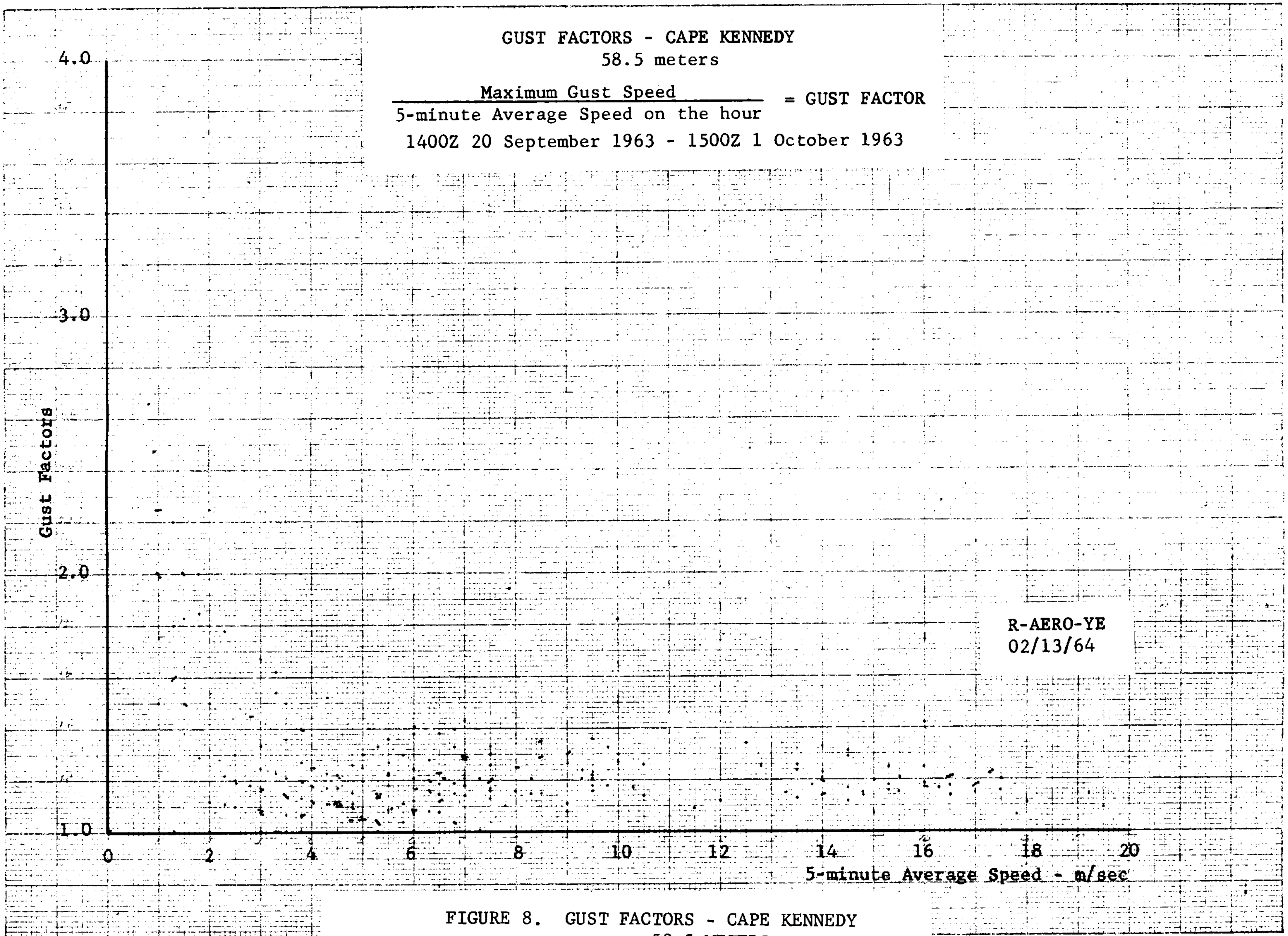

FIGURE 8. GUST FACTORS - CAPE KENNEDY
58.5 METERS

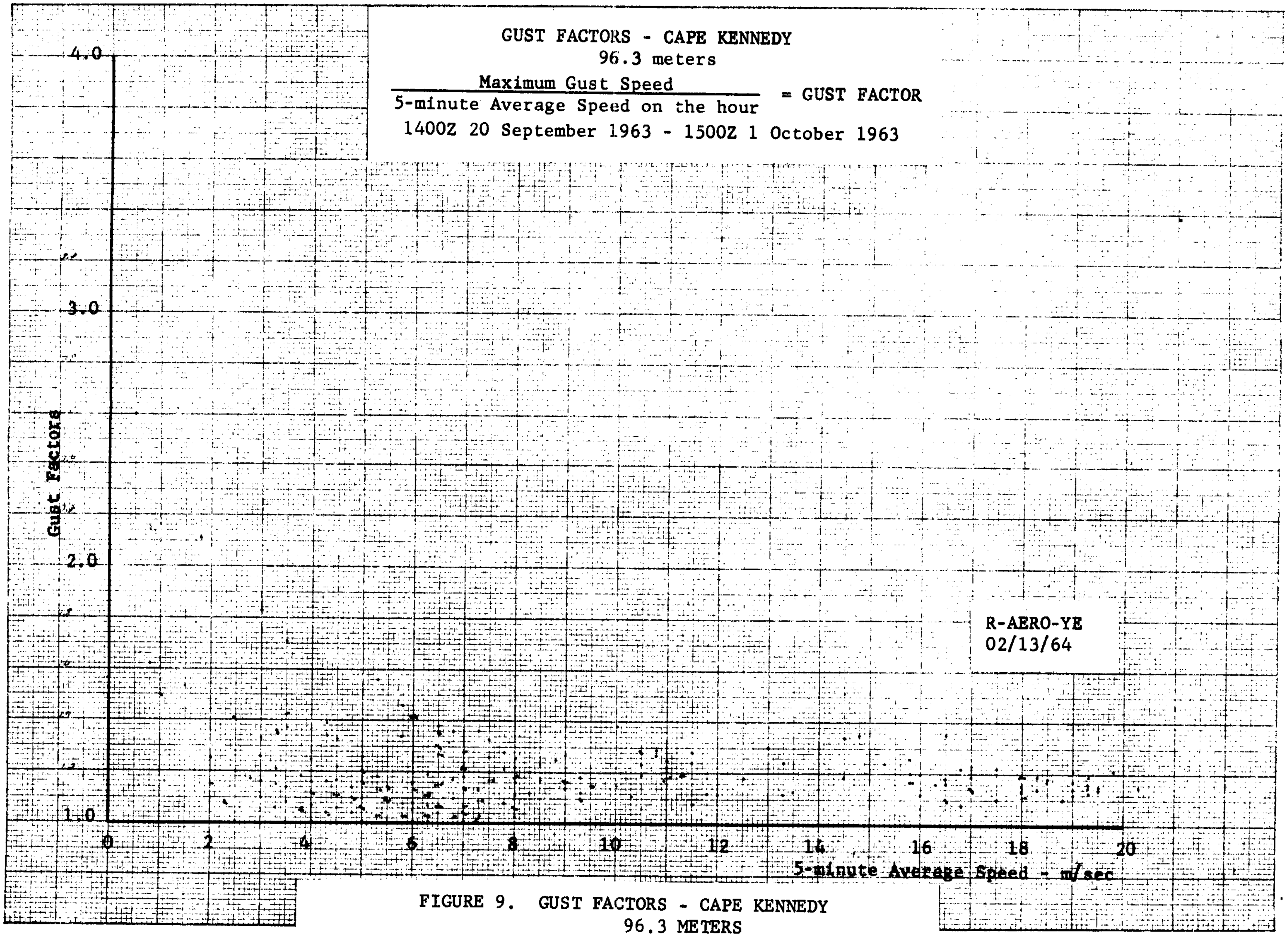

FIGURE 9. GUST FACTORS - CAPE KENNEDY
96.3 METERS

TABLE I

DESIGN WINDS PROVIDED
BY
MARSHALL SPACE FLIGHT CENTER
FOR USE AT CAPE KENNEDY

HEIGHT m	HEIGHT ft.	QUASI-STEADY STATE WIND SPEED meters per second	GUST OR PEAK WIND meters per second
		95 PERCENTILE WIND VALUES	
3.0	10	7.2	10.1
19.5	64	10.4	14.6
58.5	192	13.0	18.2
96.3	316	14.4	20.2
		99 PERCENTILE WIND VALUES	
3.0	10	9.5	13.3
19.5	64	13.7	19.2
58.5	192	17.1	23.9
96.3	316	18.9	26.5
		99.9 PERCENTILE WIND VALUES	
3.0	10	11.8	16.6
19.5	64	17.0	24.0
58.5	192	21.3	29.9
96.3	316	23.7	33.1

TABLE II.

TIME AND PERCENT OF TOTAL THAT WIND SPEED AT RESPECTIVE HEIGHTS EXCEEDED THE GUST (OR PEAK) WIND SPEEDS ASSOCIATED WITH 95, 99, AND 99.9 PERCENTILE OF THE QUASI-STEADY-STATE DESIGN WINDS DURING THE PERIOD 1600Z, 23 SEPTEMBER 1963, to 2200Z, 25 SEPTEMBER 1963.

HEIGHT		PERCENTILE 95		99		99.9	
m	ft.	TIME min	PERCENT OF TOTAL TIME*	TIME min	PERCENT OF TOTAL TIME*	TIME min	PERCENT OF TOTAL TIME*
19.5	64	2570	79.3	612	18.8	4**	0.12
58.5	192	1092	33.7	2***	0.06	0	0
96.3	316	1138	35.1	0	0	0	0

* Total Time = 3240 minutes.

** The maximum wind speed exceeded the design 99.9 percentile 19.5 m height gust or peak wind speed by less than 0.5 m/sec.

*** The maximum wind speed exceeded the design 99.9 percentile 19.5 m height gust or peak wind speed by less than 0.5 m/sec.

TABLE III.

MAXIMUM GUST SPEEDS FOR EACH MEASURED LEVEL - 1600Z SEPTEMBER 23, 1963 to 2200Z SEPTEMBER 25, 1963 AT CAPE KENNEDY, LAUNCH COMPLEX 34

HEIGHT m	HEIGHT ft.	DATE	TIME Z	MAXIMUM GUST SPEED (m/sec)	COMMENTS
19.5	64	9/25/63	0427	24.4	Maximum gust speed at 19.5 meters
58.5	192	9/25/63	0427	20.3	
96.3	316	9/25/63	0427	24.7	
19.5	64	9/23/63	2249	20.1	Maximum gust speed at 58.5 meters
58.5	192	9/23/63	2249	23.9	
96.3	316	9/23/63	2249	22.9	
19.5	64	9/24/63	2145	21.9	Maximum gust speed at 58.5 meters
58.5	192	9/24/63	2145	23.9	
96.3	316	9/24/63	2145	25.0	
19.5	64	9/25/63	2145	22.6	Maximum gust speed at 58.5 meters
58.5	192	9/25/63	2145	23.9	
96.3	316	9/25/63	2145	23.1	
19.5	64	9/25/63	0519	23.5	Maximum gust speed at 96.3 meters
58.5	192	9/25/63	0519	21.3	
96.3	316	9/25/63	0519	26.2	

TABLE IV.

MEAN SPEED AND PERCENTILE DISTRIBUTION FOR 5-MINUTE AVERAGE WIND SPEEDS ON THE HOUR AT CAPE KENNEDY FROM 1600Z SEPTEMBER 23, 1963 TO 2200Z SEPTEMBER 25, 1963 (55 OBSERVATIONS)

HEIGHT m	HEIGHT ft.	MEAN SPEED (m/sec) *	PERCENTILE 50*	95	99	99.9
19.5	64	13.91	14.51	17.56	17.99	18.12
58.5	192	14.86	15.46	17.94	18.51	18.63
96.3	316	16.91	17.54	20.13	20.82	20.95

* MEAN SPEED AND 50th PERCENTILE VALUES ARE DIFFERENT SINCE THE DISTRIBUTION IS NOT A NORMAL DISTRIBUTION.

VALUE OF p FROM ABOVE DATA USING LEAST SQUARES TECHNIQUE TO OBTAIN BEST FIT TO THE EQUATION

$$\frac{U_2}{U_1} = \left(\frac{Z_2}{Z_1}\right)^{p}$$

MEAN SPEED	PERCENTILE 50	95	99	99.9
.107	.104	.072	.078	.077

TABLE V.

GUST FACTORS FOR 5-MINUTE AVERAGE SPEED TAKEN ON THE HOUR FROM 1600Z SEPTEMBER 23, 1963 to 2200Z SEPTEMBER 25, 1963

HEIGHT meters	MAXIMUM GUST FACTOR	AVERAGE GUST FACTOR AND VARIANCE WHEN 19.5 METER WINDS ARE 12.99 - 15.56 m/sec Gust Factor	Variance	15.56 - 18.13 m/sec Gust Factor	Variance
19.5	1.41	1.299	.00407	1.279	.00274
58.5	1.31	1.166	.00213	1.194	.00247
96.3	1.26	1.153	.00209	1.165	.00114

MAXIMUM GUST CORRELATION COEFFICIENT FOR 5-MINUTE AVERAGE SPEEDS

HEIGHTS CORRELATED	19.5 METER WIND SPEED 12.99 - 15.56 m/sec	19.5 METER WIND SPEEDS 15.56 - 18.13 m/sec
19.5 and 58.5 meters	+.248	-.065
19.5 and 96.3 meters	+.350	+.243

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By Carroll Hasseltine

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense of Atomic Energy Commission programs has been made by the MSFC Security Classification Office. This report, in its entirety, has been determined to be unclassified.

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