NASA TECHNICAL
MEMORANDUM

NASA TM X-53771

August 21, 1968

NASA TM X-53771

LOW LEVEL WIND GUST AMPLITUDE AND DURATION STUDY

Aero-Astrodynamics Laboratory

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (September 1968)

TECHNICAL MEMORANDUM X-53771

LOW LEVEL WIND GUST AMPLITUDE AND DURATION STUDY

By

Dennis W. Camp

George C. Marshall Space Flight Center
Huntsville, Alabama

ABSTRACT

Presented is some information on low level wind gust amplitude and frequency of occurrence as a function of gust duration period. The wind data from which these characteristics were determined were obtained from NASA's 150-meter Meteorological Tower Facility located in the Merritt Island Launch Area at the Kennedy Space Center, Florida.

NASA - GEORGE C. MARSHALL SPACE FLIGHT CENTER

Technical Memorandum X-53771

August 21, 1968

LOW LEVEL WIND GUST AMPLITUDE AND DURATION STUDY

By

Dennis W. Camp

ATMOSPHERICS DYNAMICS BRANCH
AEROSPACE ENVIRONMENT DIVISION
AERO-ASTRODYNAMICS LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

PRECEDING PAGE BLANK NOT FILMED.

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

TECHNICAL MEMORANDUM X-53771

LOW LEVEL WIND GUST AMPLITUDE AND DURATION STUDY

SUMMARY

Presented is some information on low level wind gust amplitude and gust frequency of occurrence as a function of gust duration period. The wind data from which these characteristics were determined were obtained from NASA's 150-meter Meteorological Tower Facility located in the Merritt Island Launch Area at the Kennedy Space Center, Florida. This report shows that a statistical gust shape may be characterized by a fast build-up rate, a constant mid-portion, and a fast decay rate. Further, it is shown that the largest percentage of gusts occur for the shortest gust duration period.

I. INTRODUCTION

In the design, launch, and flight of large space vehicles, it is important to consider the magnitude of the loads caused by variations from the quasi-steady wind conditions. Such variations are commonly referred to as wind gusts. It is known that large- and small-scale wind velocity variations influence vertically rising vehicles whether on the launch pad or in flight (reference 1).

A specific problem concerning wind loading on a vertical rising vehicle is that of low-level (surface to 150-meter) wind variations (gustiness). The characteristics of gusts, such as statistical shape and frequency of occurrence, are important in determining the influence of gusts on vehicles. Exact characteristics of high frequency gusts cannot be determined from most available wind data because of the response limitations of the measuring instruments. These characteristics can be determined, with reasonable accuracy, however, for gusts with periods of a few seconds and longer (lower frequency), using conventional measuring equipment such as the Climet Model CI-14 anemometer which was used to measure the wind data for this report. The response characteristics of the Climet Model CI-14 anemometer are presented in References 2 through 4.

II. GUST CHARACTERISTICS

Before discussing the characteristics of a gust, it is expedient to define the wind gust as used in this report. A wind gust is defined as a build-up in the measured instantaneous* wind speed above a two-minute arithmetic mean wind speed to an amplitude equal to or greater than 0.5 meters per second and a decay back to the mean wind speed. The two-minute mean was computed for the first two minutes of a given set of wind data. The numerical difference between the measured instantaneous and the mean wind speeds was determined using a data interval of 0.5 second and tabulated in a frequency distribution. These differences were used to determine the statistical gusts. After all the differences (gust values) had been determined for the first two-minute mean and tabulated, a second two-minute mean was computed for the second and third minutes of the given set of wind data. The gusts for this two-minute mean were also determined and tabulated. This procedure was then stepped to the third and fourth minutes, fourth and fifth minutes, etc., until all of the wind data in the given wind record were used.

The wind gusts as determined by the procedure described above had the following characteristics: (1) An amplitude equal to or greater than the specified value of 0.5 meters per second, where the amplitude of a gust is defined to be the maximum difference between the mean and measured instantaneous wind speeds occurring within a gust. (2) A period equal to or greater than 4.0 seconds and equal to or less than 58.0 seconds ($4.0 \leqq P \leqq 58.0$). The reason for the 4.0 second minimum is that even though a gust could be defined (obtained) for a shorter period than 4.0 seconds, it was believed that the gust would be more realistically defined for the longer period. Thus, a 4.0 second minimum period was arbitrarily selected. The upper limit of 58.0 seconds was used as a cut-off point for reasons of convenience.

The gusts as defined above were classified according to gust duration period and sensor location. Class intervals for the duration period were 4.0-5.9, 6.0-7.9, 8.0-9.9, 10.0-13.9, 14.0-17.9, ..., 54.0-58.0 seconds. The starting point of a gust is the point where the measured instantaneous wind speed crosses the mean wind speed, and the end of a gust is the point where the measured instantaneous wind speed returns to the mean. Thus, it is readily seen there will, in all probability, be fewer gust points used to determine the statistics at the end of a gust than at the start and mid-portion of a gust. After all of the gusts had

---

*Instantaneous as used in this report refers to the wind speed values recorded at 0.5-second intervals using the Climet Model CI-14 anemometer and an Ampex FR-1200 magnetic tape system.

been classified, they were tabulated in a cumulative frequency distribution (CFD). The 50, 90, 95, and 99 percentage levels from the CFD's are plotted in figures 1 through 31. Figures 32 and 33 show the percentage of occurrence of gusts as a function of gust duration period. These figures show, as expected, the largest percentage of the gusts occur in the shortest gust duration period.

Figures 1 through 31 are referred to as the statistical gusts, which can be characterized by three factors: (1) a fast build-up rate, (2) a constant mid-portion, and (3) a fast decay rate. The decay rate, however, is not quite so fast as the build-up rate. An analysis of the reasons for this difference in the accelerations (build-up and decay rates) is beyond the scope of this report. It is anticipated, however, that a study of this difference will be made in the near future.

A check was made to see if the accelerations obtained for the statistical gusts were feasible. This was done by comparing the statistical gust accelerations with the theoretical maximum (limiting) acceleration possible for the anemometers used to obtain the wind data for this study (the Climet Model CI-14). The limiting acceleration was computed by use of

$$\frac{dU}{dt} = \Delta U \frac{U_e}{L} \exp\left(-\frac{U_e t}{L}\right), \tag{1}$$

where (reference 4)

$$U = \Delta U \left[1 - \exp\left(-\frac{U_e t}{L}\right)\right], \tag{2}$$

and ΔU is the change in wind speed, U_e is the final equilibrium wind speed value, L is the distance constant (0.73 meters), and t is time. The computation was performed using a time constant equal to one $\left(\frac{U_e t}{L} = 1\right)$. Several curves were computed (different ΔU values) in order that the feasibility of the acceleration rates of the statistical gusts could be checked. The feasibility of the statistical gust maximum acceleration rates can be easily checked by comparing them with the theoretical rates in figure 34. This comparison can be made by determining the slope (acceleration) of a given statistical curve. For example, the 99 percent statistical gust acceleration for the first half-second in figure 3 is approximately 8.0 m/sec^2. The 8.0 m/sec^2 value should be compared to the value of approximately 32.0 m/sec^2 given in figure 34 for an equilibrium speed of 16.2 m/sec and a ΔU of 4.0 m/sec. Thus, the comparison shows that the 8.0 m/sec^2 value is a physically possible acceleration. The procedure for determining the values cited is as follows:

(1) The acceleration for the statistical curve was found by dividing the wind speed change (ΔU) by the time interval (Δt) of the data

$$\frac{\Delta U}{\Delta t} \simeq \frac{4.0}{0.5} = 8.0 \text{ m/sec}^2. \tag{3}$$

(2) However, before the acceleration values given in figure 34 can be used, the mean wind speed value must be determined for the statistical gust shape. This mean may be estimated by use of the gust factor equation

$$GF = \frac{\bar{U} + U'}{\bar{U}} , \tag{4}$$

where GF is the gust factor and is found to be 1.45 (reference 5), $\bar{U}$ is the mean wind speed and U' is the maximum wind speed occurring within the gust (5.5 m/sec in this case, fig. 3). Thus, the mean is found to be approximately 12.2 m/sec. The gust factor value of 1.45 was determined [5] from 2957 data samples obtained for the month of September 1966, for a height of 18 meters at the Kennedy Space Center, Florida. For other heights, wind speeds, stability, etc., different gust factors may be obtained.

(3) From figure 3 it is seen that for $\Delta U = 4$ m/sec and $U_e = \bar{U} + \Delta U = 16.2$ m/sec the theoretical maximum acceleration possible for the Climet anemometer is approximately 32.0 m/sec^2. Using this type of comparison any acceleration found for a given anemometer (in this case, a Climet) may be checked to determine if the measured wind speed changes (accelerations) are possible.

Histograms were determined for the number of gusts obtained from the wind records used in this program versus gust duration time. These histograms are presented in figures 32-33. These histograms show that the largest percentage of gusts occur for the shortest duration period. Furthermore, there is no significant difference between the histograms for the various heights.

III. COMMENTS

This report has shown that a statistical gust shape is characterized by three factors: (1) fast build-up rate, (2) constant mid-portion, and (3) fast decay rate. It was also shown that the largest percentage of gusts occur for the shortest gust duration period. Furthermore, it has been shown that the Climet Model CI-14 is capable of measuring faster build-up and decay rates than observed in the free atmosphere and presented in this report.

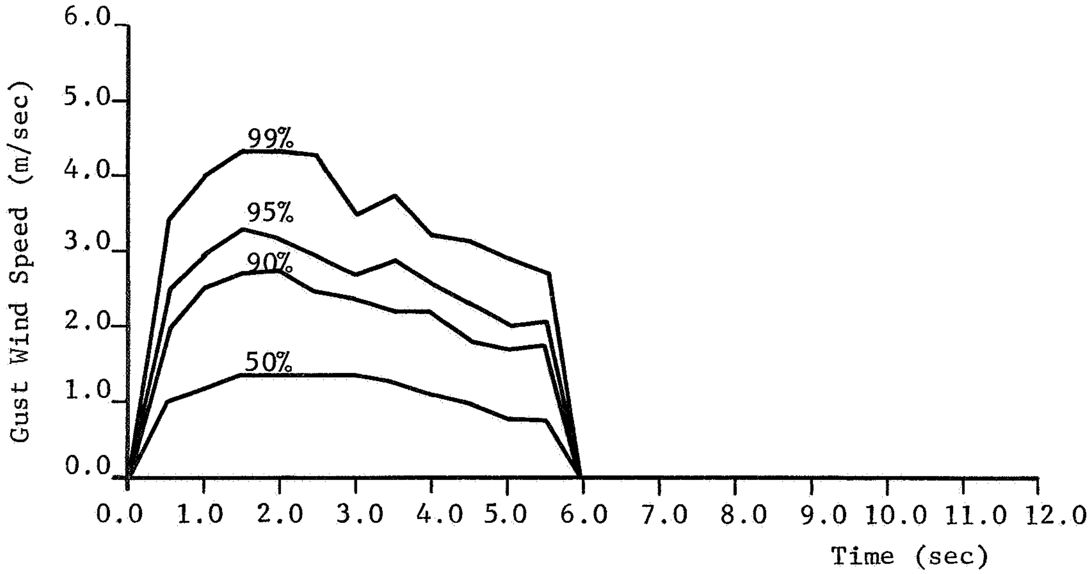

Fig. 1. Statistical Gust Based on 678 Gusts Having a Time Duration of 4 to 6 Seconds Occurring at the 18-meter Level

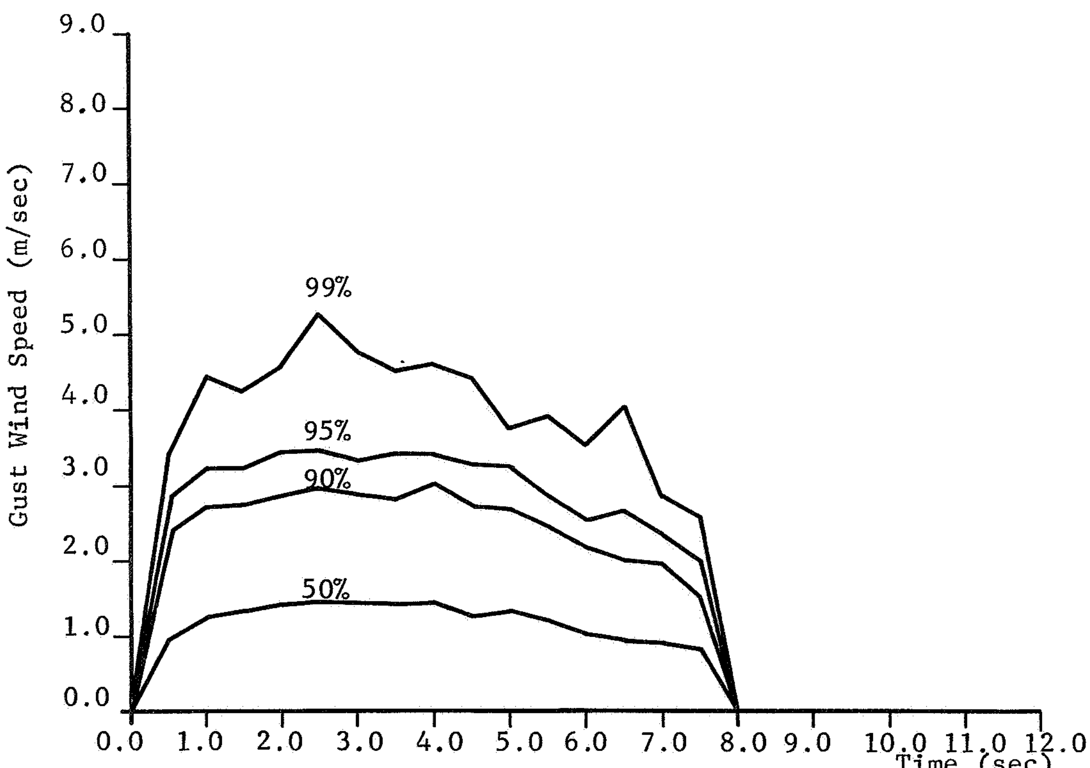

Fig. 2. Statistical Gust Based on 363 Gusts Having a Time Duration of 6 to 8 Seconds Occurring at the 18-meter Level

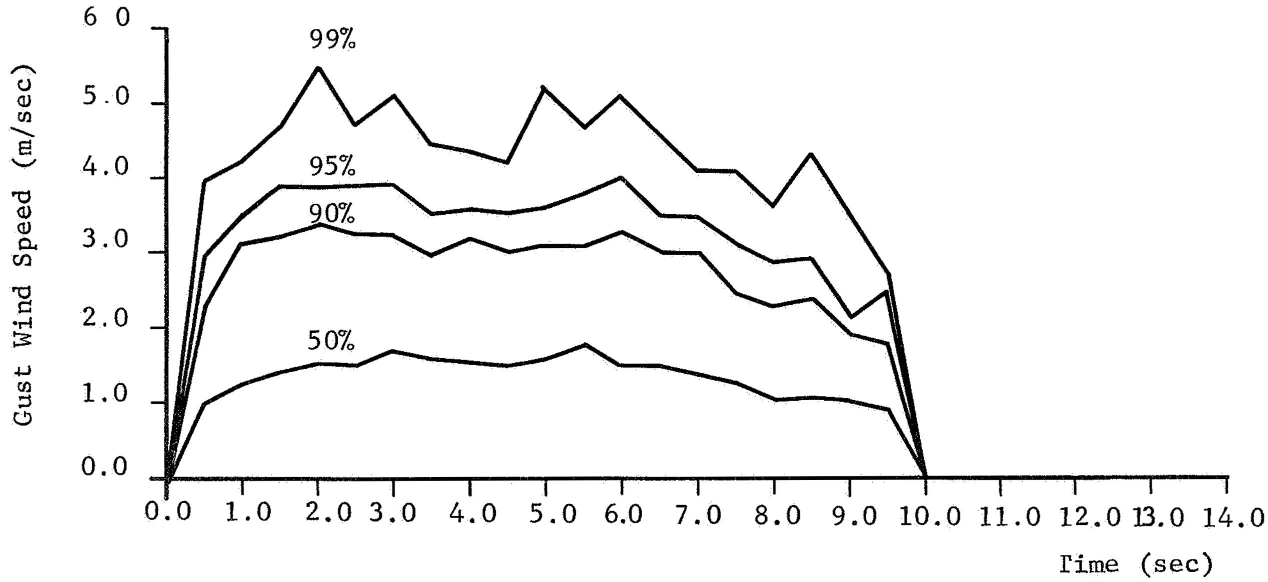

Fig. 3. Statistical Gust Based on 216 Gusts Having a Time Duration of 8 to 10 Seconds Occurring at the 18-meter Level

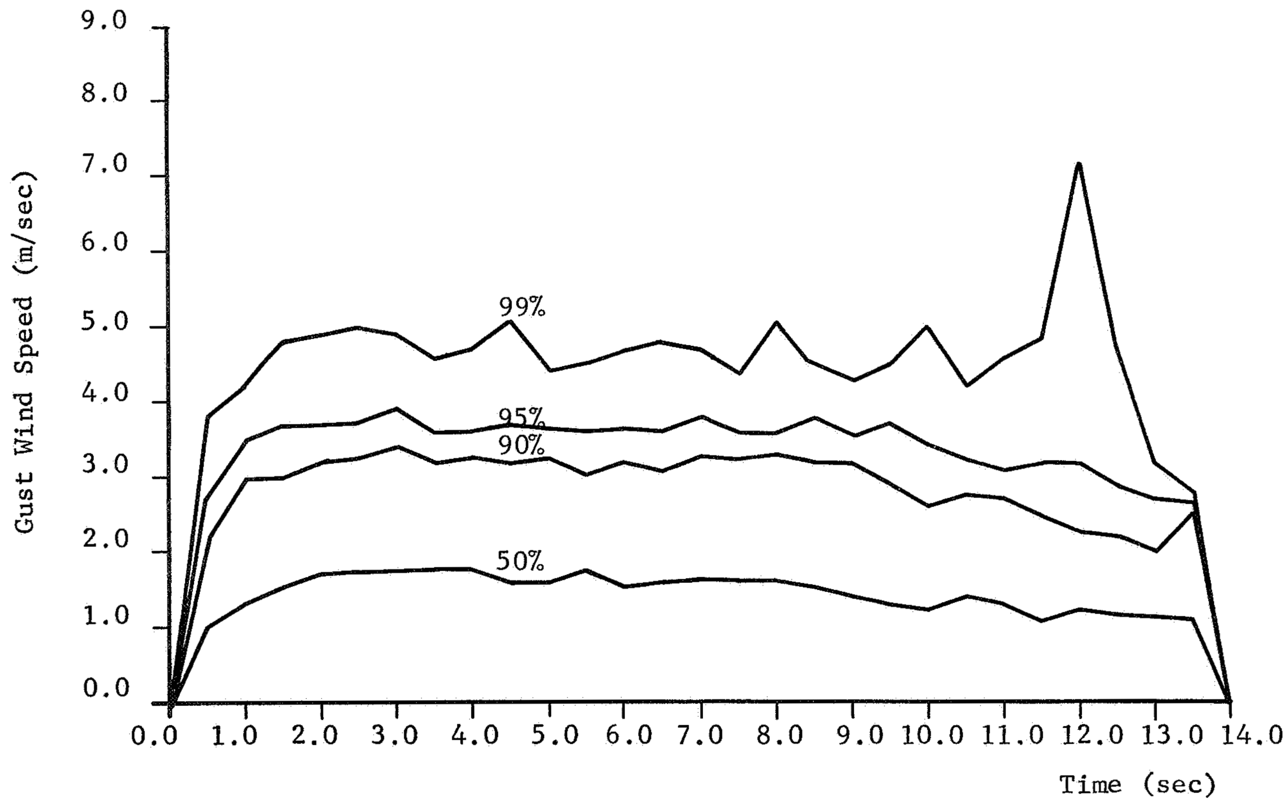

Fig. 4. Statistical Gust Based on 220 Gusts Having a Time Duration of 10 to 14 Seconds Occurring at the 18-meter Level

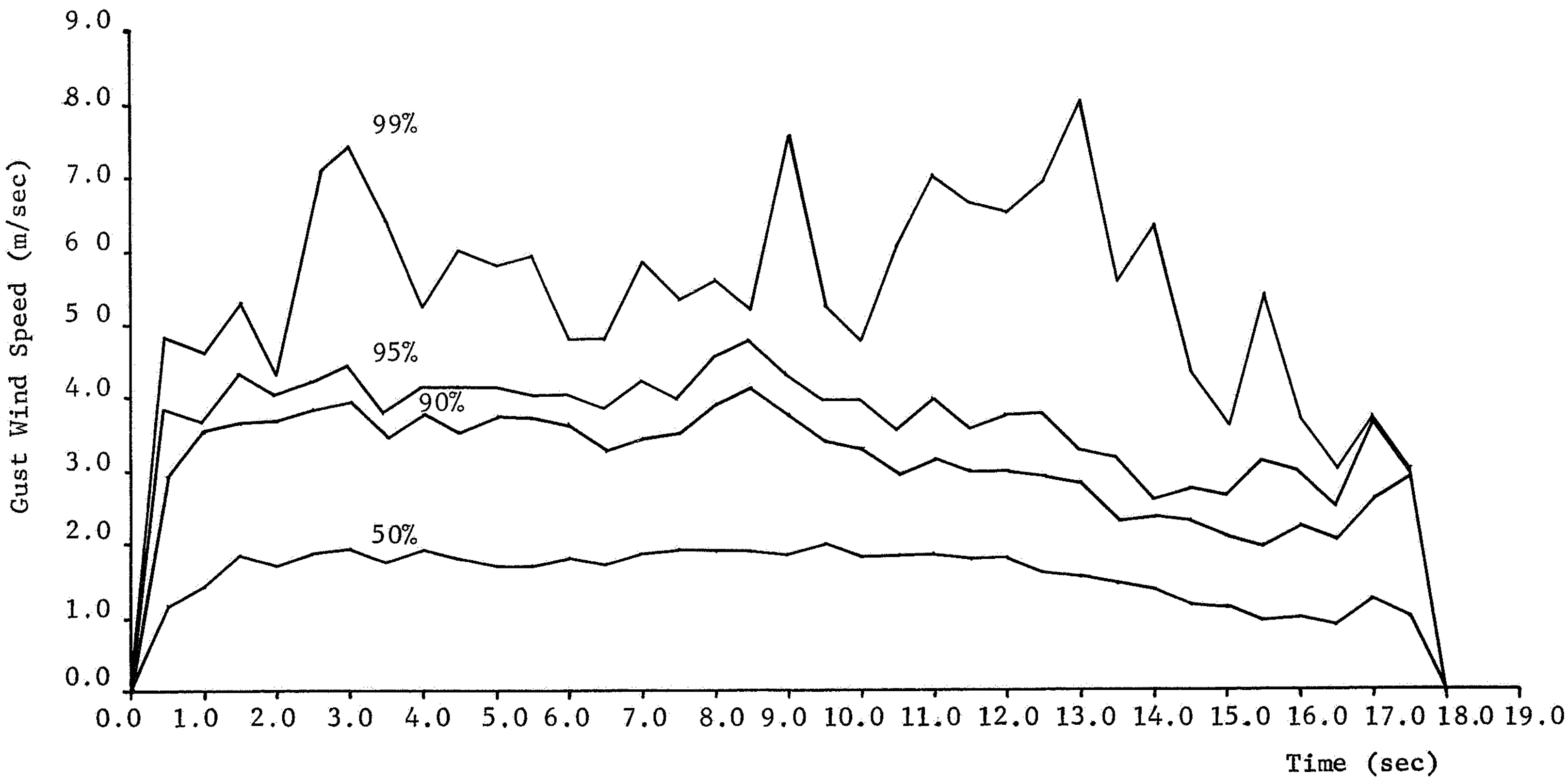

Fig. 5. Statistical Gust Based on 88 Gusts Having a Time Duration of 14 to 18 Seconds Occurring at the 18-meter Level

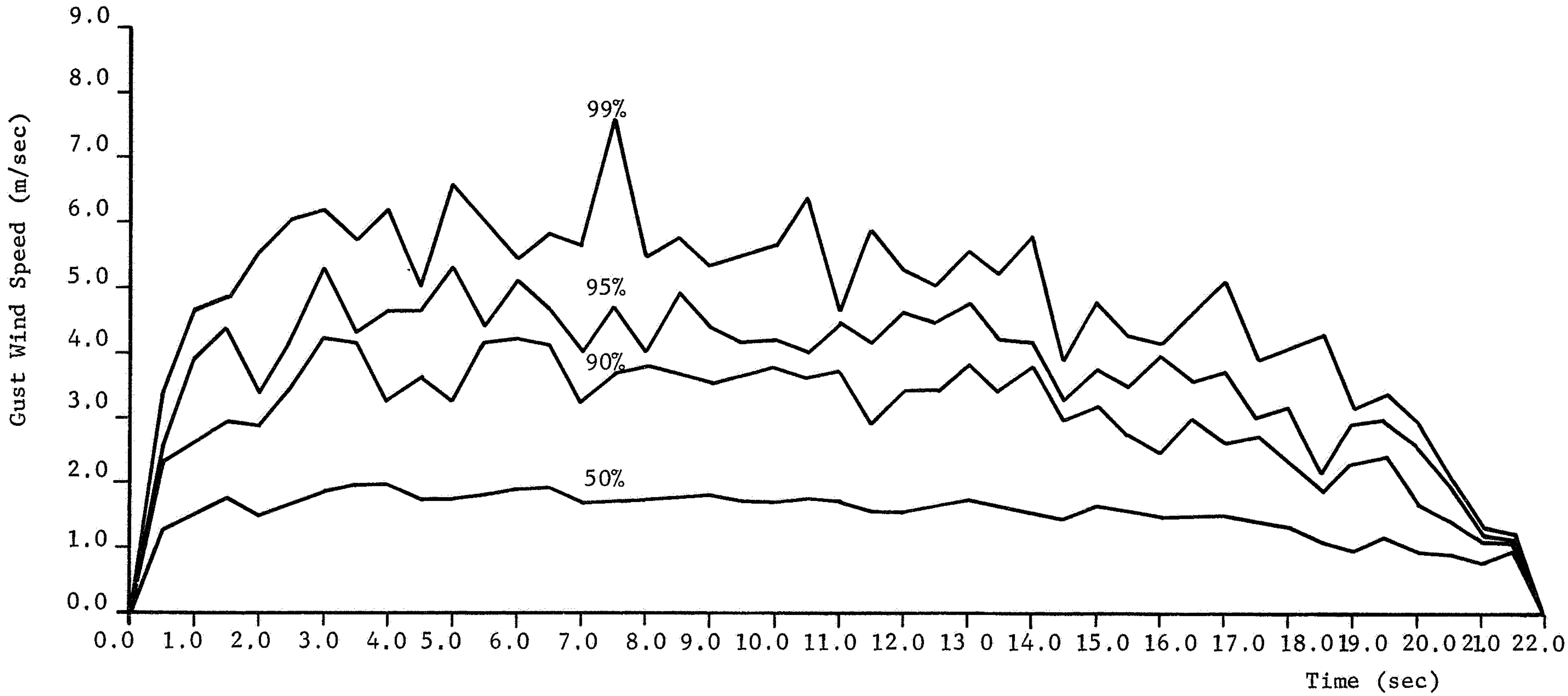

Fig. 6. Statistical Gust Based on 52 Gusts Having a Time Duration of 18 to 22 Seconds Occurring at the 18-meter Level

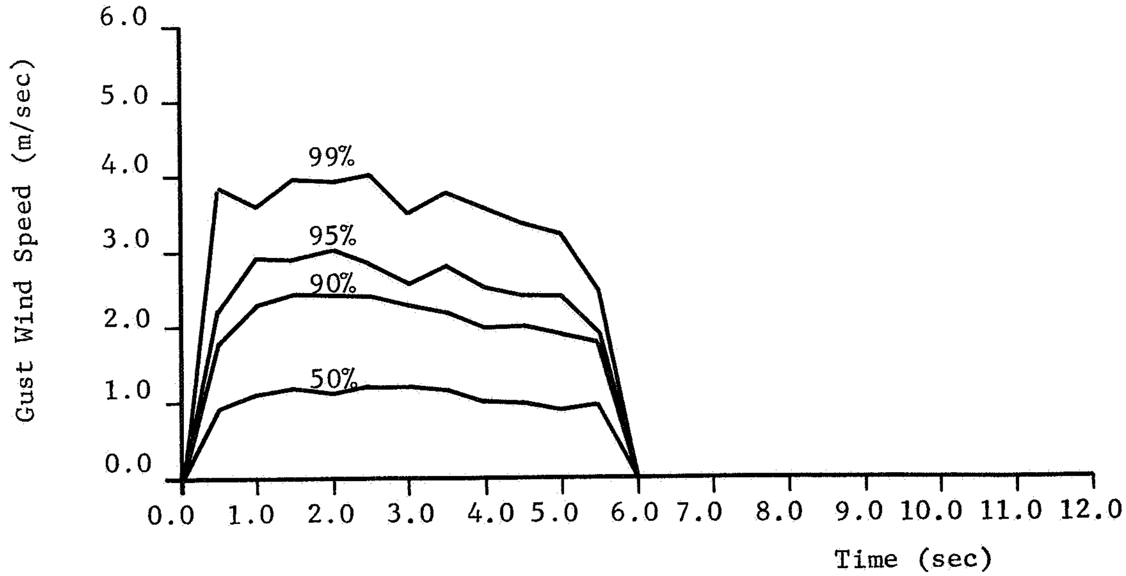

Fig. 7. Statistical Gust Based on 613 Gusts Having a Time Duration of 4 to 6 Seconds Occurring at the 30-meter Level

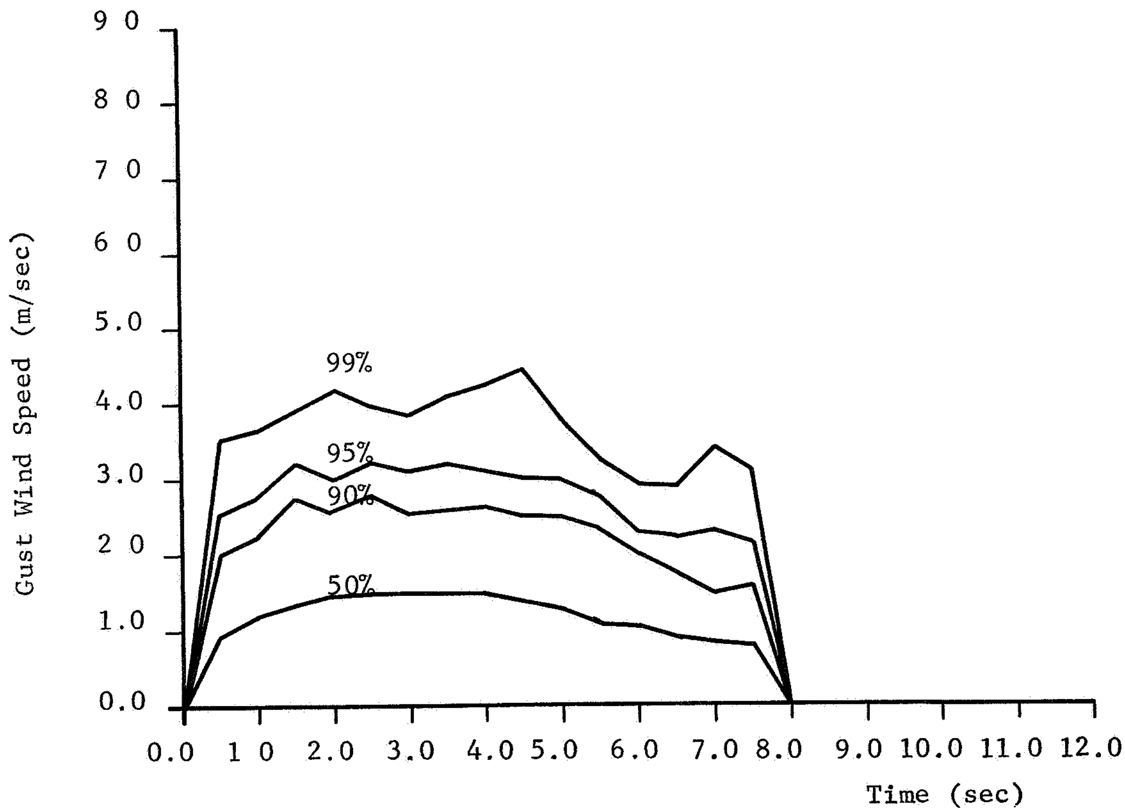

Fig. 8. Statistical Gust Based on 331 Gusts Having a Time Duration of 6 to 8 Seconds Occurring at the 30-meter Level

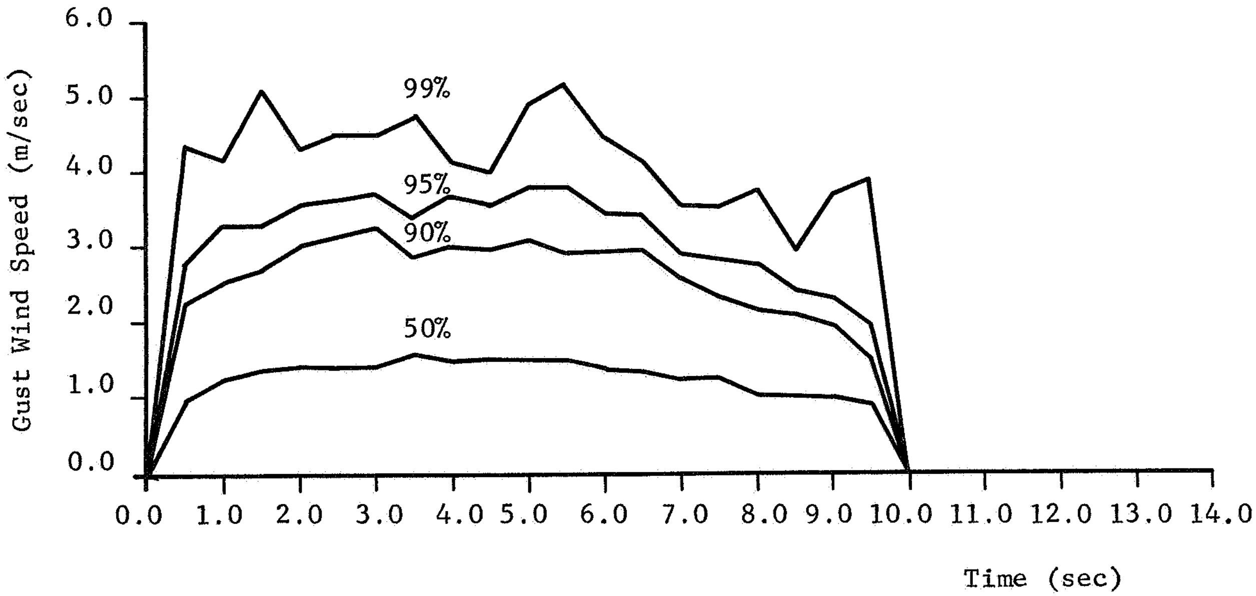

Fig. 9. Statistical Gust Based on 201 Gusts Having a Time Duration of 8 to 10 Seconds Occurring at the 30-meter Level

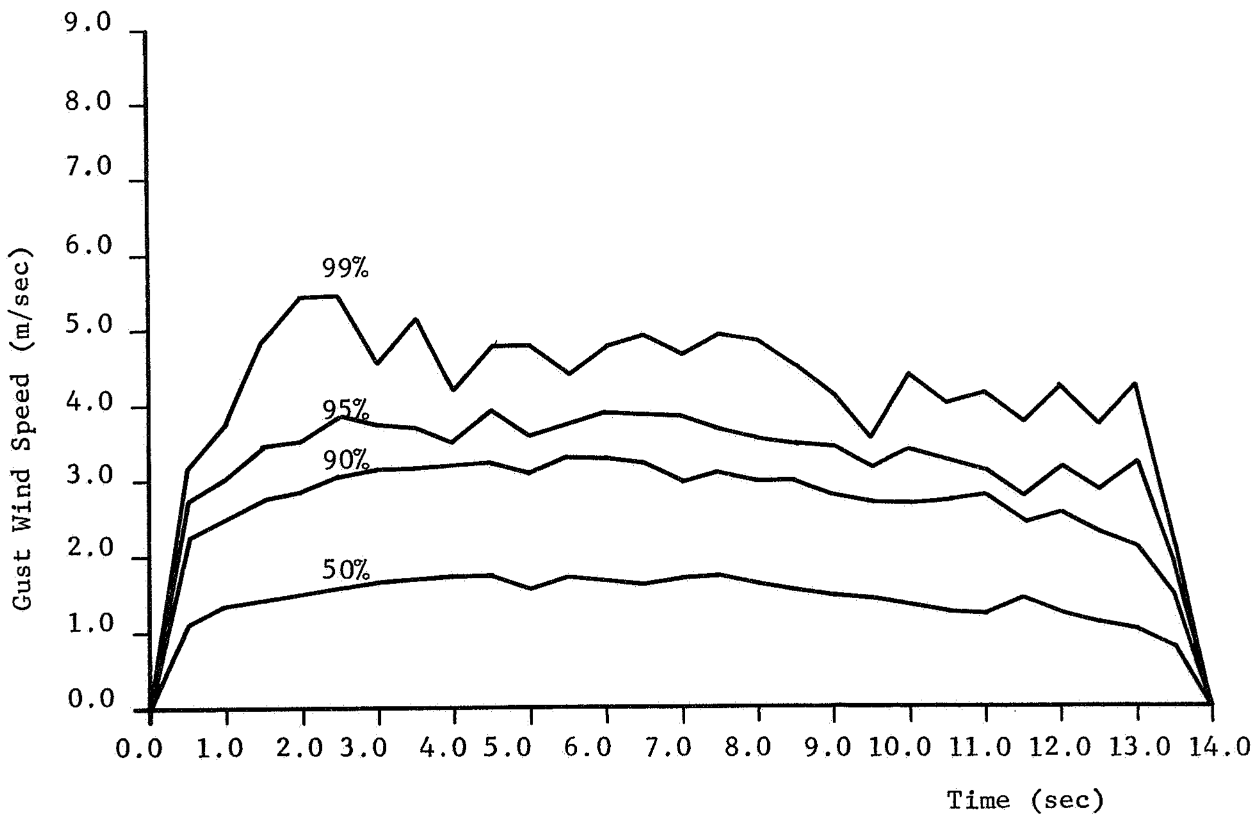

Fig. 10. Statistical Gust Based on 235 Gusts Having a Time Duration of 10 to 14 Seconds Occurring at the 30-meter Level

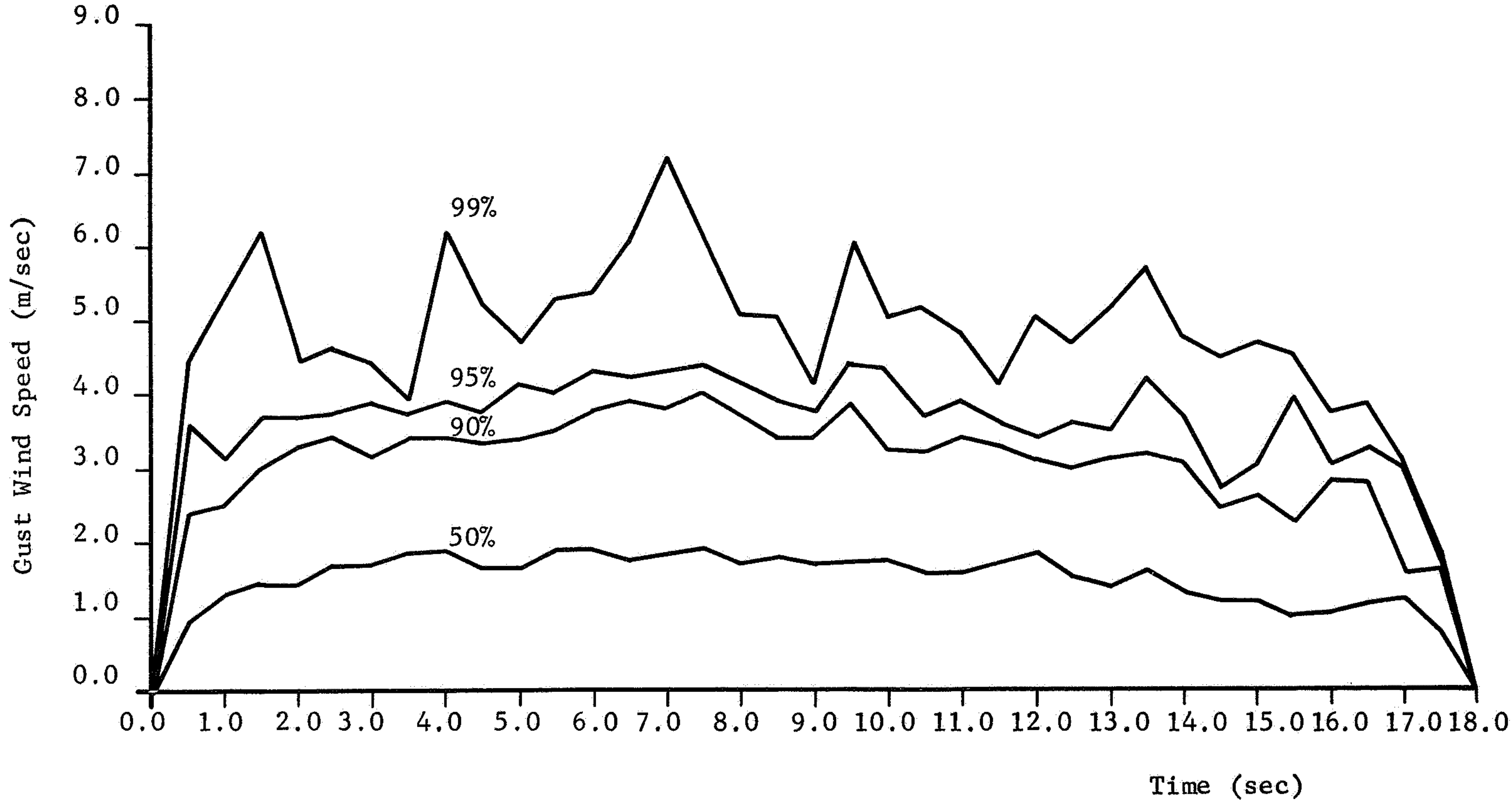

Fig. 11. Statistical Gust Based on 99 Gusts Having a Time Duration of 14 to 18 Seconds Occurring at the 30-meter Level

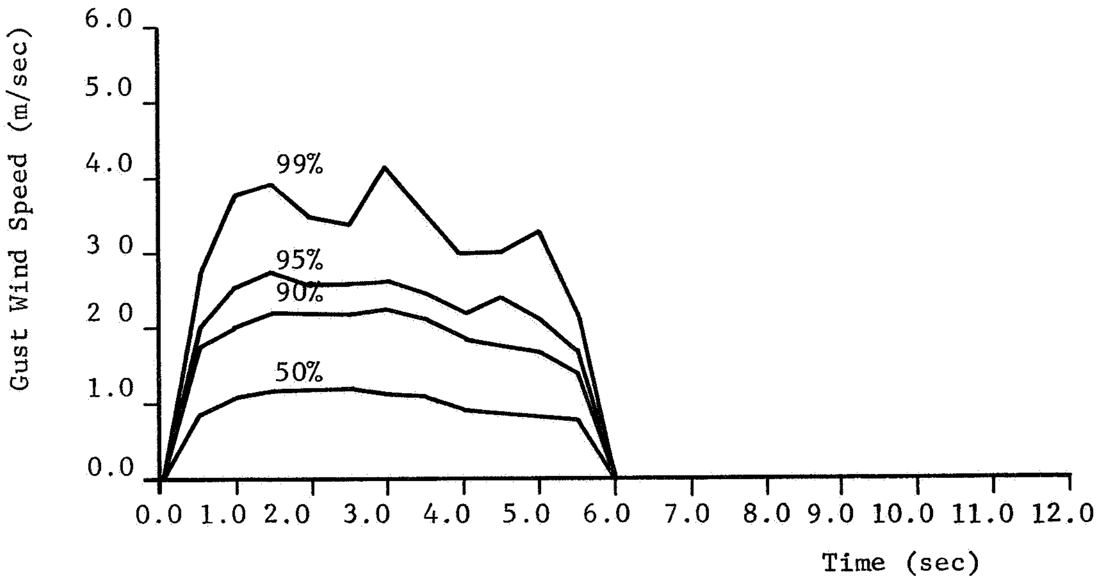

Fig. 12. Statistical Gust Based on 612 Gusts Having a Time Duration of 4 to 6 Seconds Occurring at the 60-meter Level

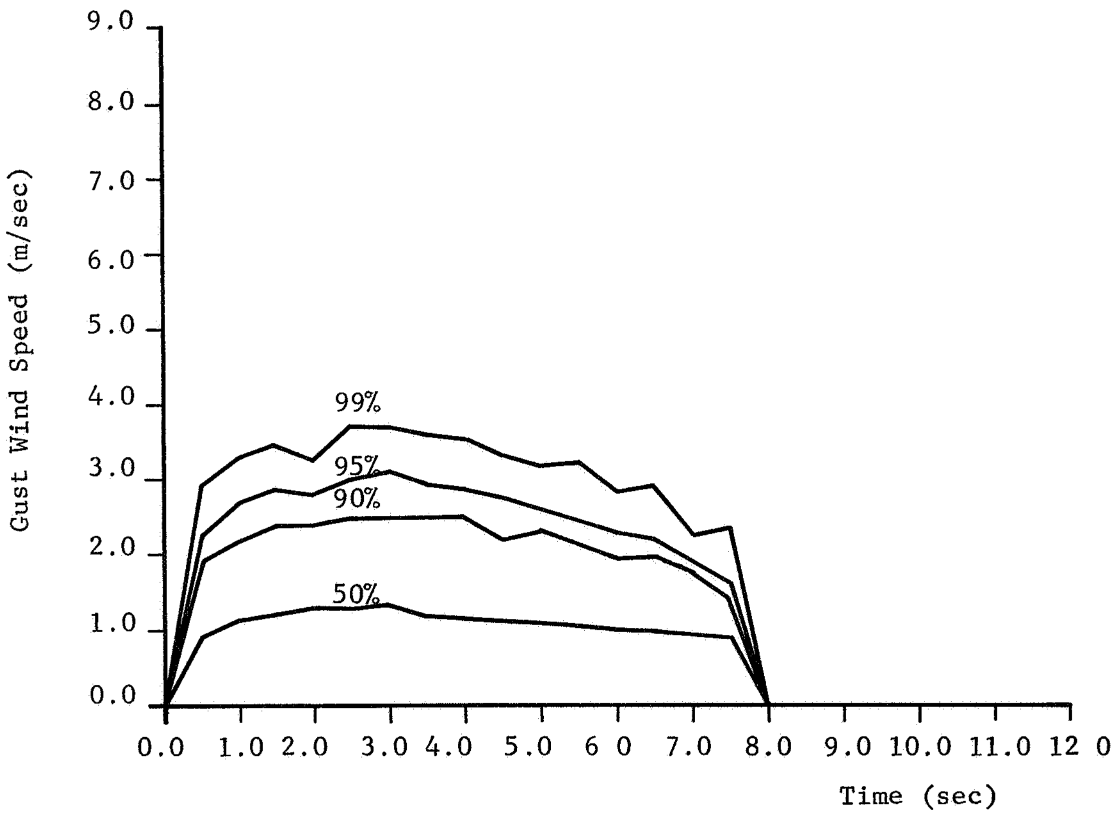

Fig. 13. Statistical Gust Based on 313 Gusts Having a Time Duration of 6 to 8 Seconds Occurring at the 60-meter Level

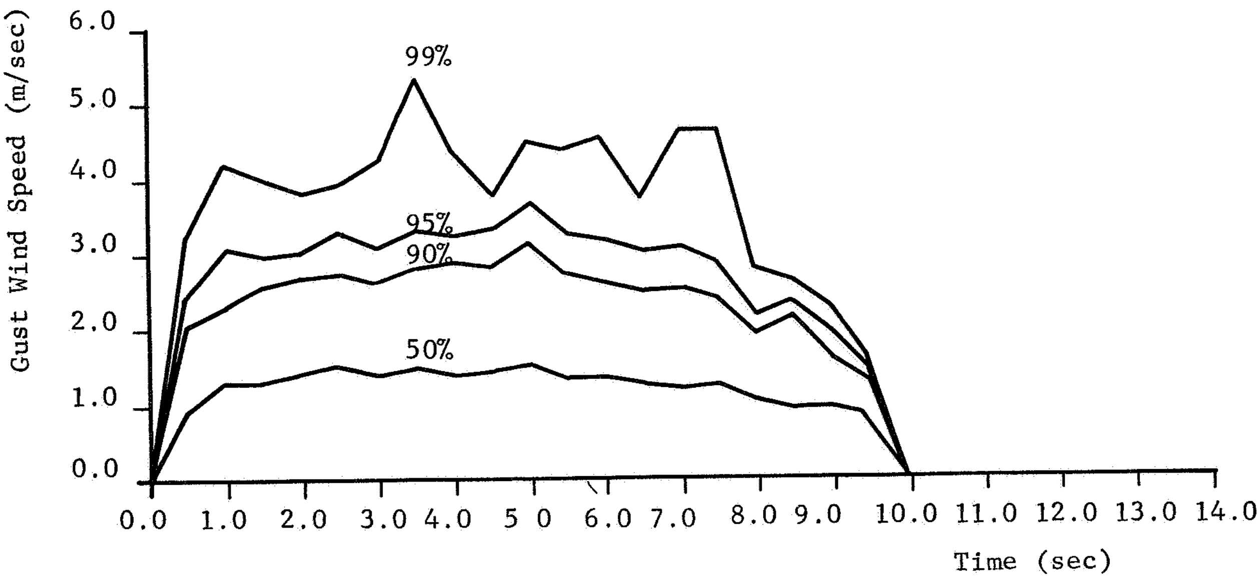

Fig. 14. Statistical Gust Based on 190 Gusts Having a Time Duration of 8 to 10 Seconds Occurring at the 60-meter Level

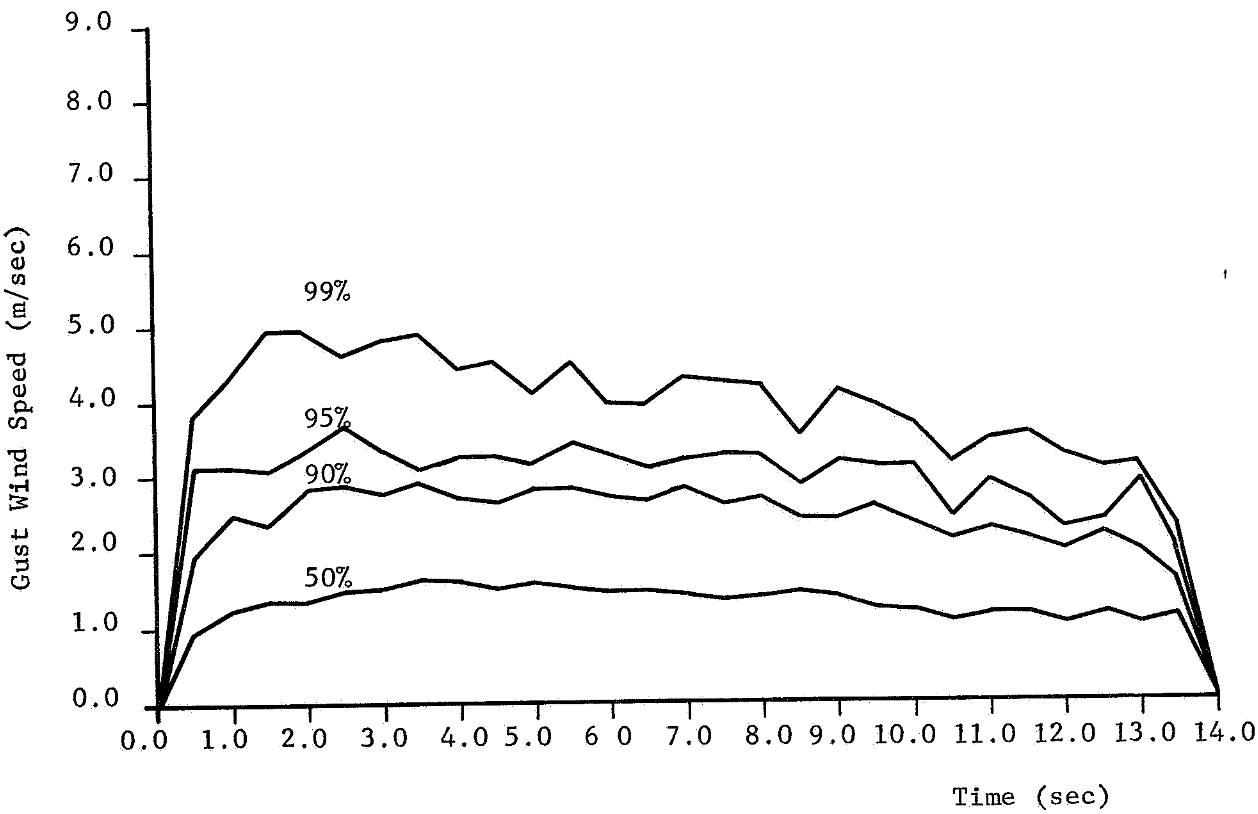

Fig. 15. Statistical Gust Based on 186 Gusts Having a Time Duration of 10 to 14 Seconds Occurring at the 60-meter Level

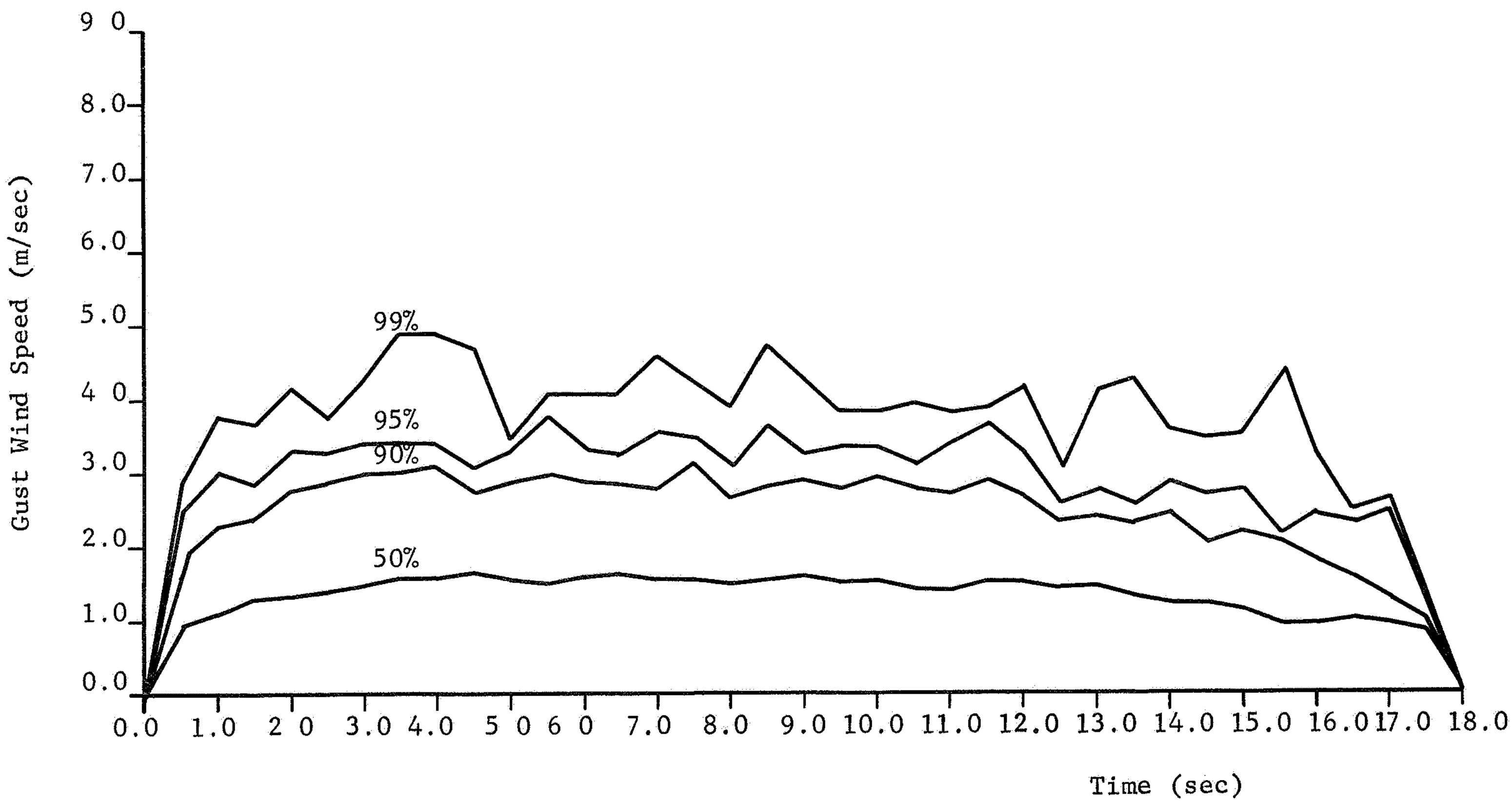

Fig 16. Statistical Gust Based on 130 Gusts Having a Time Duration of 14 to 18 Seconds Occurring at the 60-meter Level

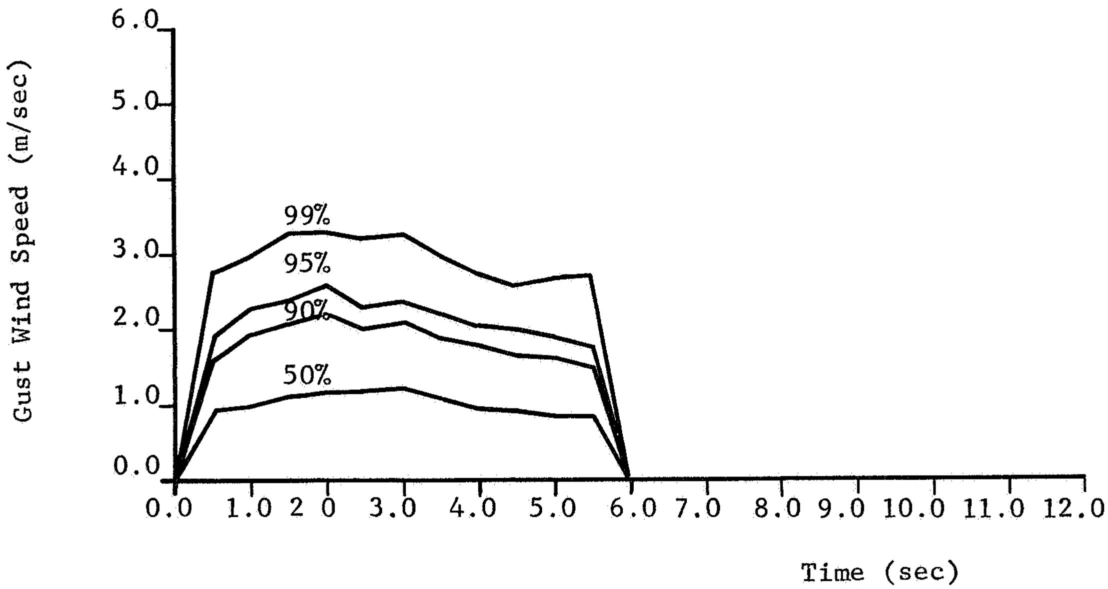

Fig. 17. Statistical Gust Based on 600 Gusts Having a Time Duration of 4 to 6 Seconds Occurring at the 90-meter Level

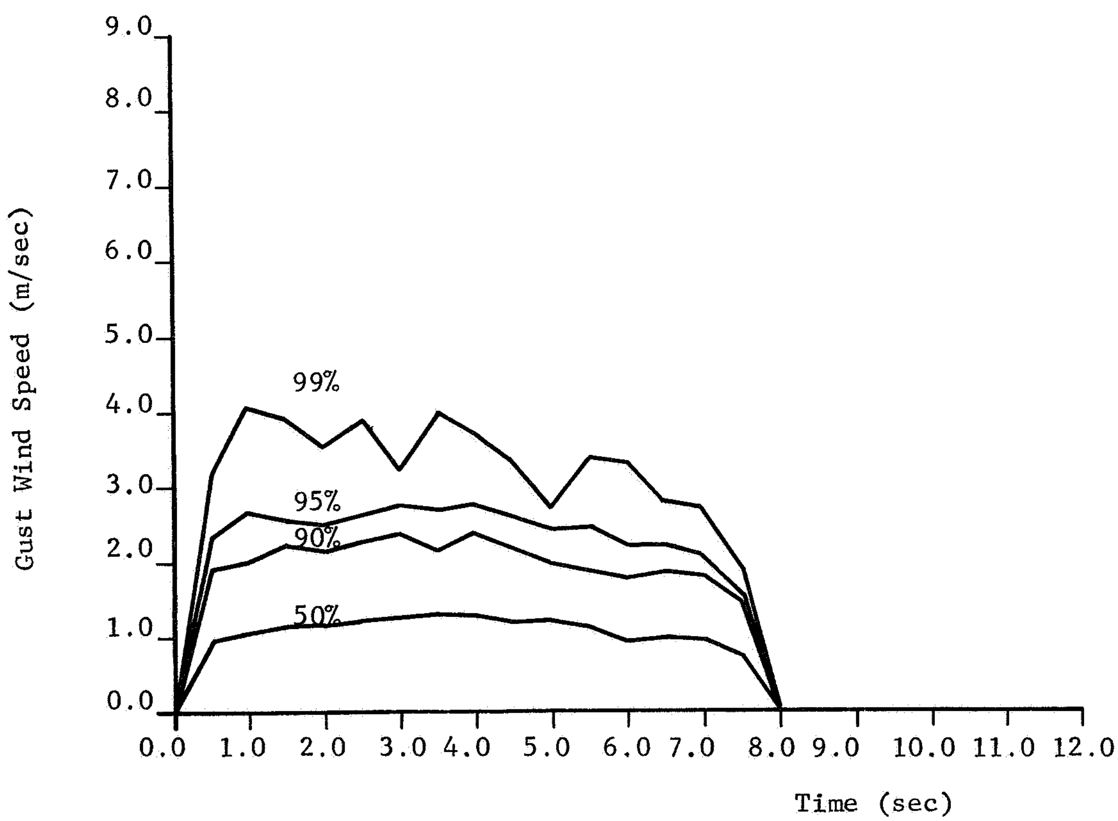

Fig. 18. Statistical Gust Based on 300 Gusts Having a Time Duration of 6 to 8 Seconds Occurring at the 90-meter Level

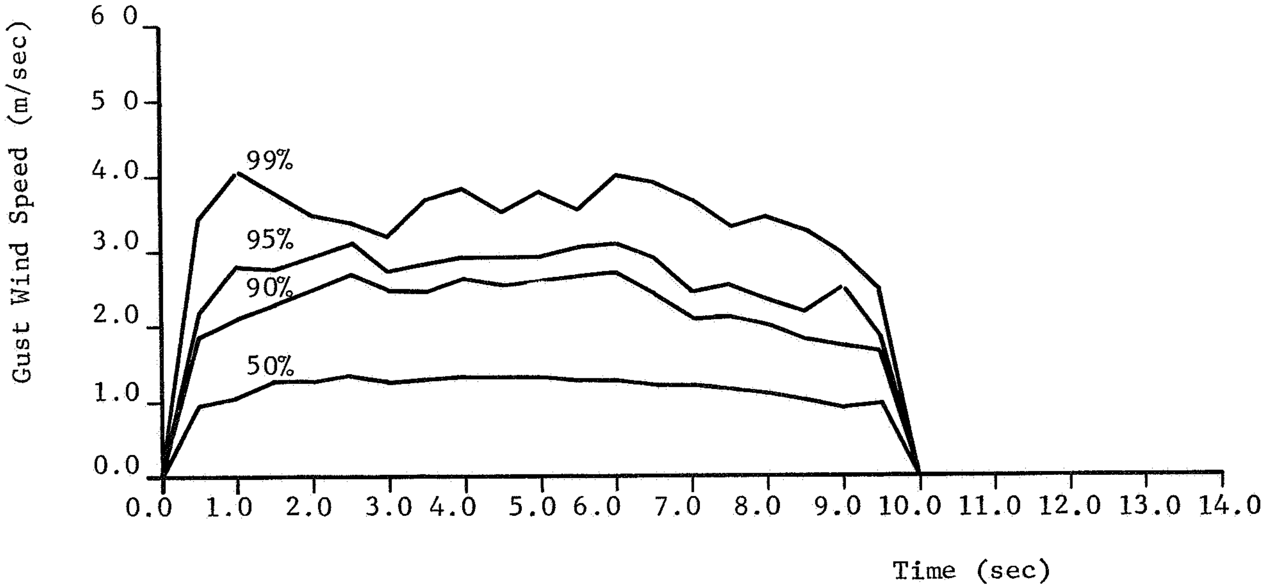

Fig 19. Statistical Gust Based on 196 Gusts Having a Time Duration of 8 to 10 Seconds Occurring at the 90-meter Level

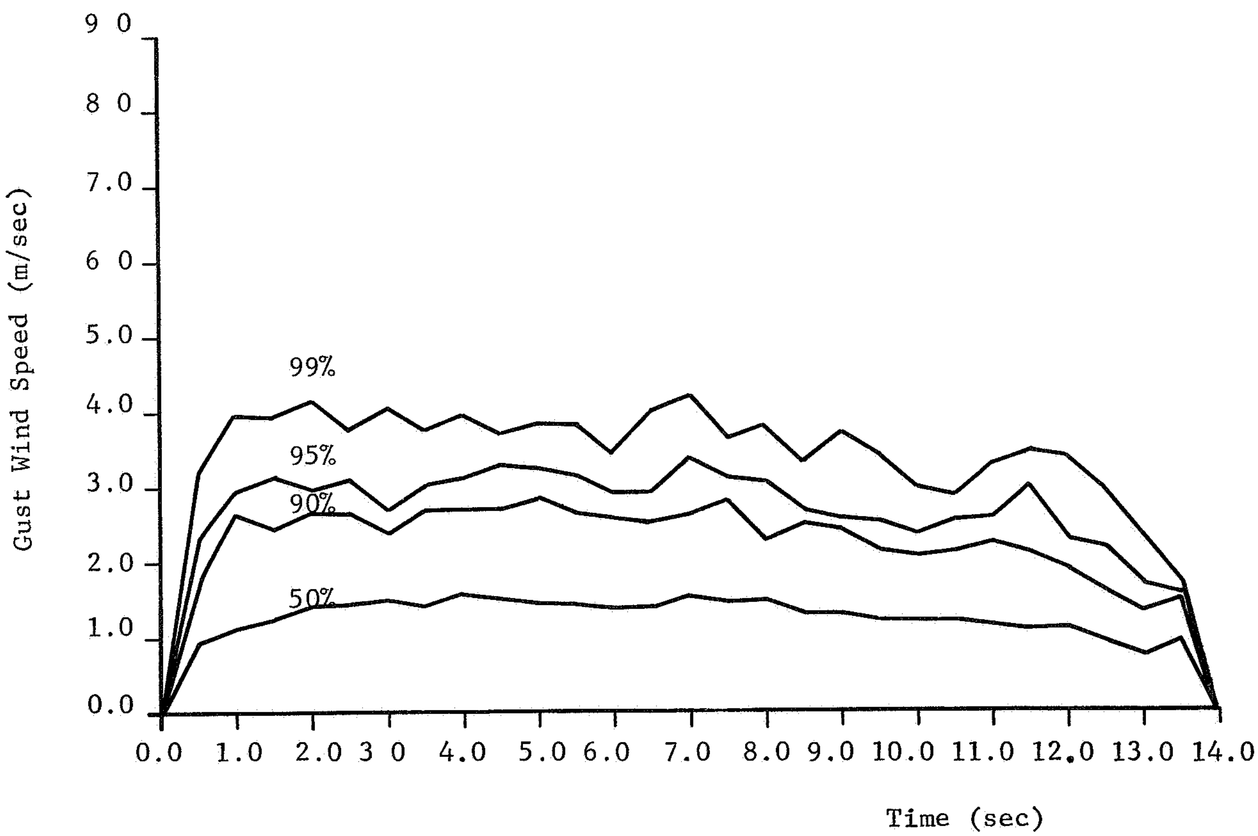

Fig. 20. Statistical Gust Based on 159 Gusts Having a Time Duration of 10 to 14 Seconds Occurring at the 90-meter Level

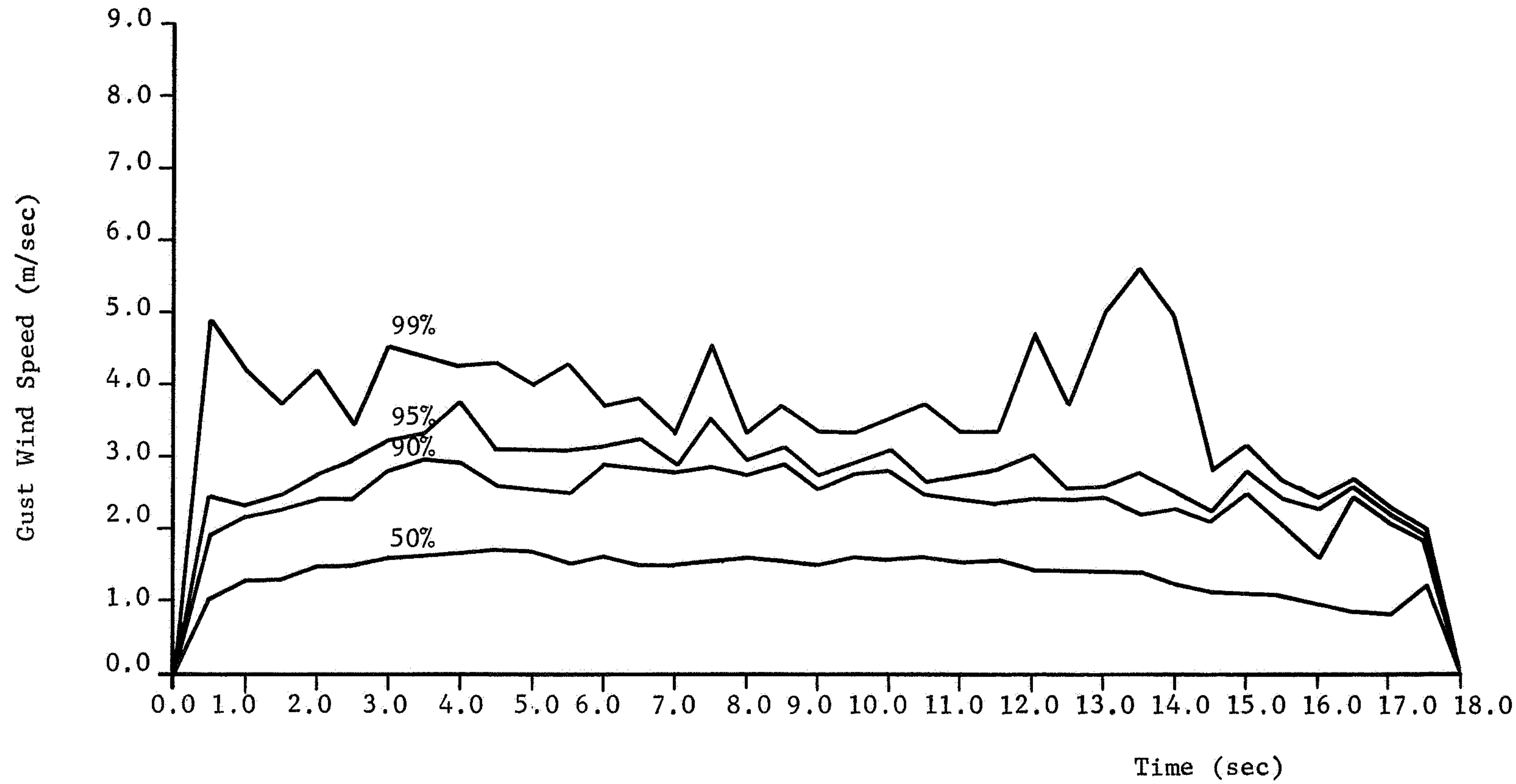

Fig. 21. Statistical Gust Based on 72 Gusts Having a Time Duration of 14 to 18 Seconds Occurring at the 90-meter Level

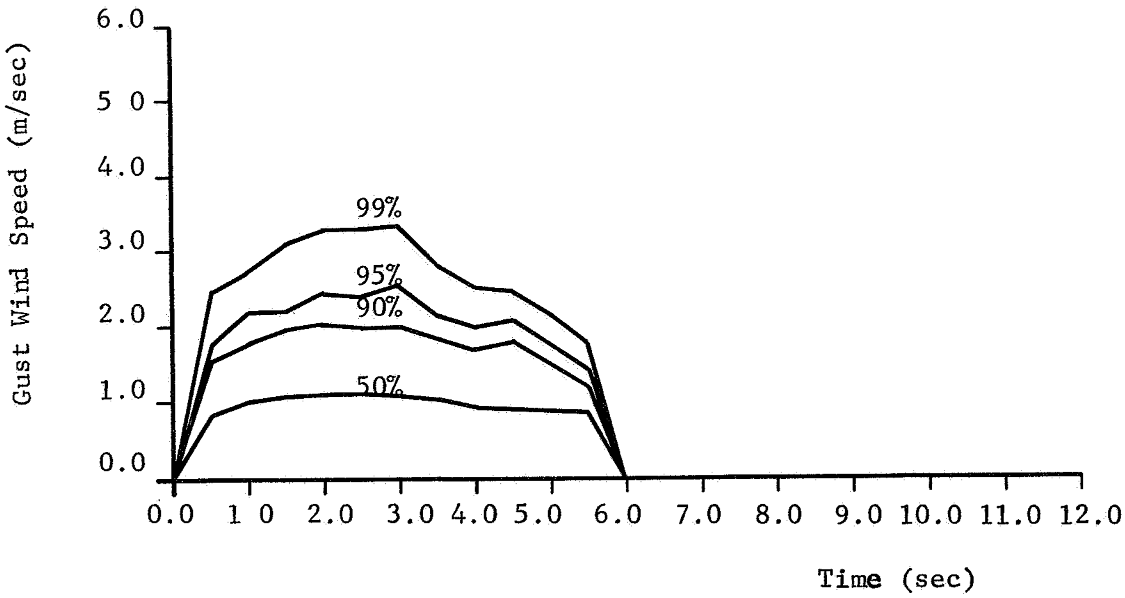

Fig. 22. Statistical Gust Based on 570 Gusts Having a Time Duration of 4 to 6 Seconds Occurring at the 120-meter Level

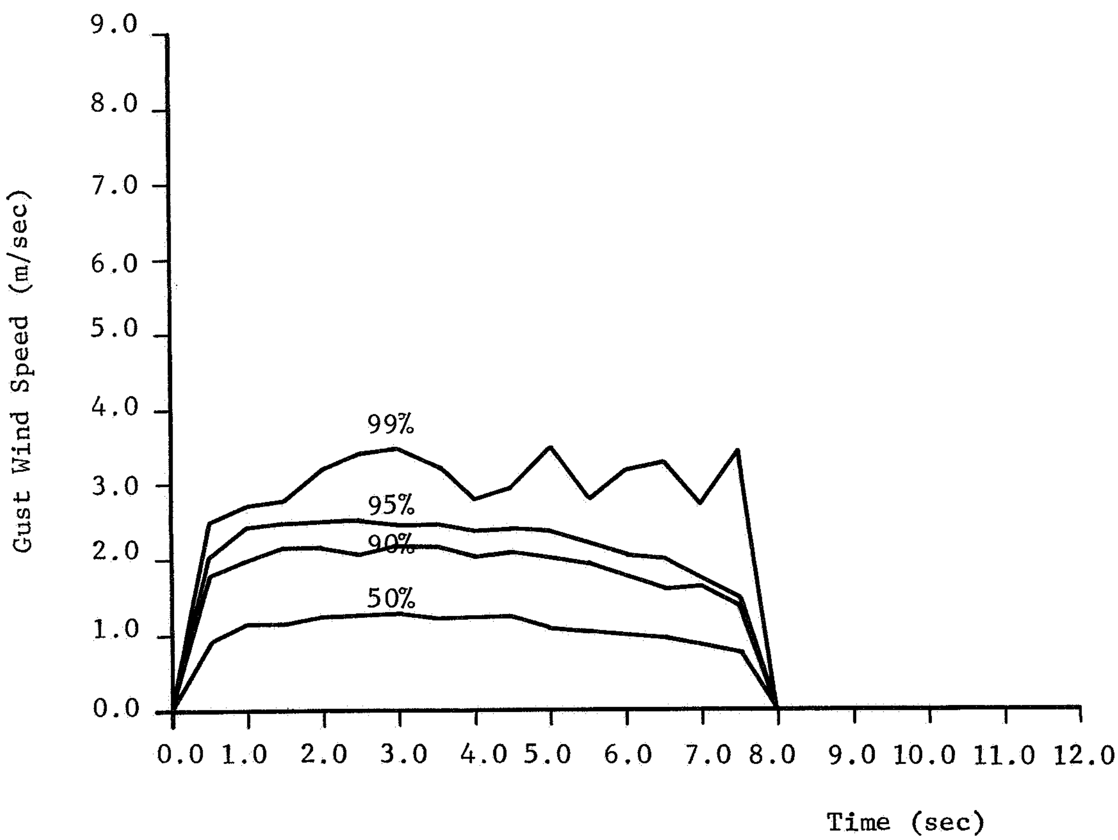

Fig. 23. Statistical Gust Based on 280 Gusts Having a Time Duration of 6 to 8 Seconds Occurring at the 120-meter Level

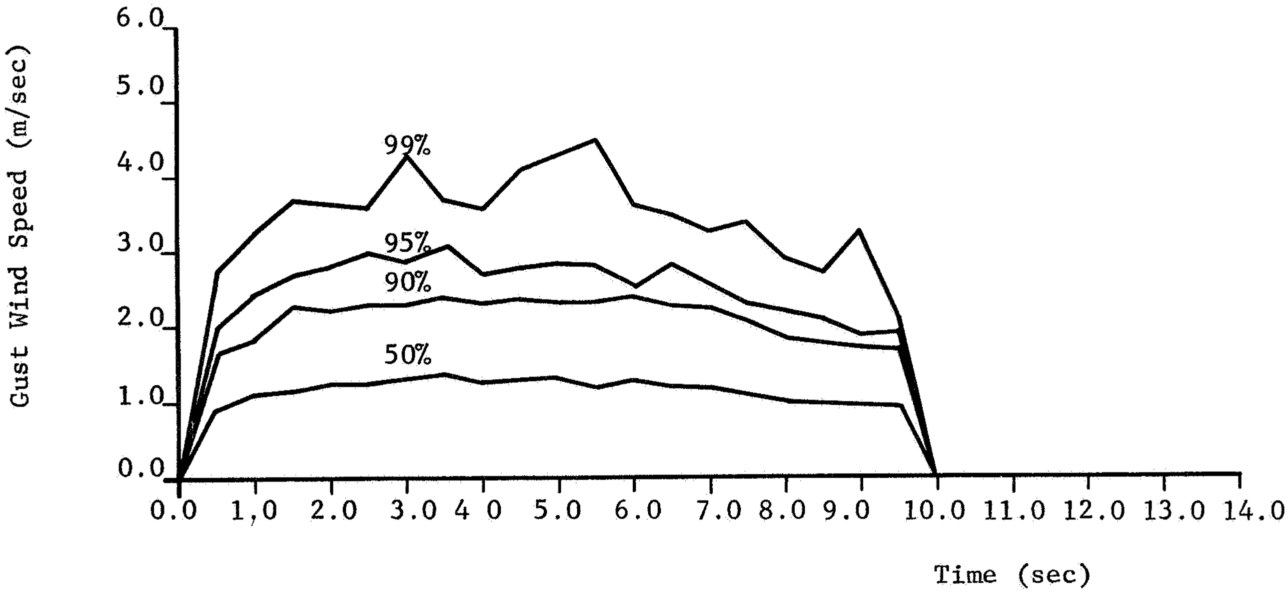

Fig. 24. Statistical Gust Based on 186 Gusts Having a Time Duration of 8 to 10 Seconds Occurring at the 120-meter Level

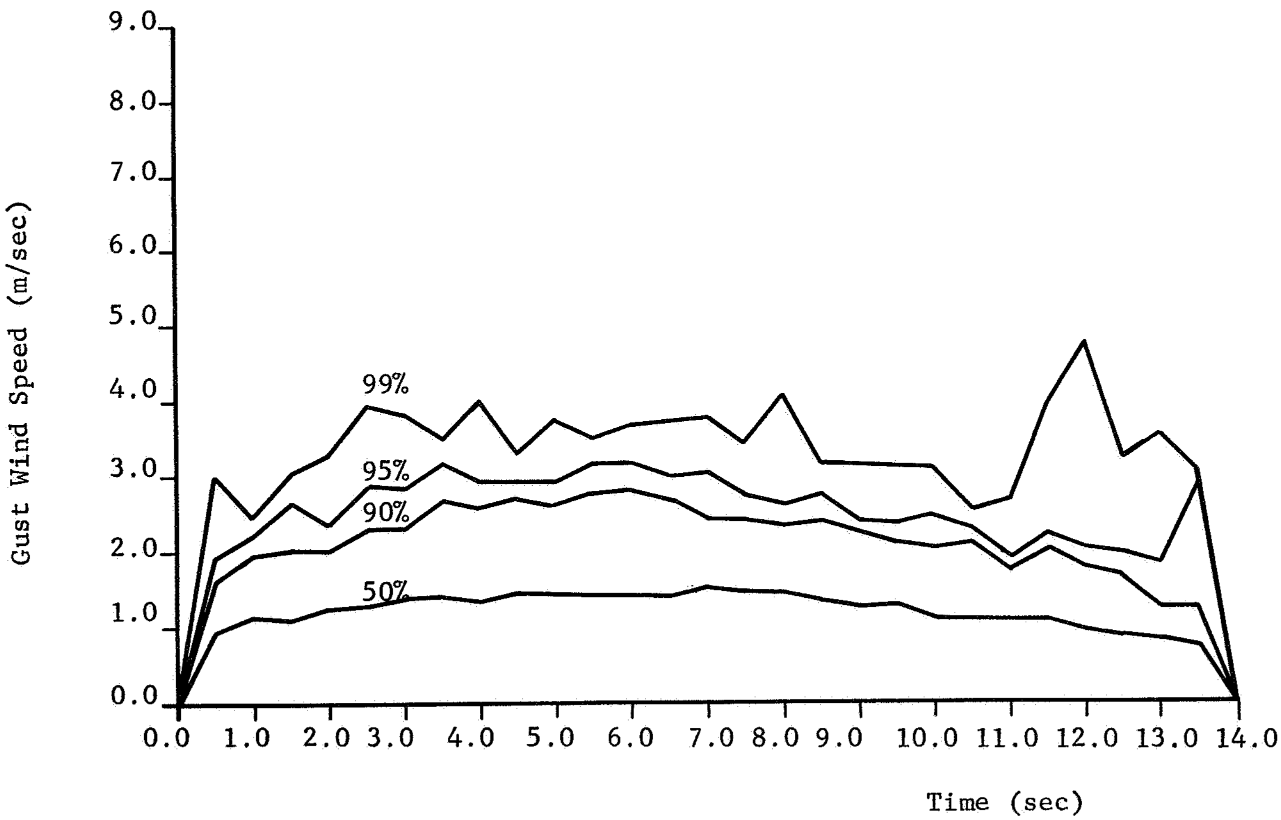

Fig. 25. Statistical Gust Based on 152 Gusts Having a Time Duration of 10 to 14 Seconds Occurring at the 120-meter Level

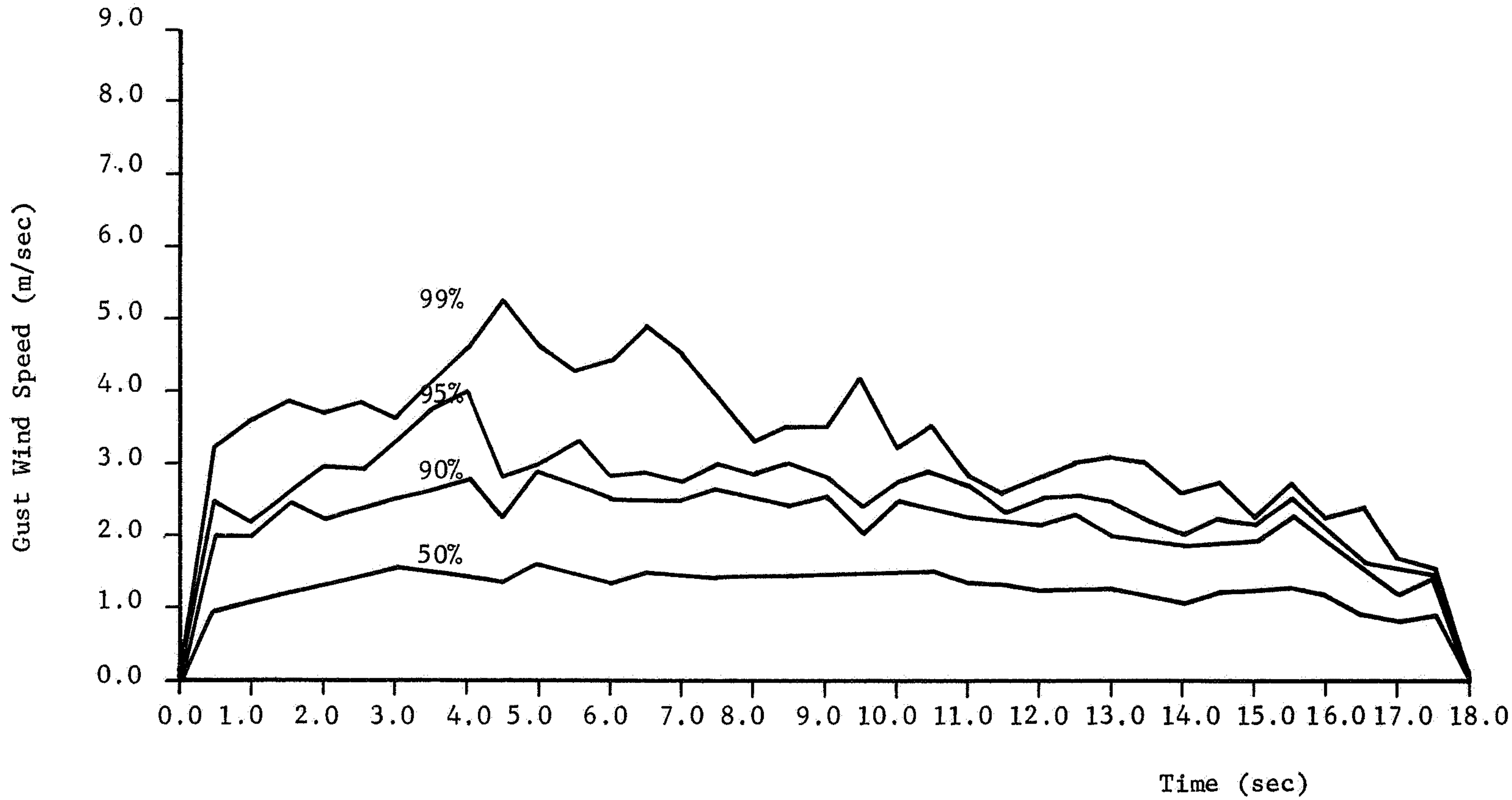

Fig. 26. **Statistical Gust Based on 75 Gusts Having a Time Duration of 14 to 18 Seconds** Occurring at the 120-meter Level

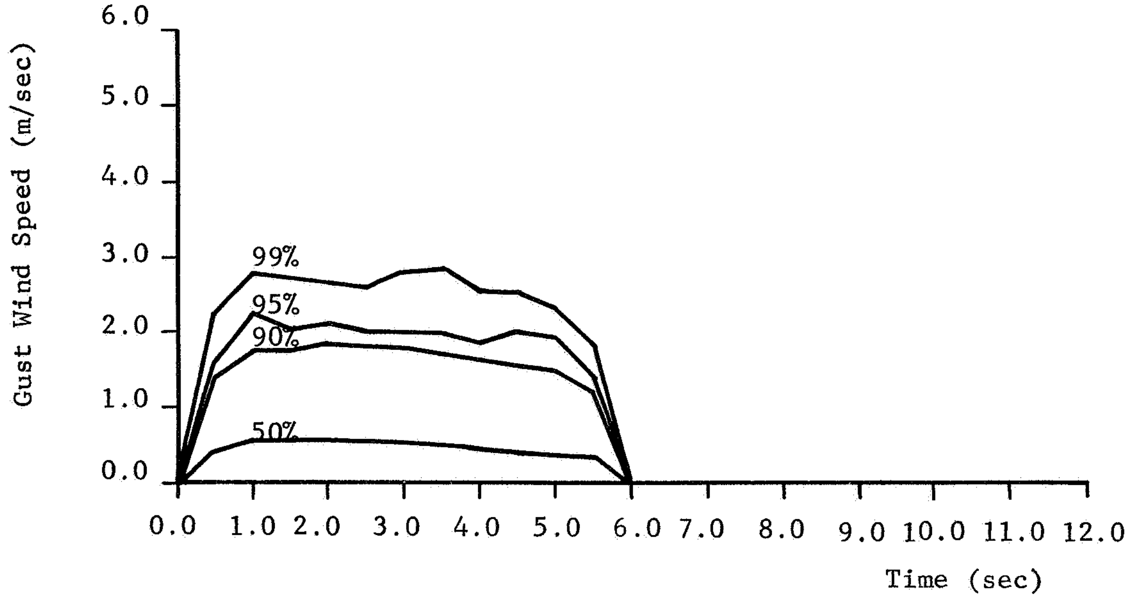

Fig. 27. **Statistical Gust Based on 587 Gusts Having a Time Duration of 4 to 6 Seconds Occurring at the 150-meter Level**

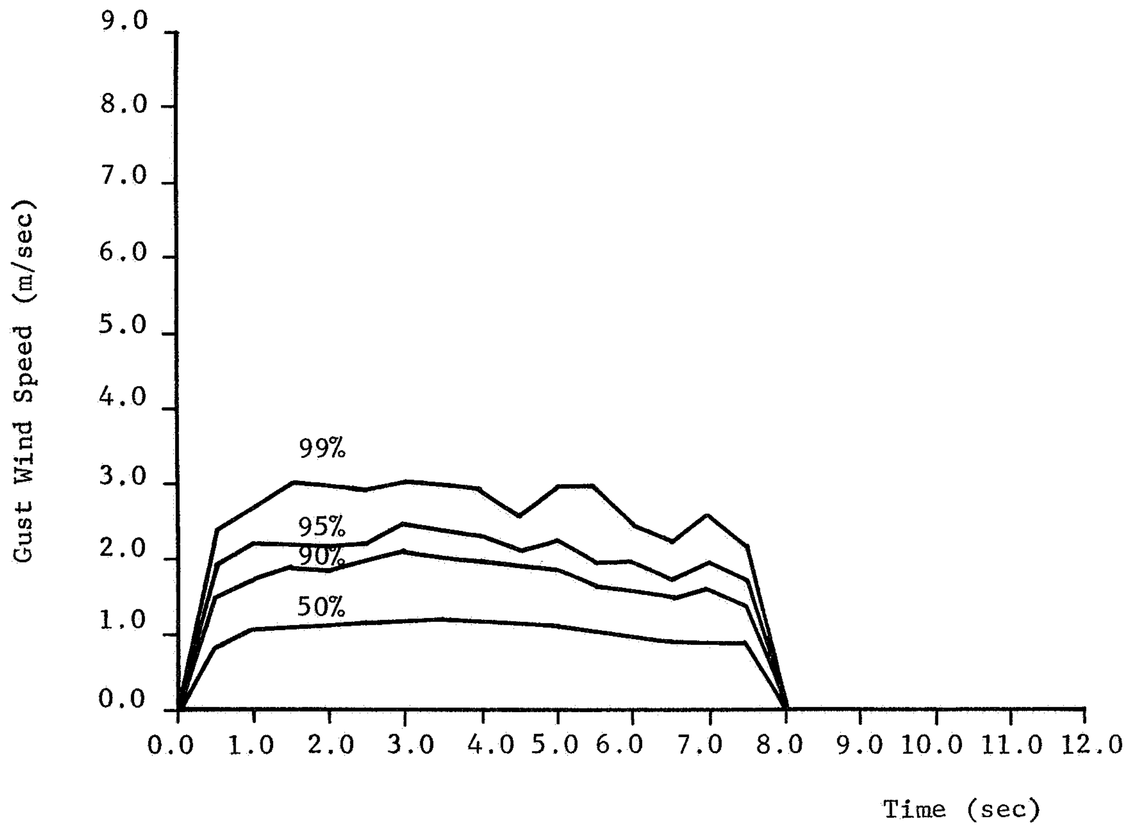

Fig. 28. **Statistical Gust Based on 265 Gusts Having a Time Duration of 6 to 8 Seconds Occurring at the 150-meter Level**

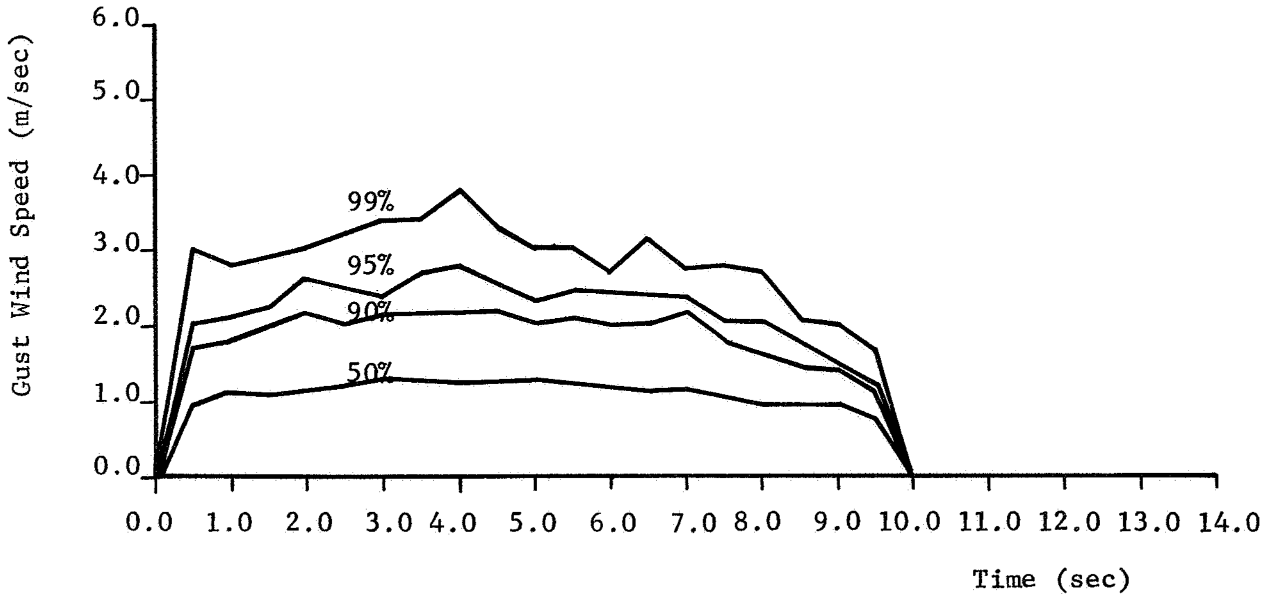

Fig. 29. Statistical Gust Based on 174 Gusts Having a Time Duration of 8 to 10 Seconds Occurring at the 150-meter Level

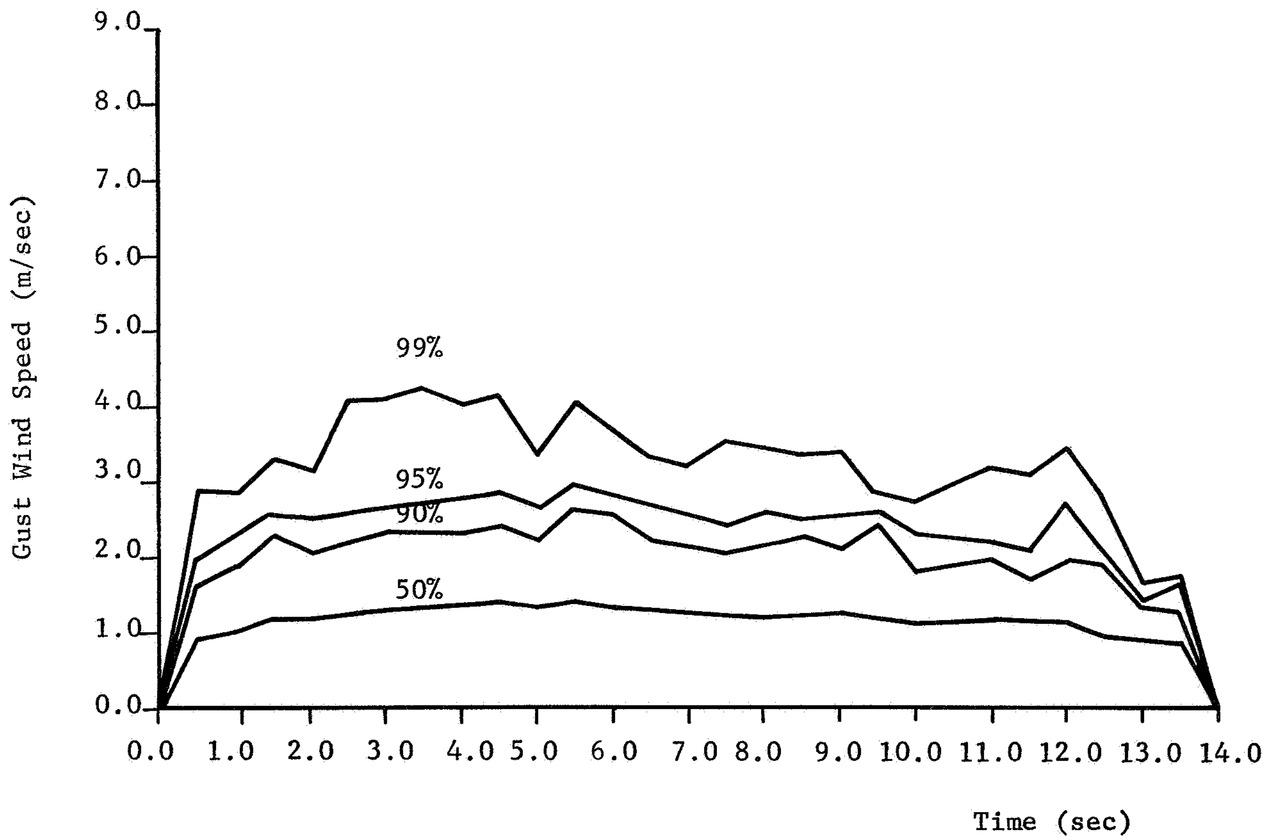

Fig. 30. Statistical Gust Based on 166 Gusts Having a Time Duration of 10 to 14 Seconds Occurring at the 150-meter Level

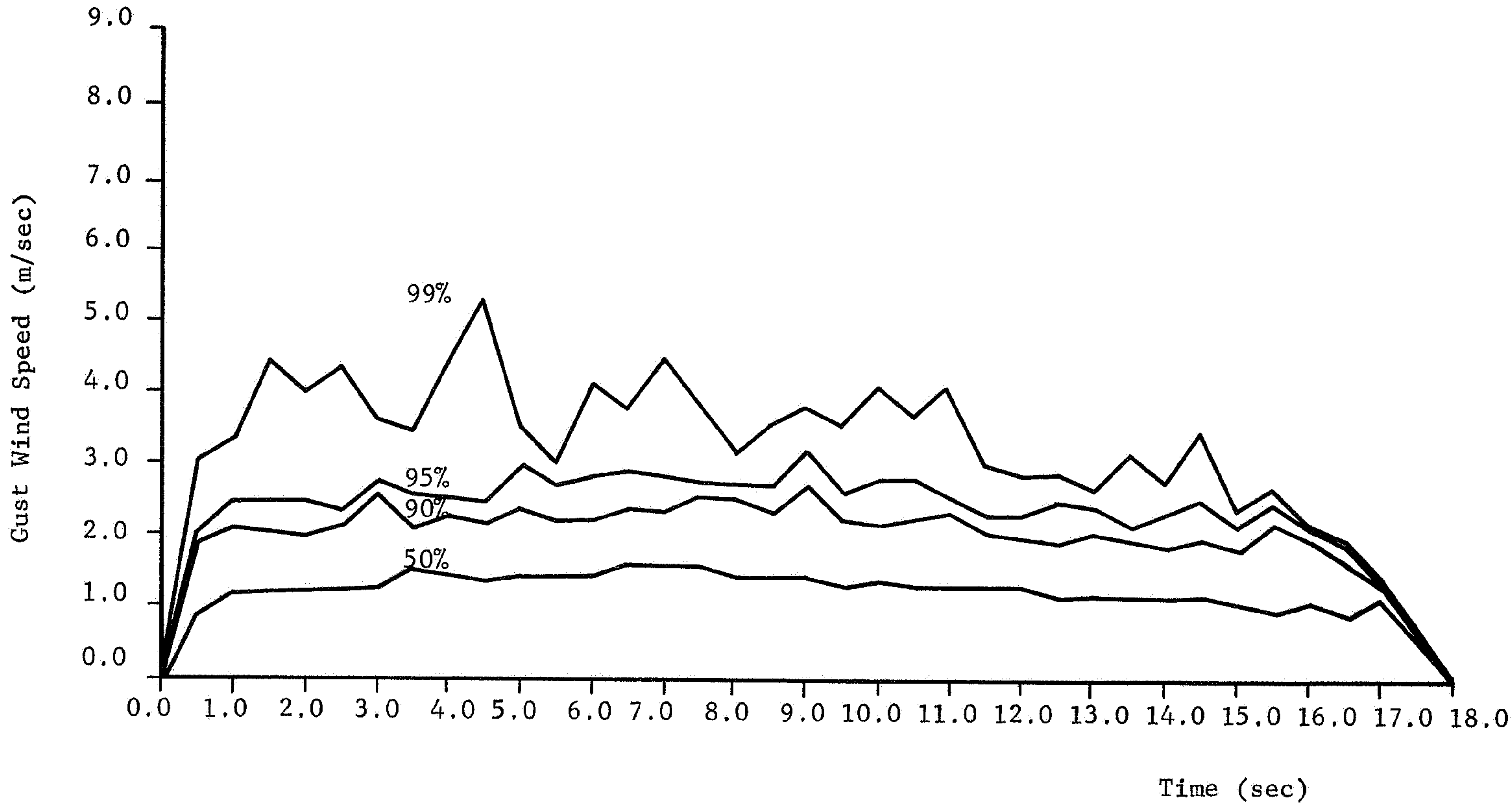

Fig. 31 Statistical Gust Based on 68 Gusts Having a Time Duration of 14 to 18 Seconds Occurring at the 150-meter Level

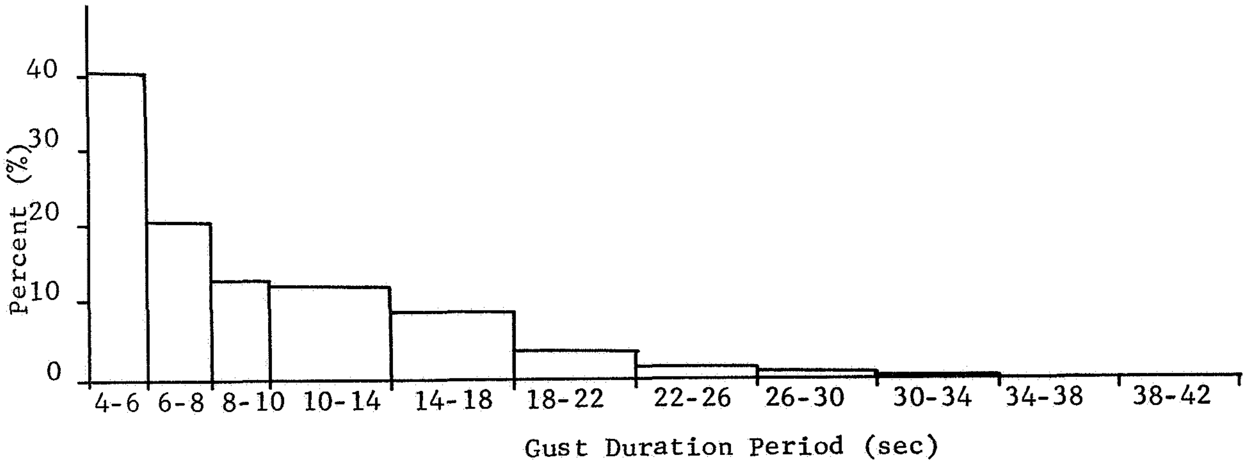

Fig. 32a. Percentage of Occurrence of Gusts Having Various Duration Periods Based on 1525 Gusts Recorded at the 60-Meter Level

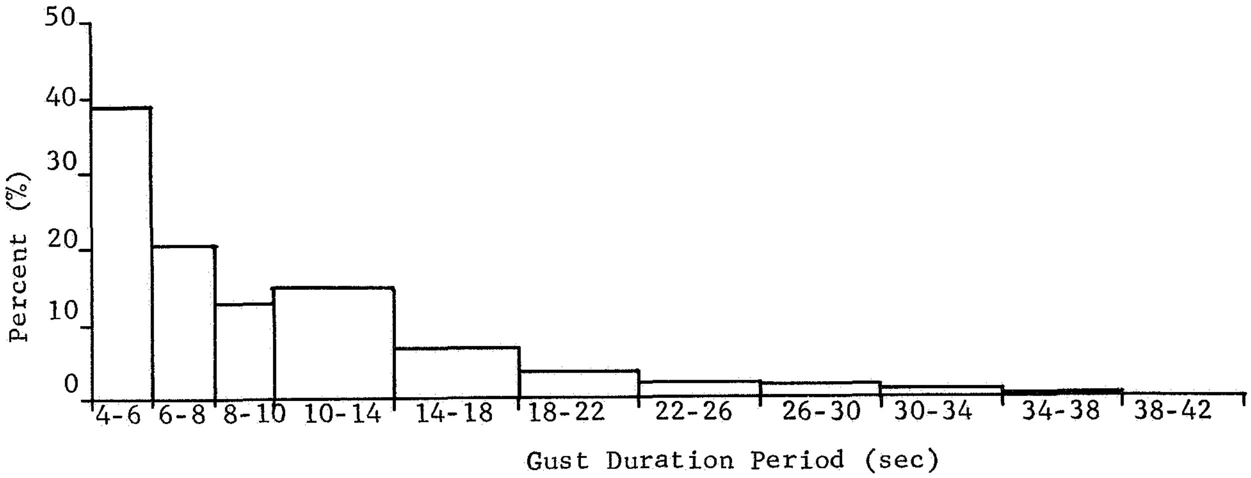

Fig. 32b Percentage of Occurrence of Gusts Having Various Duration Periods Based on 1577 Gusts Recorded at the 30-Meter Level

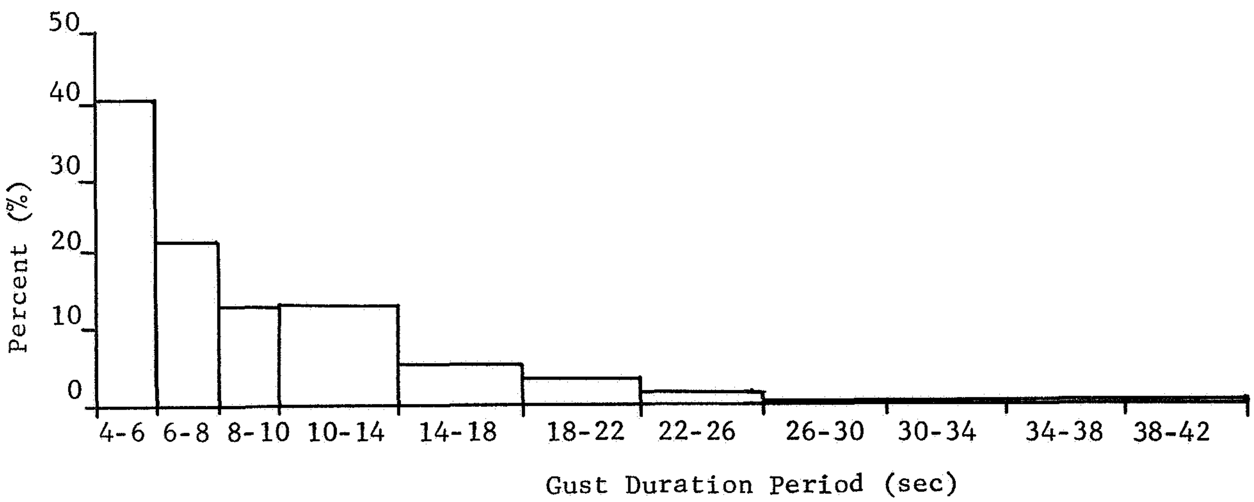

Fig. 32c. Percentage of Occurrence of Gusts Having Various Duration Periods Based on 1654 Gusts Recorded at the 18-Meter Level

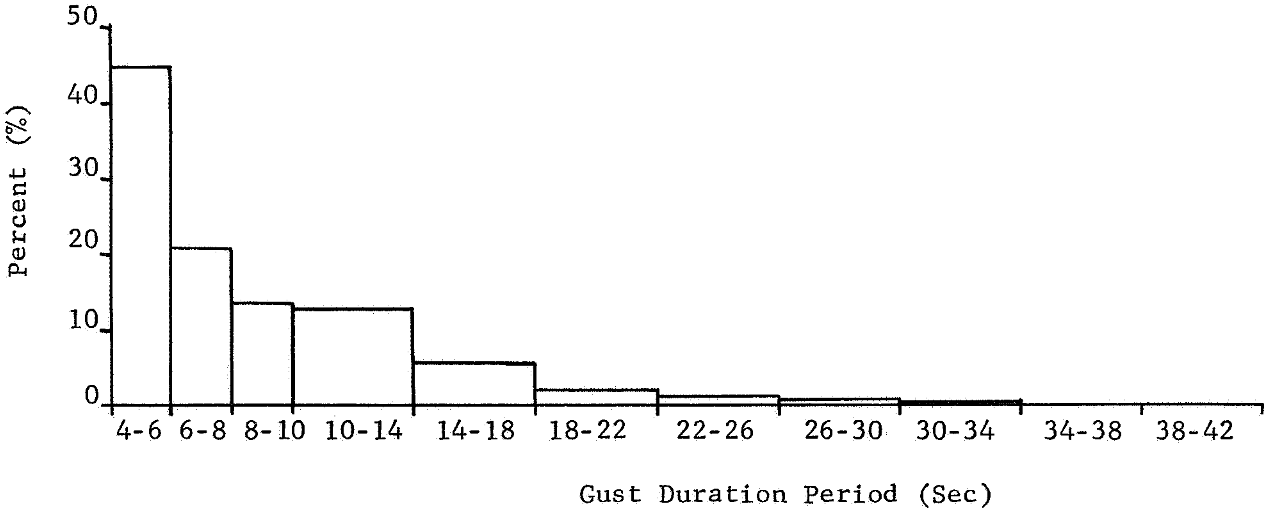

Fig. 33a. Percentage of Occurrence of Gusts Having Various Duration Periods Based on 1313 Gusts Recorded at the 150-Meter Level

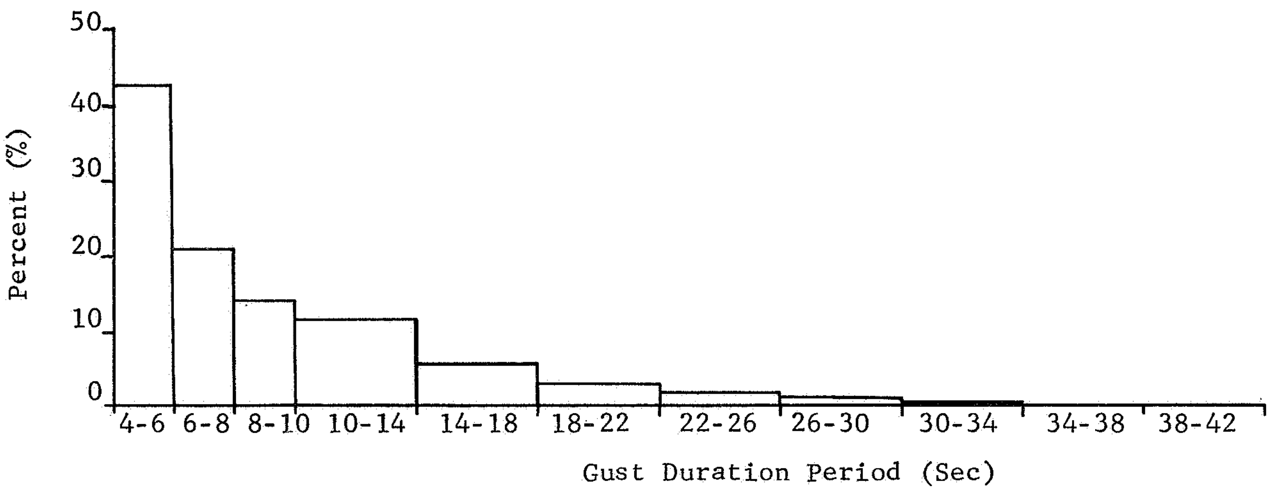

Fig. 33b. Percentage of Occurrence of Gusts Having Various Duration Periods Based on 1339 Gusts Recorded at the 120-Meter Level

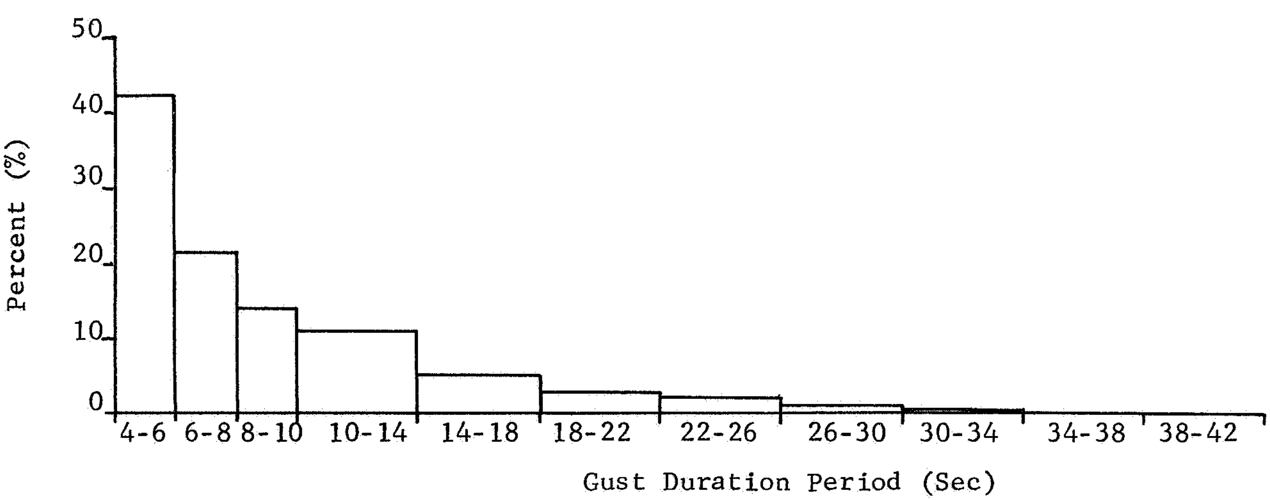

Fig. 33c. Percentage of Occurrence of Gusts Having Various Duration Periods Based on 1425 Gusts Recorded at the 90-Meter Level

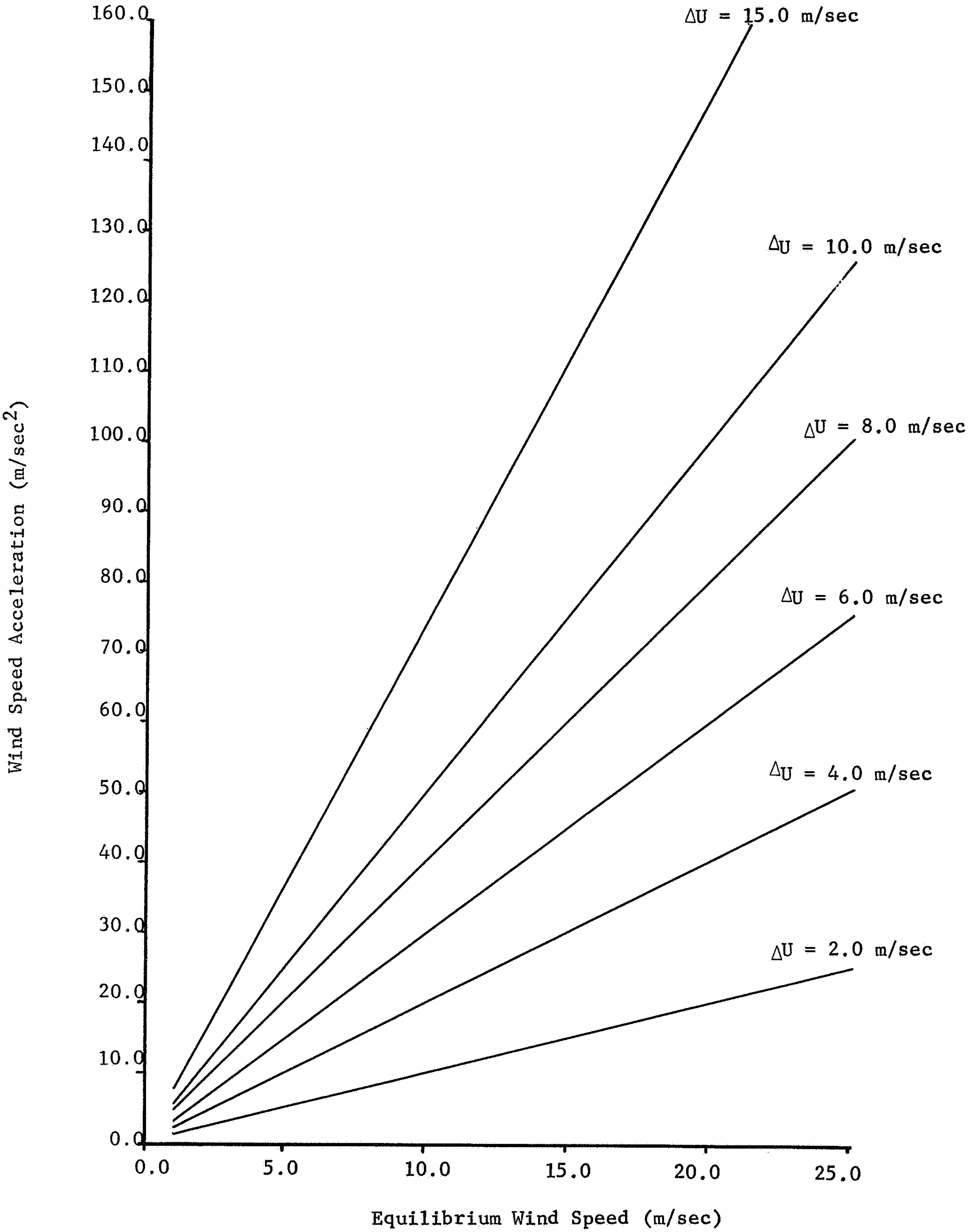

Fig. 34. Theoretical Maximum Acceleration for the Climet Model C1-14 Anemometer for a Time Constant of One Second

REFERENCES

1. "Meeting on Ground Wind Load Problems in Relation to Launch Vehicles," Compilation of Papers presented at the NASA Langley Research Center, June 7-8, 1966, NASA TMX-57779, Langley Research Center, Va.

2. Camp, Dennis W., "Analysis of Wind Tunnel Data for Several Beckman and Whitley Series 50 and Climet Model CI-14 Anemometers," NASA TM X-53271, MSFC, Huntsville, Alabama, May 26, 1965.

3. Camp, Dennis W., "Preliminary Results of Anemometer Comparison Tests," NASA TM X-53541, MSFC, Huntsville, Alabama, April 26, 1966.

4. Scoggins, James R. and Dennis W. Camp, "Ground Wind Measurements and Anemometer Response," Aero-Astrodynamics Research Review No. 5, NASA TM X-53568, MSFC, Huntsville, Alabama, Oct. 15, 1966, pp. 119-127.

5. Alexander, Margaret B., "Gust Factor Analysis from Wind Data Measured During September 1966 at NASA's 150-meter Meteorological Tower Facility, KSC, Florida," MSFC Office Memorandum R-AERO-YE-51-67, MSFC, Aero-Astrodynamics Laboratory, Huntsville, Alabama. (Ref. is available from author, R-AERO-YE)

APPROVAL NASA TM X-53771

LOW LEVEL WIND GUST AMPLITUDE AND DURATION STUDY

by Dennis W. Camp

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

This document has also been reviewed and approved for technical accuracy.

John W. Kaufman

John Kaufman
Chief, Atmospherics Dynamics Branch

Wm W. Vaughan

W. W. Vaughan
Chief, Aerospace Environment Division

Geissler

E. D. Geissler
Director, Aero-Astrodynamics Laboratory

DISTRIBUTION

DEP-T

R-EO
Dr. Johnson

R-SE
Mr. Belew (2)
Mr. E. May

R-SSL
Dr. Stuhlinger

R-COMP
Dr. Hoelzer
Mr. R. Cochran

R-P&VE
Dr. Lucas
Mr. R. Goerner
Mr.Kroll (2)
Mr. Hunt
Mr. Showers
Mr. Moore
Mr. Stevens

R-ASTR
Dr. Haeussermann
Mr. Hosenthien

I-MT
Mr. Lee Nybo

I-MO
Dr. F. Speer

I-V
Mr. L. James

I-I/IB
Col. W. Tier

MS-IP
MS-IL (8)
MS-H
HME-P
PAT
MS-T (6)
I-RM-M

R-AERO
Dr. Geissler
Mr. Jean
Mr. Thomae
Mr. Dahm
Mr. Holderer
Mr. Reed (2)
Mr. Horn
Mr. Verderaime
Mr. Rheinfurth
Mr. Ryan
Mr. Lindberg
Mr. Stone
Mr. Hagood
Mr. T. Deaton
Mr. Hardage
Mr. Baker
Dr. Heybey
Mr. J. Kaufman
Mr. Fichtl
Mr. Camp (25)
Mr. Hill
Mr. Susko
Mrs. Alexander
Mr. R. Turner
Mr. O. Smith
Mr. C. Brown
Mr. G. Daniels
Mr. R. Smith
Dr. L. DeVries
Mr. W. Vaughan (3)
Mr. J. Cremin

Tech. & Sci. Info. Facility (25)
Box 33
College Park, Md. 20740
Attn: NASA Rep (S-AK/RKT)

NASA-Lewis Res. Center
2100 Brookpark Rd.
Cleveland, Ohio 44135
Attn: Mr. J. C. Estes
Library (2)

DISTRIBUTION (Continued)

NASA Headquarters
Washington, D. C. 20546
Office of Advanced Res. & Tech.
Attn: Mr. Charak
Mr. T. Cooney
Mr. M. Ames
Mr. F. Stephenson
Mr. B. Gilstad
Mr. Wm. McGowan
Mr. D. Michel (2)
Office of Space Sci. & Appl.
Attn: Dr. W. Tepper
Mr. Wm. Spreen

NASA-Kennedy Space Flight Center
Cocoa Beach, Fla. 32931
Attn: Dr. H. F. Gruene, LV
Dr. Bruns, IN-DAT (2)
Col. Petrone, LO
Mr. Taiani, AP-OPN-4
Mr. E. Mathews, AP
Mr. Lester Keene, IN-DAT-2
Mr. R. Clark, TS
Mr. E. Amman, TS-MET
Dr. Knothe, EX SCI
Mr. Sendler, IN
Mr. P. Claybourne, DE-FSO
Mr. J. Stephens, IN-MSD

NASA-Langley Res. Center
Langley Field, Va. 23365
Attn: Mr. M. Morgan
Mr. V. Alley
Mr. I. Garrick
Mr. W. H. Reed, III
Mr. H. Tolefson
Mr. R. Henry
Tech. Library (2)

NASA-Manned Spacecraft Center
Houston, Texas 77001
Attn: Mr. William, PD-5
Mr. Donald C. Wade (3)
Mr. John Mayer (2)
Mr. Maynard, PD
Tech. Library (2)

Commander
Hdqs., Air Weather Service
Scott AFB, Ill. 62225
Attn: Dr. Robert D. Fletcher
Tech. Library (2)

Office of Staff Meteorologist (2)
AFSC (SCWTS)
Andrews AFB
Washington, D. C. 20331

Air Force Systems Command (2)
Space Systems Division
Air Force Unit Post Office
Los Angeles, Calif. 90045

Meteorological & Geoastrophysical Abstracts
P. O. Box 1736
Washington, D. C. 20013

Air Force Cambridge Res. Labs.
Bedford, Mass. 01730
Attn: Dr. M. Barad (2)
Tech. Library (3)
Mr. N. Sissenwine (2)

Dr. O. Essenwanger
AMSMI-RRA, Bldg. 5429
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Mr. Orville Daniel
PAWA/GMRD, AFMTC
MU-235, Technical Library
Patrick Air Force Base, Fla. 32925

Mr. John F. Spurling
NASA, Wallops Island, Va. 23337

Martin-Marietta Corp.
Aerospace Div.
P. O. Box 179
Denver 1, Colorado 80201
Attn: Mr. Jerold M. Bidwell

DISTRIBUTION (Continued)

North American Aviation, Inc.
Space & Information Systems Div.
12214 Lakewood Blvd.
Downey, Calif. 90241
Attn: Mr. C. D. Martin

Space Technology Lab., Inc.
Structures Dept.
One Space Park
Redondo Beach, Calif. 90277
Attn: Mr. Marvin White
Mr. Sol Lutwak

Mr. Brian O. Montgomery
MSFC Resident Representative
Kennedy Space Center, Fla. 32899

Mr. Fred Martin
General Dynamics
5873 Kearny Villa Rd.
San Diego, Calif. 92112

Lockheed Co.
Sunnyvale, Calif. 94088
Attn: Dr. Geo. Boccius
Mr. H. R. Allison

National Center for Atmospheric Res.
Boulder, Colorado 80302

Inst. for Environmental Research
ESSA - Research Laboratories
Boulder, Colorado 80302

Dr. Hans Panofsky (2)
The Pennsylvania State Univ.
503 Deitu Bldg.
Dept. of Meteorology
University Park, Pa. 16802

Dr. Geo. McVehil (2)
Cornell Aeronautical Lab., Inc.
4455 Genesea St.
Buffalo, New York 14221

Dr. James R. Scoggins
The Texas A&M Univ.
Dept. of Meteorology
College Station, Texas 77843

R. A. Taft Sanitary Eng. Center
Public Health Service
4676 Columbia Parkway
Cincinnati, Ohio 45202

Meteorology Division (2)
U. S. Army Dugway Proving Ground
Dugway, Utah 84022

Atmospheric Sciences Lab. (2)
U. S. Army Electronics Command
White Sands Missile Range,
New Mexico 88002

Dr. H. Crutcher
ESSA-National Weather Records
Center
Asheville, N. C. 28801

Dr. Frank Gifford
Dir., Atmos. Diffusion Lab.
U. S. Weather Bureau, ESSA
Oak Ridge, Tenn. 37830

Mr. T. R. Carr
Code 3251, Box 22
Pacific Missile Range
Pt. Mugu, Calif. 93041

Office of Staff Meteorologist
Air Force Eastern Test Range
Patrick AFB, Fla. 32925

Mr. N. J. Asbridge
WTWU
Air Force Western Test Range
Vandenberg AFB, Calif. 93437

DISTRIBUTION (Continued)

Mr. K. M. Nagler
Chief, Space Operations Support Div.
U. S. Weather Bureau, ESSA
Silver Springs, Md. 20910

Mr. C. A. Olson
Code 7261
Sandia Corp., Sandia Base
Albuquerque, New Mexico 87110

Mr. Lee L. Sims
USAERDAA, Meteorology Dept.
U. S. Army Electronics Proving Ground
Ft. Huachuca, Ariz. 85613

Mr. Ray E. Bieber
55-76,102
Lockheed Missile and Space Co.
P. O. Box 504
Sunnyvale, Calif. 94088

Mr. Arthur Belmont
Control Data Corp.
Minneapolis, Minnesota 55440

Mr. Stan Adelfay
Lockheed Calif. Co.
Burbank, Calif. 91500

Lockheed Missiles and Space Co.
Huntsville Research & Engr. Center
Orgn 54/50, FAC. 4
P. O. Box 1103-West Station
Huntsville, Alabama 35807
Attn: Dr. Bowman
Mr. Rod DeMandel
Mr. Stanley Krivo

Dr. Robert Stengel
Dept. of Meteorology
Mass. Inst. of Tech.
Cambridge, Mass. 02139

Office of Staff Meteorologist
WTW
Air Force Western Test Range
Vandenberg AFB, Calif. 93437

Mr. Q. S. Dalton
Code 3069
Naval Ordnance Test Station
China Lake, Calif. 93555

Office of Staff Meteorologist
PGLW
Air Proving Ground Center
Eglin AFB, Fla. 32542

Chief, Environmental Sci. Div.
Office of Asst. Dir. (RSCH)
OSD/Dept. of Defense Rsch. & Engr.
Rm. 3E-1037, Pentagon
Washington, D. C. 20301

Staff Meteorologist
SSSW
Hdq. Space Systems Div.
Los Angeles AF Station
Los Angeles, Calif. 90045

Mr. K. C. Steelman
AMSEL-RD-SM
U. S. Army Elect. Rsch. & Dev. Lab.
Ft. Monmouth, N. J. 07703

Mr. A. L. Miller
AIR-5403
Naval Air Systems Command
Washington, D. C. 20360

Mr. R. M. Fenn
KXR, DOD Code 1232
U. S. Naval Weapons Lab.
Dahlgren, Va. 22448

DISTRIBUTION (Continued)

Mr. H. Demboski
Code 421
Office of Naval Research
Washington, D. C. 20360

Cdr. T. H. R. O'Neill USN
Naval Weather Station
Code 70
Washington (Navy Yard Annex)
Washington, D. C. 20490

Meteorological Div.
U. S. Army Signal Res. & Development Labs.
Ft. Monmouth, New Jersey 07101

Meteorology Res., Inc.
464 W. Woodbury Rd.
Altadena, California 91001
Attn: Dr. Paul MacCready

Dr. Thomas A. Gleeson
Fla. State Univ.
Dept. of Meteorology
Tallahassee, Fla. 32306

Launch System Div.
Post Flight Trajectories
The Boeing Co.
Mail Stop AD-62
Huntsville, Ala. 35807
Attn: Mr. R. McCurdy
Mr. J. W. Hathorn
Mr. R. Wheeler

Mr. Joseph Goldman
Inst. for Storm Res.
3812 Montrose Boulevard
Houston, Texas 77006

Mr. D. Hargis
Solid Mechanics Dept.
Aerospace Corp.
Bldg. A2, Mail Sta. 2243
P. O. Box 95805
Los Angeles, Calif. 90045

Prof. Elmer R. Reiter
Dept. of Atmos. Sci.
Colorado State Univ.
Ft. Collins, Col. 80521

Mr. R. M. Slavin
Code: CRE
Air Force Cambridge Res. Labs.
(OAR)
Laurence G. Hanscom Field
Bedford, Mass. 01731

Dr. Sidney Teweles (W14)
Chief, Data Acquisition Div.
Environmental Sci. Services Adm.
Weather Bureau
8060 13th St.
Silver Spring, Md. 20910