REPORT No. 692

EFFECTIVE GUST STRUCTURE AT LOW ALTITUDES AS DETERMINED FROM THE REACTIONS OF AN AIRPLANE

By Philip Donely

SUMMARY

Measurements of gust structure and gust intensity were made in the lower levels of the atmosphere (0 to 3,500 ft). An Aeronca C-2 airplane was used as the measuring instrument, the gust structure being derived from the recorded motions of the airplane. Data were also obtained on wind velocities and temperatures as functions of altitude for use in attempting to correlate the gust-structure data with various meteorological quantities.

The results indicated little or no correlation between the gust velocity and the gradient distance. The data, however, did indicate that an airplane the size of the Aeronca will respond most frequently to gusts having gradient distances of the order of 30 feet. The maximum true gust velocity measured during the investigation was 25 feet per second.

A simple analysis of the relation between the maximum gust intensity and the meteorological quantities showed promise of yielding fair correlation but, owing to the nature of the relation, it was found to be impracticable to state that such correlation was real. The results indicate that much additional data and further analysis are required before predictions of gust size and intensity from meteorological observations can be attempted.

INTRODUCTION

More detailed information than has heretofore been available concerning the structure and the intensity of gusts that may be encountered in flight is required before improvements can be made to the design of aircraft structures subjected to loads applied by atmospheric gusts. An extensive statistical survey of these quantities for all conditions under which airplanes operate being obviously impracticable, the required information can best be obtained by tests devised to determine the correlation of the gust structure with the several meteorological elements.

The original requirements were based on the well-known elementary "sharp-edge gust" formula given in reference 1. By the collection of a large amount of statistical data on accelerations and air speeds during transport operations, an "effective" gust velocity for use in design has been obtained. The gust-load requirements for the structural design of aircraft have, in general, advanced as the theory of the unsteady lift of an airfoil has been developed. With the introduction of theoretical treatments of unsteady flow around airfoils, the theory of gust loads was advanced to give a more accurate estimate of the loads on an airplane structure due to atmospheric gusts (reference 2). The use of the theory and the formulas set forth in reference 2 required additional information as to gust shape and experimental verification of the theory. The experimental verification was obtained by tests in the N. A. C. A. gust tunnel (reference 3). The information concerning gust structure and intensity must, however, be obtained by measurements of turbulence in the atmosphere.

Although innumerable studies of atmospheric turbulence in relation to other meteorological elements have been made in the past, the results of these studies have been inapplicable to the structural design of aircraft. Most studies have sought to determine criterions of turbulence (references 4 and 5) or to determine the influence of the mean motions of turbulent air on meteorological elements. A few investigations (references 6 and 7) have been made to determine the actual gust structure and gust intensity in the lower levels of the atmosphere (less than 500 ft). Some measurements have been made in Germany (reference 8) of gust velocities in clouds by means of barograph records of sailplanes.

The present investigation was undertaken to determine gust size and intensity for an assumed gust shape in the lower levels of the atmosphere (0 to 3,500 ft). The first objective was to obtain data on atmospheric turbulence for use in the structural design of aircraft. The second objective was to attempt to determine the correlation between atmospheric turbulence and meteorological elements as an aid in design load specifications for aircraft.

As the measurement of gust structures at altitudes greater than a few hundred feet over the average countryside is virtually impossible by conventional anemometry, an airplane was used as the gust-measuring instrument and the gust size and intensity were determined from records of the reactions of the airplane during flight in rough air by assuming that the gust shape was known.

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The data collected for this investigation were obtained with a one-place Aeronca airplane flying in the vicinity of Langley Field, Va. Records of air speed, normal acceleration, and temperature were obtained at altitudes between 100 and 3,500 feet. About 100 flight tests were made from February 1936 to July 1938 under a wide variety of weather conditions.

METHOD AND APPARATUS

Briefly, the test method consisted in flying an airplane at a given altitude in level flight and in recording the normal acceleration and the air speed on an open time scale.

The airplane used for the investigation was the Aeronca C–2 shown in figure 1. The characteristics of the airplane as flown are given in table I.

FIGURE 1.—Aeronca C–2 airplane.

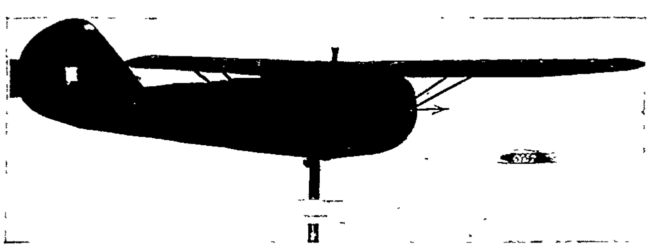


FIGURE 2.—Model of Aeronca C–2 airplane.

TABLE I

CHARACTERISTICS OF AERONCA C–2 AIRPLANE

	Preliminary tests	*Regular tests*
Weight, lb	716.5	782
Wing area, sq ft	144	144
Wing loading, lb per sq ft	4.97	5.44
Span, ft	36	36
Mean chord, ft	4	4
Aspect ratio	9	9
Center of gravity, percent mean chord	30	30
Slope of lift curve, per radian	4.73	4.73
Moment of inertia, mk_Y^2, lb-ft²	----	12,010

The meteorological quantities of interest were determined by conventional methods. The quantities measured were the temperature and the wind velocity as functions of altitude. The temperature readings at various altitudes were obtained by the pilot. The wind-velocity data were obtained from the regular pilot-balloon observations made by the United States Army meteorological station at Langley Field.

The theory given in reference 2 predicts the reaction of an airplane to a known gust and forms the basis of the evaluation of the flight records. The evaluation of records is subject to certain restrictions because of the assumptions that must be made in applying the theory to the problem.

The gust velocity is first assumed to be normal to the flight path of the airplane. The results of reference 1 indicate that no serious error is likely to be introduced by neglecting the effect of gust inclination.

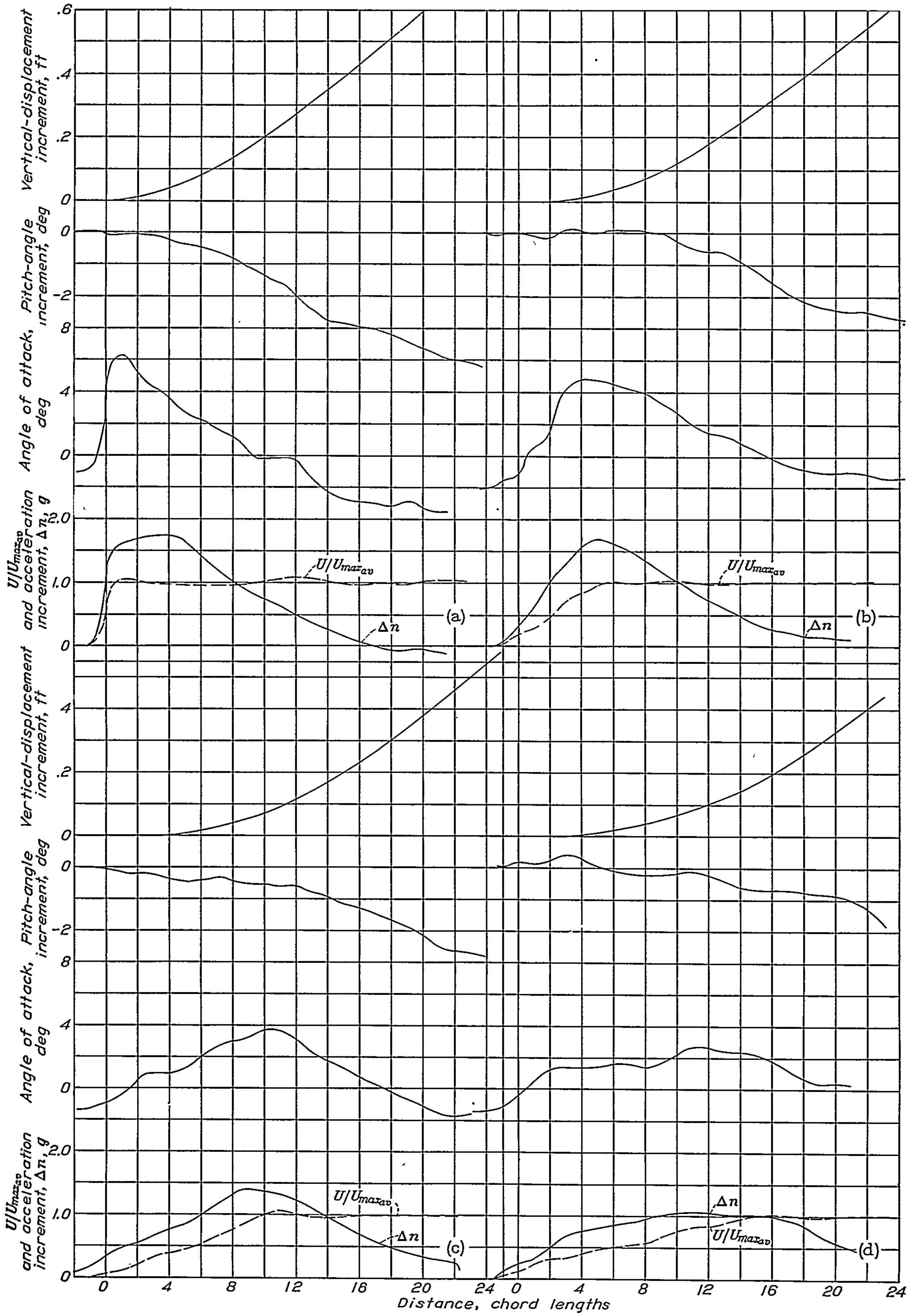
The second assumption, that the gust is two-dimensional relative to the span of the airplane, is made because there is no practical way of knowing the lateral extent of a gust encountered in flight. This assumption also specifies that the gust is symmetrical about the X axis of the airplane and causes no rolling or yawing of the airplane. Of course, the lack of knowledge as to the true lateral extent of the gust would introduce an error of unknown magnitude were the gust to cover less than the span of the airplane. The error would make the computed gust velocity less than the true gust velocity.

The third assumption is that the gust velocity varies linearly with distance; that is, the gust gradient in the direction of flight is a constant. In general, the atmospheric gust is a transient phenomenon and varies with both time and space. The eddy period, according to Brunt (reference 9, pp. 211–213), varies from ½ second to 50 seconds and the time spent by an airplane traversing a gust is of the order of ¼ second. In the analysis of acceleration records of airplanes, it therefore appears reasonable to assume that the gust velocity is a function only of space. The assumption of the linear variation of gust velocity is made for mathematical convenience. Inasmuch as the airplane "integrates" the variation of gust velocity, the assumption is a reasonable one and minor variations from linearity are unimportant.

The fourth assumption, that the airplane is in steady level flight just prior to entry into the gust, is contained in the basic theory (reference 2) and restricts the evaluation of the records. Only those acceleration peaks preceded by smooth portions of the records can be evaluated. This assumption specifies that the airplane is laterally level and is neither climbing nor diving. Slight changes in the attitude of the airplane will introduce no considerable errors in the results.

Fifth, it is assumed that the peak acceleration occurs at the point of maximum gust velocity. This assumption can be shown to be true for an airplane that does not pitch, except for the case of a sharp-edge gust (reference 2).

The final assumption is that the airplane controls are not used to modify the reaction of the airplane to the gust. In practice, the pilot used the controls a minimum amount consistent with safety.



(a) Gradient distance, H, 0 feet (sharp-edge gust).
(b) Gradient distance, H, 24 feet (full-scale).
(c) Gradient distance, H, 51 feet (full-scale).
(d) Gradient distance, H, 66 feet (full-scale).

FIGURE 3.—History of airplane motion in a gust.

On the basis of the available theory and of these assumptions, the gust can be completely described by two quantities, U and H, where U is the maximum velocity occurring in the gust and H, the gradient distance, is the distance in feet from zero to maximum gust velocity or, on the basis of the assumptions made, the distance the airplane travels from zero to maximum acceleration increment. The gradient distance H is thus equal to $V\Delta t$ where V is the forward velocity of the airplane and Δt is the time from zero to maximum acceleration increment.

Although the theory of reference 2 can be used, as outlined, it is desirable to calibrate the airplane in known gusts, if possible, to eliminate questionable accuracy that may be introduced by the simplifying assumptions of the theory. A general check of the theory made by means of tests in the gust tunnel is reported in reference 3; these tests indicate that appreciable discrepancies between the simple theory and the experimental results may exist.

The airplane being, in effect, the principal instrument, a calibration of it was made by testing a dynamically scaled model in the N. A. C. A. gust tunnel in the manner of the tests described in reference 3. The calibration consisted in flying the model through gusts of known shapes and recording its reactions as it traversed the gust.

The 1/12-scale airplane model (fig.2) is dynamically similar to the full-size airplane within the limits of practicability. Because of severe weight restrictions, it was impracticable for the weight of the model to be at quite its proper value. It was also found expedient to change the fuselage shape somewhat (figs. 1 and 2) in order to accommodate the accelerometer that had to be carried in the model. These changes should not, according to the results of numerous tests on other models, seriously affect the validity of the results. The characteristics of the airplane model pertinent to this investigation have been listed in table II. For comparison, the characteristics of a true dynamically scaled airplane model have also been included.

TABLE II

AIRPLANE-MODEL CHARACTERISTICS

	Desired	Obtained
Weight, lb	0.45	0.50
Wing area, sq ft	1.0	1.0
Wing loading, lb per sq ft	.45	.50
Span, ft	3	3
Mean chord, ft	.33	.33
Aspect ratio	9	9
Center of gravity, percent mean chord	30	30
Slope of lift curve, per radian	4.73	4.73
Moment of inertia, mk_Y^2, lb-ft²	.048	.052
Forward velocity, fps	40	40
Gust velocity, fps	6.0	6.0

The gust-tunnel tests consisted in flights of the airplane model at one gust velocity, one forward speed, and four gust-gradient distances (H=0, 24, 51, and 66 ft, full-scale). A minimum of five flights was made for each test condition to obtain mean values of the maximum acceleration increments, Δn.

The records were evaluated to give histories of events preceding and during passage through the gust. Sample results for each gust gradient are shown in figure 3. The dashed curve in the lower section shows the gust shape in percentage of average maximum gust velocity $U/U_{max_{av}}$.

The maximum acceleration increment for each flight was corrected to the nominal velocities listed in table II and then divided by Δn_s (reference 2) to give the acceleration ratio $\Delta n/\Delta n_s$ (fig. 4). The quantity Δn_s is the acceleration increment computed by the simple sharp-edge gust formula

$$\Delta n_s = (\rho a U V S)/2W$$

where ρ air density.
a slope of lift curve.
S wing area.
W weight of airplane.

The theoretical values of $\Delta n/\Delta n_s$ computed according to reference 2 have been included in the figure for purposes of comparison.

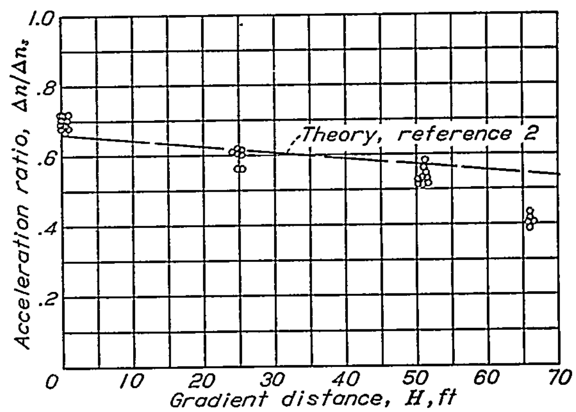


FIGURE 4.—Variation of acceleration ratio with gradient distance.

The results given in figure 4 indicate that the acceleration ratio, and therefore the gust velocities, will be in error by about ±5 percent for values of H less than 50 feet when the theory of reference 2 is used. For values of H greater than 50 feet, the experimental values of $\Delta n/\Delta n_s$ become much less than the theoretical values and indicate much greater errors.

The increasing error for large values of H is primarily due to the increasing influence of the pitching of the airplane for the longer gradient distances. Inspection of figures 3 (a) and 3 (b) indicates that, for short gradient distances, the pitching is negligible to peak acceleration. For the longer gradient distances (figs. 3 (c) and 3 (d)), however, the pitching is not negligible at peak acceleration and tends to reduce the acceleration increment, which causes a larger and larger deviation between theory (reference 2) and experiment.

Consideration of the rapid deviation of theory and experiment beyond a value of H of 50 feet introduces serious doubt as to the validity of any gust measurements for values of H greater than 50 feet. As a result of lag in lift under unsteady-flow conditions, a sharp-edge gust will indicate on an accelerometer record a gradient distance H of the order of 10 to 15 feet, or more. The 5-percent error for values of H between 15 and 50 feet is well within the experimental errors of the flight tests and will therefore be disregarded for the purpose of this report.

The use of the airplane as a measuring instrument requires, of course, instruments in the airplane to determine its reactions to gusts encountered in flight. The instruments carried in the airplane for this purpose were:

(a) N. A. C. A. air-damped accelerometer.
(b) N. A. C. A. air-speed recorder.
(c) N. A. C. A. timer (1-second interval).
(d) Kollsman altimeter.
(e) Strut thermometer.

The accelerometer and the air-speed recorder were fitted with magazine film drums and carried sufficient film for 8 minutes of record at a film speed of ⅜ inch per second.

In addition to these instruments, which were used during the general investigation, a trailing static-pressure tube, a total-pressure tube, and a recording inclinometer were used during preliminary tests to determine the airplane lift curve and to calibrate the air-speed installation.

TESTS

As the Aeronca C–2 is in the light-airplane category and is not equipped for blind flying, operations with this airplane were confined to days with surface winds less than 30 miles per hour and with fair visibility. The greater number of the flights were made within a 10-mile radius of Langley Field, over wooded farmland interspersed with creeks and salt marshes.

In preliminary flights to establish the mode of operation, no attention was paid to the weather conditions or to the altitude. The primary objects of these tests were to obtain statistical gust-structure data and to develop the test procedure. These flights were made from February to July 1936.

In the later part of the investigation, which comprised the larger portion of the flight tests, the pilot noted the temperature variation with altitude and the altitudes at which records were taken. The usual procedure was for the pilot to make a preliminary climb to determine the most turbulent altitudes and the temperature variation with altitude. On completion of the climb, the pilot returned to the two roughest levels and took 4-minute records of acceleration and air speed. The wind data at the time of flight were obtained, when available, from the meteorological station at Langley Field and were tabulated with the data obtained by the pilot. In general, records were obtained at altitudes from 150 to 3,500 feet.

RESULTS

All records of acceleration and air speed were evaluated by the theory (reference 2) to give the maximum gust velocity U and the gradient distance H for each satisfactory acceleration peak. Figures 5 and 6 show all the data obtained during the preliminary and the regular flights, respectively. Although graphs of U

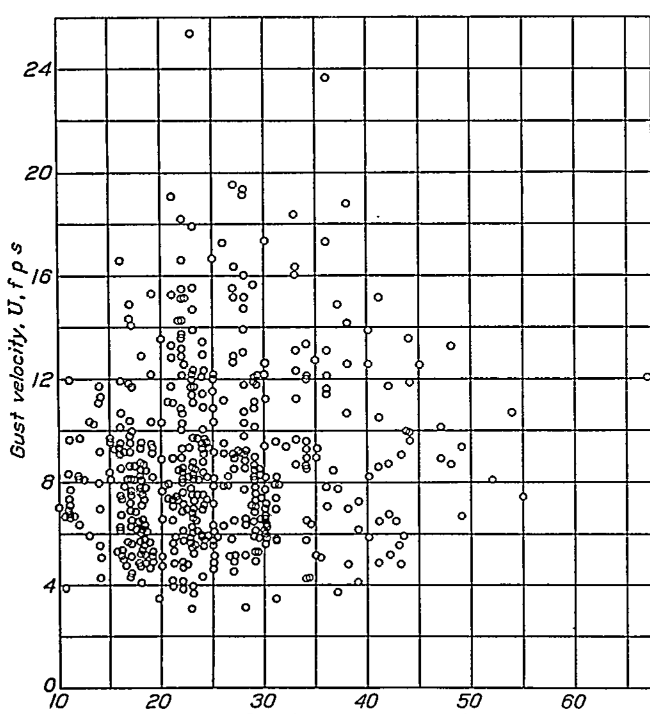


FIGURE 5.—Gust velocity U as a function of the gust-gradient distance H for preliminary flights.

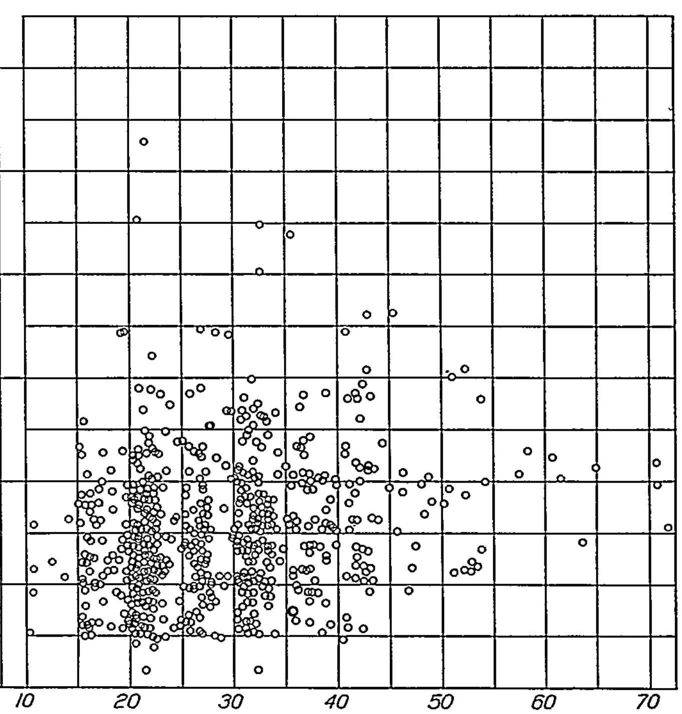


FIGURE 6.—Gust velocity U as a function of the gust-gradient distance H for regular flights.

and H were made for each run for the regular flights, they have been omitted from the present report owing to the large number of graphs involved. Table III, however, gives the maximum value of U and the corresponding value of H for each run together with the date, the time, and the altitude.

The meteorological elements considered were the potential temperature[1] θ, the potential temperature lapse rate $d\theta/dh$, and the wind velocity gradient dw/dh, where h is the height above the ground and w is the wind velocity. The pilot's observations of air temperature as a function of altitude were evaluated to give θ and $d\theta/dh$. The wind variation with altitude, obtained from the meteorological station at Langley Field, was used to compute the wind gradients at the altitudes flown. In some cases, where the altitudes flown were of the order of 150 to 300 feet, the altitude increments used in the wind observations were too large to permit evaluation of the wind gradients; they were therefore computed according to the theory outlined in reference 9 (pp. 230–245). All of the available data have been included in table III except the basic wind data, which are quite voluminous.

PRECISION

In addition to the known errors due to the limitations of the instruments, certain unknown errors exist that are due to the limitations of the airplane as a measuring instrument and to the variation of the meteorological elements with time and space. The errors due to the limitations of the airplane have been discussed in detail in regard to the calibration. In the measurement of temperature and wind velocity as functions of altitude, the element of time enters into the precision of the recorded values. The readings were made shortly before the records of acceleration and air speed and there is no assurance that the meteorological elements had not changed somewhat in the meantime. The meteorological elements were measured at a fixed locality and, although the flights were made in the immediate vicinity, the influence of local terrain may have been appreciable.

It should be emphasized that the present method of analysis gives the gust structure only if the gust shape is the one assumed.

Consideration of the foregoing factors leads to the following estimate of precision for the measured values of the various quantities:

Air speed	±1 mph
Acceleration increment	±0.1 g
Altitude	±50 ft
Temperature	±¼° C
Wind velocity	±10 percent
Gust velocity	±10 percent
Gust-gradient distance	±5 ft
Temperature gradient	±20 percent
Wind gradient	±40 percent

[1] The potential temperature θ of air is defined as the temperature attained when it is brought adiabatically to a standard pressure (reference 9, p. 38). The potential temperature lapse rate $d\theta/dh$ is the deviation of the temperature gradient and is thus a measure of the stability of the atmosphere for dry air.

In spite of the large errors listed, it is felt that qualitative deductions based on a statistical analysis of the data will be justified.

GUST-STRUCTURE DATA

The primary object of the present investigation was, of course, to collect data in statistical amounts on the structure and the intensity of gusts for use in the design of aircraft structures. Although one gust shape and one gust intensity is ideal from considerations of simplicity, the possible necessity of using more than one gust shape should not be neglected.

In connection with the choice of the proper gust shape for use in structural design, certain hypotheses have been advanced concerning the relation between U and H. Such a hypothesis is given in reference 2, which leads to a cubic parabola for the relation between U and H. The verification of this hypothesis would lead to certain deductions about the gust shapes to be used for aircraft design.

If the hypothesis of reference 2 is considered together with available information on the response of an airplane to a known gust (reference 3 and unpublished data), several important deductions are obtained:

(*a*) Within the response range of the airplane, the gust velocity will increase with the gust-gradient distance.

(*b*) The most probable gust-gradient distance as determined by airplane measurements increases with airplane size.

(*c*) The most probable maximum gust velocity, similarly obtained, increases with airplane size.

The data obtained with the Aeronca airplane can be used to make a rough check of this hypothesis in regard to (*a*). Subsequent tests of other airplanes are necessary, however, before (*b*) and (*c*) can be disproved or verified.

If the maximum energy content of the lower atmosphere is assumed to have a definite limit for the conditions under which the airplane is flown, then the envelope of the $U—H$ data should tend to follow the hypothesis of reference 2. Inspection of figures 5 and 6 shows that, for values of H between 12 and 30 feet, the maximum gust velocity tends to increase with increasing values of H. Beyond a value of H of 30 feet, the gust velocity tends to decrease with increasing values of H, which may be due to the influence of unknown factors unrelated to the hypothesis.

The actual envelope of data could be better approximated by a pair of straight lines than by a parabola. If, according to the hypothesis, the lateral extent of the gust is of the same order as the gradient distance, then a gust with a value of H of 18 feet would extend over about one-half of the airplane span. The maximum gust velocity computed from the acceleration record would thus be somewhat lower than the actual gust velocity. This difference may explain, in part, the deviation of the data from the hypothesis advanced in reference 2.

For values of H greater than 30 feet, this explanation cannot hold, the gust size being of the same order of magnitude as the span of the airplane. The decrease in U_{max} for values of H greater than 30 feet is due, apparently, to other factors that are still unknown. The present results yield no evidence either to confirm or to deny the hypothesis advanced in reference 2 although they do show the correct trend up to a gradient distance of 30 feet. Additional data on this and other airplanes are required to clarify the relation between gust intensity and gust structure.

In an attempt to determine whether any relation existed between U and H, about one-quarter of the data (1,000 points) was used to compute Galton's lines of regression (reference 10, p. 328), from which the correlation coefficient between U and H could be determined. Figure 7 shows the results of this computation. The relative slopes of the lines indicate little or no correlation between U and H. The lines do indicate, however, that the most probable gust-gradient distance for the test conditions was of the order of 30 feet.

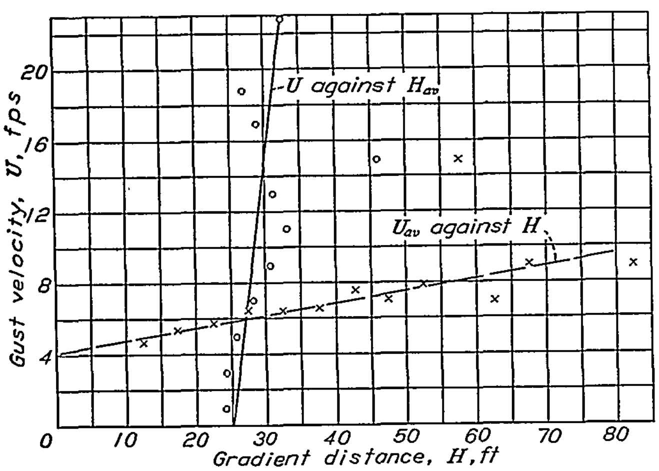


FIGURE 7.—Correlation of gust velocity and gradient distance.

CORRELATION WITH METEOROLOGICAL ELEMENTS

For the purpose of the present investigation, a possible correlation is sought between both the maximum gust intensity and the gust structure and the available measurements of meteorological elements. Many quantities that affect turbulence must, of course, be neglected owing to the limitations of the recorded data but the available information is expected to indicate the most promising lines of attack for future studies. As previously noted, little or no correlation appears between the gust intensity U and the gust size as defined by the gradient distance H. For the purpose of determining correlation coefficients, they may therefore be treated as independent quantities.

Analyses made to determine the relation of H to the other variables (θ, $d\theta/dh$, w, and dw/dh) indicated no correlation between H and any other variable treated. The general analysis simply showed that any value of H might be associated with any value of U or with any value of the other variables. The absence of correlation is felt to be primarily due to the influence of diffusion and viscosity, which are functions of time in their influence on turbulence. Inspection of the analysis of Tollmein, as reproduced in reference 11, for a jet penetrating still air indicated that the diffusion and the viscosity effects were chiefly confined to broadening the boundary layer of the jet and had little effect on the maximum velocity of the jet. The width of the boundary layer, or H, depends on the distance from the origin of the jet, which is unknown for the atmosphere.

Analyses made to determine the relation of the maximum gust velocity U with other variables (θ, $d\theta/dh$, h, and dw/dh) indicated little or no correlation between U and the other variables treated. The correlation coefficients obtained for the different variables were

θ	0.10
$\frac{d\theta}{dh}$	.05
h	−.25
$\frac{dw}{dh}$	.35

and indicate that no simple relation exists. The lack of correlation is felt to be due to the mutual effects that the different variables exert upon one another and to the influence of other factors not measured during the tests.

In further attempts to obtain correlation, various relationships involving Richardson's number $\frac{g}{\theta}\frac{d\theta}{dh}\Big/\left(\frac{dw}{dh}\right)^2$ (reference 4), as derived by Rossby, Prandtl, and others, were considered. The correlation obtained was negligible but this lack of correlation may be due to limitations of the data.

Since little success was obtained in these analyses, it was felt that a simple derivation based on elementary concepts might yield a relation between U and the other variables which would be more satisfactory. A derivation was therefore made in which it was attempted to derive a relation between the maximum gust velocity U, the lapse rate, the wind gradient, and surface roughness.

If it is assumed that a unit volume of air is set into vertical motion relative to the surrounding air, a simple equation for the motion is obtained:

$$\rho_0\frac{d^2h}{dt^2}+g(\rho-\rho_0)=0$$

where ρ_0 density of the unit volume of air at any level and ρ density of the surrounding air.
Thus, $\rho-\rho_0$ excess of air density due to lifting or depressing the unit volume.

The term $g(\rho-\rho_0)$ can be replaced by $\rho_0\left(\frac{g}{\theta}\frac{d\theta}{dh}\right)h$ (reference 9, pp. 254–257), which is the buoyant force acting on the displaced volume; the temperature lapse rate $d\theta/dh$ is assumed to be a constant.

The differential equation therefore becomes

$$\rho_0\frac{d^2h}{dt^2}+\rho_0\left(\frac{g}{\theta}\frac{d\theta}{dh}\right)h=0$$

or

$$\frac{d^2h}{dt^2}+\left(\frac{g}{\theta}\frac{d\theta}{dh}\right)h=0$$

The solution of this equation for both the stable and the unstable values of $d\theta/dh$ yields the following expressions for U.

Thermally stable:

$$\frac{d^2h}{dt^2}+\left(\frac{g}{\theta}\frac{d\theta}{dh}\right)h=0$$

or

$$\frac{dh}{dt}=U=C_1\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}\sin\left(\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}t+C_2\right)$$

or

$$U_{max}=C_1\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}$$

Thermally unstable:

$$\frac{d^2h}{dt^2}-\left(\frac{g}{\theta}\frac{d\theta}{dh}\right)h=0$$

or

$$\frac{dh}{dt}=U=C\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}\left(e^{\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}t}+e^{-\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}t}\right)$$

or, after the motion has started (i. e., when $e^{-\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}}$ becomes small), and for an arbitrary disturbance

$$U\propto C\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}\,h$$

It will be noted that the terms for the stable and the unstable lapse rates are the same except that the altitude is present for the unstable lapse rate. Now, if the restraining effect of the ground is assumed to cause vertical velocities in the atmosphere to increase with altitude (reference 9, pp. 210–214), the two expressions are identical and

$$U=C\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}\,h$$

Therefore, $U/\left(\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}\,h\right)$ is a constant, for a given set of conditions; it will be referred to hereinafter as the "gust-intensity index."

A disturbing force must be present to start the motion and it is assumed to be a function of the surface roughness and the wind velocity. Detailed information as to the terrain flown over at any instant was lacking and it was therefore assumed that the wind gradient dw/dh at the altitude maintained during instrument operation was a measure of the disturbing force (reference 9, pp. 236–245, and reference 11).

Thus, the final relation is

$$U/\left(\sqrt{\frac{g}{\theta}\frac{d\theta}{dh}}\,h\right)=C=C_1\,f(dw/dh)$$

The data tabulated in table III were used to check this relation. For the purpose of this analysis, g is taken as 9.80 meters per second per second, θ is taken as absolute C degrees of temperature, and the unit of h is 100 meters. Figure 8 shows the gust-intensity index

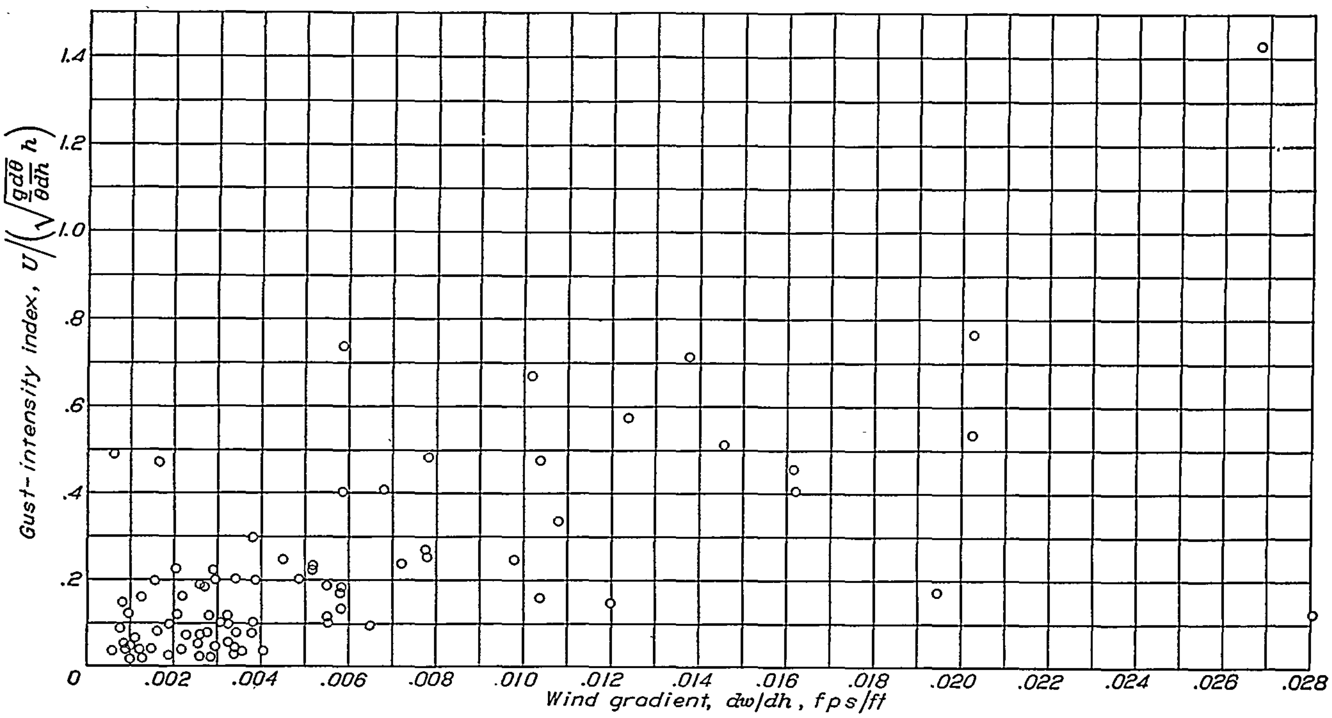


FIGURE 8.—Relation between gust-intensity index and wind gradient.

plotted against the wind gradient for all runs for which complete data were available. The results show a wide scatter of data but do indicate a tendency for the gust-intensity index to increase with wind gradient.

The data in figure 8 indicate some correlation between the gust-intensity index and the wind gradient. It was discovered, as a consequence of comments by Dr. A. M. Keuthe, that there exists such a relation between $1/h$ and dw/dh that, with the present amount of data, it is impossible to state whether the relation between the gust-intensity index and dw/dh is real. The results indicate that the motions are not random in regard to the index, for at constant altitude the data show a tendency for the gust-intensity index to increase with dw/dh.

CONCLUDING REMARKS

A great deal of additional information and study will be required before the prediction of gust size and maximum gust intensity from meteorological observations can even be attempted.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., *October 19, 1939.*

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TABLE III

SUMMARY OF GUST-STRUCTURE DATA

Date	Time (eastern standard)	Altitude, h (ft)	Gust velocity, U_{max} (fps)	Gust-gradient distance, H (ft)	Potential temperature, θ (° C abs)	Potential temperature lapse rate, $d\theta/dh$ (°C per 100 m)	Wind gradient dw/dh (fps per ft)
11–10–36	14:25	500	12.8	22	285	0.08	0.0071
		100	9.0	17	283	−1.7	.0036
11–13–36	11:05	500	10.0	21	286	−.85	.0055
		1,000	4.9	27	285	.12	.0028
11–13–36	13:30	500	9.2	21	288	1.00	.0055
		1,000	7.8	41	287	.52	.0028
11–16–36	10:05	1,500	8.5	65	274	−.10	.001
		1,000	17.5	35	276	.28	.0028
11–19–36	10:00	1,500	7.0	21	268	.26	------
		1,000	8.9	28	269	.26	------
11–20–36	12:25	1,500	10.6	33	285	.27	.0023
		1,000	10.5	33	286	−.08	.0034
11–20–36	14:45	------	9.0	21	286	------	------
11–28–36	10:10	500	17.9	32	273	1.00	.0055
		1,000	11.6	21	272	.27	.0026
12–1–36	10:10	500	8.4	23	272	.26	.0058
		1,000	5.6	22	271	.45	.0029
12–8–36	11:15	500	11.5	22	273	−.09	.0068
1–14–37	12:30	500	13.8	28	292	1.00	.012
1–15–37	10:50	1,000	21.0	21	294	−.25	.0052
		500	14.4	43	296	1.00	.010
1–18–37	14:35	500	7.8	20	294	.11	.008
		200	11.6	27	295	3.4	.020
1–25–37	12:00	500	13.9	27	294	.82	------
		200	11.2	41	294	.82	------
2–2–37	10:10	1,000	12.0	51	270	.10	.003
		500	------	----	271	−.85	.0058
2–2–37	11:50	500	16.1	32	272	−.85	.006
		300	6.2	20	273	−.20	.010
2–8–37	14:20	500	18.1	21	294	.24	.006
		200	9.2	32	294	.24	.015
2–9–37	14:25	2,000	11.3	38	291	.28	.0025
		1,500	5.5	37	292	.38	.0030
3–6–37	11:15	500	12.8	22	287	.38	.0050
		250	13.6	28	287	.38	.011
3–8–37	15:05	550	8.5	29	288	−.50	.0021
		300	11.7	30	290	−.50	.0038
3–10–37	13:30	3,500	7.3	22	269	−.07	.00009
		2,900	9.8	26	271	−.07	.0001
3–10–37	14:50	2,100	11.0	34	275	.02	.0002
		1,600	9.5	45	277	.02	.0002
3–17–37	14:20	2,500	8.9	27	276	.28	.0006
		2,000	10.6	40	277	−.10	.0007
3–24–37	9:55	1,000	11.1	22	285	.10	.0026
3–24–37	14:55	2,000	6.5	37	291	.63	.0013
		1,400	8.3	22	291	1.38	.0019
		1,000	5.0	41	291	1.72	.0026
3–25–37	10:00	2,500	7.8	35	288	.94	.0010
		2,000	10.2	32	288	−.03	.0012
3–25–37	15:05	800	14.4	53	298	.97	.003
		500	18.1	33	298	.97	.0049
3–26–37	10:40	3,000	8.9	38	271	−.10	.0006
		2,300	6.3	35	273	.96	.0008
3–29–37	10:20	3,300	8.9	26	270	−.09	.0010
		2,700	11.0	41	271	.28	.0012
3–29–37	11:55	2,200	11.1	33	276	.46	.0015
		1,500	12.8	34	277	−.10	.0022
3–29–37	14:50	1,000	12.5	35	283	−.46	.0032
		500	10.4	18	284	−1.19	.0065
3–31–37	10:20	300	21.5	37	279	−.44	.0120
4–6–37	10:55	1,000	9.8	22	290	−.06	.0029
		500	10.0	40	292	.64	.0058
4–6–37	12:05	500	22.3	31	292	−.10	.0058
		200	------	----	------	------	.015
4–7–37	7:00	1,500	13.6	22	276	−.80	.0027
		1,000	7.5	22	279	1.35	.0041
4–7–37	9:15	800	13.1	35	279	1.27	.0016
		400	11.4	42	279	−1.94	.0032
4–10–37	6:45	1,000	19.0	28	277	.26	.0039
		500	12.3	46	279	.26	.0078
4–15–37	6:05	2,000	9.2	33	287	1.0	.0028
		1,500	9.4	29	287	.28	.0038
4–19–37	8:00	450	12.5	19	288	−.43	.0072
		200	10.7	24	289	−.43	.0160
4–22–37	8:05	300	15.1	22	291	.65	.0110
		200	12.0	36	292	.65	.0160
5–28–37	13:50	700	7.6	21	305	.26	.0009
		400	10.6	28	305	−.10	.0016
6–10–37	13:10	700	11.0	27	------	-----	------
		200	13.0	36	------	-----	------
6–10–37	15:05	1,500	12.0	26	300	.46	------
		600	7.0	20	304	.46	------
6–11–37	13:10	200	18.0	24	------	-----	------
6–17–37	14:20	3,000	8.4	62	290	-----	.0065
6–21–37	14:45	------	15.4	32	------	-----	------
6–22–37	14:50	800	6.9	13	301	.40	.0034
		200	8.1	18	302	.10	.0140
7– 2–37	9:55	2,200	7.6	22	------	-----	.0004
7–20–37	10:15	1,200	6.0	35	292	.45	.0034
		200	18.8	23	294	.45	.02
7–21–37	13:10	150	11.4	16	295	−.11	.028
8–10–37	10:00	2,500	6.2	31	294	−.14	.0021
		1,400	10.6	40	298	−.14	.0038
8–10–37	12:00	200	13.4	37	304	.07	.0027
11–11–37	9:55	900	11.8	39	279	−.08	.0045
		400	14.2	37	280	−.08	.010
11–11–37	13:20	200	16.3	41	281	.65	.0200