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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED
April 1942 as
Restricted Bulletin

XC-35 GUST RESEARCH PROJECT

OPERATION IN CUMULUS CONGESTUS CLOUD ON JULY 31, 1941

MAXIMUM GUST INTENSITIES

By Flight Research Loads Section

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NACA

WASHINGTON

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RESTRICTED BULLETIN

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OPERATIONS IN CUMULUS CONGESTUS CLOUD ON JULY 31, 1941

MAXIMUM GUST INTENSITIES

By Flight Research Loads Section

On July 31, 1941 a turbulence survey was made with the XC-35 airplane of a large cumulus congestus cloud near Langley Field, Va. This bulletin presents a general description of conditions and the maximum gust intensities recorded during the flight.

FLIGHT HISTORY

The XC-35 airplane took off from Langley Field, Va., at 1455 EST and at 1557 was at 25,000 feet. A cumulonimbus cloud that had been the objective of the flight having begun to dissipate by this time, a cumulus congestus cloud about 25 miles south of the station was selected for investigation. This cloud extended from an altitude of 7000 feet up to 25,000 feet and was moving in an easterly direction.

Six traverses were made through the cloud on NW-SE and SE-NW headings starting at 23,000 feet and finishing at 14,000 feet. The instruments in the airplane were started upon entry into the cloud and stopped as the airplane emerged. The report of the flight crew indicated that the severest turbulence was encountered in the northwest, or windward, portion of the cloud.

The return flight to Langley Field, Va., was made in clear air and the airplane landed at 1655.

METEOROLOGICAL CONDITIONS

Ground and aerological observations indicated that Langley Field, Va., and vicinity was situated in an air mass of tropical maritime air with a conditionally unstable lapse rate. Conditions were similar to those existing on July 3, 1941 and described in reference 1.

Surface heating caused scattered cumulus congestus clouds to form in the late morning. During the afternoon these clouds developed into cumulo-nimbus and resulted in scattered thundershowers over Eastern Virginia. The movement of the clouds was approximately from NW to SE.

EVALUATION OF DATA AND RESULTS

The records of acceleration and airspeed were evaluated to yield:

1. The effective gust velocity, U_e (reference 2)

2. The true effective gust velocity, U_{et} (This gust velocity is analogous to true airspeed as explained in reference 1.)

3. The true gust velocity, U_t (reference 3)

4. The gradient distance, H (reference 3)

For the purpose of this bulletin, only the largest values of the gust velocities at each altitude have been noted. These values and the corresponding acceleration increments Δn are given in table I. The average of the maximum positive and negative gust velocities were computed from the data of table I and plotted against altitude in figure 1.

Since the period of record multiplied by the average speed for each traverse represents the width of the cloud on the line of flight, it has been possible to draw a rough sketch of the cloud (fig. 1). On this sketch the recorded accelerations have been reproduced in order to indicate the horizontal distribution of turbulence at the various altitudes. It will be noted that the acceleration records are arranged so that the rough portions of each traverse are directly over one another. This arrangement further defines the shape of the cloud and is probably justified on the basis of the requirement of continuity of the turbulent belt.

PRECISION

As noted in reference 1, the precision of the results can be only estimated at the present time. The following values represent the best estimate that can be made now:

Gust velocity (U_e, U_{et}, U_t)	±10 percent
Gradient distance, H	±15 feet

DISCUSSION

Although the intensity of the turbulence experienced during this flight was only moderate (the maximum effective gust velocity was only two-thirds of the current design value of 30 fps), the results are nevertheless of considerable interest. The plot of gust velocity against altitude (fig. 1) shows clearly that the intensity of the turbulence increased with altitude until the top of the cloud was approached, where a sharp falling off of the turbulence was observed. This result agrees with theoretical expectations for a cloud in the active developing stage, insofar as the continuous release of latent heat of vaporization as the moist air continues to ascend causes a more or less continuous vertical acceleration and hence increasing velocity and turbulence.

It should not, of course, be presumed from this result that increasing turbulence with altitude should be expected in all clouds, for the phase of the cloud activity governs the vertical structure of turbulence. For example, in contrast with the present case, the turbulence decreased with altitude above 16,000 feet in the cumulo-nimbus and cumulus congestus clouds investigated on July 3, 1941 (reference 1). In that case the cumulo-nimbus cloud had already reached maximum growth at the time of the survey and the cumulus congestus cloud did not attain high altitudes. It seems likely that, had the survey of July 3, 1941 been extended to the lower altitudes within the cumulus congestus cloud, a vertical structure generally similar to that of the cumulus congestus cloud reported herein would have been found.

The observations in the present case also clearly indicate that the roughest zones within the cloud at each altitude were on the windward side except at the top and were of about the same width throughout the vertical extent.

It is of some interest in this connection that the general shape of the cloud, determined by considerations of continuity in the turbulent belt as well as by direct measurement of the width at each level, harmonizes qualitatively with the theoretical flow pattern of a single convective current superimposed on a slight translatory movement. Such a flow pattern is given in figure 45 of reference 4.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
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TABLE I

Altitude (ft)	Δn (g units)	U_e (fps)	U_{et} (fps)	U_t (fps)	H (ft)	Δn (g units)	U_e (fps)	U_{et} (fps)	U_t (fps)	H (ft)
23,000	0.4	10.4	15.1	20.2	130.0	-0.4	-9.6	-13.8	-17.9	61.6
	.4	8.6	12.5	16.5	90.0					
22,500	0.7	17.4	24.9			-0.8	-19.0	-28.1		
	.7	17.3	24.7	31.8	56.6	-.6	-15.3	-21.9		
	.7	16.0	22.9			-.7	-16.3	-23.3		
	.8	16.5	23.6			-.6	-14.0	-19.8		
						-.7	———	———	-32.0	99
21,000	0.9	19.0	26.5			-0.8	-17.6	-24.6		
	.7	16.6	23.1			-.7	-16.4	-22.9		
	1.0	19.0	26.5			-1.0	-22.3	-31.1		
	.7	14.7	20.5			-.7	-15.0	-20.9	-27.0	45.2
	.7	14.0	19.6			-.9	-16.7	-24.3		
	.9	17.7	24.7			-.7	-14.8	-20.6		
	.7	14.3	20.0			-.9	-17.6	-24.6		
	.4	8.0	11.0	15.0	63.0	-.8	-18.3	-25.5		
19,800	1.0	18.1	24.8			-0.8	-15.2	-20.8		
	.6	12.4	17.0			-.8	-14.7	-20.1		
	.8	15.0	20.5			-.3	-6.0	-8.0	-11.0	190
	1.2	24.6	33.6							
	.8	15.0	20.4							
	.4	11.0	14.0	20.0	202.0					
16,300	0.8	16.6	21.4			-0.8	-18.1	-23.3		
						-.7	-15.8	-20.4		
	.5	14.0	17.0	23.0	73.0	-.2	-5.0	-7.0	-10.0	99.0
13,700	0.9	18.6	23.0			-0.6	-13.6	-16.0		
	.3	8.0	10.0	14.0	74.0	-.6	-14.0	-16.8	-24.0	123

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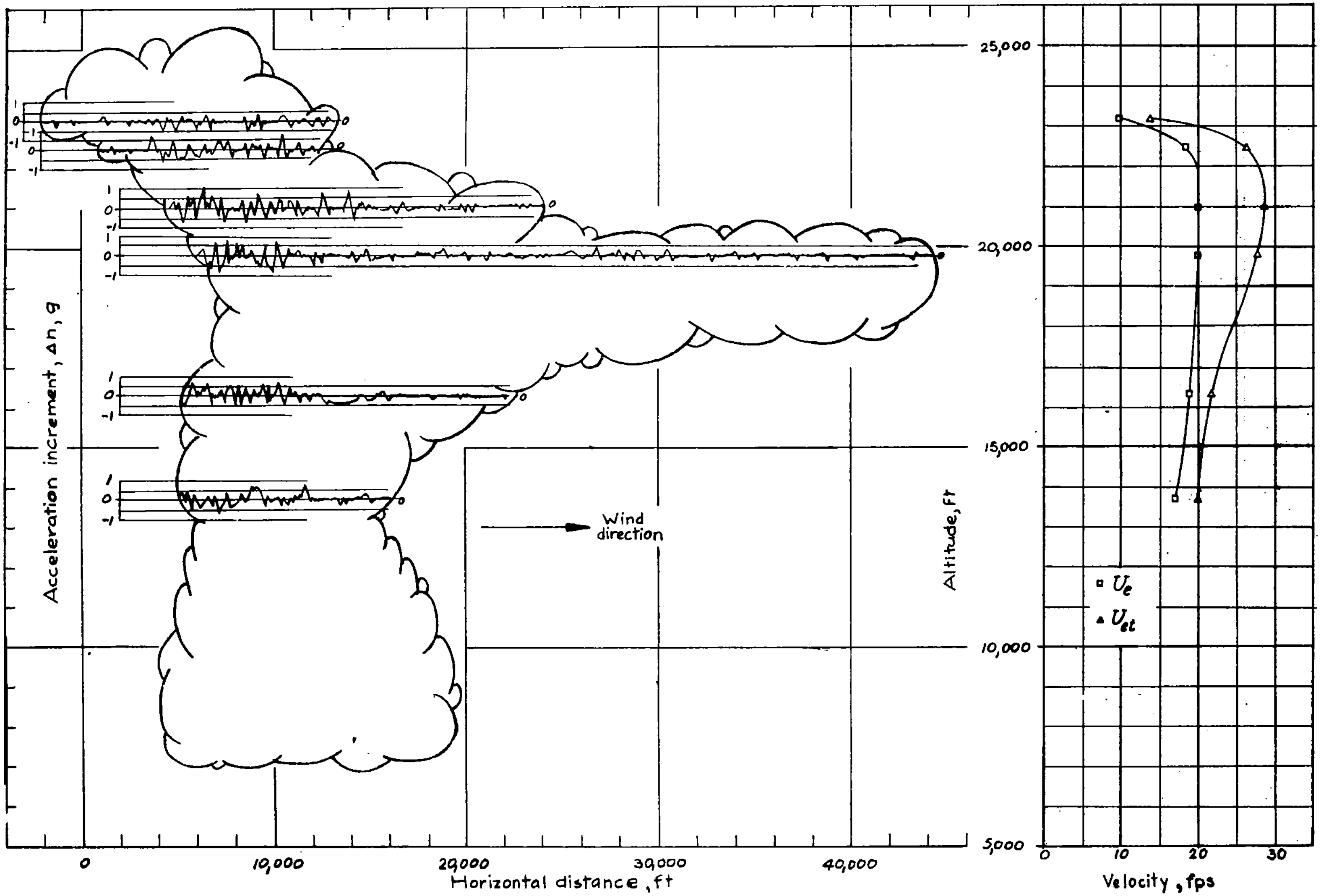

Figure 1.- Horizontal and vertical distribution of turbulence.

Fig. 1