Docket No. SA-95 File No. 3640-44

CIVIL AERONAUTICS BOARD

ACCIDENT INVESTIGATION REPORT

Adopted: January 7, 1946 Released: January 15, 1946

TRANSCONTINENTAL AND WESTERN AIR - HANFORD, CALIFORNIA

NOVEMBER 4, 1944

TWA's Flight 8 of November 4, 1944, failed structurally in the air near Hanford, California, while on regular transcontinental schedule from San Francisco to New York. All 21 passengers and the three crew members were killed.

Flight 8 was scheduled to depart from San Francisco at 1500 PWT[1] but was delayed approximately one hour due to the necessity of certain small repairs. These were made and certified to be satisfactory by a Civil Aeronautics Administration Air Carrier Maintenance Inspector and were in no way material to the accident which followed on the flight. At departure the plane was loaded with 1714 pounds of mail and baggage, 410 gallons of fuel and 21 passengers, of whom 20 were military personnel. Total weight at the time of take-off was almost exactly the full 25,200 pounds allowable, and the load was distributed properly.

Flight 8 took off at 1600 and proceeded according to plan to a cruising altitude of 10,000 feet for Burbank on an instrument clearance. It reported over Fresno on schedule cruising at 10,000 feet and estimated Bakersfield at 1735. At 1712 the crew was last contacted by the company and given a routine message which was acknowledged. Thereafter, at intervals of a few minutes, numerous unsuccessful attempts were made to contact the flight. At no time did the captain report any difficulty with the airplane or comment on the weather.

A number of persons near Hanford saw the plane enter a rapidly forming thunderstorm and some heard it in the cloud. Shortly thereafter, parts of the plane were seen falling from the base of the overcast which was at about 1500 feet. An ignited flare, broken free from its chute and appearing as a ball of fire, was the first object seen. This was followed by several major and many lesser portions of the aircraft. The main portion, consisting of the center section,

1/ All time referred to herein is Pacific War and based on the 24-hour clock.

the pilots' compartment, right outer wing panel, the engines and the landing gear, struck the ground in an attitude slightly past vertical and burned on impact.

The main wreckage was concentrated in two areas approximately 1/2 mile apart although small parts were found as far as 3-3/4 miles from the main portions.

A detailed examination of the wreckage and the airplane's maintenance record led to the following significant conclusions which are further supported in detail by Appendix I and II attached hereto:

1. The left wing had failed initially in a downward direction (with respect to the fuselage) just outboard of the landing light.

2. The horizontal tail surfaces had also failed in flight.

3. There was no evidence of a mechanical failure in any other part of the aircraft's structure, nor in the controls, engines, propellers, instruments or accessories except that which resulted from the initial failure.

4. There was found no evidence that there had been any weakening of the aircraft's structure prior to the accident, nor that the airplane's maintenance had been below standard.

5. There was no evidence of any explosion or fire in the air.

6. There was no evidence of damage by lightning or hail.

7. There was no evidence of collision with any object in flight.

On the day of the accident an extensive low pressure area was causing cloudiness and showers over the Pacific Coast area, with its center a short distance off Vancouver Island. At 0830 an occluded front extended out of the low pressure center into British Columbia, thence into Idaho and Nevada, and then southwestward across the San Joaquin Valley north of Bakersfield to the Pacific near Santa Maria.

In the San Joaquin Valley this front moved slowly southward and had reached the extreme south end of the valley by the time of the accident. In the moist polar Pacific air mass north of the front a new low center formed aloft during the day with a line of convergence across the northern portion of the San Joaquin Valley. This was later carried as a secondary cold front which moved southward.

It was along the line of this secondary front that one or more thunderstorms developed. The one that is directly associated with the accident apparently reached its most vigorous stage at about two miles north-northwest of the main portion of the wreckage. This local thunderstorm produced squall winds of 30 to 35 miles per hour at ground level, rain estimated to have been 2.5 inches in not more than an hour and small hail. Strong squall winds, heavy rain and hail occurred in a restricted area along the probable flight path and within three miles of the location of the main portion of the wreckage. Other evidence and computation indicate that the top of the thunderstorm was at 15,000 to 20,000 feet above sea level, the freezing level between 9,000 and 9,500 feet with probable icing of varying degree above this level and a probable maximum buoyancy effect of about 55 feet per second. (Not to be confused with the sharp-edged gusts values referred to in Appendix III.)

The storm conditions which existed in the vicinity of the accident were partly determined by study of official weather reports but much additional information regarding local conditions was obtained from 13 ground witnesses and from seven pilots who flew through the area at about the time. In what are commonly referred to as "thunderstorm cells", which existed at the time there is some reason to believe that the maximum turbulence occurs at about the time each cell reaches the development stage where heavy rain and hail occur. Apparently the flight entered the thunderstorm at the time of the probable maximum severity. It, therefore, could have encountered quite severe vertical currents ranging from small to large updrafts or downdrafts, or both. Relatively, however, this thunderstorm appeared to be less severe than many mid-western summer thunderstorms and it does not seem reasonable to believe that its degree of turbulence would have been unique.

Due to the cloud conditions in that general area, it cannot be definitely determined whether or not the pilots saw the cumulo-nimbus cloud before they flew into it. From all the information available it appears most probable that they were flying between layers of cloud before reaching the storm. If this is correct both the bottom and the top of the storm cloud would have been hidden and it is further possible that other types of clouds near the cumulo-nimbus could have obscured the cumulo-nimbus sector that otherwise would have been visible. This condition could very well have given the appearance of the two cloud layers converging and thus give no clue to the pilot that he was encountering a cumulo-nimbus cloud.

This is pertinent to this report in that it is entirely possible that the pilots might have been taken by surprise on entering a turbulent cloud. Certain preparations such as reduction of airspeed which would reduce the structural stress placed on the airplane's structure by turbulence are acknowledged to be good technique when entering a cumulo-nimbus cloud. Had the pilots entered the cumulo-nimbus cloud at a high cruising speed due to surprise, this would increase the severity of the action of any gusts and turbulence encountered. Encountering severe turbulence in this manner might have caused temporary loss of control during which the airplane could have become inverted with the resultant inability of the airplane to withstand structural stress it would normally have withstood in a normal attitude and speed of flight through a cumulo-nimbus cloud.

Inasmuch as this aircraft was equipped with a flight analyzer, a barographic device that automatically records altitude against time, a detailed study of the recordings of this device was made and both the recording and the interpretation thereof are given in Appendix II to this report. This study reveals that the airplane was undoubtedly in an unusual position of flight at the moment of structural failure and was in all probability inverted at that moment. From the study of this barographic record and the wreckage, it must be concluded that the airplane had gotten into an inverted position either through turbulence or temporary loss of control and that failure of the airplane structure must have occurred at that moment.

CONCLUSION AND FINDINGS

Based on all the evidence available to the Board in this case, it therefore becomes evident that structural failure occurred while the airplane was inverted and certainly not in a normal flight attitude. This being true, severe turbulence would naturally cause structural failure of the airplane whereas it would be improbable that failure would have occurred had the plane remained in a normal flight attitude. The reason for the airplane becoming inverted can only be surmised.

Based on all the evidence available, the Board therefore finds:

1. The aircraft, crew and air carrier were properly certificated.

2. A secondary front with thunderstorms was not predicted although showers were expected along the flight path and thunderstorms had been anticipated along the primary front.

3. Normal flight was interrupted when the aircraft entered a cumulo-nimbus cloud of considerable intensity.

4. A cumulo-nimbus cloud reached its maximum development in the Hanford area at approximately the time of the accident.

5. The aircraft was in an abnormal attitude of flight, i.e., inverted, at the time of the actual structural failure.

6. The left wing and in all probability the tail surfaces also failed structurally from severe turbulence.

7. There was no evidence of any collision, explosion, fire in the air or damage by lightning or hail.

PROBABLE CAUSE

On the basis of all the evidence available the Board determines that the probable cause of this accident was the failure of the airplane's structure as a result of severe turbulence. An important contributing cause was the fact that the airplane was undoubtedly in an abnormal attitude of flight, i.e., inverted, at the instant of structural failure. The cause of the airplane becoming inverted has not been determined.

BY THE CIVIL AERONAUTICS BOARD:

/s/ L. Welch Pogue

/s/ Harllee Branch

/s/ Oswald Ryan

/s/ Josh Lee

SUPPLEMENTAL DATA

Investigation and Hearing

The Civil Aeronautics Board received notification of the accident at approximately 1900 on November 4, 1944, and immediately initiated an investigation in accordance with the provisions of Section 702 (a) (2) of the Civil Aeronautics Act of 1938, as amended.

The Senior Air Safety Investigator of the Board's Santa Monica Office arrived at the scene at approximately 0300, November 5. He was later assisted in the investigation by other members of the Board's Safety Bureau staff.

Present at the investigation and hearing were representatives of the Civil Aeronautics Administration, Douglas Aircraft Company, Wright Aeronautical Corporation and Company personnel.

In connection with the investigation the Board ordered a Public Hearing and designated the Chief of the Investigation Section, Safety Bureau of the Board, as Presiding Officer. Other members of the Board's Safety Bureau staff participated in the hearing which was held in two sessions. The first convened November 11, 1944, at Kings County Court House, Hanford, California, near the scene of the accident to hear local witnesses. On November 20, 1944, the hearing reconvened at the United States Post Office and Court House Building, Los Angeles.

Air Carrier

At the time of the accident Transcontinental and Western Air, Inc., a Delaware corporation with headquarters in Kansas City, Mo., was operating as an air carrier under a certificate of public convenience and necessity and an air carrier operating certificate, both issued pursuant to the Act. These certificates authorized the company to fly persons, property, and mail between various points including San Francisco and Burbank.

Flight Personnel

Captain Alford Thomas Bethel, age 32, of Burbank, California, First Officer George Edward Smith, age 30, of Kenmore, New York, and Hostess Myrtle Irene Miller, age 27, of North Hollywood, California, comprised the crew. The captain and first officer were properly certificated and the captain was qualified for the route.

Aircraft

The aircraft, NC 28310, was a Douglas DC3 manufactured in July 1940. It was sold to American Airlines who sold it to TWA in July 1942. There is no record of this airplane having been involved in any previous accident. In addition to the usual minor alterations, which included compliance with factory maintenance bulletins, the wing tips had been reinforced. Total flying time was 13,167 hours with 975 hours since last major overhaul. This plane was equipped with Wright Cyclone G102 900 h.p. engines and Hamilton Standard propellers. Total time on the engines was 8300 hours and 16,327 hours, with 70 and 48 hours respectively since overhaul.

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APPENDIX I

DESCRIPTION OF THE WRECKAGE

The tail section, parts of the left outer wing panel, pieces of the passenger compartment, mail pouches, personal baggage and the bodies were scattered over an area of approximately one square mile. The main structure of the airplane consisting of the wing center section, landing gear, right wing panel, the engines and the pilots' compartment remained intact until it struck the ground. This unit struck the ground in a slightly past vertical attitude, imbedding the engines several feet, approximately 1/2 mile from the other wreckage concentration. A fire followed the impact and destroyed the center section, cockpit, controls, instruments, and most of the right landing gear. The condition of the left landing gear indicated that it was in a retracted position prior to impact.

In reconstructing the series of failures which occurred in the air it appears that the left wing outer panel failed initially in a downward direction (with respect to the fuselage) at station 267, (located just outboard of the landing light.) The panel apparently sheared off, swung back and against the underside of the fuselage, striking it at a point just aft of the passenger compartment door. The force of the blow came from the bottom and right side of the fuselage. This outer wing panel, in addition to being sheared off at station 267, became separated spanwise between the front and center spars. The wing tip became separated from these two parts. These latter failures are believed to have occurred subsequent to the initial failure at station 267. On the wing tip a sharp gash ran chordwise. It appears that this was caused by one of the control cables in the fuselage, although the evidence is not conclusive.

It is believed that the blow from the outer panel caused the entire passenger cabin to shatter allowing the occupants, seats, etc., to fall to the ground. The majority of seat belts were either broken at their attachments or contained abrasions caused by slippage through the buckles. An analysis of the breaks indicated forces in an upward and forward direction.

The portion of the fuselage aft of the passenger compartment door and the tail assembly, except the elevators and rudder, fell to the ground in one piece. There was conclusive evidence that the tail surfaces had also failed in the air. This failure appeared to have originated in the stabilizers and possibly the elevators due to forces acting in an upward direction. As a result both elevators and the rudder became detached. Both sides of the stabilizer sustained major breaks at their roots as the result of upward forces. They also showed definite signs of a reversal of air load. This was evidenced by a diagonal wrinkle starting inboard at the trailing edge and extending outboard to the leading edge. It was not possible to ascertain definitely whether the wing or the tail surfaces failed first, but it seems most probable that both failures were the result of the same violent air loads and the interval of time between them was negligible.

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APPENDIX II

INTERPRETATION OF THE FLIGHT ANALYZER RECORD

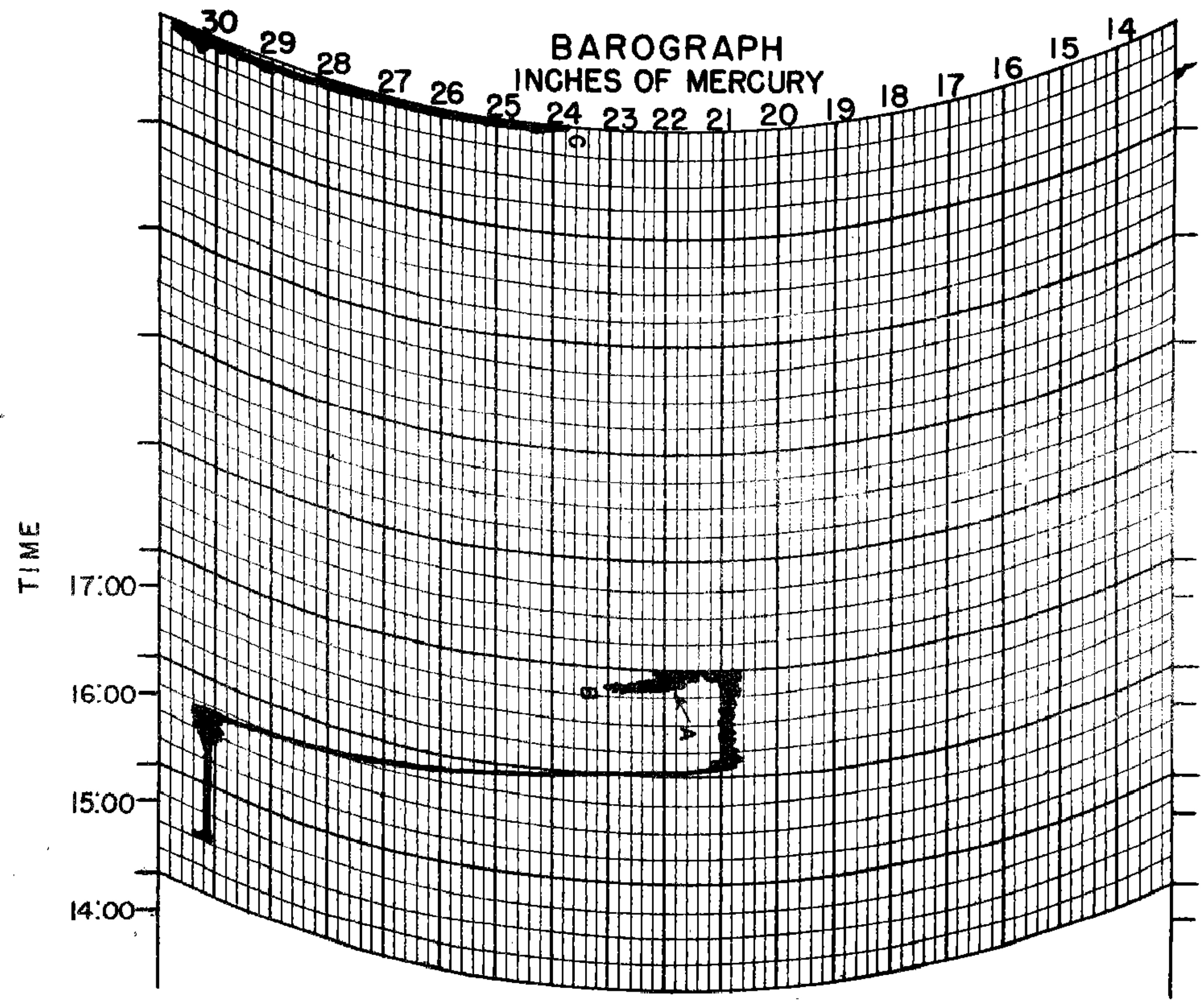
The airplane was equipped with a flight analyzer. This analyzer was adjusted to record the altitude and the radio contacts with relation to the flight time. The "altitude" portion of the recording card has been reproduced and is attached. Extraneous marks on the card have been deleted from the reproduction to avoid confusion.

The card indicates normal operation of the airplane from the time of take-off from San Francisco until about 1713, at which time there can be noted an abrupt gain of altitude to about 10,200 feet, immediately followed by a long descent, evidenced by a series of irregularities in the graph. First there were two instances (at approximately 9600 and 9200 feet) where the descent seemed to have been checked (or reversed) with a simultaneous displacement back along the "time" direction. The descent continued to about 8400 feet, at which altitude the graph indicates the beginning of a rapid ascent to an altitude of 9000 feet, accompanied by a displacement of the time element by about 1/32 of an inch. From 9000 feet, the descent is resumed with an additional slight reversal of the time element. At 7400 feet, there occurs a complete discontinuity of the graph, which is finally picked up at the extreme upper end of the card at an altitude of 6600 feet, from where it continues to the ground. Due to the effect of time reversal present on the graph, it is not possible to establish quantitatively the rates of descent and ascent indicated in the last portion of the graph.

The two most significant points on the graph are the reversal of time (marked A on the reproduction) and the discontinuity (from point B to point C on reproduction). In order to interpret this action of the graph correctly, it is essential to correlate it with the position of the flight analyzer as it was located in the airplane. This instrument was mounted upright against the left wall of the fuselage, with the plane of the card and carrier coincident with the fore-n-aft plane of the aircraft. The downward movement of the carrier, driven by clockwork, gives the time element on the card, the pen being stationary in the up and down direction and pivoted from above to swing with the change in atmospheric pressure. The gears driving the carrier have a small amount of play, which is apt to vary somewhat with each instrument; however, it is not expected to exceed 1/32 of an inch or so. The friction in the clockwork can be overcome by a pull of about 1½ pounds (24 ounces).

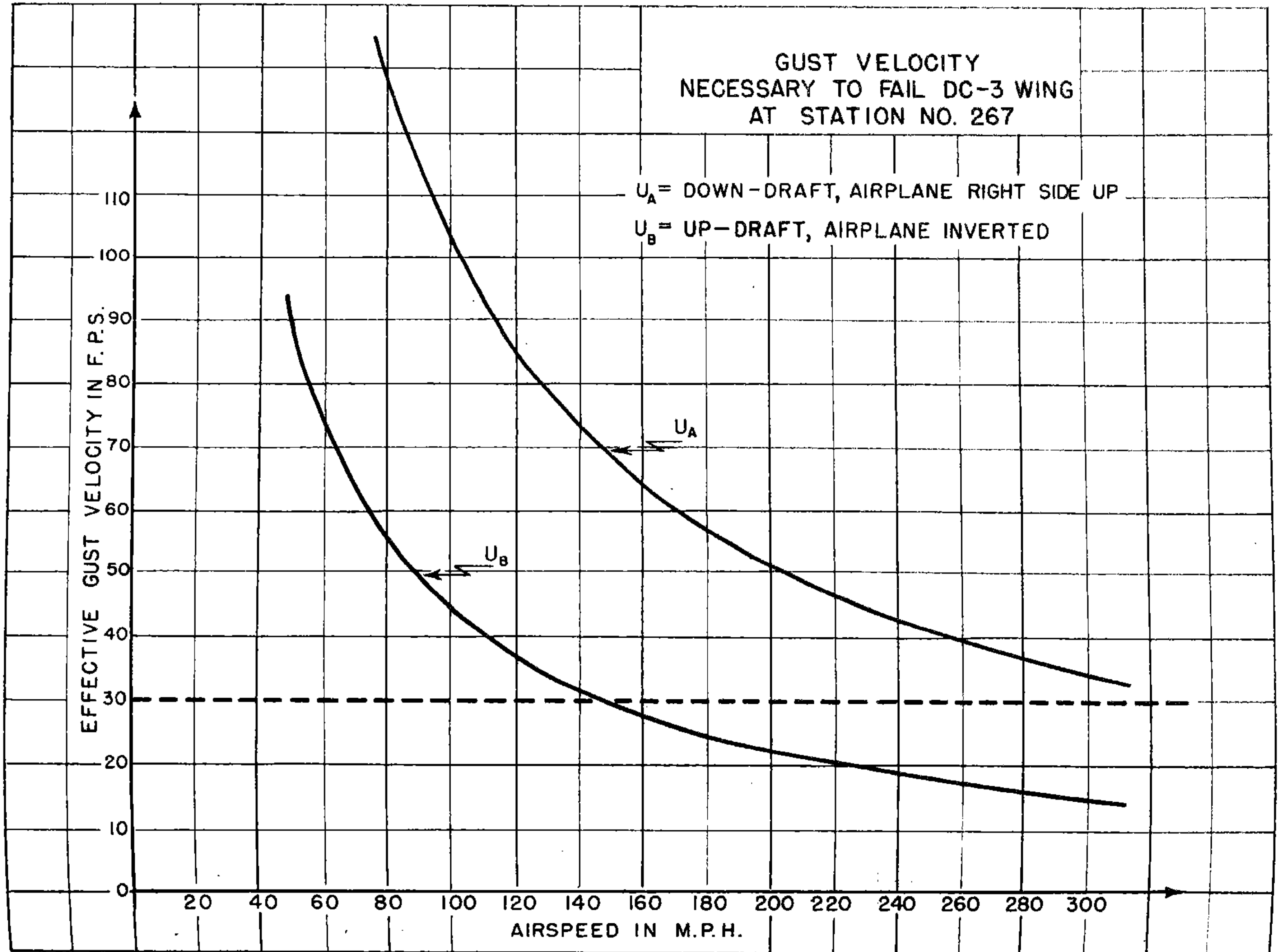
Thus, with the carrier and card weighing $2\frac{1}{2}$ ounces, it takes about 10g to displace the carrier and card along the time direction to any appreciable degree.

With the above in mind, the significance of points A, B and C of the graph becomes clear. First, there is little doubt that the aircraft was carried from 8400 to 9000 feet, probably by an updraft. This, however, was accompanied by a reversal of time; i.e., by the movement of the carrier in an upward direction with respect to the instrument proper. Such a motion, with the airplane in an updraft, could only occur if the instrument were upside down; i.e., the aircraft inverted. Otherwise the motion would be inconsistent with the inertia effects in an updraft. Since the airplane was being lifted by an updraft, the logical deduction is that it was in an inverted position at that time. After descending to 7400 feet, there occurs the discontinuity of the graph. Not only were the carrier and card moved down abruptly, but the pen was separated from the card. As stated before, such a downward movement of the carrier can occur only under an acceleration of at least 10g with the force acting from below the instrument. The separation of the pen is most apt to occur under loads from the face of the instrument; i.e., lateral forces from the right side of the fuselage. Forces of 10g or more are extremely unlikely in a DC3 as a result of air loads. Therefore, a force other than that originating from a gust or from a maneuver must have occurred at an altitude of 7400 feet. It is believed that the force causing the discontinuity of the graph resulted from the wing striking the fuselage.



FLIGHT ANALYZER RECORD
T.W.A. DC-3 NC28310
November 4, 1944

ACCIDENT INVESTIGATION DIVISION
SAFETY BUREAU CIVIL AERONAUTICS BOARD


GUST VELOCITY
NECESSARY TO FAIL DC-3 WING
AT STATION NO. 267
U_A = DOWN-DRAFT, AIRPLANE RIGHT SIDE UP
U_B = UP-DRAFT, AIRPLANE INVERTED
U_A
U_B
EFFECTIVE GUST VELOCITY IN F.P.S.
0
10
20
30
40
50
60
70
80
90
100
110
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
AIRSPEED IN M.P.H.

C I V I L A E R O N A U T I C S B O A R D

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APPENDIX III

ANALYSIS OF FAILURES

In the subject flight the storm area encountered in the vicinity of Hanford was conducive to rather severe vertical displacements of air. However, there is no indication that the severity was in any way extraordinary, and it is therefore improbable that there were developed, particularly at the altitude flown, gusts of sufficient velocity to exceed the 30-foot per second sharp-edged gust values used in the design of the DC3. This is especially true of the probable down gusts which are not believed to have been more than about one-half of the design value.

Taking into account the computed strength of the DC3 wing at the point of failure, a relation can be established between the airspeed of the airplane and the sharp-edged gust velocity necessary to fail the wing at station 267.

From Douglas Report #992 (Wing Stress Analysis for DST), page 148 (dated 3-17-36) the minimum margin of safety in compression of bottom surface at station #267 (point of failure) is 39% in condition II (down loads on wing - relative to airplane). The design load factor used was -1.86 corresponding to a V_L of 330 fps (225 mph) and a weight of 24,000 lbs.

Thus the load factor causing failure would be:

$$-1.86 \times 1.39 = -2.585$$

In the subject accident the airplane left San Francisco with a 25,202 lb. load. After one hour and 19 minutes of flight when the accident occurred the load is estimated to have been reduced to 24,500 lbs. At this load the equivalent load factor for failure would be:

$$-2.585 \times 24{,}000/24{,}500 = -2.532$$

The correlation of this load factor with airspeed and gust velocity may be presented by using the usual empirical expression. Thus:

$$\pm 2.532 = 1 \pm \frac{1.08 \times 4.53\ UV}{575 \times 24.83} \quad : \text{where}$$

24.83 is the wing loading corresponding to 24,500 lbs.
4.53 is the slope of the lift curve (from Douglas Stress Analysis).
1.08 is the gust coefficient for a wing loading of 24.83.
575 is a conversion factor.
U & V are the gust velocity and airspeed respectively.

From the above the following relation exists:

A. The sharp-edged gust velocity, in a downdraft with the airplane upright, will be:

$$U_A = \frac{10,310}{V};$$

B. The sharp-edged gust velocity, in an updraft with the airplane upside down, will be:

$$U_B = \frac{4,470}{V};$$

Curves for U_A and U_B are drawn on the attached sheet. The horizontal line running through the 30 fps gust value is the limit of probable gust velocities encountered, as expressed by the design criteria in the Civil Air Regulations.

Referring to the curves and assuming arbitrarily a 15-foot per second down-gust, it will be noted that, in order to fail the wing in a downward direction (aircraft in normal attitude), the airplane would have to attain an impossibly high speed. Even for the design 30-foot per second down-gust*, the speed would have to be above 300 m.p.h. which, although possible, appears extremely improbable under the circumstances. This seems to preclude almost definitely an assumption that a down-gust was responsible for the wing failure. On the other hand, if an up-gust equal to the design value of 30 feet per second (sharp-edged) had occurred while the airplane was inverted the curves reveal that failure could have occurred at any speed above 150 m.p.h. This definitely indicates a much greater probability of the wing failing in an up-gust while the airplane was in an inverted position, and is consistent with the conclusions reached from the study of the flight analyzer record.

In studying the wing failure it is necessary to consider the reasons why the initial failure occurred at station 267. From all available design data, it appears that, regardless of the direction of failure involved, the structure in the vicinity of station 267 has ample margin of safety and is far from being the weakest point in the wing. Although this statement is based mainly upon values given in the manufacturer's stress analysis, it has been substantiated indirectly by static tests and there is no reason to believe

*Although a 30-foot per second sharp-edged gust is generally used as a design value in level flight conditions, higher equivalent sharp-edged gust values have been recorded in isolated cases.

that the actual conditions are materially different insofar as static loads on the wing are concerned. Furthermore, past experiences on DC3 airplanes does not indicate station 267 to be critical.

In general a number of reasons may exist for unpredictable failures such as flutter modes, concentration of stress critical under fatigue conditions, dynamic and inertial effects, and abnormal span-load distribution due to turbulence. It is believed that in this case the predominant factor influencing failure at station 267 was an abnormal distribution of air load along the span of the wings, together with dynamic overstress apt to occur in violent gusts.

According to results of the NACA's gust research, there is a great variety of types of distribution resulting from turbulent air, and these distributions are not necessarily subject to rational predictions. It is, therefore, very probable that the turbulence encountered within the storm area near Hanford influenced the air loads on the wing in a manner imposing more severe stresses at station 267.

Wing failures on DC3 and similar model airplanes are known to have occurred in the past. Those failures of a major character were all located just outboard of the wing tip connection, which was known to be the weakest point in the wing structure. In view of these failures, the wing tips of DC3 aircraft were reinforced. These new tips, possessing more strength than the original ones, are performing satisfactorily. However, although the over-all strength of the wings thus has been apparently increased, it does not necessarily indicate that the reinforced wing tips render the aircraft safer than it had been previously. By increasing the strength of the wing tips the critical point may be moved to some other location on the wing - under certain conditions of air loads - and the failure at the new point may involve more serious consequences to the airplane than if the wing tips had failed. It should be noted that in only one case of wing tip failure known to the Board did the accident result in fatal injuries to the occupants, and even in this instance two persons survived the final crash. Apparently, on the DC3, the loss of the wing tips, even if followed by the loss of the ailerons, does not necessarily render the airplane completely uncontrollable. Such is probably not the case if the wing failure occurs somewhere inboard of the wing tip connection as, for instance, at station 267.**

The advantage of designing for "controlled failures"; i.e., structural design with a purpose of incorporating the weakest point where failure would be less likely to result in serious consequences, has been long known. However, only very recently has concerted study been taken up on this important phase of aircraft design.

** Since the Hanford accident there has occurred another wing failure on a model very similar to the DC3. Due to relative inaccessibility of the wreckage it was not possible as of this date to ascertain the exact location of the failure. However, all evidence indicates that most, or even all of the outer panel was severed.

The strength of the DC3 tail surfaces, as established by stress analysis and static tests, is apparently more than adequate to withstand the design loads. However, it is possible that, under certain unpredictable flight conditions, a failure can occur, The failure of the tail surfaces in the subject accident resembles very closely the failure which was sustained by the tail surfaces of another DC3 at Fairfield, Utah, on December 15, 1942. (For a detailed discussion of that accident, see the Board's release dated October 11, 1943, File No. 2905-42, Docket No. SA-78) It is extremely significant that on at least two previous occasions (including the Fairfield accident) the horizontal tail surface failures were associated with a failure of the wing.*** It, therefore, becomes more probable that the air loads on the horizontal tail surfaces of a DC3, and perhaps of other model aircraft, are affected by flow conditions over the wings in a manner not normally assumed in design, and that a wing failure is apt to influence adversely the load distribution on the tail. The Board, therefore, feels the urgent need of accelerating the general study of tail surface loading with the ultimate view of revising the pertinent design criteria.

Although it is also possible that the tail surface failure on DC3's may originate from an unknown flutter condition, this does not seem probable in view of the nature and circumstances of the known cases of failure. Additional information on this question should be available in the very near future when final results of studies and tests now being conducted by the C.A. and the Douglas Company become available.

Subsequent to the examination of the wreckage at the scene of the accident 41 items were retained for study by the Board and other government agencies, including 31 structural specimens referred to the U. S. National Bureau of Standards. The latter were subjected to detailed study and tests to ascertain if possible their strength properties. The results did not show evidence of damage from fatigue, corrosion or defective material or workmanship. Although 3 of 8 submitted ball bearings showed evidence of damage from "brinnelling" it is very probable that this damage was caused by the accident. Although no indications were found that the wings, the tail surfaces or any other part of the airplane's structure had been weakened through relatively long service or other factors, this phase is being given further consideration. So far, studies of the subject do not indicate any hidden ill effects on the structural materials merely due to long life. It is conceivable that long service of complete assemblies, such as a wing panel, may induce some looseness within the connections, and/or such fatigue of connecting elements as to alter their strength to some degree. No affirmative evidence of any such loss of strength has been found however in the present case or any previously investigated.

*** This does not include the case described in footnote ** where, in addition to the wing failure, there had also occurred a complete failure in the air of the horizontal tail surfaces.