# AIR SAFETY BOARD
## REPORT

## TO THE CIVIL AERONAUTICS AUTHORITY

## AS A RESULT OF AN INVESTIGATION OF AN ACCIDENT INVOLVING AIRCRAFT

Accident involving aircraft NC 13727 of Braniff Airways, Inc., near Oklahoma City, Oklahoma, March 26, 1939.

An accident involving aircraft of United States registry, NC 13727, while operating as Trip One of Braniff Airways, Incorporated, of March 25, 1939, having occurred in the vicinity of Oklahoma City, Oklahoma, on the 26th day of March, 1939, with the resultant destruction of the aircraft, fatal injuries to eight persons aboard, and serious injuries to the remaining four occupants, the Air Safety Board of the Civil Aeronautics Authority on the same day directed that full and complete investigation of the accident, pursuant to the provisions of Section 702 (a) (2) of the Civil Aeronautics Act of 1938 (52 Stat. 973, 1013), be immediately begun, and that the facts, conditions and circumstances relating to the accident and the probable cause thereof be determined. It was further ordered that the investigation include such field investigation and research and such public or private hearing or hearings as might be considered necessary.

For the purpose of carrying out the above order, the Air Safety Board designated R. D. Hoyt, Chief of the Investigation Division of the Air Safety Board, as Investigator in charge, and Robert W. Chrisp, Senior Attorney Examiner, Examiners Section of the Air Safety Board, as legal advisor to the Investigator in charge during the field investigation and as Examiner empowered to order and conduct such public or private hearing or hearings in connection with the investigation

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as the Board might direct. It was further ordered that Mr. Hoyt and Mr. Chrisp be assisted and advised by W. S. McDuffee, Executive Officer of the Air Safety Board, Phil C. Salzman and George W. Haskins, Power Plant Engineers, Air Safety Board.

The investigation, research and hearings were carried out under the direct supervision of Thomas O. Hardin, Vice Chairman of the Air Safety Board.

Investigation of the accident was begun on the 26th day of March, 1939, by the above-named personnel and the public hearing in connection therewith was temporarily delayed pending improvement in the physical condition of survivors of the accident.

A public hearing was ordered and held in the City of Dallas, State of Texas, on the 8th and 9th days of June, 1939, and was subsequently reopened by the Hearing Examiner in the City of Washington, District of Columbia, on the 27th day of June, 1939.

Having considered the evidence adduced during the investigation, the following facts, conditions, and circumstances relating to the accident and conclusion as to the probable cause thereof are hereby reported, and recommendations, which, in the opinion of the Air Safety Board, will tend to prevent similar accidents in the future, are hereby made to the Civil Aeronautics Authority:

FACTS, CONDITIONS, AND CIRCUMSTANCES

Braniff Airways, Incorporated, a corporation organized and existing under and by virtue of the laws of the State of Oklahoma, having duly filed applications for certificates of convenience and necessity over certain routes in accordance with the pertinent provisions of the Civil

Aeronautics Act of 1938 and regulations issued thereunder, was operating at the time of the accident as an air carrier engaged in interstate air transportation. Subsequent to that date, a certificate of public convenience and necessity was issued by the Civil Aeronautics Authority to Braniff Airways, Incorporated, authorizing it, subject to the provisions of such certificate, to engage in air transportation with respect to persons, property and mail via certain named intermediate points between the terminals of Chicago, Illinois, and Dallas, Texas.

Aircraft NC 13727, operated on the flight, was a Douglas Model DC-2, manufactured by the Douglas Aircraft Corporation of Santa Monica, California. This model is approved by the Civil Aeronautics Authority for air carrier operation over the route flown by Braniff Airways, Inc., with an approved gross weight of 18,200 pounds. It was powered with two Wright Cyclone Engines, Model GR 1820 F 2A, and Hamilton Standard Controllable Pitch (two-position) Propellers, hub models 3E-50, and blade models 6111-6. According to the testimony of Stanley Shatto, Supervisor of Maintenance, Braniff Airways, the left engine had a total time of 5,142 hours and 15 minutes, and had operated 294 hours and 57 minutes since the last overhaul, while the right engine had a total time of 5,511 hours and 11 minutes, and had operated 397 hours and 8 minutes since last overhaul. Overhaul period on this type engine, approved in the Maintenance Competency Letter issued to Braniff Airways, Inc., under date of July 11, 1938 by the Bureau of Air Commerce and subsequently adopted by the Civil Aeronautics Authority, is 525 hours.

The crew consisted of Captain Claude H. Seaton, First Officer

Malcolm Wallace, and Flight Hostess, Louise Zarr. Captain Seaton had accumulated a total of approximately 9,060 hours flying time of which about 4,500 hours were flown at night, and approximately 1,253 hours in Douglas DC-2 aircraft. First Officer Malcolm Wallace had accumulated a total of 2,244 hours flying time, of which 526 hours were in DC-2 aircraft. Both airmen were possessed of required ratings and Certificates of Competency for the flight and equipment involved. Miss Louise Zarr, 25, of Waco, Texas, was employed by Braniff Airways in March, 1937, and had served as Flight Hostess for approximately two years.

Braniff Airways Trip One of March 25, 1939, scheduled to operate between Chicago, Illinois, and Dallas, Texas, with scheduled intermediate stops at Kansas City, Missouri, Wichita, Kansas, and Oklahoma City, Oklahoma, departed from Chicago at 9:20 p.m. (CST), after a twenty-minute delay due to connections. The trip proceeded normally from Chicago to Oklahoma City, making regular scheduled stops at Kansas City, Missouri, and Wichita, Kansas. A short time before the trip arrived at Oklahoma City, Captain Seaton was asked by the Dallas Dispatcher "whether the aircraft was OK to proceed to Brownsville, Texas." In reply to this message the pilot reported, "Ship OK". The maintenance and overhaul shops of Braniff Airways are located at Dallas, Texas, and it is customary to request a report on the condition of all aircraft prior to arrival at that point in order that they may be cleared for further use if desired.

The trip arrived at Oklahoma City at 2:37 a.m., having made up 6 minutes of the 20 minutes lost at Chicago, and departed at 2:42 a.m., after being properly cleared by the Dallas Dispatcher. At

2:41 a.m., the United States Weather Sequence Report showed the weather over the route to be flown to be as follows:

> Oklahoma City, instrument weather, ceiling 700 feet, overcast, visibility 12 miles, light rain, temperature 55, dew point 55, wind north 8, barometer 29.58.
>
> Ardmore, ceiling unlimited, thin scattered clouds at 900 feet, visibility 15 miles, temperature 58, dew point 56, wind east-southeast 3, barometer 29.57.
>
> Gainesville, ceiling 1200 feet, overcast, visibility 9 miles, temperature 66, dew point 58, wind south-southwest 6, clouding is changeable.
>
> Dallas, contact weather, ceiling 1600 feet, thin broken clouds, visibility 10 miles, temperature 65, dew point 63, wind west-southwest 6, barometer 29.59.
>
> Fort Worth, contact weather, ceiling unlimited, scattered clouds at 6000 feet, visibility 7 miles, temperature 60, dew point 59, wind west-northwest 12, barometer 29, visibility variable, Zonot (ultra high frequency zone marker inoperative).

At the time of departure from Oklahoma City, the gross weight of the aircraft was 17,563 pounds including mail, cargo, 360 gallons of fuel, and the following passengers who gave their addresses as indicated:

> Mr. C. E. Erickson, Pepsodent Company, Chicago, Illinois;
> P. E. Smith, Corpus Christi, Texas;
> P. T. Bates, Thompson-Bates & Sons Co., Denver, Colorado;
> Miss J. Allen, Evanston, Illinois;
> B. Grossman, 24 Fox Avenue, Aurora, Illinois;
> J. Caric Galleon, Mexico City, Mexico;
> B. Coplon, 2136 E. 75th Street, Chicago, Illinois;
> Mrs. E. Henkley, Port Isabel, Texas; and,
> Miss Georgia Shelton, Manhattan, Kansas.

The aircraft started the take-off from the south end of the north-south runway about 2:45 a.m., and crossed the north boundary of the field in a normal climb. According to the testimony of Captain Seaton and First Officer Wallace, the manifold pressure on the left engine dropped noticeably just after passing that point. Captain Seaton throttled that engine slightly and continued to climb straight ahead. Since the trouble in the engine appeared to develop rapidly, attended by considerable noise and vibration, Captain Seaton ordered the First Officer to cut the fuel supply to the left engine and to notify the airport that they were returning. The First Officer operated the fuel selector valve as directed, and radioed as follows: "Turn on the light OK City we are coming in." Following this he opened the cover of the emergency control box and set the fire extinguisher selector control valve on the left engine as a precautionary measure in case of fire.

After reaching an altitude of approximately 500 feet, Captain Seaton turned the aircraft to the northwest, leveled out, and headed into the wind. At this time there was considerable noise in the left engine, but the aircraft was under control and operating satisfactorily on the increased power of the right engine. A left turn of approximately 115° was then made and the aircraft proceeded in a southerly direction, well to the west of the west boundary of the airport.

Captain Seaton now had an opportunity to observe that the lower third of the left engine cowling was missing and that the remainder of the cowling was disarranged and damaged, the corner apparently being bent back. During this time the fuel warning indicator light came on, indicating that the fuel supply to the left engine was exhausted. The left engine was entirely inoperative after that time, although the propeller continued to rotate. At a point approximately west-northwest of the Airport Administration Building, a loud commotion set up in the left engine, accompanied by severe vibration from the windmilling propeller and buffeting caused by the disarranged engine cowling. This aircraft was equipped with a single control located in the pilot's cockpit to adjust the pitch position of both propellers simultaneously. It is necessary that the propellers be in low pitch position to provide maximum power for take-off and for single engine operation. The aircraft yawed violently to the left and the air speed dropped from 110 m.p.h. to less than 80 m.p.h. Captain Seaton found that he was unable to effectively operate the rudder control. He called upon First Officer Wallace to assist him and increased the power output of the right engine in an effort to maintain flight. The use of additional power from the right engine appeared to aggravate the situation and the Captain closed the throttle in an effort to regain control, in order to effect the emergency landing which now became inevitable. While both Captain Seaton and Mr. Erickson, a passenger who was seated on the left side of the aircraft, were in a position to observe the left engine, neither of them during this period looked at the engine and were unable to testify as to what further disarrangement of the cowling was occurring. Following the yaw, the aircraft was headed in a southeasterly direction, losing altitude rapidly and under only partial control. The aircraft crashed at approximately 2:48 a.m., the accident resulting in fatal injuries to Flight Hostess Louise Zarr and passengers--P. T. Bates, B. Grossman, J. C. Galleon, B. Coplon, Mrs. E. Henkley, Miss Georgia Shelton and Miss J. Allen. Captain Seaton, First Officer Wallace and passengers--P. E. Smith and C. E. Erickson sustained serious injuries. The wreckage was partially destroyed by fire which originated upon or immediately after impact.

Examination of the wreckage and surrounding terrain disclosed that the left wing tip struck the ground at a point 94 feet west of the center of a road which runs parallel to the west boundary of the Oklahoma City Airport. At this time the aircraft was apparently headed in a southeasterly direction. At a point 25 feet east and 38 feet south of the point where the left wing tip first touched the ground, the left engine struck the ground with considerable force. At 25 feet east and 19 feet south of this point the nose of the aircraft plowed into the ground with sufficient force to break it open, as was evidenced by the battery parts and debris which were strewn along the path of the aircraft toward the road. The left wing broke away from the center section and came to rest in the road 57 feet south and 94 feet east of the first point of contact. Both propellers with the engine gear cases attached were also found in the road.

The left engine was apparently torn out of the nacelle when it first struck the ground. It continued on and came to rest, separated from the aircraft, approximately 51 feet east of the road. The aircraft bounced, rotating to the left, cleared the fence on the west side of the road, and came to rest headed in a westerly direction, approximately 219 feet east of and 82 feet south of the point where the left wing had first contacted the ground.

The right engine came to rest near and to the left of the nose of the aircraft, apparently having been torn away from the nacelle at the point of final impact. The cabin and wing center sections were destroyed by fire; the right wing and tail surfaces, as well as the detached left wing, were not burned. The oil tanks were torn loose and came to rest 205 feet and 270 feet respectively beyond the wreckage of the aircraft. The evidence indicated that fire resulted from oil and/or gasoline being spilled over the hot exhaust collector ring of the right engine and that there was a considerable lapse of time, three minutes or more, after the crash before a fire of any considerable magnitude developed.

The tail group control surfaces were intact and undamaged, except for abrasions which were probably caused by flying debris resulting from the crash. The rudder control tab was set in neutral and all controls appeared to have been functioning normally prior to the impact.

One surviving passenger testified that before he was able to release his safety belt and extricate himself from the wreckage there was fire in and around the right engine and also along the edge of the left stub of the wing center section near which the right engine came to rest. The other surviving passenger, who also had considerable difficulty in freeing himself from his seat and safety belt, testified that fire inside the cabin followed a small stream of gasoline which apparently originated in the vicinity of the pilots compartment and ran down the aisle. The evidence clearly indicates that the two surviving passengers did have great difficulty in releasing their safety belts and that as a result they sustained serious burns while extricating themselves from the wreckage. At least one other passenger was alive and conscious following the crash, although it is not known whether this person was able to make any effort to leave the aircraft.

The safety belt on this type Douglas DC-2 aircraft passes through a clip fastener located under the chair arm on the aisle side of the seat. The release cannot be easily reached except with the near hand, and its position does not lend itself to quick manipulation during an emergency. Examination also reveals that this release could easily be jammed by partial collapse of the seat structure.

Examination of the engines at the scene of the accident disclosed that No. 6 cylinder was missing from the left engine. As a result of this discovery, a search for the missing cylinder was made along the probable flight path of the aircraft. This cylinder was found about 2,800 feet north of the north boundary of the airport and 850 feet west of a projection of the center line of the north-south runway. A felt pad and rocker box cover and the outer engine cowl cable were found a few feet from the cylinder. The piece of engine cowl ring which had been carried away by the cylinder was found 2,549 feet north of the north boundary of the airport and 621 feet west of a projection of the center line of the north-south runway. A pressure baffle was also recovered within 15 feet of this piece of cowling. The piston of No. 6 cylinder was found 3,393 feet north of the north boundary of the airport and 2,003 feet west of a projection of the center line of the north-south runway. A small piece of this piston was picked up 341 feet west and south of the piston. From the location of these parts it was indicated that the aircraft was traveling in a northwesterly direction at the time these parts were falling from it. The probable flight path of the aircraft as indicated by the positions of recovered parts, and by the statements of various eye-witnesses, is attached hereto and designated as Appendix "A".

The engine and propellers were removed to the Company overhaul shop at Dallas, Texas, where both engines were disassembled and inspected in the presence of officials of Braniff Airways and representatives of the engine manufacturers, the Civil Aeronautics Authority and the Air Safety Board.

Both engines had been considerably damaged by impact with the ground. The front gear case of each engine had been broken off when the propellers struck the ground. During this inspection it was found that all hold down studs of No. 6 cylinder on the left engine had been broken off, and that the cylinder, in parting from the engine, caused the destruction of the piston and battering of the No. 6 articulated (connecting) rod.

Examination of the broken studs with a binocular microscope disclosed evidence of progressive fatigue fractures in each stud. The crankcase pad displayed evidence of scuffing due to looseness of the cylinder on the pad.

Previous to the last overhaul of the left engine the manufacturer had recommended that engine hold down nuts should be tightened by the use of a calibrated torque wrench. The recommended force to be used to tighten these nuts was 425 to 450 inch pounds as indicated on the dial of the torque wrench. All cylinder hold down nuts had been tightened in accordance with this recommendation when this engine was last overhauled.

During the disassembly of this engine, after the accident, the position of each hold down nut on No. 1 cylinder and No. 5 cylinder was marked and as each nut was loosened the torque force required was recorded. The hold down nut was then tightened to its original position and the force required was also recorded. The hold down nuts of the remaining cylinders were loosened by the use of a torque wrench and the force required was recorded.

Similar studies were made on a number of other engines of the same model which were in the shop at that time, some of which had run a full overhaul period, and the results of these tests were recorded for comparison with the results observed on the engine. which failed.

It was found during these tests that there was little uniformity in the tightness of nuts on any of these engines, and that there seemed to be no material difference in the degree of uniformity between those which had been tightened by the use of a torque wrench and those which had been tightened without the torque wrench.

It was also found that the hold down flanges on a number of cylinders removed from these engines were not perfectly true, which condition could account for the lack of uniformity of tightness of the hold down nuts of these particular cylinders.

At the time the accident occurred, Braniff Airways was in the process of installing new crankcases on all its Wright Cyclone Engines. This replacement crankcase incorporates a new type cylinder hold down stud and nut which is locked by means of a stainless steel safety wire instead of a Pal Nut. Since the accident, this modification has been completed on all Wright Cyclone Engines operated by Braniff Airways. Repeated failures of cylinder hold down studs revealed by this and other investigations of similar accidents indicate, however, that both the old and new methods above described of attaching cylinders to crankcases of this type engine are inadequate to meet current air carrier operating conditions.

The crankcase and cylinder hold down flanges of cylinders No. 5 and 6 of the left engine were sent to the National Bureau of Standards, Department of Commerce, Washington, D. C., for examination and report. The report of this agency is attached hereto and designated as Appendix "B".

Further investigation of accidents experienced by various air carriers developed the fact that an engine failure involving an identical type aircraft, which was being flown in scheduled air carrier service, occurred on December 22, 1938.

At the time this failure occurred, the aircraft was being flown at an indicated altitude of 7500 feet. Weather conditions were good, with unlimited visibility. The No. 6 cylinder of the left engine was forced off, carrying with it the lower one-third of the engine ring cowling in a similar manner to the failure on aircraft NC 13727.

The pilot in this instance trimmed the aircraft for single engine performance and started for an emergency field, which was approximately 15 miles distant. Within one to one and one-half minutes after the failure, the remaining cowling slipped back on the engine and flared out in front, creating a tremendous drag on the left side of the aircraft. Terrific vibration and buffeting set up immediately as a result of the continued rotation of the propeller on the inoperative engine and the displacement of the cowling, making it impossible to maintain control by using any appreciable amount of power. This condition was aggravated due to the fact that both propellers were operated by a single-propeller pitch control, located in the pilots compartment, which would not permit placing the propeller on the inoperative engine in high pitch. Even with the right engine throttled, flaps fully extended, landing gear down, and an indicated air speed of only 90 m.p.h., the vibration and buffeting continued to such extent as to make it extremely difficult to maintain control. However, the altitude at which the failure occurred was sufficient to permit the aircraft to glide to an emergency field where a safe landing was effected.

Examination of evidence on file with the Air Safety Board reveals that during the past fourteen months four other accidents have occurred in air carrier operations as the result of engine failure which affected the controllability of the aircraft in a similar manner. In none of these cases was the aircraft equipped with full feathering propellers or other means of stopping the propeller from rotating, thereby eliminating vibration and reducing drag after the engine has ceased to function.

In the first of these accidents, involving a Douglas DST, a cylinder failure occurred near Cleveland, Ohio, on May 24, 1938, resulting in the destruction of the aircraft and fatal injuries to eleven occupants.

An accident involving a Douglas DC-2 aircraft occurred on

October 18, 1938, at Montgomery, Alabama, when the hold down studs failed on No. 6 cylinder of the right engine. Although there was no loss of life, the pilot was painfully burned and the aircraft destroyed by impact and fire.

On December 22, 1938, No. 6 cylinder of the left engine on a Douglas DC-2 was forced off following stud failures, and a safe landing was effected near Hayesville, Ohio, after serious difficulties were experienced in the control of the aircraft. A detailed description of this accident is included in this report.

Of particular interest is the incident involving another DC-2 aircraft which occurred near Kansas City, Missouri, on July 15, 1939, indicating that even the installation of brakes on the propellers would not eliminate all the hazards incident to single-engine operation under the conditions outlined above. In this particular instance, the engine "seized" after failure, completely locking the propeller. The drag resulting from the resistance produced by the flat surface of the blades against the air stream materially decreased the controllability of the aircraft and prevented the pilot from sustaining level flight above 2,500 feet, even with the operative engine under full power.

Four out of five aircraft referred to above were equipped with Wright Cyclone engines, Model GR 1820 F 2A, and controllable pitch (two-position) propellers. The fifth was equipped with a Pratt and Whitney Wasp (twin-row) engine, Model 1820B, and constant speed propellers.

SUMMARY OF FINDINGS

1. Aircraft NC 13727 was certificated as airworthy by the Civil Aeronautics Authority, and had been inspected and maintained in accordance with the currently effective Air Carrier Operating Certificate of Braniff Airways, Inc.

2. Both airmen held required ratings and Certificates of Competency for the flight and equipment involved, and were authorized in the Company's currently effective Air Carrier Operating Certificates for service over the route of Braniff Airways Trip One of March 25, 1939.

3. Braniff Airways Trip One of March 25, 1939, was properly dispatched from Chicago, Illinois, and was subsequently cleared from Kansas City, Missouri, Wichita, Kansas, and Oklahoma City, Oklahoma, in accordance with approved Company procedure and currently effective Air Carrier Operating Certificate issued by the Civil Aeronautics Authority.

4. The weather at Oklahoma City, Oklahoma, at the time of departure was instrument weather, ceiling 700 feet, overcast, visibility 12 miles, light rain, temperature 55°, dew point 55°, wind north 8 m.p.h., barometer 29.58.

5. The aircraft began its take-off from the south end of the north-south runway of the Oklahoma City Municipal Airport at 2:45 a.m., (CST), and the take-off and climb were normal until the aircraft had passed the north boundary of the airport.

6. Immediately after passing the north boundary of the airport and at an altitude of approximately 100 feet, a partial loss of power occurred in the left engine.

7. Subsequent to reaching an altitude of approximately 500 feet, a turn was made to the northwest. During this turn the No.6 cylinder of the left engine was forced off and fell clear of the aircraft, carrying with it the lower one-third of the engine ring cowl. Immediately following this, the piston was also thrown clear.

8. A turn of approximately 115° was then made and the aircraft proceeded in a southerly direction.

9. At a point west-northwest of the Airport Administration Building, there was a further displacement of the engine cowling. This displacement caused a buffeting effect of the aircraft, accompanied by severe vibration produced by the continued rotation of the propeller on the inoperative engine. This effect of these forces combined with the necessary rudder and aileron control required to maintain direction, resulted in such drag that the aircraft yawed violently to the left and stalled, from which attitude the pilot was unable to recover before the aircraft struck the ground.

10. The aircraft crashed at 2:48 a.m. (CST), at a point 119 feet west of the west boundary of the airport, and 2,094 feet north of an extension of the south boundary, and came to rest just inside of the airport.

11. The accident resulted in destruction of the aircraft by impact and fire, fatal injuries to Flight Hostess Louise Zarr, passengers--P. T. Bates, B. Grossman, J. C. Galleon, E. Coplon, Mrs. E. Henkley, Miss Georgia Shelton and Miss J. Allen, and serious injuries to Captain Claude H. Seaton, First Officer Malcolm Wallace and passengers--P. E. Smith and C. E. Erickson.

12. The fire, apparently resulting from oil and/or fuel being spilled over the hot exhaust collector ring of the right engine, partially destroyed the wreckage.

13. The failure of the left engine resulted from progressive fatigue fractures of the hold down studs of No. 6 cylinder.

14. The propeller pitch control mechanisms on this aircraft were operated by a single manual control located in the pilots compartment.

15. Three of the five instances of engine failure included in this report were caused by the failure of the cylinder hold down studs of No. 6 cylinder; another, by the failure of a cylinder barrel, and the fifth by a broken oil line causing the engine to "seize".

16. The investigation of these accidents indicates that the difficulties experienced in maintaining control of the aircraft subsequent to the loss of power from one engine, two of which instances resulted in destruction of the aircraft and loss of life, and a third in the destruction of the aircraft, might have been averted through the use of full feathering propellers or similar propeller control mechanisms on the aircraft involved.

## PROBABLE CAUSE

A stall, induced by a violent yaw, resulting in loss of control from which the pilot was unable to recover.

## CONTRIBUTING FACTORS

1. Failure of hold down studs on the No. 6 cylinder of the left engine which resulted in the cylinder being forced off, carrying with it the lower third of the engine ring cowling.

2. Displacement of the remaining portion of the left engine ring cowling, which caused buffeting, as a result of disturbances of the air

flow over the tail surfaces, and increased the drag on that side of the aircraft.

3. Severe vibration induced by the continued rotation of the propeller.

4. Lack of individual propeller pitch controls which would have permitted the pilot to increase the pitch of the propeller on the inoperative engine, thereby reducing the speed of rotation and consequently the vibration from the effect of "windmilling".

## RECOMMENDATIONS

1. In view of the fact that a known and approved means of eliminating the hazards incident to the continued "wind-milling" and resistance of a propeller on an inoperative engine already exists, and that such mechanisms are presently available for the majority of the types of multi-engine aircraft currently used by air carriers and can be made available for all such types within the reasonably near future, it is believed that the five experiences enumerated in this report--all of which have occurred within the last fourteen months and four of which have occurred since the creation of the Civil Aeronautics Authority and the Air Safety Board--sufficiently indicate the pressing need for immediate adoption by the Civil Aeronautics Authority of the following recommendation:

That the Civil Aeronautics Authority require all multi-engine aircraft operated by all air carriers in the transportation of passengers in interstate, overseas and/or foreign air commerce, to be equipped with full feathering propellers or other propeller control mechanisms which permit the pilot to completely stop the rotation of any propeller in such an attitude as to afford a minimum of resistance. It is further recommended that the Civil Aeronautics Authority require the installation of such propeller control mechanisms on all aircraft above described on the earliest date or dates possible under existent circumstances. (It is, of course, recognized that the installation of full feathering propellers has already been completed on a number of air carrier aircraft by several air carriers, and that this recommendation as a practical matter will affect only such air carrier aircraft as have not already been so equipped).

(Note: In order to expedite this safeguarding of life and property in air transportation, it is suggested that the Authority in fixing and determining fair and reasonable rates of compensation for the transportation of mail by aircraft, give due consideration to the expense that would be incurred by air carriers in complying with this requirement.

It is of interest to note in connection with this recommendation, that it has long been the established policy of the Federal Government to recognize and accept responsibility for financial burdens imposed upon air carriers in the enforced or recommended adoption of known technical improvements materially increasing the efficiency and safety of commercial aviation--even long prior to enactment of Section 406 (b) of the Civil Aeronautics Act of 1938 which requires the Civil Aeronautics Authority to consider, as an element in the establishment of fair and reasonable rates for the transportation of mail by aircraft, the amount which, "** together with all other revenue of the air carrier," would " * * enable such air carrier under honest, economical, and efficient management, to maintain and continue the development of air transportation to the extent and of the character and quality required for the commerce of the United States, the Postal Service, and the national defense." An illustration of this policy was the continued payment by the Post Office Department over a period of approximately four years (1930-1934) of 6 cents per mile compensation to air carriers, in addition to the basic contract rate for the transportation of mail, provided the carriers employed aircraft equipped with two-way radio. That such action by the Federal Government is directly responsible for the adoption and use of costly communication equipment in air carrier aircraft, and that it has been reflected in the amazing advancement of American air transportation's efficiency and safety is beyond question. Because similar results inevitably would attend the installation of full-feathering propellers or similar propeller control mechanisms, the immediate adoption of the above recommendation in this regard cannot be urged too strongly.)

2. It is recommended that, prior to the installation of propellers of the type hereinabove described, the Civil Aeronautics Authority require the installation of a separate manual control for each propeller in all air carrier aircraft equipped with controllable pitch propellers.

3. A recommendation was made to the Civil Aeronautics Authority by the Air Safety Board under date of October 31, 1938 that the Civil Aeronautics Authority require a substantial reduction in engine power output of air carrier aircraft in all cases where there was reason to believe that safe power limits were being exceeded for take-off, climb or

cruising. It is understood that the majority of the air carriers voluntarily made reductions in engine power output during the 1938-1939 winter operations but that no official action was taken in this regard by the Civil Aeronautics Authority. Since, from the point of view of safety, an excessive number of mechanical and structural power plant failures have occurred both before and after October 31, 1938 --some of them resulting in loss of life and destruction of aircraft -- the desirability of reducing currently approved ratings for power plants used in air carrier aircraft, particularly during take-off and initial climb, is clearly indicated, and it is hereby recommended that the Civil Aeronautics Authority determine the extent of and require such reduction.

4. It is recommended that a study be made by the Civil Aeronautics Authority of methods now used to secure the engine ring cowling on the Douglas DC-2 and other aircraft, with a view to determining the possibility of fastening the cowling in such a manner as to prevent the displacement of remaining portions in the event that any one section or sections is damaged or carried away.

5. It is recommended that the Civil Aeronautics Authority require that all aircraft of United States registry be equipped with safety belts having uniform approved type quick-release devices, which device, when a safety belt is in use, shall be in such position and of such type that it can be quickly and easily released with either hand. It is further recommended that this requirement be made effective on the earliest practicable date.

ALLEN and HARDIN, members of the Board, concur in the above report and recommendations. SMITH, member of the Board, concurs in the report and recommendations with the exceptions below noted:

Exceptions of SMITH, member:-

While I concur in the substance of the findings and conclusion as to probable cause contained in this report, I am not in agreement with certain portions of the recommendations as submitted in the Majority Report of the Air Safety Board.

Recommendation 1 and 2: I concur in these two recommendations, with exceptions below noted, and am of the opinion that the Authority as well as the Industry should give special attention to this particular development which is among the many projects now being studied by both parties.

I concur heartily in the apparent feeling of the other Board Members that every reasonable step should be taken to insure more safety in air transportation but I am unable to concur in the action of the majority of the Board in making certain recommendations with reference to the fixing and determining of fair and reasonable rates of compensation of the transportation of mail by aircraft.

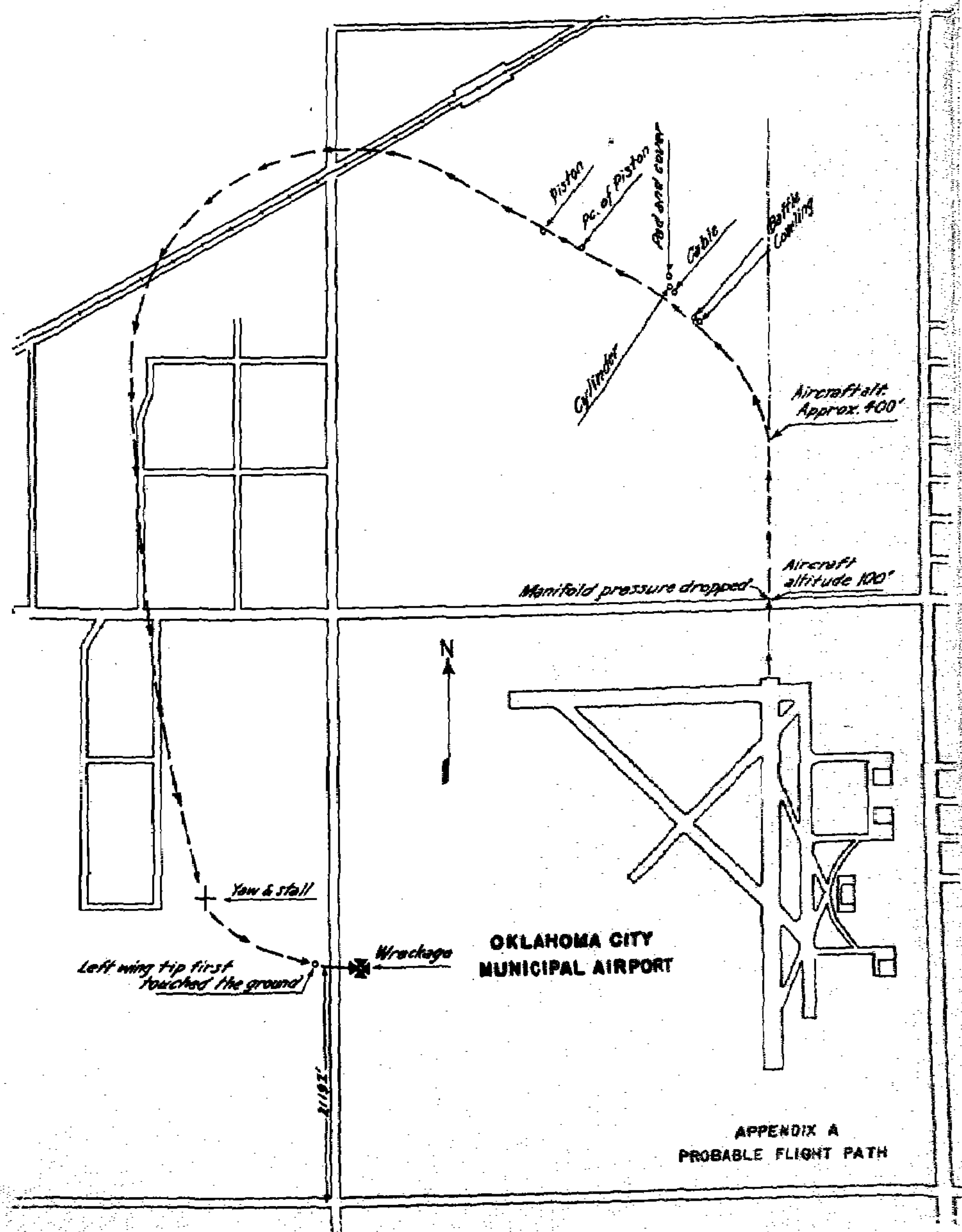
The Civil Aeronautics Act of 1938 clearly vests exclusively in the Authority the function of determining air mail rates, and it is further my opinion that the Air Safety Board's function is limited to the recommending of preventive measures and that it would not only be unfair, but that it might even prejudice the case to handicap the Authority in determining the method it shall adopt in bringing about any suggested safety measures, for the Air Safety Board to make non-pertinent and also limited recommendations obviously beyond the scope of Title VII of the Act.

Recommendation 3: I concur in the substance of this recommendation and wish to emphasize the importance of a practical solution thereof.

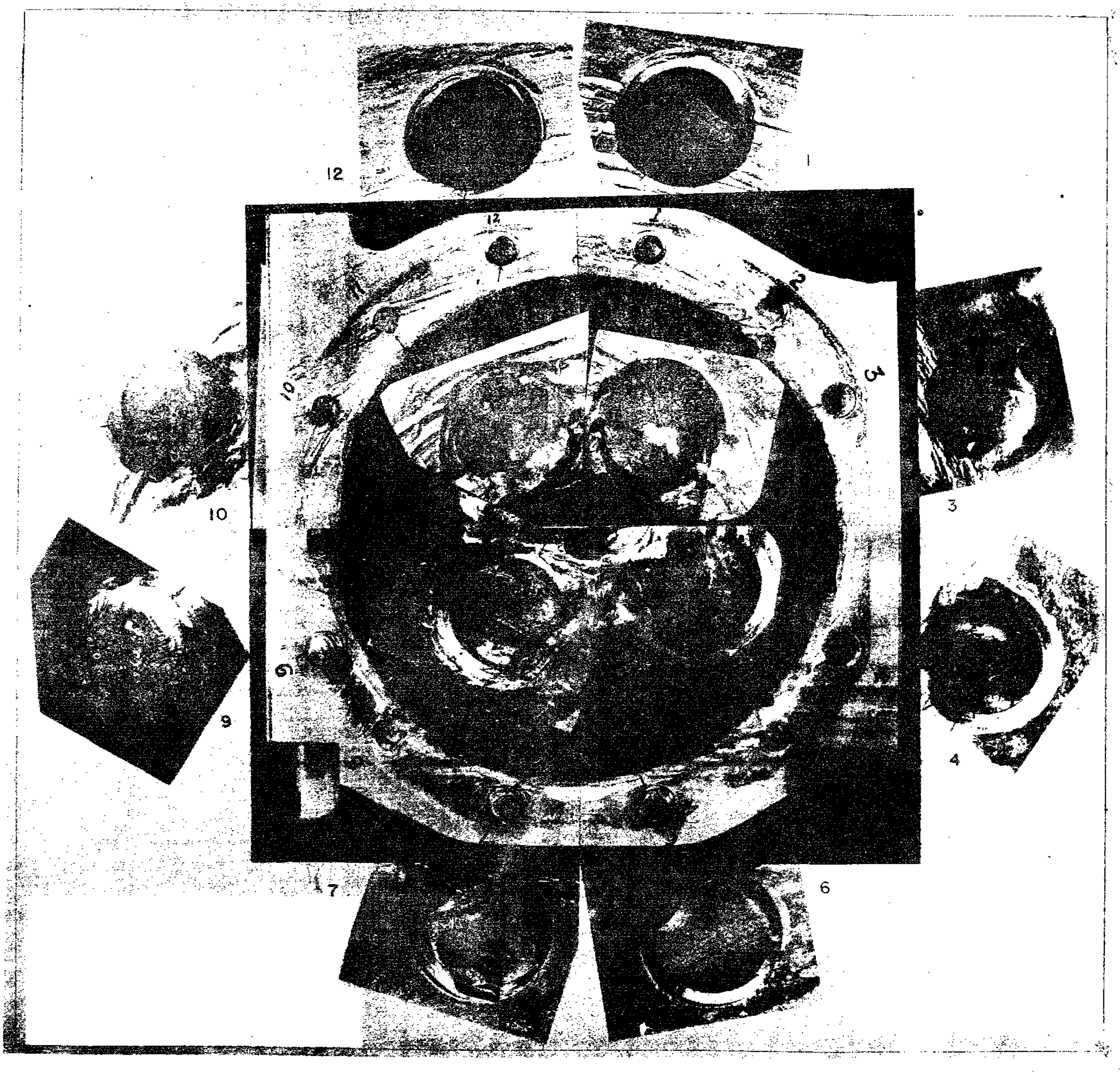
Recommendations 4 and 5: I concur in these recommendations.

BY DIRECTION OF THE BOARD

Executive Officer




APPENDIX A
PROBABLE FLIGHT PATH


12
1
12
2
3
10
10
3
9
9
4
7
6

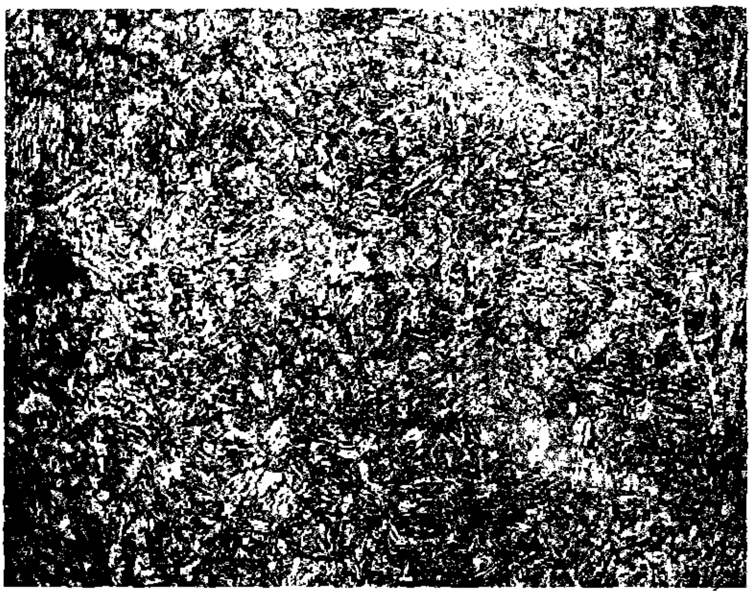


Fig. 2. - Microstructure on longitudinal section of one of failed studs, No. 6 cylinder. Structure is typical of unetched and tempered alloy steel. Etched in 1 percent nitric acid in alcohol. x 500.

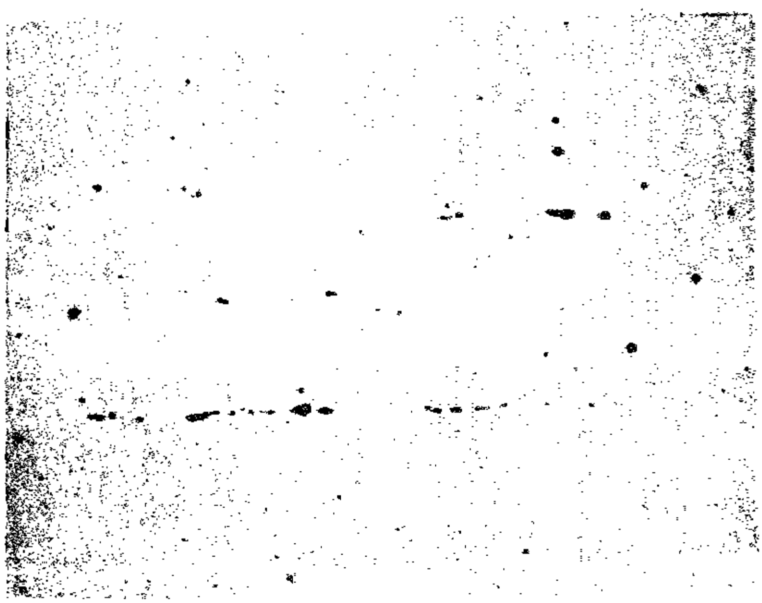


Fig. 3. - Appearance of nonmetallic inclusions on polished, unetched specimen shown in Fig. 2. x 100. Although fairly numerous, the nonmetallic inclusions are not considered to have had any significance to the failures.

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APPENDIX "B"

UNITED STATES DEPARTMENT OF COMMERCE
WASHINGTON

May 15, 1939

NATIONAL BUREAU OF STANDARDS

Report

on

Examination of

Crankcase and Broken Hold-Down Studs

Submitted by

Air Safety Board

Civil Aeronautics Authority

Washington, D. C.

I. Introduction

At the request of the Air Safety Board, April 8, 1939, examinations were made of a crankcase and two cylinder flanges from the left engine of an airplane of the Braniff Airways which had crashed at Oklahoma City on March 26, 1939.

In the request from the Air Safety Board, the following were mentioned as specific items for study:

a. Determine the cylinder hold-down stud, of No. 6 cylinder, which was the first to fail.

b. Determine the progression of successive stud failures, previous to the separation of the cylinder from the engine.

c. Does inspection indicate that looseness of one or more of the cylinder hold-down nuts is responsible for failure?

d. Was the No. 8 stud or nut loose previous to failure?

e. Where did failure originate?

f. Was any stud or nut loose previous to failure?

g. A statement of comparison condition of unfailed studs.

h. Photograph of fractures on studs.

i. Examine for cracks in studs on other cylinders.

j. Report on reasons for flange hole distortion in No. 6 cylinder (Mr. Newton to furnish dimensions and other observations made at Dallas).

k. Examine, microscopically, nut seats on cylinder flanges for lapping and give interpretation of possible causes.

l. Caliper several remaining studs for possible permanent set in undercut section and to establish variation in tolerance in dimension of this section.

Details concerning the circumstances at the scene of the crash; the construction of the engine; and the operation and maintenance of the engine were furnished verbally by representatives of the airline, the engine manufacturer, the Civil Aeronautics Authority and the Air Safety Board, while the examinations were underway at the National Bureau of Standards. Photographs showing the condition of the engine before it was dismantled were also furnished.

According to statements made by these representatives, it had been established that the crash resulted from a failure, in the air, of the left engine; and further, that the complete separation of No. 6 cylinder from the crank case had caused the failure of the engine.

II. Examination of Crankcase and Broken Studs

Only the crankcase and the cylinder flanges from No. 6 and No. 5 cylinders were submitted to the National Bureau of Standards. The appearance of the No. 6 cylinder-flange seat on the crankcase is shown, in the condition as received, in the photograph, Figure 1, accompanying this report. It was evident that fracture of the 12 hold-down studs had permitted the cylinder to be separated bodily from the crankcase. It was further evident, from the appearance of the fractured surfaces that on each stud a considerable portion of the section had been severed by a fatigue fracture. The characteristic markings of fatigue fractures are plainly evident on photographs of the fractured surfaces of the studs at 6 diameters magnification, placed in appropriate positions on the photograph of the flange seat, Figure 1. The location of the origin of the fatigue fracture on each stud, according to the best estimate that could be made from the appearance of the markings, is indicated by arrows on the photographs. It is noteworthy that according to these estimates the fractures on each stud, except No. 10, originated at or near that portion of the circumference of the stud closest to the cylinder sleeve.

III. Details of Broken Studs

It was desired, in order to make more detailed examinations of the fractured studs, to remove them from the crankcase, without damage to the fractured surfaces. This was readily accomplished by sawing into the crankcase to, but not into, the studs. The following data were obtained by visual examination of the portions of the studs thus removed. The studs are designated by number, 1 to 12, in a clockwise direction, starting at the forward side of the crankcase, as shown in Figure 1.

| Stud No. | Remarks |
|---|---|
| 1 | Fatigue fracture had progressed about halfway across the section. Ten full threads remained in crankcase. |
| 2 | Fatigue fracture had progressed more than halfway across the section. Eleven full threads remained in crankcase. There was a crack in the thread groove between the first and second threads below the fractured surface. |
| 3 | Fatigue fracture less than halfway across section. Ten full threads remained in crankcase. There was a crack about halfway around the circumference, in the thread groove between the first and second threads below the fractured surface. |
| 4 | Fatigue fracture less than halfway across the section. Ten full threads remained in crankcase. No additional cracks. |
| 5 | Fatigue fracture about halfway across section. Ten threads in crankcase. No additional cracks. |
| 6 | Fatigue fracture more than halfway across section. Fracture had occurred in nut, between first and second thread beyond reduced section. No additional cracks. |
| 7 | Fatigue fracture well over halfway across section. Fracture had occurred in nut, between first and second thread beyond reduced section. No additional cracks. |
| 8 | Fatigue fracture over halfway across section. Ten threads remained in crankcase. No additional cracks. |

Stud No. Remarks

9 Fatigue fracture well over halfway across section. Fracture had occurred in nut, between second and third thread beyond reduced section. No additional cracks.

10 Fatigue fracture had progressed practically entirely across the section. Nine threads remained in crankcase. No additional cracks.

11 Fatigue fracture had progressed over about 90 percent of section. Ten threads remained in crankcase. No additional cracks.

12 Fatigue fracture had progressed over about 90 percent of section. Ten threads remained in crankcase. No additional cracks.

IV. Summary of Data on Broken Studs:

(a) 1 stud fractured between the 9th and 10th threads from bottom of stud.

1 stud fractured between 11th and 12th threads from bottom.

7 studs fractured between 10th and 11th threads from bottom.

3 studs fractured in the nut.

(b) Fatigue fractures had severed:

practically all of the section on stud No. 10;

nearly all of the section on Nos. 11 and 12;

well over half the section on Nos. 2, 6, 7, 8, and 9;

about half the section on Nos. 1 and 5;

less than half of the section on Nos. 3 and 4.

(c) All of the fractures in the studs had originated in the bottoms of thread grooves at or close to the threads that emerged from either the crankcase or the stud nut. The fracture in each stud therefore occurred in the region of maximum stress, in the stud as a whole, with the added effect of stress concentration due to the thread groove. As fatigue fractures are stress fractures, there were no unusual features in the manner of failure of the studs.

V. Possible Sequence of Failure in Studs

Some importance was attached to the sequence of failure of the studs if this could be determined. As the cylinder flange was intact, except for certain distortions, it was obvious that all 12 studs were broken before the cylinder left the crankcase. It is unlikely, although possible, that fatigue fractures were progressing in all 12 studs simultaneously.

Ordinarily it would be considered that the studs on which the fatigue fractures had progressed farthest across the section were the ones to fail first, and those with the least areas of fatigue fracture were the ones to fail at the end when sudden rupture took place because the unsevered portions of the studs were inadequate to carry the normal load. According to this reasoning, studs Nos. 10, 11, and 12 were the first, or among the first to fail; Nos. 3, 4, 1, and 5 the last, or among the last to fail; while Nos. 2, 6, 7, 8, and 9 were intermediate. According to this sequence the cylinder would have been loose on the side containing studs 7, 8, 9, 10, 11, and 12 while it was still held to the crankcase on the side with studs 1, 2, 3, 4, 5, and 6. This sequence of failure is a conjecture not subject to positive verification.

VI. Examinations of Unbroken Studs and Microstructure and Hardness of Stud Material

The studs from the remaining 8 cylinders, except for 2 or 3 which had already been removed from No. 5 cylinder seat, were unscrewed from the crankcase with a 10-inch Stillson wrench applied to the projecting portions of the studs, carrying the S. A. E. Threads. These studs were carefully examined, after cleaning free of grease, with a binocular microscope, at moderate magnification, with particular attention to noting whether or not there were any cracks in roots of the threads. No cracks were found. The studs were then etched lightly and again examined, by two observers, with the same result; no cracks were found in any stud.

The most unusual feature about the failure therefore was the fact that all 12 studs on No. 6 cylinder were fractured, while the 96 studs on the remaining 8 cylinders were intact. These circumstances indicate that either the studs on No. 6 cylinder were different from the other studs; that the nuts on the studs of No. 6 cylinder were not drawn up equally with those on the other cylinders; or that the operating conditions in No. 6 cylinder were different from those in the other 8 cylinders.

The first of these possibilities was investigated. A specimen for metallographic examination and hardness tests was cut from the lower end of each of the failed studs, leaving the fractured surface intact. The representative microstructure on one of these studs is shown in Figure 2. This structure is typical of a quenched and tempered alloy steel. The appearance of the nonmetallic inclusions on the polished but not etched surface of this specimen is shown in

Figure 3. The microstructure and appearance with respect to the nonmetallic inclusions on the specimens from the remaining 11 broken studs could not be distinguished from those shown in Figures 2 and 3. The same was true for 2 specimens from unbroken studs from cylinders Nos. 5 and 8.

As the specimens were not suitably shaped for determinations of Rockwell numbers, hardness tests were made with a Vickers Hardness Tester, using a 30 Kg load. The Vickers numbers ranged from 326 to 341, with an average of 333. Rockwell C scale numbers equivalent to the Vickers numbers ranged from 33 to 35 with an average of 34. On the two unbroken studs from cylinders 5 and 8 the Vickers numbers were 328 and 330, equivalent to Rockwell C scale numbers 33 and 34. Rockwell tests were made directly on one stud, chosen at random, from each of the 8 groups of unbroken studs. These numbers ranged from 30 to 36, with an average of 32. As there was a chance for error in making the Rockwell tests on the studs, the slightly lower average obtained by the Rockwell tests is not considered to be significant. It was concluded, on the basis of the examinations made that the broken studs were not different, metallurgically or physically, from the unbroken studs.

Positive evidence indicating that the nuts on cylinder No. 6 had or had not been drawn up the same as those on the other cylinders was not available from examinations of the parts concerned after the failure. There was a definite impression of the cylinder flange on the crank case pad, Figure 1. This impression was more deeply marked in the regions of studs Nos. 7, 8, and 9, and 1, 2, and 3, than in the regions of studs 10, 11, and 12, and 4, 5, and 6. This condition might be considered to indicate that one or more of the nuts on the studs 7, 8, 9, --1, 2, 3 had been less tight than those on the other axis, 10, 11, 12 --4, 5, 6; permitting a rocking of the cylinder that resulted in the deeper markings on the crankcase pad. This condition would also have made the stresses higher in one or more of the studs 10, 11, 12 --4, 5, 6 than in the looser studs, a condition which could be reconciled with the conjecture that studs 10, 11, and 12 might have been among the first to fail. Although it is possible that the impression of the cylinder flange on the crankcase pad was caused, in part at least, by looseness between flange and seat because some of the nuts had been insufficiently tightened, it is equally possible that the battered condition occurred only after some of the studs had been fractured, permitting the flange to batter on the seat.

Likewise, the appearance of the seating of the stud nuts on the top of the cylinder flange did not permit any definite conclusions to be made that any of the nuts had been less tight than others, before the failures occurred.

The distortions observed in the No. 6 cylinder flange were caused, most likely, by the battering of the piston against the cylinder skirt after the cylinder had been pushed out from the crankcase.

No indications of any different operating conditions in cylinder No. 6 was obtained in the examinations of the parts submitted.

There was therefore no evidence to prove, or even to indicate, that either the nuts on the hold-down studs on cylinder No. 6 had not been tightened like those on the other cylinder, or that the operating

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conditions in cylinder No. 6 were different from those in the other cylinders of this engine.

VIII. Summary and Conclusions

1. Failure of the 12 hold-down studs on No. 6 cylinder had permitted the cylinder to be pushed out of the crankcase while the engine was in operation.

2. Failure of the studs resulted from fatigue fractures which, on each stud, had severed a considerable portion of the section before sudden complete rupture took place.

3. In each stud, the fatigue fracture started in the root of a thread groove. In 9 of the studs the thread groove in which the fatigue fracture originated was the first or second groove in the stud, below the surface of the flange seat on the crankcase. In three of the studs, Nos. 6, 7, and 9, the fatigue fracture started in the nut in the first or second thread groove beyond the reduced section on the stud. In each stud the crack had originated therefore at a point of localized maximum stress.

4. No cracks were found in any of the studs of the other 8 cylinders removed from the crankcase. Metallurgical examination and hardness tests indicated that the material of the broken studs could not be distinguished from that of the intact studs.

5. No positive evidence was obtained that any of the nuts on the broken studs had been tightened differently from those on the unbroken studs, nor that the operating conditions in No. 6

cylinder were different, before the failure, from those in the other cylinder. It is, however, a reasonable assumption that one or both of these conditions existed, in view of the fact that all 12 studs on one of the 9 cylinders failed, whereas no cracks or failures occurred in 96 identical studs in the other 8 cylinders in the same engine.

6. Thread grooves in bolts or studs subjected to repeated or vibratory stresses are known to cause localized stress concentrations resulting in a lowering of the endurance of the bolt from that indicated by fatigue tests on smoothly machined and polished specimens of the bolt material.

7. There are a number of ways in which the damaging effect of thread grooves can be lessened:

(a) By grinding the thread grooves as smooth as possible the damaging effect due to stress concentration is much less than in machine cut threads. The threads on the studs, both broken and unbroken, appeared to be as smooth as could be obtained by any commercially practicable operation of grinding.

(b) Rolled threads are known to be less damaging than ground or cut threads. It is not believed that rolled threads would be practical on the type of steel used in these studs.

(c) Reducing the unthreaded shank of a bolt or stud to a diameter less than the root diameter of the threads is known to change the stress distribution so as to overcome, to a certain extent at least, the stress concentration effect of the thread grooves. It is known that the maximum stress in the threaded portion of a bolt or stud occurs just inside the point of emergence of the thread from the nut, or member into which the stud is driven. The reduced section on the studs submitted did not extend into the crankcase nor into the nut. A more efficient design would have been obtained by lengthening the reduced section on these studs.

(d) The stress concentrating effect of thread grooves of conventional design, U. S. Standard, S. A. E., or other similar designs, can be lessened possibly by threads of drastically different design. At least one such design has recently been recommended for cylinder hold-down studs.

8. Improvements that might be obtained in the endurance strength (resistance to failure under repeated stresses) of hold-down studs or similar threaded parts, by changes in material or shape of the "stud", or by changes in finish or design of the threads, can be evaluated quantitatively by laboratory tests on the actual threaded parts.

E. C. Crittenden, Acting Director.

Lyman J. Briggs, Director

FOR IMMEDIATE RELEASE
January 9, 1940

# AIR SAFETY BOARD
Civil Aeronautics Authority
Washington, D. C.

The crash of a Pan American Airways' twin-engined flying boat at Rio de Janeiro on August 13, 1939, with fatal injuries to all but two of the sixteen persons aboard was attributed by the Air Safety Board to "loss of power from the left engine during the landing approach, necessitating an attempted landing under extremely hazardous conditions" in a report transmitted to the Civil Aeronautics Authority and made public today.

The accident occurred after a scheduled air line flight from Miami through the West Indies and down the east coast of South America, the last leg of which was from Victoria, Brazil, to Rio. The report said that the aircraft had circled over Rio and was making a normal approach to the seaplane landing area adjoining the air line's Rio base, in accordance with the company's established operating procedure, when it suddenly lost power from the left engine, yawed to the left, and started a descending turn in the same direction.

The airplane continued to lose altitude and to turn at a sharper and steeper angle until it struck a caisson anchored at right angles to a small island in the harbor immediately adjacent to its landing approach path. All four members of the crew and ten passengers were fatally injured in the accident, one passenger escaping with serious and another with minor injuries.

Ample evidence was obtained during the Air Safety Board's investigation of the accident that the left engine suffered a sudden loss of power at a critical time during the landing approach, although, since available evidence failed to supply any conclusive explanation for this loss of power, and a detailed examination of the engine, after disassembly, revealed no indication of structural failure or mechanical defects in flight, the report stated that "the cause of the loss of power from the left engine is unknown." Sailors from the Brazilian battleship, Minas Geraes, anchored nearby, who immediately swam or rowed to the scene of the accident and participated in firefighting and rescue activities were praised by the report for having demonstrated "a high degree of courage."

A copy of the full report is attached.