Docket No. SA-120 File No. 1232-46

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

ACCIDENT INVESTIGATION REPORT

Adopted: November 29, 1946 Released: December 18, 1946

TRANSCONTINENTAL AND WESTERN AIR, INC., READING, PA., JULY 11, 1946

The Accident

NC 86513, owned and operated by Transcontinental and Western Air, Inc., crashed approximately one mile northeast of Reading Airport, Reading, Pennsylvania, at 1140, Eastern Standard Time*, July 11, 1946, as a result of fire in the forward baggage compartment which produced smoke of such density that the pilot was unable to maintain sufficient control of the aircraft to effect a normal landing. Five crew members were fatally injured; the instructor pilot was seriously injured; and the Lockheed Model 049, Constellation, was demolished by impact and fire**.

History of the Flight

NC 86513, hereinafter referred to as Aircraft 513, was assigned to Reading Airport for use in Constellation transition in the training program of the International Division of TWA. Aircraft 513, with

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* All time referred to herein is Eastern Standard and based on the 24-hour clock.

**The following report is a summary of the findings of the investigation of this accident and the detailed examination of the aircraft involved. Since the date of the accident, however, extensive modifications of the Lockheed Model 049 have been accomplished in order to eliminate the mechanical deficiencies which contributed to this accident. The primary cause of this accident has been eliminated. Other deficiencies revealed by the accident have been eliminated or are under further study. A resume of the modifications which have been accomplished is appended hereto. (See page 28.)

Student Captain A. N. Nilsen at the controls, departed Reading Airport at 1121, for a local instrument training flight. Instructor Captain R. F. Brown occupied the co-pilot seat at the time of take-off and throughout the subsequent flight. Observers in the vicinity of the Reading Airport testified that shortly after take-off from Runway 13, at an altitude of approximately 300 feet, the aircraft was seen to yaw sharply to the right in a manner indicating that at least one engine had been throttled in simulation of power failure, and that, immediately thereafter, the aircraft descended to an extremely low altitude over an area of western Reading. After turning off the take-off course approximately 45 degrees, the aircraft was pulled up into a steep climbing attitude after which it resumed a normal climb toward the south.

The aircraft climbed to an altitude of 3,000 feet to an area approximately four miles east of the Reading Airport at which time, at the instruction of Captain Brown, Captain Nilson leveled off to begin practice of instrument approach procedures. Shortly thereafter, the flight crew detected an odor resembling burning insulation, but did not immediately determine the source. At approximately 1137, the flight engineer went aft in order to determine the origin of the smoke. Upon opening the galley door, he observed that the entire cabin was filled with a very dense smoke and he returned to the cockpit and reported to Captain Brown that "the whole cabin is on fire".

The crew immediately attempted to combat the fire with the cockpit fire-extinguisher but were unable to enter the cabin because of the dense smoke and intense heat. The smoke quickly filled the cockpit

through the open galley door, rendering visibility extremely poor and making it difficult for the pilots to observe the instruments. The student flight engineer opened the cockpit crew hatch in an attempt to clear the cockpit of smoke, however, the opening of the hatch increased the flow of smoke from the cabin toward the cockpit and shortly thereafter it became impossible for Captain Brown to observe any of the instruments or to see through the windshield.

Captain Brown opened the window on the right side of the pilot compartment and attempted to fly the aircraft back to the Reading Airport for an emergency landing while descending with the engines throttled and with his head out of the side window. With the increased intensity of the heat and denseness of the smoke in the cockpit, it became impossible for the pilots to maintain effective control of the aircraft. At an altitude of approximately 100 feet, two miles northwest of the airport, Captain Brown withdrew his head from the window and attempted to "ditch" the aircraft "blind". The aircraft contacted two electric power wires strung about 25 feet above the ground, and the left wing tip glanced against scattered rocks and struck the base of a large tree. The aircraft settled to the ground, slowly rotating to the left, as it skidded approximately 1,000 feet across a hay field, causing disintegration of the left wing panel, flaps and aileron. The aircraft continued to yaw to the left and, after having rotated more than 90 degrees, it plunged through a row of trees and telephone poles lining a road bordering the field, coming to rest in a pasture at a point approximately 150 feet beyond the road and pointing approximately 180

degrees from its original heading at the time of initial impact. Gasoline was spilled from the ruptured tanks and fire broke out consuming the major portions of the wreckage. When local farm workers arrived at the scene approximately one minute after the aircraft had come to rest, Captain Brown was observed walking away from the wreckage and Captain Nilsen was seen lying on the ground to the rear of the trailing edge of the right wing approximately six feet from the fuselage. Both pilots were taken to the Reading Hospital where Captain Nilsen died shortly afterward. The remaining four crew members died in the wreckage.

Investigation

The wreckage of the aircraft was lying approximately one-half mile northeast of the Reading Airport in a pasture, the southwestern extremity of which lay adjacent to the airport. Although extensive disintegration had occurred before the aircraft came to rest, the major portion of the fuselage and wings were oriented toward the north with various parts of the aircraft scattered back along the path of motion for a distance of approximately 1200 feet. A series of scars had been cut across the field from the point of initial contact with the ground extending south southeast to the point at which the aircraft came to rest. Indications of a flash fire were observed adjacent to the ground path of the aircraft at a point at which gasoline spilled from a ruptured fuel tank and ignited, burning the hay stubble as the aircraft skidded across the field.

The entire empennage had been severed from the fuselage aft of the rear pressure bulkhead. The left wing had disintegrated from the tip inboard to the vicinity of No. 1 engine nacelle before the aircraft came to a stop. Although still attached to the fuselage, the remaining portion of the left wing had been subjected to intense heat and the area forward of the rear spar was almost completely destroyed by fire. The right wing remained relatively intact, however, large areas were burned inboard of the No. 4 engine nacelle. All six sections of the right wing flap and the three inboard sections of the left wing flap were attached and in the retracted position. The right main gear and the nose gear were found in the retracted position. The fuselage was almost entirely consumed by the fire.

Although seriously injured, Captain Brown was able to make three statements concerning the nature of the difficulties encountered in flight and the information provided proved extremely valuable in the conduct of the investigation. He explained that the take-off was accomplished by Captain Nilsen who was under the instrument flying hood and that both right engines were throttled in order to simulate engine failure during take-off. Shortly thereafter, a climb was established using normal climb power on all four engines. After leveling off at 3,000 feet, simulated QDM approach procedures were initiated*.

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* QDM Approach Procedures involve the use of a Ground Automatic Direction Finding Station which receives transmissions from an approaching aircraft and automatically computes its bearing from the station. The ADF controller thus advises the flight of the inbound headings necessary to intercept and follow a predetermined approach path to the field. These approach procedures are simulated at Reading by requiring the instructor to act in the capacity of the ground communicator and to transmit the necessary instructions to the student pilot over the aircraft's "intercom" system.

Captain Brown stated further that, immediately prior to starting the approach procedures, he had been requiring Captain Nilsen to maneuver the aircraft with No. 4 engine throttled. Shortly after the smoke was discovered, the flight engineer called out: "Feather No. 4", to which Captain Brown replied that it was No. 3 engine which was "backfiring" and that there was no need for feathering No. 4 propeller. No explanation was contained within these statements as to the association between the alleged backfiring and the fuselage fire, nor were the reasons indicated for the flight engineer's desire to feather No. 4 propeller. At the time the flight engineer had discovered smoke in the cabin, the descent to the field was started. It was the opinion of Captain Brown that he had escaped from the aircraft after it came to rest by crawling through the side window.

Numerous witnesses in the vicinity of Reading Airport were located who observed the flight of 513 immediately prior to its crash. Among these witnesses were two pilots of a TWA DC-3, which was flying in the traffic pattern at the time the accident occurred, and several company personnel who were at the airport and observed the last few moments of flight. All witnesses agreed that the aircraft approached Reading Airport in a relatively steep descent from the northeast and in a shallow left bank, appearing as though a landing was contemplated at Reading Airport. Several of the lay witnesses reported engine noise, which they identified as backfire, and smoke from various portions of the aircraft. The majority of observers, including the DC-3 pilots,

observed light smoke streaming behind the No. 3 engine nacelle; other witnesses observed smoke from the No. 2 engine nacelle and, still others, directly behind the fuselage. Among the numerous witnesses from whom statements were obtained, none observed any visible fire while the aircraft was in flight.

Examination of the powerplants revealed no evidence of fire while in flight. Engines Nos. 1 and 2 were torn from their respective wing positions before the aircraft came to rest. No. 3 engine was detached from the aircraft but located within five feet of its normal position. Engine No. 4 was found in its normal position but detached from the wing. Inspection of the remains of the induction systems of all four engines including the thermocouples and the "mitey midget" fire detectors disclosed no evidence of an induction fire. Examination of the power sections and cylinders in all four engines and such pertinent steel parts as the propeller shaft, crank shafts, reduction gears, and accessory drive shafts and gear assemblies revealed no evidence of mechanical failure other than that caused by impact. However, powerplant units Nos. 3 and 4 had been subjected to intense heat as a result of the fire on the ground. Almost all aluminum and magnesium parts were either completely or in part melted or reduced to ashes and much of their steel components bore evidence of intense heat. It is therefore impossible to state conclusively that no malfunctioning had occurred in these engines prior to impact. From the examination of No. 1 engine, however, it was determined that no malfunctioning had occurred in this powerplant while in flight.

Nothing was found in the remains of the aircraft to suggest malfunctioning of the control system, the hydraulic system, the fuel system, the oxygen system , or the alcohol system prior to impact. No evidence was disclosed which indicated that the flares with which the aircraft was equipped had in any manner contributed toward the accident. Again it must be remembered that the aircraft had been so badly burned that the condition of parts of the above systems could not be determined in many instances. However, the testimony of maintenance personnel reveals that these systems were functioning normally prior to departure from Reading Airport and the statements of Captain Brown contain no reference to indicate malfunctioning of these systems while in flight. The cabin supercharger and drive shafts had been removed from this aircraft prior to the accident in accordance with instructions from the Civil Aeronautics Administration as a result of a previous accident which had occurred to this model aircraft.

In order to facilitate investigation of the wreckage, a serviceable Constellation was brought to Reading by TWA and made available to the Board. The use of this aircraft made it possible to determine more accurately and quickly the relative positions of various components, and to determine their possible location within the wreckage. It was observed that specially designed bolts were installed throughout various parts of the aircraft in order to provide relatively air-tight electrical conductors through the skin of the pressurized fuselage. Three such bolts are located on each side of the forward baggage compartment and lead into each wing root section. These bolts are commonly referred to as through-studs.

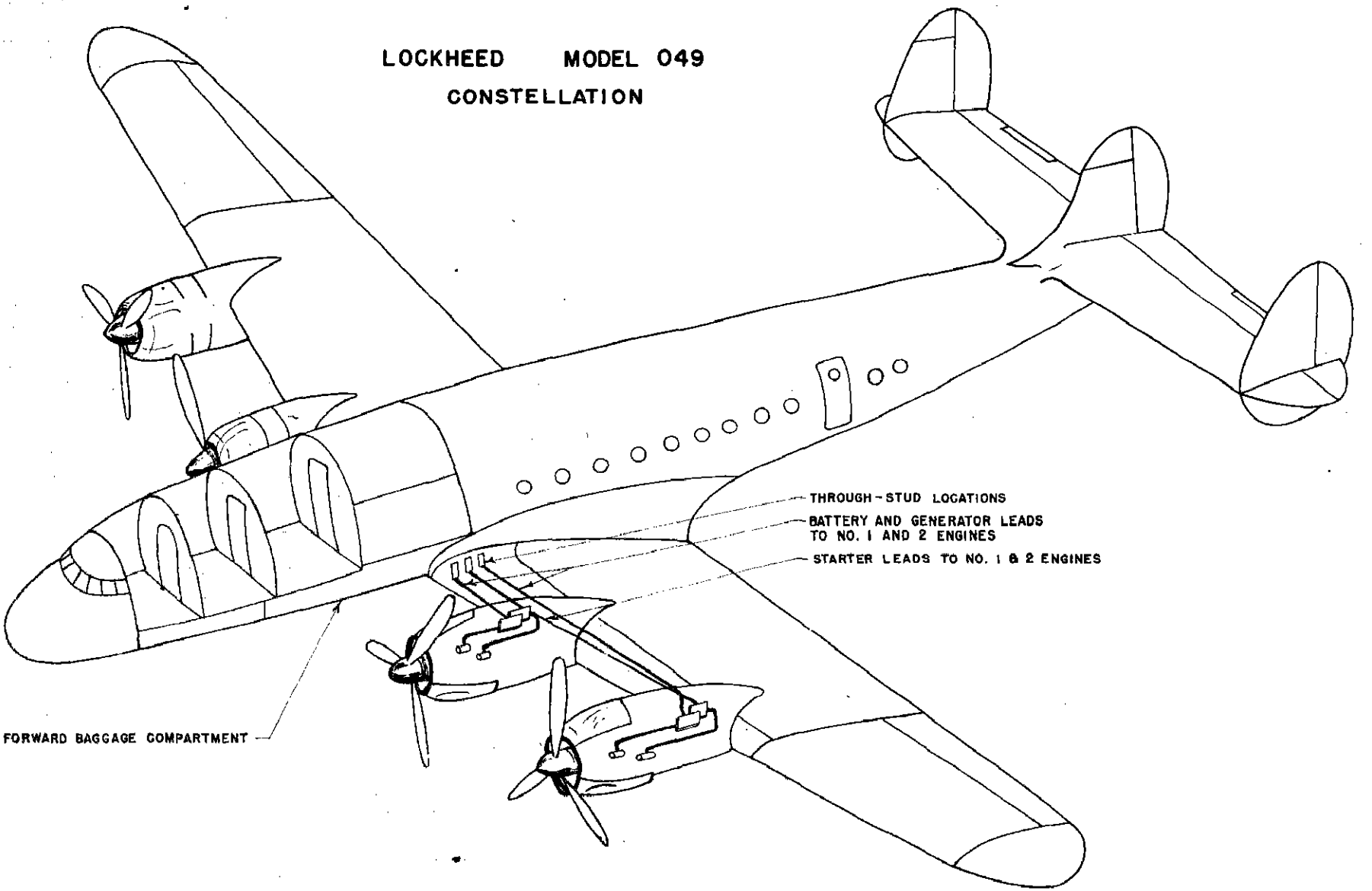

FIG. 1 THE ABOVE DIAGRAM IS A SCHEMATIC ONLY AND DESCRIBES THE APPROXIMATE LOCATION OF THE THROUGH STUDS WITHIN THE LEFT WING-ROOT SECTION. A SIMILAR INSTALLATION IS INCLUDED WITHIN THE RIGHT WING.

Inspection of the generator and starter leads and the fuselage through-studs in the forward baggage compartment of the serviceable aircraft disclosed that some of the Irvolite coverings of the cable lugs and studs were severely charred. In view of the fact that high external temperatures could not have been present in this area, it was obvious that this charring had resulted from internal heating. It was further observed that the glass wool lining of the baggage compartment in the proximity of the through-studs was saturated with hydraulic fluid. Because hydraulic lines pass through the forward baggage compartment, it is apparent that the leakage had occurred from hydraulic line fittings.

The remains of the six through-studs from Aircraft 513 were subsequently located and it was noted that some of them appeared to have been subjected to local burning suggestive of electrical arcing. These studs were sent to the National Bureau of Standards for closer inspection in order to determine their condition prior to the crash. The National Bureau of Standards subjected the six through-studs to extremely detailed study immediately upon their receipt. The conclusions of this investigation established the fact that all of the through-studs from Aircraft 513 contained evidence of arcing and that at least two of these studs were sufficiently burned due to arcing as to have caused a fire while in flight. It was further determined that the length of time necessary for the studs to have been burned to the extent observed in at least two of the studs from Aircraft 513 covered a period considerably longer than that which elapsed during the disintegration of the aircraft

subsequent to initial impact with the ground and until the aircraft came to rest. A supplementary test conducted by the Bureau of Standards concerning the electrical resistance of an assembly consisting of a through-stud and a cable lug discloses that the contact resistance or the electrical resistance between dissimilar surfaces in the stud assembly is excessive and that, under conditions of peak-load, relatively high temperatures could be expected. Because electrical resistance increases with temperature, under conditions of sustained peak-loads, temperatures could be expected to reach critical proportions, and arcing could be expected. The Bureau of Standards report, therefore, indicates that, if in contact with inflammable materials, such an installation could readily have produced fire when operated at high electrical loads for long periods of time.

A sketch was prepared by the Board from information submitted by engineers of Lockheed illustrating the proper installation of the through-stud assembly. The Bureau of Standards study of the studs removed from Aircraft 513 disclosed that none of the studs were assembled in accordance with that sketch. Both steel and aluminum washers were employed; the lugs used were of both copper and aluminum; brass and steel nuts were used, and the bolts themselves were of brass composition. The almost indiscriminate use of materials of different compositions, according to the Bureau of Standards report, aggravated the high contact resistances of the studs and, therefore, increased the

All six of the through studs recovered from the wreckage bore indications of intense local heating attributable to electrical arcing. The consumed portion of the three studs illustrated indicate the extensiveness of the arcing (arrows). The localized nature of the burned areas and the sharpness of the threads on the remainder of the bolts dispel the possibility of the damage having resulted from external heating.

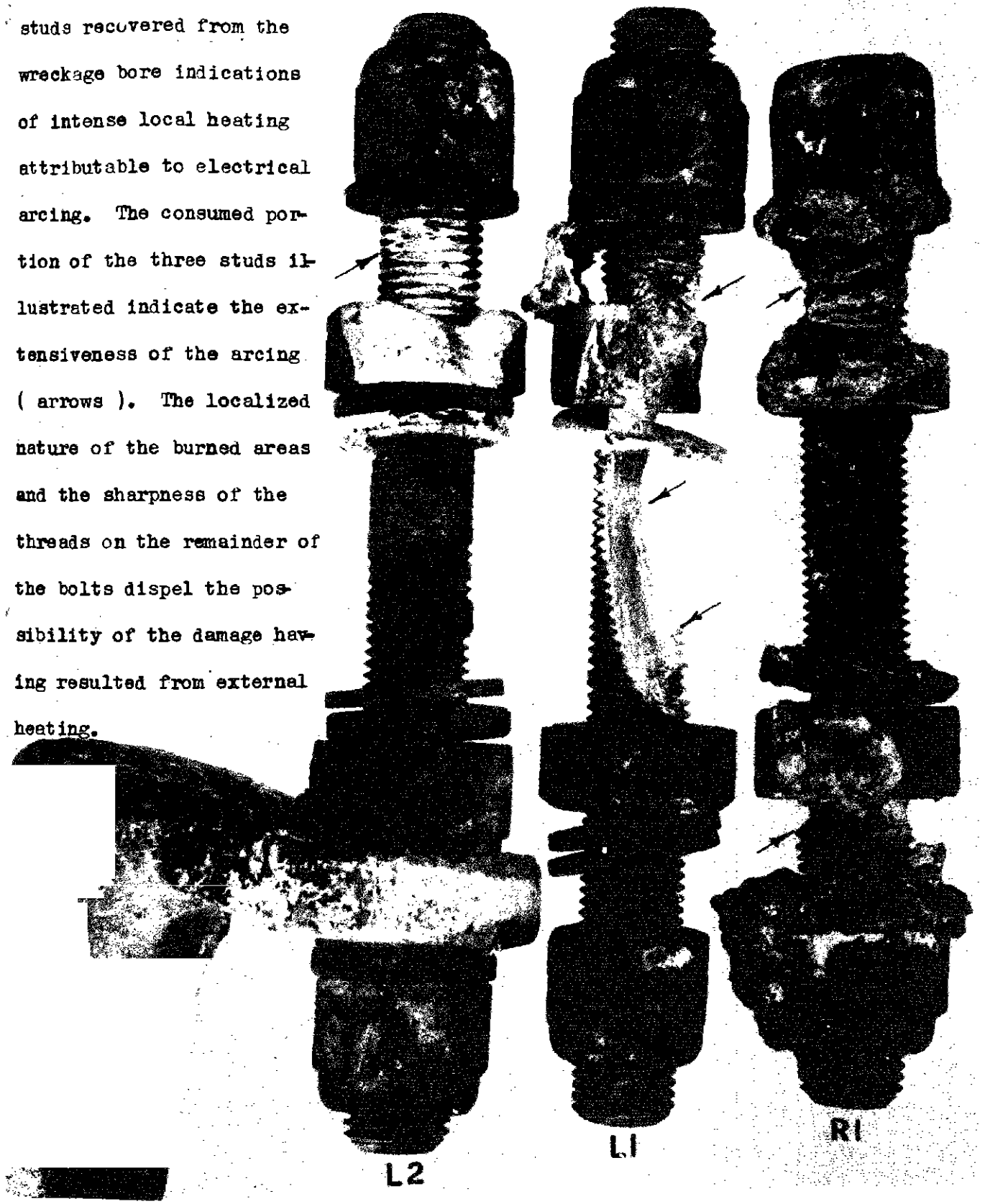

Fig. 2 Evidence of arcing on 3 of the lead-through studs. L1 and L2 are from the left side of NC 86513; R1 is from the right side.

likelihood of pitting and the development of high internal temperatures.

Laboratory tests were also conducted by Lockheed Aircraft Corporation to determine the possibility of fire hazard from an improperly installed through-stud assembly. A mock-up was constructed to simulate a section of the outer panel of the forward baggage compartment and a through-stud installed in this section with the extreme inboard nut loose. As long as the stud was not actually in contact with the fuselage skin, excessive temperatures were not developed. However, the first stud to be tested in contact with the skin was burned in two within 60 seconds as a result of intense electrical arcing. The same test was repeated to simulate a situation in which the inboard lead contacted a hydraulic line after falling from the skin. Such contact caused sufficient arcing to puncture the line and, under hydraulic pressures of 100 psi or greater, the fluid invariably ignited and burned with intense heat. The findings of the Lockheed tests, therefore, indicate that, in the event of a faulty installation in which contact with the fuselage skin results, sufficient energy may be dissipated at the through-stud position to ignite surrounding inflammable materials. It was further indicated that the resultant arcing may burn the stud in two and that current may continue to be fed to the inboard lead should the lead subsequently become grounded before the reverse current relay opens.

Testimony of maintenance personnel disclosed the fact that No. 2 generator had become inoperative during a previous flight and that inspection of the aircraft the day before the accident revealed a

generator lead burned away from the cable lug at the generator terminal box. Approximately 10 inches of insulation had burned off the cable from the terminal box rearward. Inasmuch as replacement parts were not available at Reading at the time, all three leads to the box were disconnected and each terminal insulated with friction tape. The three leads were then taped together and secured to the rubber vacuum line to prevent contact with other parts in the nacelle. No other portion of the electrical system was checked. The corrective measures taken by the mechanic were noted on the aircraft log. Testimony of electrical engineers indicates that the corrective action accomplished by the aircraft mechanic might have reduced the system voltage sufficiently to have hampered recharge of the batteries slightly if the No. 2 generator switch were inadvertently placed in the "On" position, but that such a condition could not be regarded as hazardous. Possible reduction in the system voltage could have been averted by disconnection of the equalizer lead in the No. 2 nacelle junction box which, in this instance, had not been accomplished.

Captain Brown's description of the smoke condition in the cockpit was corroborated by the inspection of a piece of plexi-glass windshield which was found near the wreckage. The inside face of this portion of the cockpit windshield was coated with a dark, sooty material which, it was determined, had accumulated prior to impact with the ground. Lockheed Aircraft Corporation conducted a series of tests in order to determine the air flow within the cabin and cockpit under conditions imposed by opening various windows and doors throughout the aircraft and

to determine the pattern in which the smoke would trail from the aircraft if released from the cabin or cockpit. In summarizing the first of these tests, it was noted that smoke originating in the forward baggage compartment would penetrate the floor of the cabin near the galley door, but that little smoke entered the crew compartment until the door between the galley and the crew quarters was opened. Opening of the side window in the cockpit caused a rapid increase of the flow of smoke toward the cockpit. Opening of the crew hatch further increased the rate of flow into the cockpit and did not cause any clearing of the smoke from the pilot and co-pilot positions. However, opening of the emergency exit on the left side of the passenger compartment over the wing changed the direction of air flow toward the rear. With this one exception, the air flow was pronouncedly toward the pilot compartment.

In the test conducted in order to determine the pattern of smoke behind the aircraft, the test equipment was not adequate for the development of sufficient smoke to be visible from other aircraft. The result of this test indicated that, in order to be visible to ground observers or from other aircraft, a very large volume of smoke is necessary. Ignition of sound-proofing saturated with hydraulic fluid due to arcing in the defective through-stud installation produced extremely dense, black smoke and severe fire in other tests conducted by Lockheed. Testimony of a Lockheed engineer indicated that the normal pressure distribution throughout the forward baggage compartment and wing root section makes possible a flow of smoke from the forward

baggage compartment into the wing root section toward the Nos. 2 or 3 engine nacelle if a sufficiently large hole is burned through the fuselage skin in this area. This testimony indicates, therefore, that smoke could have flowed into the No. 3 engine nacelle and escaped into the air stream behind it. Although this question was also the subject of flight tests conducted by Lockheed, the results of these tests did not confirm the above observation because of the inadequacy of the smoke generating equipment employed.

No fire or smoke-detection equipment was installed in the baggage compartment or cabin of Aircraft 513. Fire in the baggage compartment or unoccupied cabin would, therefore, under normal circumstances, escape notice by the flight crew for a considerable period of time. The only fire-extinguishing equipment available to the flight crew consisted of a carbon dioxide hand extinguisher in the crew compartment. One carbon tetrachloride extinguisher was located just aft of the galley door and another in the rearward portion of the cabin. Neither of these extinguishers was removed from its bracket by the flight crew in this instance. The baggage compartments of Constellation aircraft are not readily accessible to the flight crew and no extinguishing agent could be directed against a fire in this area.

The maintenance and overhaul records of Aircraft 513 were thoroughly examined by representatives of the Board. No discrepancies were found in any of these records, nor were any entries made which gave any evidence of difficulties in the history of this aircraft which may have contributed toward the accident. Aircraft 513 was in airworthy condition, as far as could be determined from these records, prior to the time of take-off from Reading Airport.

At the time of the accident a southerly air flow was bringing warm moist air into eastern Pennsylvania. Throughout the early morning of July 11, low stratus clouds and relatively restricted visibilities characterized the general weather situation in the vicinity of Reading. The ceilings improved during the morning until at the time of the accident scattered stratus clouds were above 4,000 feet and the visibility five miles or greater. The weather conditions at the time of the accident, therefore, were satisfactory for contact operation up to and including 3,000 feet and in no manner contributed to this accident.

The International Division of Transcontinental and Western Air maintains its central training school at the Reading Airport. The curriculum of the school includes ground and flight instruction related to Constellation transition. The flight curriculum includes instruction in ground handling characteristics of the Constellation and other phases of transitional training, landings and take-offs, and instrument flying. Until the time of the accident, Captain Nilsen had completed approximately 15 hours of flight training. The flight of July 11 was to be devoted to practice of QDM procedures simulating the approach pattern used at Geneva, Switzerland. Instruction in QDM procedures is required in the flight training curriculum of the International Division because these procedures represent the only system in effect for instrument approach to Geneva. The simulation of engine failure during take-off while the student pilot is "under the hood" is included in the instrument training program at Reading, and is considered an essential portion of this training. Officials of TWA do not regard the reduction of power during take-off as being hazardous to engine operation.

Discussion

Considerable attention was given the manner in which the take-off of Aircraft 513 from Reading Airport was accomplished in order to determine whether the throttling of two engines during take-off could have resulted in damage to the engine, or in any way have caused engine malfunctioning. The evidence available to the Board indicates that, when properly accomplished, such a maneuver need have no adverse effect on powerplant operation. While the extent to which the aircraft was permitted to descend following take-off may give rise to a question of pilot judgment, no evidence has been disclosed which would indicate that this maneuver in any way contributed to the accident.

As a result of the tests conducted by both the National Bureau of Standards and Lockheed Aircraft Corporation, as well as the condition of the electrical system within the serviceable aircraft inspected by the Board, it is apparent that electrical arcing had been caused by a defective through-stud installation and that such arcing was of sufficient duration and intensity to ignite the forward baggage compartment lining while in flight. In view of the condition of the baggage compartment lining in other Constellations, it is likely that leakage of hydraulic fluid had also taken place in the forward baggage compartment of Aircraft 513 and that the fuselage lining was saturated with fluid. The smoke present within Aircraft 513, according to the testimony of Captain Brown was similar to that produced under conditions simulated by Lockheed. Some possibility exists that one of

the through studs located on the right side of the fuselage which had been burned in two prior to impact had grounded against a hydraulic line permitting a continued flow of electric current. Such a situation may have caused a puncture of the hydraulic line permitting the fluid to escape in a highly inflammable spray. The presence of intense local heating due to arcing would also have resulted in burning of insulation surrounding the aluminum cables and may have accounted for the odor of "burning insulation" reported by Captain Brown.

The primary deficiency in the electrical system lay in the design of the through-stud. The high contact resistances and consequent arcing that may be expected between the surfaces of dissimilar materials in the stud assembly have been noted above. However, the investigation also disclosed the danger of the studs grounding against the inner surfaces of the holes in the fuselage skin through which they pass. Although insulating material separated the studs from the fuselage skin at these points this separation was maintained primarily by pressure of the nuts at each end of the stud against the micarta insulating blocks on each side of the fuselage skin. It became evident that redesign of these studs was necessary in order that a stud which becomes loose for any reason whatever would be prevented from grounding against the fuselage skin. It further became apparent that modification of the installation of the baggage compartment soundproofing was necessary so that hydraulic fluid leakage into that area would be prevented from accumulating in dangerous quantities. Furthermore, development and

service test of a satisfactory hydraulic fluid of reasonably low inflammability, or preferably of a non-inflammable composition, must be accelerated in order that all modern aircraft may be provided with a safe hydraulic fluid within the near future. It was necessary that all combustible materials within the cabin insulation and other parts of the aircraft structure be removed from the baggage compartments or substitutions should be made with non-inflammable materials.

The statement of Captain Brown indicates that immediately after leveling off at 3,000 feet, Captain Nilsen was instructed to maneuver the aircraft while "under the hood" with various combinations of powerplants in operation. It is apparent that during these maneuvers the flight crew became concerned about the odor of smoke. With any one engine throttled during these maneuvers, it is normal that some after-firing would occur. It is reasonable to assume, therefore, that the flight engineer, after having discovered the dense smoke in the fuselage, had erroneously interpreted the after-firing as back-fire. On this assumption, it would have been reasonable for the flight engineer to have advised feathering No. 4 engine. Captain Brown indicated that, at the time the flight engineer was checking the origin of smoke within the cabin, he was in the process of increasing the power on No. 4 engine and throttling No. 3 engine. The after-firing which was audible to the crew was most likely from No. 3 engine and Captain Brown attempted to call this fact to the attention of the flight engineer. In view of this sequence of events, it can be concluded that the impressions of the flight crew concerning powerplant malfunctioning were not substantiated by actual engine failure.

Observers in the vicinity of the scene of the accident who testified as to "back-firing" of the aircraft as it descended toward the field, in all probability, heard the after-firing of all four engines. Furthermore, the testimony of a Lockheed engineer indicates that smoke originating within the forward baggage compartment may flow through the leading edge of the wing into No. 3 or 2 engine, if holes were burned through the fuselage skin into the wing-root sections. This smoke would have been dispelled from No. 3 or No. 2 engine nacelles in a manner similar to that described by witnesses. While it is impossible to determine conclusively that no engine malfunctioning had occurred, it is definitely established that powerplant fire or failure had in no sense contributed to this accident and that the occurrence of such malfunctioning or fire is highly improbable.

For the third time within the past year, a major accident has occurred in an air carrier aircraft which could readily have been avoided, had an adequate fire-detection system been installed.* In each instance, the fire originated in inaccessible or remote areas of the aircraft and was able to develop to sufficiently severe proportions before detection to render a safe emergency landing impossible. A smoke-detection system would, without a doubt, have made it possible for the flight crew to take corrective action soon enough to permit a safe return to the airport.

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*Reference: Accident Investigation Reports, Docket No. SA-106, Adopted: July 16, 1946; and Docket No. SA-112, Adopted: Sept. 27, 1946. See also the Appendix, Page 28.

The problems of the flight crew were further complicated because, having detected the fire, insufficient means were at their disposal to control it. The forward baggage compartment of the Constellation was not readily accessible to the flight crew, and no means were available by which to control the fire remotely. No extinguishing system was provided for the baggage compartment. Moreover, the cabin air circulating system provides an ideal air flow within the baggage compartment to sustain the fire. Although Captain Brown has described the attempt of the crew to extinguish the fire, none of the hand extinguishers on board the aircraft were used. It is evident, therefore, that hand fire extinguishers are totally inadequate for the type of fire which occurred in this instance and that remote extinguishment equipment is essential for all sections of an aircraft not regularly occupied by, or easily accessible to, passengers or crew. Furthermore, such areas as the baggage compartment should be susceptible of that control necessary to seal the compartment as effectively as possible in order to prevent circulation of air within the compartment, distribution of smoke and/or flames from one compartment to another, and dissipation of the extinguishing agent.

The reason for the loss of control of the aircraft immediately prior to impact, and therefore the most immediate cause of the accident, was the inability of the pilots to maintain adequate control because of the denseness of the smoke within the crew compartment. Lockheed tests indicate that the smoke must have been sufficiently pungent to have made it impossible for a normal individual to endure breathing the

the smoke for even a short period of time. While the composition of this smoke has not been exactly determined, it is apparent from the statements of Captain Brown that it was impossible to maintain control of the aircraft from either of the pilot's seats. Opening of the crew hatch in the side of the crew compartment aggravated the smoke condition in the cockpit considerably, and this fact was confirmed by flight tests conducted subsequent to the accident. It is significant to note that opening of the rear emergency exit door altered the direction of flow towards the rear of the cabin. However, inasmuch as this fact was not known to the crew, even had it been possible for members of the crew to enter the cabin, they were unaware of the advantages to be derived from such action. It therefore appears essential that study be made of air flow control within the cabin and crew compartments of all aircraft engaged in air carrier service and that all flight crews be advised accordingly in order that proper action may be taken in the event of fuselage fires.

Inspection records compiled by the Board subsequent to the date of the accident pertaining to all major air carriers employing this model aircraft indicate that the condition of the through-studs and the leakage of hydraulic fluid within the forward baggage compartment was prevalent in this model. It is difficult to understand that such a situation could have been permitted to persist over an appreciable period of time without corrective action having been taken. The Lockheed Model 049 provides ample accessibility for ground inspection of the forward baggage compartment and failure to observe such a

condition as must have existed in Aircraft 513 prior to its last flight indicates the inadequacy of inspection policies then in effect. That the above situation was not an isolated incident became readily apparent after this accident when similar conditions in forward baggage compartments were observed in several such aircraft. It was observed that insufficient coordination existed between the Civil Aeronautics Administration, the aircraft manufacturers and the air carrier operators, and that in several instances field inspectors were insufficiently informed as to malfunctionings observed within newer aircraft. The existence of inspectional deficiencies assumes particular significance in the light of the fact that the Constellation was provided a "service test" while in military employment during the war, and that such service test will not be available to the same extent for types of aircraft presently in the pre-production stages. It is of primary importance, therefore, that more comprehensive inspectional policies be instituted by the agencies concerned, that these policies be rigidly adhered to and that coordination throughout the industry concerning unsatisfactory reports and/or mechanical interruption reports be improved.

Findings

Upon the basis of all available evidence, the Board finds that:

1. The company, aircraft, and crew were properly certificated for the flight.

2. Aircraft 513 departed Reading Airport at 1221 for a local instrument training flight with the student pilot under the hood and, during the course of the take-off, both right engines were throttled to simulate engine failure.

3. Following take-off, a normal climb was established to 3,000 feet and after leveling off, engine failure was again simulated by throttling of engines No. 4 and 3 in that sequence while the student pilot was still "under the hood."

4. The operation of the powerplants in the manner indicated above would not have been likely to induce engine malfunctioning nor had it contributed toward the accident in this instance.

5. Approximately 16 minutes after take-off, the crew members detected an odor resembling burning insulation.

6. The flight engineer opened the galley door and found the cabin filled with dense black smoke and reported this condition to the captain.

7. Fire extinguishing efforts were not possible due to the denseness of the smoke within the cabin and the hand fire extinguishers were not discharged in flight.

8. The flight engineer, upon hearing after-fire from one of the right engines, erroneously associated this after-fire with the smoke in the cabin and requested that No. 4 engine be feathered.

9. The pilot immediately initiated a descent toward Reading Airport with all engines throttled.

10. Hearing the sound of the throttled engines during the descent, ground observers erroneously interpreted normal powerplant after-fire as back-fire.

11. During the descent, the student flight engineer opened the crew hatch in an attempt to alleviate the smoke condition within the crew compartment.

12. Opening of the crew hatch increased the rate of flow of smoke from the cabin through the galley door into the cockpit, rendering it impossible for the pilots to observe the flight instruments or to see out through the windshield.

13. Captain Brown opened the window on the right side of the crew compartment and attempted to fly the aircraft with his head out of this window.

14. Shortly before contact with the ground, Captain Brown reseated himself in the co-pilot's seat, pulled back on the controls and "ditched" the aircraft "blind".

15. The aircraft was extensively damaged as a result of impact and, after coming to rest, gasoline and other inflammable materials from ruptured tanks ignited and the aircraft was almost completely consumed by fire.

16. All six through-studs in the forward baggage compartment contained some evidence of arcing and at least two of these studs were sufficiently burned during flight to have ignited the fuselage insulation.

17. Inspection of other 049 aircraft indicated that sufficient hydraulic fluid leakage into the forward baggage compartment to saturate the fuselage insulation could be expected in this model.

18. No fire or smoke-detectors were located in any section of the fuselage.

19. The baggage compartments are not readily accessible to the flight crew in flight for purposes of fire control.

20. No fire-extinguishing equipment was available for use within the forward baggage compartments.

21. The flight crew was uninformed as to the nature of air flow in the fuselage and the possibilities of controlling such air flow.

22. It was determined that no possible engine malfunctioning could have contributed to this accident although the absence of engine malfunctioning could not be completely confirmed.

Probable Cause

The Board determines that the probable cause of this accident was failure of at least one of the generator lead through-stud installations in the fuselage skin of the forward baggage compartment which resulted in intense local heating due to the electrical arcing, ignition of the fuselage insulation, and creation of smoke of such density that sustained control of the aircraft became impossible. A contributing factor was the deficiency in the inspection systems which permitted defects in the aircraft to persist over a long period of time and to reach such proportions as to create a hazardous condition.

Conclusions

On the basis of the investigation of this accident, the Board concludes that:*

1. The design of the generator lead through-studs installed in this aircraft rendered those studs susceptible to grounding to the fuselage skin and the development of extremely high local temperatures due to electrical arcing.

2. The through-stud design, furthermore, contained excessively high contact resistance, which, at peak loads, may cause arcing even when the stud is properly installed.

3. The presence of inflammable fuselage insulation in the vicinity of the through-stud installation created a fire hazard.

4. Hydraulic fluid leakage into the forward baggage compartment of 049 aircraft presented a serious fire hazard.

5. The baggage compartments of 049 aircraft were not readily accessible from the cabin or crew compartment for purposes of fire control.

6. 049 aircraft were inadequately provided with fire or smoke-detecting systems within the fuselage.

7. 049 aircraft were inadequately provided with fire-extinguishing equipment for possible fuselage fires and require remote extinguisher systems for the baggage compartments.

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* The conclusions are stated in the past tense in view of modifications that have been made in model 049 aircraft and which are referred to on Page 28.

8. Insufficient attention had been provided the subject of air flow control within aircraft presently employed in air carrier service.

9. Inspectional policies which have heretofore been followed did not provide adequate assurance of the elimination of particular categories of deficiencies of design or construction within newer aircraft.

BY THE CIVIL AERONAUTICS BOARD:

/s/ J. M. Landis

/s/ Oswald Ryan

/s/ Harllee Branch

/s/ Josh Lee

/s/ Clarence M. Young

The investigation of this accident disclosed several serious defects in the electrical system of the Model 049 as well as deficiencies in fire preventive and extinguishing equipment installed in the aircraft. Investigation of the accident involving this model aircraft at Willimantic, Conn., June 18, 1946, revealed serious defects in several engine nacelle components. As a result of these accidents the Board initiated studies to determine the extent of the hazards arising out of specific design deficiencies of the Model 049 aircraft. During the past year the Board has been engaged in the amendment of those Parts of the Civil Air Regulations which are concerned with protection of air carrier aircraft from possible fire, however, the findings of the above studies contributed materially in the preparation of the amendments which were promulgated by the Board September 20, 1946. These amendments were designed to eliminate the possibility of fire occurring as a result of inadequate fire preventive installations in all air carrier aircraft.

Under the emergency authority vested in the Administrator of Civil Aeronautics and in view of the deficiencies disclosed as a result of this accident, the CAA, immediately following the accident, suspended the airworthiness certificate of the Lockheed Model 049 for a period of 30 days. During this period conferences were conducted by the CAA with representatives of the aviation industry and an agreement was reached whereby certain modifications would be accomplished in this model aircraft in order that it be returned to service as expeditiously as possible.

The principal modifications which were required are summarized as follows:

1. Electrical System:

The insulation of certain wiring was modified to prevent possible damage from chafing and to prevent contact with parts of the aircraft. The fuselage through-stud assemblies were replaced with units of a new design. Undersized aluminum conductors in the generator circuits were replaced with copper cables. A general improvement was accomplished in circuit breakers, fuses, and control switches to prevent shorting.

2. Powerplants:

Fire extinguisher protection for the accessory section of the engine nacelles was provided and the extinguishing system was modified to provide two 30-pound discharges instead of the three 15-pound discharges of the original system. Provisions were made for increased drainage and ventilation of the engine nacelles aft of the firewall in order to prevent the accumulation of combustible fluids or vapors. Fluid-carrying lines in the engine nacelle were made more fire resistant. More sturdy attachments were provided for these lines and protection was provided against chafing. The alcohol tanks were replaced by tanks of a heavier gauge steel. Several modifications were accomplished in the exhaust collector ring to prevent failure of this component.

3. Miscellaneous:

Prior to reinstallation and use of cabin supercharger drive shafts, modifications were made to prevent failure of the shafts. Certain hydraulic lines were relocated to reduce possible fire hazards and, in some instances, to prevent contamination of the oxygen system. Drains were provided in the baggage compartments to prevent accumulation of hydraulic fluid.

The CAA required the manufacturer to conduct an accelerated service test of 50 hours following the completion of the above modifications before this aircraft could be used in scheduled operations. The first Constellation was returned to service August 24, 1946.

SUPPLEMENTAL DATA

Investigation and Hearing

The Civil Aeronautics Board was notified of the accident at 1330, July 11, 1946, and an investigation was immediately initiated in accordance with the provisions of Section 702 (a) (2) of the Civil Aeronautics Act of 1938, as amended. Air Safety Investigators of the Board's New York and Washington Offices arrived at the scene of the accident at 1730 the same day, and were subsequently assisted in the investigation by other Investigators of the Safety Bureau's staff.

A public hearing was ordered by the Board and was held at Reading, Pennsylvania, July 30, 31, and August 1, 1946.

Flight Activity

Transcontinental and Western Air, Inc., operating under the laws of Delaware and having established its headquarters in New York, was conducting a training program for flight personnel of its International Division at Reading, Pennsylvania. The Training School, including both Flight and Ground curriculums, was approved by the Civil Aeronautics Administration.

Flight Personnel

Captain Richard Farrow Brown, age 27, of Cocoa, Florida, was pilot instructor in command of the aircraft. Until the date of the accident, he had accumulated a total of 2,477 hours flying time, of which 196 hours were obtained in Lockheed 049 aircraft. Captain Arthur Normal Nilsen, age 33, Norfolk, Massachusetts, was student pilot, receiving

transition training. Until the date of the accident, he had accumulated a total of 5,520 hours, of which approximately 15 hours were obtained in this model aircraft. John Jacob Staufer, age 36, Alexandria, Virginia, was flight engineer and Charles Carmon Semola, age 32, of Arlington, Virginia, was a student flight engineer, receiving familiarization instruction in 049 aircraft. William Eugene Amther, age 29, of Washington, D.C., and Douglas Lee Herrin, age 25, of Tuscaloosa, Alabama, accompanied the flight as assistant first officers. All flight crew personnel were properly certificated and otherwise qualified for their respective duties.

Aircraft

NC 86513, a Lockheed Constellation 049, was manufactured in February, 1946, and until the date of the accident had accumulated a total of 959 hours of flying time. The aircraft was equipped with Wright R-3350-35 engines incorporating Hamilton Standard propellers. The total time accumulated by each engine was 597 hours for No. 1, 848 hours for No. 2, 848 hours for No. 3, and 377 hours for No. 4. The time since the last major overhaul was 374 hours for Nos. 1, 2, and 3 engines, and 377 hours for No. 4. During the local training flight at Reading, Pennsylvania, the aircraft total weight was within its maximum gross load limits and the load was distributed with respect to its center of gravity within approved limits.