REPORT OF THE CIVIL AERONAUTICS BOARD

Of the investigation of an accident involving civil aircraft of the United States NC 16086 which occurred near Centerville, Utah, on November 4, 1940.

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TABLE OF CONTENTS

I.

CONDUCT OF INVESTIGATION

An accident involving aircraft NC 16086 while operating in scheduled air carrier service as Trip 16 of United Air Lines Transport Corporation (hereinafter referred to as "United") occurred in the vicinity of Centerville Utah, on November 4, 1940, at approximately 4:42 a.m. (MST) resulting in the destruction of the airplane and fatal injuries to everyone on board. At approximately 9 a.m. (EST) on November 4, 1940, personnel of the Civil Aeronautics Board (hereinafter referred to as the "Board") received notification that Trip 16 was long overdue at Salt Lake City and later on that day received definite information that the trip had met with an accident.

INSPECTION OF THE WRECKAGE

Immediately after receiving this information, the Board* initiated an

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* By virtue of Reorganization Plans No. III and No. IV promulgated by the President and made effective June 30, 1940, the accident investigation function exercised by the Air Safety Board was transferred to the Civil Aeronautics Board. By the same orders, the Air Safety Board was abolished.

Since the effective date of the Reorganization Plans, the Board's only safety functions are accident investigation, the promulgation of safety rules, regulations, and standards, and the suspension and revocation of safety certificates. It is the function of the Administrator of Civil Aeronautics, an executive officer in the Department of Commerce completely independent of the Board, to administer and enforce the safety rules, regulations, and standards, in addition to the function vested in him by the Civil Aeronautics Act of establishing, operating, and maintaining the air navigation facilities on the civil airways, including radio ranges, radio markers, and communication facilities. The Administrator of Civil Aeronautics and his staff are referred to as the "Civil Aeronautics Administration".

While the Civil Aeronautics Board acts independently of the Secretary of Commerce, the Administrator of Civil Aeronautics performs his functions under the direction and supervision of the Secretary.

investigation of the accident in accordance with the provisions of section 702(a)(2) of the Civil Aeronautics Act of 1938, as amended. Accident investigators of the Board arrived in Salt Lake City early on the morning of November 5 and immediately proceeded to the scene of the accident. Upon their arrival they took custody of the wreckage and began their inspection.

The record shows that weather conditions in the Salt Lake area prevented any search for the airplane over the higher terrain until about 9 a.m. on November 4. The wreckage was sighted from the air at about 10:35 a.m. and ground crews were immediately organized and dispatched to the scene of the accident. From the time of the arrival of the first person at the scene of the accident until the arrival of the Board's investigators, the wreckage was under constant guard by public officials. William A. McIlraith, the town marshal of Centerville, Utah, arrived at the scene of the accident at approximately 2 p.m., November 4, 1940, and was the first to arrive there. He deputized as guards six or seven men who accompanied him. Shortly after his arrival, members of the Utah State Road Patrol arrived and undertook the duty of guarding the wreckage. They maintained constant guard until the arrival of the Board's investigators. Before leaving the scene of the accident on November 5, the Board's investigators employed as guards several deputy sheriffs of Davis County. The deputy sheriffs remained on guard constantly until the wreckage had been carefully examined by the representatives of the Board and the condition of all parts of the airplane had been ascertained.

The radio equipment of the airplane and certain propeller parts were removed from the scene of the accident to the Salt Lake City Airport in order that a more adequate inspection might be made of them. During the transportation of this equipment it was under constant guard either by an investigator

of the Board or by one of the deputy sheriffs who had been employed by the Board to guard the wreckage. The inspection of all parts of the aircraft was completed by the Board on November 15, 1940, and aircraft NC 16086 was released to United on that day.

PUBLIC HEARING

In connection with the investigation of the accident, a public hearing was held in Salt Lake City, Utah, beginning on November 12 and continuing through November 24, 1940. G. Grant Mason, Jr., one of the five members of the Board, was designated by the Board as Presiding Examiner and S. G. Tipton, Assistant General Counsel of the Board, was designated by the Board as Associate Examiner. They were assisted by Jerome Lederer, Director of the Safety Bureau of the Board, Frank E. Caldwell of that Bureau, and, from time to time, by Ford Studebaker and Herbert Hucke, who had been retained as radio experts* for the purpose of this investigation.

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* Mr. Studebaker, now employed by American Export Airlines as Chief of Communications, has been engaged in aviation radio work since 1917. From 1917 to 1919 he served with the United States Navy as radio electrician. In 1919 he entered the service of the United States Army Air Corps as radio engineer and during his service participated in the development of the radio range as an air navigation facility. From 1930 to 1935 Mr. Studebaker acted as radio engineer for American Airlines, from 1935 to 1937 as communications supervisor for Chicago and Southern Airlines, and, from 1937 until his employment in 1939 with American Export Airlines, was employed by the Bureau of Air Commerce and the Civil Aeronautics Authority as an air carrier inspector--radio. Thus from 1919 until the present time, Mr. Studebaker has had experience with the radio range both from the standpoint of the ground equipment and also the use of the range in flight as an air navigation facility.

Mr. Hucke has served in various capacities as a radio engineer since 1925. From 1925 to 1931 he was employed by the Radio Corporation of America and from 1931 to 1938 was employed by United Air Lines as a radio engineer and chief communications engineer. From October, 1938, until May, 1940, Mr. Hucke served with the former Air Safety Board as a radio expert, and from May, 1940, until the present time with the Radio Corporation of America.

In accordance with its policy of cooperation with State governments, the Board granted to the Utah State Aeronautics Commission the opportunity to participate in the hearing. While, due to illness, the Chairman of the Commission, Mr. W. D. Hammond, was unable to attend any of the sessions, and Mr. George Abbott appeared at only one session, the Vice Chairman of the Commission, Mr. Preston G. Peterson, and the Director of the Commission, Mr. Joseph S. Bergin, were present at almost all sessions of the hearing and participated in the questioning of witnesses.

All the evidence available to the Board at that time was presented at the hearing. One hundred and thirty-seven exhibits were introduced and seventy-eight witnesses testified, including personnel of United, the United States Weather Bureau, the War Department, the Civil Aeronautics Administration,* the Civil Aeronautics Board, and other experts in the various technical subjects involved in the investigation.

The Examiners, the representatives of the Safety Bureau, and the Members and Director of the Utah State Aeronautics Commission, were the only ones designated to ask questions directly of any witness. However, the Associate Examiner, acting under instructions of the Board, announced at the opening of the hearing that any person who had any evidence, questions, or suggestions to present for consideration in the proceeding might submit them in writing to the Examiners. Over 300 such questions were submitted and, at the close of the hearing, the Presiding Examiner announced that every question had been asked except in a few instances when the subject-matter of the question had previously been covered by the testimony or when the question was clearly inappropriate to the type of proceeding being conducted. In the course of the

* See footnote page 1.

investigation many suggestions were submitted to the Board and all have been carefully considered.

Upon the basis of all the evidence available to it at this time, the Board herewith makes its report in accordance with the provisions of the Civil Aeronautics Act.

II.

SUMMARY AND ANALYSIS OF EVIDENCE

AIR CARRIER

United, a Delaware corporation, was operating at the time of the accident as an air carrier under a certificate of public convenience and necessity and an air carrier operating certificate issued pursuant to the Civil Aeronautics Act of 1938, as amended. These certificates authorized it to engage in air transportation with respect to persons, property, and mail between various points, including Oakland, California, and Salt Lake City, Utah, via San Francisco and Sacramento, California, and Reno and Elko, Nevada.

FLIGHT PERSONNEL

On the flight in question, the flight crew consisted of Captain Howard M. Fey and First Officer Thomas E. Sandegren.

The record shows that Captain Fey, who at the time of the accident held airline transport pilot certificate No. 4503, had accumulated a total of 16,855 hours flying time, of which 2,160 hours were in Douglas DC-3 type airplanes. He received his flight training in the United States Army Air Corps in 1923 and served in the Army from 1923 until 1928. Shortly after leaving the Army he secured a Federal transport pilot certificate and began his

service as an airline transport pilot with the Maddux Air Lines, Los Angeles, California. He had served as a captain with United and its predecessor companies since January 17, 1930. Captain Fey operated in and out of Salt Lake City during the entire period of his service with United and its predecessor companies, having flown from Portland, Oregon, to Salt Lake City until March 1, 1938, and from Oakland, California, to Salt Lake City from March 1, 1938 until the date of the accident.

Captain Fey had logged during his flying experience approximately 234 hours of instrument flight time. He had received a routine flight check under simulated instrument conditions on November 2, 1940, and the check pilot reported that the instrument ability shown on that flight was "standard", the highest rating given under company practice. Two pilots, who had ridden as first officers with Captain Fey, testified that they considered him to be a capable instrument pilot.

Captain Fey's last physical examination required by the Civil Air Regulations* was taken on May 24, 1940, and showed him to be in a satisfactory physical condition. In addition, in accordance with the established procedure of United, he had been subjected to a thorough physical examination by a company physician on February 27, 1940, and that examination showed him to be in good physical condition.

First Officer Sandegren, who at the time of the accident held airline transport pilot certificate No. 37828 had acquired 3,341 hours of flight time of which 2,500 hours had been secured in Douglas DC-3 type airplanes. He received his flight training in the United States Army Air Corps and was

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* The holder of an airline transport pilot certificate is required by section 21.252 to take a prescribed physical examination every six months.

employed by United as First Officer on June 7, 1937, shortly after leaving the Army. A short time prior to the accident he had been promoted from First Officer to Captain and had flown as Captain for approximately 27 hours.

First Officer Sandegren had logged approximately 153 hours of instrument flight time and had been given a flight check under simulated instrument conditions by a company check pilot on June 10, 1940. He also had been rated by the check pilot as "standard".

First Officer Sandegren had taken the physical examination required by the Civil Air Regulations on May 31, 1940, and the company physical examination on March 11, 1940, both of which indicated that he was in satisfactory physical condition.

Thus it appears from the evidence that both Captain Fey and First Office Sandegren were physically qualified, held the proper certificates of competency, and, by reason of their training and experience, were competent airline pilots in both instrument and contact operation.

AIRPLANE AND EQUIPMENT

The airplane involved in the accident, aircraft NC 16086, was a Douglas DC-3A, serial No. 1925. It was manufactured by the Douglas Aircraft Corporation of Santa Monica under approved type certificate No. 669 and was delivered to United by the manufacturer on February 4, 1937. The airplane had accumulated a total of approximately 8,694 hours of flight time. It was equipped with two Pratt and Whitney twin Wasp S1C3G engines rated at 1100 h.p. each. The left engine, serial No. 1508, had accumulated a total of about 3,653 hours and the right engine, serial No. 1534, a total of about 4,007 hours. The engines were equipped with Hamilton Standard hydromatic, constant speed,

full-feathering propellers. The right propeller hub had accumulated a total of about 6,471 hours and each of the blades about 1,135 hours. The left propeller hub and blades each had a total of about 6,447 hours.

The radio equipment installed in the airplane included four receivers, a radio range receiver (UAL ES-198), a two-way plane to ground communication receiver (Western Electric type 12-A, modified), an auxiliary receiver (RCA type AVR-7A, modified) which could be used either for range reception or for reception on the company circuit, and an ultra-high frequency marker receiver (Western Electric type 27-A, modified). Also installed in the airplane were a receiving dynamotor (Eclipse type 80-2, model 2749), a transmitting dynamotor (Eclipse type 80-2325A), and a 50-watt radio telephone transmitter, (UAL ES-271). The transmitter was licensed by the Federal Communications Commission. The airplane was equipped with overhead and belly fixed antennae and also with a loop antenna. Head phones and microphones were provided for both the Captain and the First Officer and a switch arrangement was installed so that either or both could use any of the receivers. The airplane was also equipped with two of the anti-static discharge cartridges which had been developed and used by United Air Lines for the purpose of reducing precipitation static.

Complete de-icing equipment was installed on the airplane as well as a full complement of the necessary instruments required by the Civil Aeronautics Administration and by United. In addition, the airplane was equipped with the necessary facilities for providing oxygen for the passengers and crew. These included an oxygen bottle of 1,300 litres capacity with four outlets, one for use by the Captain, one for the First Officer, and two for the passenger compartment.

At the time of the accident, aircraft NC 16086, equipped as above described, held a currently effective airworthiness certificate which authorized the transportation of 21 passengers and a crew of four and the operation of the airplane at a standard gross weight of 24,400 pounds and a provisional gross weight of 25,200 pounds.

It appears from the record that the airplane and its equipment had received the overhauls, inspections, and checks which are provided for in company practice and approved by the Civil Aeronautics Administration. The wings, fuselage, and center section are required to be overhauled at or before the completion of each 5,000 hours of flight time and an engine overhaul is required at or before the completion of each 625 hours. The empennage, landing gear, wheels, brakes, tail wheel assembly, nacelles, control system, hydraulic system, electrical system, aircraft accessories, engine accessories, propellers, aircraft engines, engine instruments, fixed plane radio equipment, fuel and oil system, and oil tanks and lines are all required to be overhauled at each engine overhaul (625 hours' flight time). Aircraft NC 16086 had accumulated about 2,299 hours since the last overhaul of the wings, fuselage and center section, and had accumulated about 520 hours since the last overhaul of the engines, propellers, and other parts and equipment.

In addition to the overhauls described above, the airplane and its equipment is, as a matter of practice, given other routine periodic inspections and checks. United requires three types of inspections. The number one inspection is merely a visual inspection of the airplane and its equipment given at service stations along the route as the trip progresses. The number two check is an inspection which is performed after each 25 to 40 hours of flight time. It consists of uncowling and inspecting the engine and inspecting the

airplane and its component parts. There are no accessories changed at this time unless they are found to be malfunctioning. The number three check is performed after about 100 to 125 hours of flight time and in addition to all the work which is required to be done in the number one and number two checks, the spark plugs are changed, the main oil screens are checked, the landing wheels are removed, disassembled and inspected, floor boards are removed from the companionway, and the control cables are inspected. The record contains reports of all the checks which were made of aircraft NC 16086 during the last 95 hours preceding the accident. From these records it appears that all of the required inspections and checks were made and that only a few minor deficiencies were noted and those were promptly remedied.

United also requires its flight personnel to file, at the end of each trip, a trip log upon which they insert any comments they may have as to the operation of the aircraft, engines, instruments, and radio. The record includes trip logs for the last ten trips made by NC 16086 and they contain only a few minor criticisms made by the pilots on the operation of the engines and it appears that the necessary adjustments to eliminate these deficiencies were promptly made. No criticisms were made of the performance of the aircraft, engines, instruments, or radio on the flight which was made by the airplane from Oakland to Los Angeles and return on November 3, 1940, which terminated just a short time prior to the take-off of the airplane for Salt Lake City. In addition, a number two check had been given the airplane just prior to its departure from Oakland for Salt Lake City on November 3 and the report of this inspection indicates that the airplane and its equipment were in proper condition at the conclusion of the inspection.

Thus, from all the evidence available to us, we find that the airplane

and its equipment had been properly maintained and were in an airworthy condition at the time of the take-off from Oakland for Salt Lake City on November 3.

HISTORY OF THE FLIGHT

The flight plan prepared for Trip 16 by Captain Fey at Oakland and signed by him, First Officer Sandegren, and Philip Showalter, United dispatcher at Oakland, provided for a flight from Oakland to Salt Lake City with stops at San Francisco and Sacramento, California, and Reno and Elko, Nevada. He estimated the total time from Oakland to Salt Lake City, including taxiing time, as 4 hours and 9 minutes. Captain Fey anticipated contact flight from Oakland to Reno with northwesterly winds of about 10 to 12 miles per hour at flight altitudes* and an instrument flight from Reno to Salt Lake City with a west wind from 18 to 22 miles per hour at flight altitudes. In view of the fact that instrument weather conditions prevailed at Salt Lake City, Wendover, Utah, was designated as an alternate field for Salt Lake City in accordance with the applicable provisions of the Civil Air Regulations.

Trip 16 departed Oakland at 10:20 p.m. (MST*), cleared by the United dispatcher at Oakland to Reno, Nevada, in accordance with company procedure. The flight proceeded without incident to Reno, departing from that point at 1:00 a.m., cleared to Salt Lake City by United's Salt Lake City dispatcher. The 12:35 a.m. sequence weather reports were available at Reno at the time Trip 16 was dispatched and were attached to the company clearance form. These reports showed that at Elko the ceiling was unlimited with scattered clouds at 3500 feet and visibility over 9 miles. At Ventosa, Nevada, and Wendover, Utah,

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* Unless the contrary is indicated, hereafter all references to time will be to Mountain Standard Time and all references to altitude will be in terms of feet above mean sea level.

report for Salt Lake City was probably available and, in addition, a number of special reports which had been filed between the regular 12:35 a.m. and 1:35 a.m. sequences. These reports showed light to moderate snow at Salt Lake City with extremely variable ceiling and visibility. At 12:50 a.m., Salt Lake reported a snow ceiling of 500 feet and visibility of 1/2 mile, at 12:58 a snow ceiling of 1000 feet and visibility of 2 miles, at 1:02 a snow ceiling of 500 feet and visibility of 1/2 mile, at 1:20 a snow ceiling of 1000 feet and visibility of 3 miles, and at 1:35 a snow ceiling of 1000 feet and visibility of 3 miles. These reports indicated that there was little wind on the ground at Salt Lake City.

The remainder of the history of Trip 16 from the time it departed Elko at 2:32 a.m. until it crashed at 4:42½ a.m. must be gathered, for the most part, from the radio log* showing the contacts made between the flight crew of Trip 16 and United ground stations and the card taken from the flight recorder** installed in the tail of the airplane. The log shows that at 2:53 a.m., the Airway Traffic Control Center at Salt Lake City cleared Trip 16 from Wendover to the Salt Lake City Airport control tower and designated the trip as No. 1 to approach.*** From that time until 3:20 a.m., United's Salt

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* Radio logs showing communications pertaining to Trip 16 and other flights are contained in Appendix B which may be secured, if desired, upon request direct to the Public Information Section, Civil Aeronautics Board, Washington, D. C.

** An instrument designed and used to make a continuous record of the various altitudes at which the airplane flies, the times at which a radio transmitter is used, and the periods during which the automatic pilot is being used.

*** See footnote page 12. This clearance indicated that traffic conditions at Salt Lake City were such that Trip 16 would be able to begin an approach immediately upon arrival over the Salt Lake City station and would not have to await the completion of an approach and landing by any other aircraft.

Lake City ground station attempted to contact Trip 16 in order to transmit this clearance but was unable to do so. At 3:20 a.m., United's ground station at Sacramento advised the ground station at Elko, which in turn reported to Salt Lake City, that Trip 16 wished to be called on day frequency.* Consequently, Salt Lake City tried to contact Trip 16 on day frequency but was unable to do so. Finally, at 3:25 a.m., First Officer Sandegren of Trip 16 called Salt Lake City and inquired as to whether Salt Lake City had received Trip 16's Wendover report. Salt Lake City replied that they had not because of snow static. First Officer Sandegren then stated that they had passed over Wendover at 3:07 a.m. and that they estimated arrival over Salt Lake City at 3:40 a.m. He reported that they had the 3:20 a.m. weather report for Salt Lake City as 1300-foot ceiling, overcast, with visibility of 5 miles. At 3:26 a.m. Salt Lake City advised Trip 16 that Airway Traffic Control had cleared the trip from Wendover to the control tower as No. 1 to approach. First Officer Sandegren reported Trip 16 over the Timpie marker (about 40 miles west of Salt Lake City) at 3:28 a.m. at 13,000 feet and stated that the trip was descending to arrive over the Salt Lake City radio range at 11,000 feet. Salt Lake City acknowledged this message and gave the information to Airway Traffic Control.

United's Salt Lake City radio log shows the following contacts between Trip 16 and Dispatcher Edson, who was stationed at the remote microphone and receiver located outside the Administration Building on the Salt Lake City Airport:

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* Certain radio frequencies available to air carrier aircraft and ground stations are normally used only at night while others are normally used only during the day.

"3:43 AM - Fey, Trip 16, to Salt Lake City: 'Over the Salt Lake Range Station at 3:40. What's the weather?' Dispatcher Edson, Salt Lake City, to Trip 16: 'The last weather report gave ceiling 1300 feet, overcast, visibility 8 miles with light snow. The Saltair beacon is visible but low clouds or smoke in the West and Southwest. Conditions are still good north of field.' Fey, Trip 16, to Salt Lake City: 'What was that special weather report we heard a little while ago which reported visibility 5/8 of a mile?' Edson: 'That was not Salt Lake. We can see the Saltair beacon.'* Fey: 'We are over the field at 13,000 feet.' Edson: 'OK. The thing to watch is this low drifting stuff to the west and southwest of the field.' Fey, Trip 16, acknowledged.

"3:44 AM - Salt Lake City to Trip 16: 'Are you at 13,000 feet or at 11,000 feet?' Fey, Trip 16: 'We are still at 13,000 feet. We are on top.' Salt Lake City acknowledged.

"3:48 AM - Salt Lake City to Trip 16: 'The wind on the field is calm. You may land south on the concrete runway.' Fey, Trip 16: 'I can hear you but can't read you. Will call later.' Salt Lake City acknowledged.

"4:01 AM - Fey, Trip 16, to Salt Lake City: 'Go ahead now.' Salt Lake City repeated the landing instructions. Fey, Trip 16: 'On top again 14,000 feet. There is an awful lot of static in here. We are going to try to come in again. Will be over the range pretty soon.' Salt Lake City acknowledged. Fey, Trip 16: 'Repeat, Salt Lake.' Salt Lake: 'Just OK'd your report.' Fey, Trip 16: 'OK, We have heavy static.'

"4:01 AM - Airways Traffic Control to Salt Lake City: 'Advise Trip 16 that if he misses his second attempt to try his third attempt from 7,000 feet on the north leg or climb to 13,000 feet on the west leg of the Salt Lake Range.' This message relayed to Trip 16 and acknowledged.

"4:03 AM - Fey, Trip 16: 'We were over the Range Station at 14,000 feet at 4:00 AM, just in the tops of the clouds.' Salt Lake City acknowledged.

"4:05 AM - Dispatcher Edson to Trip 16: 'Another snow flurry moving in from the north. The visibility to the north is about one mile.' No answer.

"4:10 AM - /United's radio operator noted:/ 'Snow static.'

"4:10 to 4:11 AM - Edson to Trip 16: 'Weather Bureau has a special weather report: ceiling 900 feet, light snow, visibility 3 miles, but

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* See footnote page 17.

it appears much poorer to me. The visibility is about one mile. Go ahead.' No answer. Salt Lake City ground station called Trip 16. No answer.

"4:12 AM - /United's radio operator noted:/ 'Heavy snow static Salt Lake.'

"4:23 AM to 4:26 AM - Salt Lake City to Trip 16: 'The visibility southwest is only about 1/2 mile.' No answer. Salt Lake City to Trip 16: 'Do you read?' Dispatcher Edson to Trip 16: 'Visibility about 2 miles to the north. Can see the Range Station plainly. Just turned the lights out southwest of the field. Think we have good visibility.' Fey, Trip 16: 'Lots of static at times. Fire all over things and can't hear the range. /Fey refers to what is known as "St. Elmo's fire", a form of static electricity and not harmful to airplanes./ I don't know whether we can get in or not. Unless we can pick up the field will have to get out of here.' Salt Lake City: 'OK, what altitude are you at now?' Fey, Trip 16: 'We are still on top at 14,000 feet.' Salt Lake City acknowledged. /At the hearing Dispatcher Edson testified that at 4:26 AM he heard Trip 16 pass over or near the airport./

"4:30 AM - Airways Traffic Control to Salt Lake City: 'Trip 16 is cleared to proceed from Salt Lake City to Elko airport. He is to cruise at 13,000 feet. No essential traffic has been reported. Have Trip 16 keep us advised.' /Dispatcher Edson had requested clearance for Trip 16 to return from Salt Lake City to Elko./

"4:31 AM - Salt Lake City called Trip 16. No answer.

"4:33 AM - Salt Lake City called Trip 16. No answer.

"4:37 AM - Salt Lake City to Trip 16: 'Do you read?' Edson to Trip 16: 'Another snow flurry in here now. Visibility one mile or a little less and Trip 11 is estimated over Salt Lake at 4:47 AM at 14,500 feet. If you are unable to make your approach we want you to return to Elko. We will have Trip 11 go to Elko and adjust the cargo.' Fey, Trip 16: 'OK, we are on the north leg /of the Salt Lake City radio range/ at 9,000 feet and there are breaks in the clouds out here. It is quite a bit thinner. Think we can come down out here and follow the lake in if you want us to do it that way.' Edson: 'OK - If you want to do it that way. Will keep you advised. I cannot see Range station. I can faintly see the north boundary lights.' Fey acknowledged. /A recording of this radio conversation was being made on an automatic recording machine which was in operation in the United dispatch office in Oakland, California. The record made reveals that the operator at Salt Lake City did not copy the above conversation verbatim. The recording shows that Edson's acknowledgment was: "That is OK to continue your approach, Howard. I will keep you advised."/

"4:40 AM - Fey, Trip 16: 'We are over Layton at 8,000 feet now.' Edson: 'OK, Howard. The wind is north about 3 and still think it is OK to land straight in.' Fey: 'The stuff is broken out here much better.' Edson: 'OK, Howard.'

"4:41 AM - Edson, Salt Lake City to Fey: 'The north boundary lights now obscured. The visibility about 3/4 of a mile but very variable.' Fey acknowledged."

Dispatcher Edson attempted many times thereafter to contact Trip 16 but no further word was received from the trip. During the hour that Trip 16 was flying in the vicinity of Salt Lake City, the reports of weather observations made by United States Weather Bureau observers in Salt Lake City indicate that the ceiling and visibility were highly variable by reason of frequent snow squalls. The weather reports show that at 3:04 a.m. there was a snow ceiling of 1300 feet with visibility of 8 miles, at 3:35 a snow ceiling of 400 feet with visibility of 5/8 of a mile, at 3:50 a ceiling of 2700 feet with visibility of over 9 miles,* at 4:13 a snow ceiling of 900 feet and visibility of 3 miles, and at 4:35 a ceiling of 1000 feet and visibility of 5 miles. During this period light to moderate snow was reported with north and northwest winds of 4 to 7 miles per hour. As is indicated by the radio log, both Captain Fey and the ground station were experiencing heavy static intermittently.

The flight recorder card which was recovered from the airplane shows that following a normal climb after leaving Elko, the airplane cruised at about 13,000 feet, descending as it approached Salt Lake City to about 12,000 feet following which it again ascended. This would indicate that Captain Fey, after

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* The 3:35 and 3:50 weather reports explain the conversation between Captain Fey and Dispatcher Edson at 3:43 (see page 15). Captain Fey apparently had heard the 3:35 weather report indicating visibility of 5/8 of a mile. Dispatcher Edson, who was at the remote microphone on the airport, had not heard this report but was personally observing the weather. After this conversation with Captain Fey, he requested the Weather Bureau to make a special observation. This was done and the report made at 3:50 indicated visibility of over 9 miles.

CONDITION OF AIRPLANE AND EQUIPMENT IMMEDIATELY PRIOR TO IMPACT

During the investigation of the accident, the question necessarily arose as to whether any abnormal functioning by the airplane or its equipment had contributed to the accident. A thorough inspection was made of the wreckage of aircraft NC 16086 and a substantial amount of testimony was received at the hearing as to the results of this examination.

It appears that all parts of the airplane were accounted for and that no parts were found along the flight path, thus leading to the conclusion that no parts of the airplane failed and broke off during flight. Nor did it appear that any control failure could have contributed to the accident, for while the control surfaces were badly damaged, the damage clearly occurred at the time of the impact, and while some of the control cables were broken, the ends were attached and the character of the breaks indicated that they also had occurred at that time. An examination of the engines and propellers revealed that the damage they had sustained had occurred at the time of impact and the nature and extent of this damage indicated that the engines and propellers were functioning properly and at the reduced power which would have been normal during a let-down procedure. A generous supply of fuel and oil was found in the tanks and engines.

It seems clear that no radio failure occurred prior to impact for the aircraft radio equipment, when removed from the scene of the accident and bench-tested, was found to be in remarkably good condition. After a few minor repairs and adjustments necessitated by damage obviously resulting from impact, all of the equipment functioned normally. The radio range receiver and the auxiliary receiver were found tuned to the Salt Lake City radio range.

the communications short wave receiver was found tuned to United's day frequency of 5592.5 kilocycles and the transmitter, when turned on, operated on the same frequency.*

Thus, from the evidence developed from the inspection of the wreckage of aircraft NC 16086 and all other pertinent evidence in the record, we conclude that the airplane and its equipment were operating normally at the time of the crash.

SALT LAKE CITY RADIO RANGE

From the radio contacts made by Trip 16 shortly before the accident, it appears that Captain Fey was using the Salt Lake City radio range in working his let-down-through procedure, and certain evidence existing at the time the investigation of the accident was begun gave rise to a question as to whether the radio range was operating normally at the time Captain Fey was using it. Therefore a substantial amount of evidence, both oral and documentary, was received at the hearing bearing upon the history of the Salt Lake City radio range, the characteristics of the present range and other air navigation facilities used in connection with it, the system established for monitoring the range, and the condition of the range on the morning of November 4. A summary and analysis of this evidence follows.

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* A detailed description of the condition of the wreckage of aircraft NC 16086 is contained in Appendix E which may be secured, if desired, upon request directed to the Public Information Section, Civil Aeronautics Board, Washington, D. C.

History of the Salt Lake City Radio Range

The first radio range* to be installed for Salt Lake City was a medium power loop type range* located about 1-1/2 miles north of the Salt Lake City Airport. This range was placed in operation in 1929 and served until 1933 when it was replaced on the same site by a full power vertical radiator type station.* This station was modernized in 1938 under the direction of the then Administrator in the Civil Aeronautics Authority to produce the present full power simultaneous voice broadcast and range type station.* This modernization work was begun in August and completed in October, 1938.

When the modernization of the Salt Lake City range was completed, the

* A radio range is a radio system which radiates radio frequency fields in such a pattern that lines of equal field strengths exist along predetermined courses over the earth's surface. These lines of equal field strength are called legs or courses of the radio range. A listener, when on one of these legs, receives a steady dash, referred to as an "on course" signal. On one side of the leg he would receive an "A" (dot-dash) and the area in which this signal is received is referred to as an "A quadrant." On the other side of the leg he would receive an "N" (dash-dot) and the area in which this signal is received is referred to as an "N quadrant." Four courses are produced by each radio range and in the most simple installations these courses lie at 90 degrees to each other. However, by the introduction of certain circuit arrangements, the courses can be made to assume angles other than 90 degrees and this alignment is called "squeezing" or "bending," depending upon the pattern formed. Identification signals are transmitted in both the "A" and "N" quadrants so that a listener can determine to what range he is listening. The identification signal is also heard while listening to the on course signal. The Civil Aeronautics Administration operates 278 radio range stations along the civil airways throughout the United States.

A medium power range is one of three power classifications into which the Civil Aeronautics Administration ranges may be divided. These classifications are:

Full power -- greater than 150 watts
Medium power-- 50 to 150 watts
Low power -- less than 50 watts

A loop type range is a radio range which employs loop antennas for its radiating system, while a vertical radiator type range is one which employs towers or vertical radiators for its radiating system.

A simultaneous voice broadcast and range type station is a radio range over which radio telephone messages can be transmitted at the same time the station is radiating range signals. Such a station also makes weather broadcasts on a scheduled basis.

station consisted of two range transmitters and a positive station location marker* transmitter with the necessary accessory units installed in a transmitter house at the range station site and an auxiliary power unit which automatically starts and picks up the electrical load in the event of a failure of the commercial power supply. The tower installation and the transmission line feeder cable (used to supply the radio frequency energy to the various towers) which had been used for the station before modernization, were retained except that the towers were modernized by the installation of rain shields* and the erection about their bases of a counterpoise system.* The course alignment of the range was left unchanged. In order to permit the range to serve two of the airways which intersected at Salt Lake City, it has been "squeezed" and "bent" so that the published bearing of the north leg is 152 degrees magnetic, the south leg 343 degrees magnetic, the east leg 232 degrees magnetic, and the west leg 70 degrees magnetic,**the angles between adjacent legs of the range thus varying from 80 to 111 degrees.

The equipment of the range station is controlled by means of a dialing system from the Airways Communication Station located in the Administration

* A positive station location marker is a transmitter which produces a field concentrated in a small area directly over its antenna system. Such transmitters are located at radio range stations to act as radio location markers.

Rain shields are metal shields which are placed around insulators of a radiating system for the purpose of protecting those insulators against rain, snow, sand, etc.

A counter-poise system as used with a radio range is a wire screen platform held horizontally above the ground by supporting stanchions. This entire metallic structure is connected to the ground. Such systems are put around the base of vertical radiators to offset the effect of waving and growing vegetation, the ebb and flow of tides, etc.

** See Appendix C, a map showing the Salt Lake City Radio Range and the area surrounding Salt Lake City.

Building at the Salt Lake City Airport. The control lines between the control station and the radio range station, which are leased from the local telephone company, are partly underground and partly overhead.

In addition to the range and positive station location marker installed at Salt Lake City, fan markers* were installed on each of the four legs of the range and additional range stations established at three points in the Salt Lake Valley. The fan markers were located as follows:

Layton, Utah - On the north leg approximately 18 miles north of the Salt Lake range;

Coalville, Utah - On the east leg approximately 30 miles east of the Salt Lake range;

Riverton, Utah - On the south leg approximately 19 miles south of the Salt Lake range;

Timpie, Utah - On the west leg approximately 37 miles west of the Salt Lake range.

The three range stations were: A medium power vertical radiator type range and voice station with positive station location marker at Plymouth, Utah - 78 miles north of the Salt Lake station; a medium power vertical radiator type range and voice station with positive station location marker at Wendover, Utah - 106 miles west of the Salt Lake station; and a medium power loop type range and voice station at Tintic, Utah - 64 miles south southwest of the Salt Lake station.

In the fall and winter of 1938, after the Salt Lake City range had been modernized, difficulty was encountered in the maintenance of the course alignment and in obtaining good course definition. Thereafter, additional

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* A fan marker is a transmitter installed on a range leg some number of miles from the radio range and which produces a fan-shaped area of signal concentrated in the immediate vicinity of the location of the fan marker.

work was done on the range and in mid-December the patrol pilot under the Administrator in the Civil Aeronautics Authority reported the courses to be properly aligned and satisfactory so far as course definition, signal strength, and effective voice modulation were concerned. Numerous multiples* were found on the east and west legs and mild key clicks** were also reported on these legs.

However, about December 15, 1938, shortly after the patrol pilot's flight check, a United pilot, after a special flight check in the vicinity of the station, reported that the courses had become indefinite and confusing. Another flight check was made by the patrol pilot and it was his opinion that the range was still operating properly. Those flight checks and discussions led to the calling of a conference at Salt Lake City at which representatives of the Civil Aeronautics Authority, the air carriers operating in and out of Salt Lake City, and their pilots were present for the purpose of making a further study of the operation of the station. The conference resulted, insofar as the air carriers and their pilots were concerned, in the conclusions expressed in their letter of January 9, 1939, addressed to the Civil Aeronautics Authority at Washington, D. C., the pertinent parts of which are as follows:

* Multiples are areas which exist at points other than on the courses of a radio range but in which on course signals are received. These multiples might be termed false courses.

** Key clicks are abnormal clicking noises which accompany the radio range signals.

"(1) It is our opinion that the operation of the new approved SBRA* is equivalent to the former BRA.*

"(2) We accept this SBRA in its present operating condition.

"(3) It is also our opinion that the present method of monitoring the north leg of the present Salt Lake SBRA is inadequate and that immediate steps must be taken to protect this leg against shifting in either direction. This can preferably be done by either a remotely controlled receiver located not more than 5 miles north of the range station with the monitoring being done at the Salt Lake control quarters (sic).

"(4) In line with recommendation #3 we believe that continuous and more accurate monitoring is required on all final approach legs at fields located in mountainous terrain.

"(5) However, the acceptance of the above-mentioned facility changes in no way our opinion that a completely new range in a better location in the Salt Lake Valley is imperative, since the present SBRA even as the former BRA affords only the minimum requirements for safety.

"We also recommend that a thorough survey be made by a committee of pilots of Western Air Express and United Air Lines, together with Civil Aeronautics Authority engineers, in order to select the best possible site, giving consideration to engineering and piloting points of view. This site preferably should be located north and possibly somewhat west of the present location but not more than 25 miles from the present location.

"(6) If this selected site is located at such a distance and direction from the airport that an airport localizer is required, then this recommendation includes the installation of such a facility.

"All concerned are agreed that the importance of the above recommendations warrant immediate action so that if at all possible an improved facility or facilities can be operating in the Salt Lake Valley by November 1, 1939."

* The term "SBRA" is the Civil Aeronautcis Administration designation for a simultaneous, scheduled broadcast, full power, vertical radiator radio range.

The term "BRA" is the Civil Aeronautics Administration designation for a scheduled broadcast, full power, vertical radiator radio range.

The letter was signed by J. R. Cunningham for United; by C. N. James for Western Air Express; and by F. M. Crismon, C. M. Christenson, and L. R. Schram as the Pilot Committee--Radio, for United.

From January 9, 1939, until November 4, 1940, there were a number of occasions on which the alignment of the Salt Lake radio range was reported to be abnormal. From the evidence it appears that the following "Notices to Airmen" were issued during this period:

On May 24, 1939, Wendover reported frequent shifting of the west leg with light "A," on course, and "faint N signals" being received. This report was made at 9:40, and at 2:17 p.m. a "Notice to Airmen" was issued stating that the range had resumed normal operation.

On June 26, 1939, Plymouth reported that a "moderate 'A'" was being received at that station instead of the normal "faint 'N'". This report was made at 12:47 p.m. and a return to normal operation was reported at 1:30 p. m.

On January 5, 1940, Tintic reported that a "light 'A' signal" instead of the usual "moderate 'N' signal" was being received. This report was made at 9:04 a.m. Salt Lake advised that the misalignment was apparently caused by the tower insulators being covered with snow. The snow was removed and Tintic reported normal operation at 11:17 a.m.

On February 15, 1940, a Western Air Express pilot reported that the south leg of the Salt Lake range was displaced by a substantial amount west of the published bearing. This report was made at 11:15 a.m. According to testimony which is given in greater detail below, the cause of the shift was snow on the insulators. At 1:CC p.m. the range courses were ground-checked and according to these checks, the range had at that time returned to normal operation.

On April 9, 1940, a Notice to Airmen was issued stating that a United pilot reported the north leg of the Salt Lake range 6 to 8 degrees west of the published bearing. This report was made at 5:00 a.m. At 10:55 a.m., a Notice to Airmen was issued advising that the previous report should be disregarded and that the Salt Lake range was apparently operating normally.

On July 9, 1940, Wendover reported that the Salt Lake range was occasionally shifting to "light N", whereas a "light A" was the normal signal received. This report was received at 10:40 a.m., and at 12:25 p.m., Wendover reported that the Salt Lake range had returned to normal operation.

The abnormal operation of the range on February 15, 1940, was reported by Captain Wooster of Western Air Express. From his testimony and that of his first officer, it appears that the south leg was displaced approximately 25 degrees to the west of the published course when he made his observations. This malfunctioning of the Salt Lake City range was reported to the Airways Communications Station at Salt Lake City and shortly thereafter (at 11:36 a.m.) a Notice to Airmen was issued stating that the range was functioning improperly and should be used for homing only. At 1:15 p.m., another Notice to Airmen was issued which stated that the Salt Lake range was at that time apparently operating normally, which fact had been established by ground checks only. W. F. Lindsay, the radio electrician for the Civil Aeronautics Administration, who investigated the reported course displacement, sent a telegram on the morning of February 16, 1940, to the Regional Office of the Sixth Region which reads in part as follows:

"Range now operating normal. Difficulty today due to snow on insulators. Snow had to be removed repeatedly due to thawing snow on towers falling down and re-covering insulators. Condition cleared about 11:30 a.m. /February 15, 1940/ as indicated by equipment meters. . ."

Mr. Charles E. Givens, the principal radio electrician for the Civil Aeronautics Administration at the Salt Lake Station, also testified concerning the condition of the radio range equipment on the morning of February 15, 1940. Mr. Givens stated that he inspected the tower insulators and found snow on them and on the rain shields. He attempted to clear away this snow but the temperature had risen and the snow slid down from the towers and covered the insulators faster than he could clear it off. Mr. Givens further stated that no difficulty or abnormality was found in the transmitting equipment or keying device inside the station but that the readings of the currents delivered to the towers were other than normal. From the testimony concerning the operation of the Salt Lake range on February 15, 1940, it would appear that the course displacement on that morning resulted from a condition produced by the accumulation of snow across the insulators of the radiating towers and the presence of moisture produced by the melting of this snow.

Installation and Use of the Salt Lake City Airport Localizer

During the period between the completion of the modernization of the Salt Lake City radio range and the time when the range was judged to be satisfactory for use as outlined in the letter of January 9, 1939, already discussed, the City of Salt Lake City, with the financial and technical assistance of United, installed a low-power range station, commonly referred to as a "localizer". It appears that the localizer was installed as a result

of complaints received from United pilots concerning the operation of the newly modernized Salt Lake range. The localizer was located about 3,000 feet northeast of the terminal building of the Salt Lake City Airport and the legs were so aligned that the north leg of the localizer coincided with the north leg of the Salt Lake range station, with all four legs lying at 90 degrees to each other. The transmitter used for the localizer also served as the airport control tower radio station and was operated by the airport control tower operator on duty. The output of the transmitter when used for the localizer was, according to testimony, approximately 100 watts and it operated on the same frequency as that assigned to the control tower, namely, 278 kilocycles.

After the installation of the localizer had been completed during the first few days of December, 1938, it was used by pilots of United Air Lines under conditions of low ceilings and restricted visibilities to check the alignment of the north leg of the Salt Lake City radio range. This was done during an approach and let-down-through procedure by one flight officer remaining tuned to the range and the other to the localizer, or by one officer switching back and forth. If the signals from the two facilities failed to coincide, it would be apparent that either the range or the localizer was functioning abnormally and the trip would discontinue the approach and proceed to another airport.

Shortly after this procedure was established, it was made an integral part of the prescribed let-down procedure contained in the competency letters attached to the air carrier operating certificate of United and thus all United pilots flying into Salt Lake City were required to

use the localizer in the manner described above while making a let-down-through procedure. However, in May, 1939, Mr. James E. Read, who was then the Senior Air Carrier Inspector in Charge, Sixth Region, of the former Civil Aeronautics Authority, and now holds the same position with the Civil Aeronautics Administration, amended United's competency letter to eliminate this requirement. He testified that this action was taken because the localizer was not owned or operated by the Federal Government and it was his opinion, therefore, that his staff would be unable to inspect the localizer so as to determine its adequacy as an air navigation facility and the manner in which it was maintained. In addition, he stated that a flight check of the localizer had shown that its usable distance was between six and eight miles. He also pointed out that the transmitter utilized in connection with the localizer was also used by the Airport Control Tower at the Salt Lake City Airport for issuing traffic instructions. He feared that confusion might result from using the same transmitter for the two purposes, in view of the fact that when the localizer signals were being radiated, no voice broadcast could be made and vice versa. However, he stated to representatives of United at that time that he had no objection to the use of the localizer as a secondary aid in connection with a let-down-through procedure and that as far as he was concerned, United could instruct its pilots to use it in that way.

The localizer was used by United pilots until September 3, 1940, when it was removed at the request of the United States Army which had leased from Salt Lake City the land on which the localizer was installed. The localizer was removed without objection from United. Communication for the purpose of

airport traffic control was carried on thereafter by means of a transmitter temporarily installed in the Airport Administration Building. According to testimony given on November 16, 1940, by Messrs. Carl E. Kusrow and Verne E. Halliday, both employees of the City of Salt Lake City, the re-installation of the localizer was under way but had been delayed to some extent by a change in plans for the buildings being erected by the Army and by the necessity of awaiting delivery of necessary electric cable.

Monitoring System* for Salt Lake City Radio Range

Documentary evidence and oral testimony in the record indicate that the Civil Aeronautics Administration operates, with respect to the Salt Lake City radio range, an unusually complete monitoring system, one which is particularly designed to detect relatively slight variations in course alignment. The system includes monitor receivers established at five different locations. Three of these are receivers located in outlying radio range stations, one at Tintic, Utah, south of Salt Lake City, one at Wendover, Utah, west of Salt Lake City, and one at Plymouth, Utah, north of Salt Lake City. The Tintic, Utah, station is in an "N" quadrant of the Salt Lake City range and lies approximately 12 degrees west of the published course of the south leg. When the Salt Lake City range is operating normally, a light "N" signal is received by the receiver at Tintic. The Wendover station is on the west leg of the Salt Lake City range and slightly

* The term monitoring system as used in connection with a radio range designates the system whereby signals from the range are periodically received at various locations for the purpose of determining whether the range is functioning normally.

in the "N" quadrant. However, when the range is operating normally, a light "A" is received at Wendover, which condition is probably due to the receiving antenna system or to structures near this antenna which produce a distorted field. The Plymouth, Utah, station is in an "N" quadrant of the Salt Lake City range, lying approximately 2 degrees east of the published course of the north leg and, when the range is operating normally, receives a light "N".

The other two monitor positions are in the Airways Communications Station of the Civil Aeronautics Administration at Salt Lake City with one receiver being located within the station itself and the other, a remote receiver, located north of the station of the north leg of the Salt Lake City range. The receiver located in the Communication Station is in an "A" quadrant and when the range is operating normally, receives a moderate "A". The remote receiver is located just off the published course of the north leg in the "N" quadrant and when the range is operating normally, receives a light "N".

According to the testimony at the hearing, the remote monitor system is the only one of its kind in the country, having been installed as a result of the difficulties which had been encountered in stabilizing the alignment of the on course signals of the Salt Lake range and upon the recommendation of the air carriers and the pilots who used the range. The receiver for this system had been located on the north leg because this leg is used as the final approach leg for the Salt Lake Airport and had been established in the "N" quadrant of the north leg in order that any slight deviation of that leg to the east toward the Wasatch Mountain range might be

detected and pilots using that leg in a let-down procedure warned as to the abnormal alignment of the leg.

The remote monitoring system was installed at Salt Lake City in the early spring of 1940. The receiver, suitably protected by weatherproof housing, was located in the "N" twilight zone of the north leg approximately one and one-half miles from the Salt Lake station and derives the power necessary for its operation through an underground power cable. The output of the receiver is carried to the radio range station over another underground line. At the radio range station house, this line is connected to an amplifier, the output of this amplifier being connected, in turn, to an Esterline-Angus recording meter. This recording meter is of the type which marks with ink a strip type chart which is moved at a uniform rate underneath the inking pen of the recorder mechanism. Thus, there is provided at all times during which the system is in operation a record which indicates the relative intensities of the "A" and "N" signals being received at the spot at which the remote monitor receiver is located.

In addition to being connected to the input of the line amplifier which supplies energy to actuate the Esterline-Angus recorder in the radio range station, the output of the receiver is also connected to the line which is used to conduct the voice broadcast energy from the Airways Communication Station on the Salt Lake Airport to the modulating sections of the transmitters at the range station. Since this line is used only during times broadcasts are being

made, it provides a convenient means by which the operator can make use of the remote monitoring receiver to monitor his own range. When used in conjunction with the monitoring system, this line is connected at the Airways Communications Station to the in-put of an amplifier, the output of which is connected to head sets and to a milliammeter, this combination thus providing both aural and visual monitoring of the range at the Communications Station by means of the remote system.

Mr. Theodore K. Johnson, Communications Inspector of the Sixth Region of the Civil Aeronautics Administration, with jurisdiction over the Salt Lake City station, testified concerning the standard procedures prescribed by the Administration to govern radio range monitoring. As applied to this particular case, the range stations at Tintic, Wendover, and Plymouth are required to monitor the Salt Lake range for a period of at least 3 minutes in each hour, at Wendover approximately 37 minutes after each hour, at Plymouth about 46 minutes after each hour, and at Tintic approximately on the hour. According to Mr. Johnson's testimony the scheduled times of monitoring are not definitely prescribed by written instruction but are established by oral instructions given by the Communications Inspector during inspections of the station concerned, and while the times may vary slightly if more pressing duties prevent monitoring at the prescribed schedules, the monitoring is supposed to be done at approximately the same period in each hour in order to prevent two or more of the stations assigned to monitor different legs of a particular range from performing their monitoring simultaneously.

The monitor operators are required to record their findings on a "Daily

Radio Range Monitor Report".* On this form columns are provided for the entry of the following information: The time each range is monitored, the name of the range being monitored, the range identification signal, the characteristics of the interlock, the dominant signal received, the signal strength of the received signal, and any remarks which the operator might think pertinent. The operators are instructed as to the manner in which the signals should be observed and the various characteristics of range operation which should be especially noted in order to make proper entries concerning interlock and signals received. The signal strength must be indicated under the proper heading by means of the international scale QSA1** to QSA5.** Under the remarks column if the range operation is considered normal, the phrase "Operation normal" must be entered and if any variations from normal operation are noted, the characteristics of the abnormality must be entered with a short statement as to the action taken.

The monitor operators are also instructed*** as to the action to be taken in the event that a range being monitored is functioning abnormally. The operator must immediately notify the station concerned of his observations and send a copy of the dispatch to the Regional Office of the Civil Aeronautics Administration for the region in which the station is located. If the monitoring station observes that the faulty operation is not corrected

* Manual of Operations, Communications Section, Chapter B, Part 8.

** The terms QSA-1, QSA-2, QSA-3, QSA-4 and QSA-5 are used to indicate the signal strength of a received radio signal. QSA-1 is a signal which is barely readable, whereas QSA-5 is the maximum signal which the receiver being used will deliver.

*** Manual of Operations, Communications Section, Chapter B, Part 3.

within one hour of the time the trouble was first reported and in the absence of advice from the station concerned that corrective measures have been taken, a second dispatch must be sent to that station and a copy transmitted to the Regional Office. Although the instructions do not specify the means of communication the distant monitor stations should use to advise the station being monitored of any malfunctioning, the testimony indicated that use was usually made of the Government teletypewriter circuits, but also that instructions did not forbid the use of other means of communication in case the Government teletypewriter circuits were not available or could not be used.

These instructions are, of course, applicable to the Tintic, Wendover, and Plymouth stations in the performance of the monitoring of the Salt Lake City range. In general, they are also applicable to the operation of the remote monitor receiver by the operators in the Salt Lake City station. They must monitor the north leg at approximately 24 minutes after each hour, and, while they may supplement their aural monitoring by visual observation of the milliammeter, they are not required to do so.

When the remote monitoring system was first installed, the operators at the Salt Lake City station were instructed to observe, and to record on the Daily Communication Report, the readings shown by the milliammeter which is connected to the remote receiver and located in the Airways Communications Station. After the first month of operation of the remote receiver, however, the recording of the meter readings was discontinued and from the testimony of those Salt Lake operators who were witnesses, it would appear that observations of the meter readings were also in great part discontinued. A number

of reasons were given for this, one being that the month's test had shown the same results to be obtained by the aural as by the visual observations, and another that the visual readings were not considered reliable and the aural observations were therefore preferred. Concerning the unreliability of the meter readings, testimony was given that two sources of trouble had been experienced, which made use of the meter difficult: First, a defective gain control in the line amplifier, and second, the susceptibility to interference of the line connecting the amplifier at the Airways Communication Station to the receiver output at the range station. These causes combined with the attitude of the operators, as expressed by one of them, of trusting "more to our ears than we did to our eyes" resulted in the general abandonment of the remote monitor system meter for visual observations.

The employees of the Civil Aeronautics Administration whose duties include monitoring are primarily radio operators. Upon employment, or upon assignment to a particular station, they are supposed to be given instructions by the operator in charge of the station, which instructions cover their monitoring duties and all other phases of their work. The instructions concerning their monitoring duties are imparted, principally, by demonstration of signals received, but there is also provided a pamphlet which describes the operation and use of the radio range facilities. The operators are required to read this pamphlet and to indicate that they have read and understand its contents by placing their initials on it.

All radio operators employed by the Civil Aeronautics Administration are selected from a certificate of eligibles issued by the United States Civil Service Commission. To qualify for listing on this certificate of eligibles

an applicant must have had at least two years' experience as a radio operator, must be able to send and receive telegraphic signals at the rate of 30 words a minute and must be able to type at a speed of 50 words a minute by typewriter or 35 words a minute by teletypewriter. The operators are paid in accordance with the following classifications and pay scales:

Under Communications Operator, beginning at	$ 1260 per year
Junior Communications Operator, beginning at	1500 per year
Assistant Communications Operator, beginning at	1620 per year
Communications Operator, beginning at	1800 per year
Senior Communications Operator, beginning at	2000 per year
Principal Communications Operator, beginning at	2300 per year

The monitoring of the Salt Lake range and the performance of duties incidental to monitoring appears to constitute only a minor part of the work performed by the operators at Tintic, Wendover, and Plymouth. These operators were required to monitor other range stations, to make hourly weather observations, to make special weather observations when necessary, to transmit all these weather observations by teletype, to broadcast their own special weather observations and special observations from other stations, and to stand by at all times for radio calls from aircraft.* The operators at the Salt Lake station, in addition to duties similar to those of the operators at Tintic, Wendover, and Plymouth, broadcast weather observations on a regular schedule. However, not less than two operators are on duty at all times at the Salt Lake station since there is more activity there resulting from the scheduled broadcasts and increased teletype traffic.

The automatic recorder which is attached to the remote monitor receiver on the north leg of the Salt Lake range is not used as a part of the monitoring system described above. The recorder is located in the radio range station house which is some distance from the Airways Communication Station

* These operators rarely communicate with air carrier aircraft since air carrie usually provide their own plane to ground radio facilities.

in which the local monitor operators perform their duties. The electricians of the Civil Aeronautics Administration, whose duties include the making of periodic inspections of the equipment located at the radio range station site, are responsible for the care of the automatic recorder. At the hearing Mr. Givens, one of these electricians, testified that he made it a practice to remove the recorder trace, which is approximately 100 feet long, from the automatic recorder each day and to install a new tape but that he rarely examined the trace carefully in view of the fact that he had no suitable means for rolling or unrolling the roll of paper. However, he stated that he had, on occasions, examined particular traces carefully when some abnormality in the functioning of the range had been reported.

He testified as to a survey which he had made during the month of April, 1940, in which he had carefully examined the trace as recorded for a period of seven days and had compared it with reports of the stations responsible for the monitoring of the Salt Lake City range and with any pilot or other reports which had been received concerning the operation of the range. His survey indicated that while the normal ratio of "N" to "A" is 100/90, the traces examined during that month indicated that the ratios varied at times from 100/94 to 100/85. He compared the indications on the recorder trace with the relative humidity on the days to which they applied and it appeared to him that as the relative humidity grew higher, the comparative strength of the "A" signal became less, and as the relative humidity became lower, the comparative strength of the "A" signal became greater. Moreover, in reporting on this survey, he stated that:

"The Remote Monitor receiver seems to be extremely sensitive to voltage variations. The recorded trace position varies slightly under stable voltage supply, and with any variation in supply voltage the trace position varies as much as 50 percent, 'A' to 'N' ratio remaining constant when measured at mid-scale.

"It is believed that with a regulated voltage supply the recorder trace would be extremely accurate. With the present unregulated supply, numerous small variations are recorded which do not seem to have any bearing on the north course displacement. With the volume varying the pattern across the tape it will be necessary to apply some correction to arrive at a figure representing true ratio of 'A' to 'N'.

"When the trace is near the center of the chart, 2.5 milliamperes, a course displacement of 2 degrees in space moves the trace width approximately .1 milliamperes, or one division on the chart. This does not hold true of the lower end, 0-1.5 milliamperes, or at the high end, 3.5 to 5.0 milliamperes.

"The meter at DTX* seems to show the same indications, that is, one division or .1 milliampere, indicates 2 degrees displacement in space."

Concerning Mr. Givens' statement as to the change in trace amplitude for a given course displacement, Mr. Lindsay, a radio electrician for the Civil Aeronautics Administration, who helped to determine this value, later testified that the change in trace referred to by Mr. Givens had resulted from a rotation of the entire range pattern by 2 degrees and that readings for greater displacements were not taken. Thus, even though it is possible to determine mathematically what the trace amplitude should be for other amounts of rotation of the range pattern, this information is of little value in attempting to determine leg displacements where the range pattern is distorted.

* The Salt Lake City Airways Communication Station.

Condition of the Salt Lake City Range on the Morning of November 4.

In seeking to determine the condition of the Salt Lake City radio range at the time Captain Fey was attempting to use it in his let-down-through procedure on the morning of November 4, we have the benefit of extensive testimony and documentary evidence bearing upon this question. This includes the monitor reports of the radio stations responsible for monitoring the Salt Lake range, the testimony of operators who made these reports, the testimony of maintenance personnel of the Civil Aeronautics Administration, the testimony of pilots who flew the range on the morning of November 4, and the testimony of various radio engineers and experts. This evidence will be summarized hereinafter.

Monitor Reports

Communications Operator Andrews was on duty as the broadcasting and monitoring operator at the Salt Lake City Airways Communications Station at the time of the accident. Mr. Andrews began his tour of duty at 4:00 p.m., November 3, and should have been relieved by Communications Operator Daley at midnight. However, having overslept, Mr. Daley did not arrive at the station until 5:00 a.m., November 4, and Mr. Andrews, therefore, remained on duty until shortly after that time. From 4:00 p.m. until 8:00 p.m., November 3, Mr. Andrews was on the broadcast watch; from 8:00 p.m. until midnight he was on the teletype watch and, upon the failure of Mr. Daley to report for duty at midnight, Mr. Andrews again took the broadcast watch and, as noted above, continued on that watch until approximately 5:05 a.m. of November 4.

Mr. Andrews testified that during the period he was on the broadcast watch on November 4—midnight to 5:05 a.m.—he monitored the Salt Lake range at 12:23 a.m., 1:24 a.m., 2:24 a.m., 3:24 a.m., and 4:24 a.m.; that he

received a faint "N" aurally each time, and observed that the operation was normal. During this entire period he was unable to make use of the visual indicating meter because, due to static conditions, the needle of the meter deflected all over the scale. Mr. Andrews testified that he had never experienced static conditions at the Salt Lake City station as severe as they were on that night. The static conditions were sufficiently severe to interfere with aural monitoring of the range, as well as with the visual monitoring. The static received on what Mr. Andrews referred to as the high frequencies—i.e., 3105, 4495 and 6210 kilocycles—was generally heavier than that received on the intermediate frequencies. Asked whether or not, in his opinion, what he thought he heard as a faint "N" might have been a faint "A", Mr. Andrews replied:

> "In regards to that, as I say, the faint 'N' was heard under static conditions and I believe, to the best of my knowledge that it was a faint 'N'. However, in copying a signal under the static conditions your accuracy is not as good as it would be under normal conditions where you have a good clear signal."

Mr. Alton J. Daley, Communications Operator, testified that he had the broadcast and monitoring watch of the Salt Lake station for the period from 5:05 a.m. to 8:00 a.m., November 4, 1940. Mr. Daley arrived at the Salt Lake station at approximately 5:00 a.m. on November 4 and took over the broadcasting and monitoring duties from Mr. Andrews. He stated that at the time of taking over the watch there was no indication of any abnormality at the station, with the possible exception of the log notations concerning static conditions. Nothing unusual occurred, to his knowledge, until 5:37 a.m., when the Airways Traffic Control Office at Salt Lake called on the inter-phone circuit and stated that the Salt Lake range had been reported as operating

improperly, which report had apparently been made by United since the United dispatch office telephoned Mr. Daley two minutes later to advise him that one of their pilots had reported the malfunctioning by radio. Mr. Daley immediately monitored the north leg and received a light to moderate "A" signal instead of the normal light "N". This was the first time he had monitored the north leg since he had come on duty that morning because, due to the press of other business, he had failed to monitor as scheduled at 5:24 a.m.

At 5:45 a.m., Mr. Daley attempted, by telephone, to contact Mr. Walker, the senior operator, at his home but was unable to reach him. At 5:47 Mr. Daley attempted to call Mr. Davis, the operator in charge of the station, at his home but again was unable to complete his call. After he had completed the 5:48 broadcast, Mr. Daley telephoned Mr. Davis—at 5:52—and gave him the report regarding the range. Mr. Davis requested Mr. Daley to obtain reports from the distant monitor stations. Prior to his conversation with Mr. Davis, Mr. Daley had requested a monitor report from the Wendover station but due to the fact that the other circuits at the moment were busy, he had not sent requests for monitor reports to Tintic and Plymouth. At approximately 5:58, Mr. Daley called Mr. Givens, the Maintenance Electrician, and advised him of the reported malfunctioning of the range and about the same time requested Tintic by teletype to monitor the Salt Lake City range. Reports were received from Wendover at approximately 6:04 and from Tintic shortly thereafter, both stating that the Salt Lake City range was normal. At approximately 6:30 a.m., Mr. Daley requested a monitor report from Plymouth and, after at first reporting that the range was normal, Plymouth advised about 6:55 a.m. that the range was abnormal. According to Mr. Daley's testimony this was the first outlying station monitor report that

indicated malfunctioning of the range. At 7:00 a.m. or a little thereafter, Mr. Daley informed Mr. Davis, who had arrived at the Communications Station, of his activities and Mr. Davis took charge. About 8:00 a.m., Mr. Givens, the Maintenance Electrician, arrived at the Airways Communications Station and reported to Mr. Davis that he had checked the range and had found that the courses were displaced and that the range was functioning abnormally. Mr. Davis then issued a general warning through a "Notice to Airmen" which was broadcast from the Salt Lake range at 8:22 a.m.

Mr. John Monroe Bradford, Assistant Communications Operator for the Civil Aeronautics Administration, was performing the monitoring duty at the Tintic, Utah, range station during the period from midnight to 8:00 a.m., November 4, 1940. Mr. Bradford stated that he had monitored the Salt Lake City range at the scheduled time (on the hour) all during his watch and had, at 6:20 a.m. and at the request of Salt Lake, made a special monitoring observation, and had detected no abnormality in the signals. However, at 7:03 a.m. while monitoring on his usual schedule, he received a moderate "A" instead of the normal light "N". Mr. Bradford stated that this "A" had the same predominance over the "N" as the "N" normally had over the "A". He testified that he was unable to notify the Salt Lake station that the Salt Lake City range was malfunctioning, as required by regulations of the Civil Aeronautics Administration, because the teletype circuit over which communications are sent between Tintic and Salt Lake was out of order, a matter which Mr. Bradford discussed by telephone with the proper teletype maintenance office in Salt Lake City at 7:10 a.m. in order that service might be re-established. Mr. Bradford was relieved from his watch at 8:00 a.m. The Tintic station

notified the Salt Lake station of the result of the monitoring performed at Tintic a short time after 8:48 a.m. when the teletype circuit was restored to normal operation.

Joseph Dunato, Assistant Communications Operator for the Civil Aeronautics Administration, was on duty at the Wendover station from 1:00 a.m. until 9:00 a.m., November 4, 1940. Mr. Dunato testified that during his tour of duty at the Wendover station on the morning of November 4 he monitored the Salt Lake range at the scheduled monitor periods--37 minutes past each hour--and that at no time did he receive a signal from the Salt Lake range other than the normal "A". He testified that at 5:39 he was requested by Salt Lake to monitor that station and that in response to this request he monitored for about eight minutes, during which time he received the usual "A" signal and therefore concluded that the Salt Lake range was operating normally. He advised Salt Lake to this effect immediately thereafter.

Mr. Thomas O. Sessions, Assistant Communications Operator for the Civil Aeronautics Administration, was on duty from midnight to 8:00 a.m., November 4, 1940, at the range station at Plymouth, Utah. Mr. Sessions testified that he monitored the Salt Lake range at the prescribed times during the entire period he was on watch and that until about 6:37 a.m. he received the usual "N" signals which indicated that the range was operating normally. Just before 6:34 a.m., Mr. Sessions received a request from Salt Lake for special monitoring of that range and he monitored for a period of three minutes during which time the "N" signal received indicated that the range was normal. Mr. Sessions immediately advised the Salt Lake station that the range was operating normally, but that heavy snow static was being received. About three minutes later, however, he again listened to the Salt

Lake range and discovered that the north leg of the range was swinging. When he began listening he received what he believed to be a faint "N", but after approximately two minutes he received a faint "A". Then it changed to the normal faint "N" for a short time, after which it again swung over to a faint "A" and apparently continued to be a faint "A" for the remainder of the time Mr. Sessions listened. Mr. Sessions immediately advised Salt Lake by means of the teletype circuit of the swinging of the range. He continued to monitor the Salt Lake range whenever he had a chance and testified that with the exception of one period when "it swung back to normal for just a minute", the signal received at Plymouth was a moderate "A". Mr. Sessions testified that during his entire watch the signals received from the Salt Lake range were of normal intensity. He experienced heavy static during his watch, some of which he classified as snow static.

The Plymouth "Daily Communications Report" and the "Range Monitor Report" covering the period of Mr. Sessions' watch on the morning of November 4, indicate that certain duties were performed during the period from 5:00 a.m. to 6:00 a.m., whereas the corresponding teletypewriter records on which the times are stamped automatically, indicate that these duties were performed during the period from 6:00 a.m. to 7:00 a.m. In explaining these discrepancies Mr. Sessions testified that he had maintained a "scratch" log during his watch and transferred the entires from this rough log to the official log after he came off watch at 8:00 a.m. He stated that in making this transfer he had apparently changed the indicated times by one hour and had omitted from his records all activities which had taken place from 5:00 a.m. to 6:00 a.m.

Even though he knew that an airplane had been unreported in the Salt Lake City area during his watch, he destroyed his scratch log after finishing his watch with the result that this period—5:00 a.m. to 6:00 a.m.—can be reconstructed only from his memory.

Mr. Sessions' log as corrected by him during his testimony does not therefore include entries concerning the monitoring of the Salt Lake range at the scheduled monitoring time of 5:46 a.m. However, he was quite positive that he had monitored the Salt Lake range at 5:46 a.m. and that the operation of the range at that time had been normal. Mr. Sessions further stated that there was no doubt in his mind that had a faint "A" been present at some time prior to 6:46 a.m., he would have noticed it since in weather of the type prevailing on the morning of November 4, he usually monitored the Salt Lake range at periods not exceeding twenty minutes apart. Specifically, he remembered monitoring the range at 6:05 or 6:06 and observing that the range was operating normally.

Pilot Reports

In attempting to determine the alignment of the Salt Lake range immediately before and after the accident on the morning of November 4, 1940, testimony was taken from a number of airline pilots who had made use of the range during those periods.

Captain Orvis M. Nelson of United flew that company's Trip 4 of November 3, 1940, from Oakland to Salt Lake City, arriving there at 11:16 p.m. It was necessary for him to work a let-down procedure at Salt Lake, using the north leg of the Salt Lake City range. He took bearings from time to time and, in so far as he could tell, the leg was properly aligned.

Captain Earl E. Garbutt flew United's Trip 14 of November 3, 1940, from Portland, Oregon, to Salt Lake City. The trip proceeded from Portland in a normal manner to the vicinity of Burley, Idaho. At Burley the flight entered an overcast which apparently was broken as Captain Garbutt testified that he located himself by ground contact over Locomotive Springs, Utah, and that he could see a number of breaks when he was in the vicinity of Ogden. The flight intersected the north leg of the Salt Lake range at approximately 12:17 a.m. in the vicinity of Ogden, Utah, where, according to Captain Garbutt's testimony, he could establish his position by reference to the ground. After 12:17 he was either in the overcast or on top and therefore Captain Garbutt was unable definitely to locate his position with respect to the ground. After intersecting the north leg of the range at Ogden, he changed his heading so as to follow the north leg into the range station, crossing the cone of silence at 12:28. The trip was required to hold on the Salt Lake City range for about 40 minutes because of traffic and during this time Captain Garbutt flew back and forth on the north leg between the cone of silence and a point possibly six miles north of the Layton marker. During this period radio bearings were taken on the Salt Lake range station to determine, as a matter of routine, whether or not the north leg was properly aligned and it was Captain Garbutt's opinion that the alignment of the leg was normal and that the range was functioning in all other respects in a satisfactory manner. At 1:08 a.m., he crossed the Salt Lake cone of silence and proceeded eastward to Denver, Colorado, rather than landing at Salt Lake and for that reason the Salt Lake range was not used for a let-down procedure.*

*Due to weather and traffic conditions, Captain Garbutt was to be held for an additional period before being permitted to land and since he had no passengers or cargo destined for Salt Lake City, he elected to proceed to Denver.

Captain Frank Edward Dace operated Western Air Express Trip 10 of November 3 which arrived in the vicinity of the Salt Lake station about midnight and remained there until 1:00 a.m., November 4, when, because of weather and traffic conditions, he returned to Las Vegas without landing at Salt Lake. Captain Dace stated that his flight was over Tintic at 11:44 p.m. and that to the best of his memory he tuned in the Salt Lake range at approximately 11:54 p.m. The flight was at that time on instruments and so far as Captain Dace could determine, the signals which he received from the Salt Lake range indicated that the alignment of the range was normal. The flight continued on the south leg of the range to the Salt Lake cone of silence, arriving at that point at 12:08 a.m. From this time until 1:15 a.m., when he detuned his receiver from the Salt Lake range on his way back to Las Vegas, Captain Dace had been on the north, the west, and the south legs of the range at various times. He stated that in so far as he could determine, considering the fact that he was on instruments, the alignment of those legs was normal.

Captain James Going flew United Air Lines Trip 10 of November 3 from Portland, Oregon, to Salt Lake City, arriving over the Salt Lake cone of silence at 1:51 a.m. A normal let-down procedure was then executed using the north leg of the Salt Lake range, and the trip was on the ground at 2:03 a.m. The trip was on instruments during the time it was on the north leg and until the range station was crossed on the final approach where the lights of the field became visible. However, Captain Going stated that during his let-down procedure he followed his usual practice of checking the alignment of the north leg of the Salt Lake range by use of his direction

finder and it was his opinion that the bearing of this leg was in accordance with the published bearing within an accuracy of four degrees and that from this information he judged that the north leg was properly aligned.

Captain Christenson, flying United's Trip 11 from Denver, Colorado, to Salt Lake City, tuned to the Salt Lake range when in the vicinity of Coalville, Utah, at approximately 4:35 a.m. At this time a heavy "A" signal with very light background was received. Captain Christenson testified, however, that he was unable to locate his position definitely with respect to the ground due to the fact that he was on instruments or on top. From this point the trip continued toward Salt Lake on a heading of 240 degrees and, according to Captain Christenson's estimates, passed 1/16 to 1/8 of a mile south of the cone of silence at 4:46 a.m. During the flight from Coalville to the Salt Lake range station, he continued to receive a heavy "A" signal.

After crossing the Salt Lake range station, the trip continued on the heading of 240 degrees until an "N" twilight was received. The heading was then changed toward the north and the ship proceeded across the "on course" signal and out into the "A" quadrant where the heading was changed to 253 degrees and the flight proceeded out the west leg. Approximately 2 minutes after crossing the station, the trip broke out of the overcast and the lights of Garfield and the Saltair Beacon became visible. After a westbound flight of about 7 minutes on the west leg, a turn was made and the flight proceeded eastward along the west leg until the positive station location marker at the Salt Lake station was received. Here at 5:04 a.m., a 180-degree turn was made to the left and the west leg again followed away from the station. Captain Christenson testified that on this shuttle he did not cross the "on course" but flew "mostly in the heavier 'A' twilight".

According to the radio log, Captain Christenson reported to Dispatcher Edson at 5:08 that he was over Garfield (a large smelter 12 miles south southwest of the Salt Lake range station and bearing about 25 degrees south of the published bearing of the west leg) and that the clouds were well broken so that he could see lights and beacons on the ground. He testified that at this time he became particularly suspicious of the range because "I knew the course I had flown across there would have given us some indication of the 'N' twilight and we were receiving none".

According to Captain Christenson's testimony, he returned to the Salt Lake cone, arriving at that point at 5:29. During this shuttle, at 5:20 a.m, Captain Christenson advised Dispatcher Edson that he would begin a standard instrument approach at 5:30 and at 5:24 Dispatcher Edson transmitted to him his Airway Traffic Control clearance for such an approach. About that time Captain Morton of Trip 9, who was then northeast of Salt Lake City, contacted Captain Christenson by radio and requested information concerning the heading which Trip 11 had flown from Fort Bridger to Salt Lake. Captain Christenson replied to Trip 9 that the magnetic headings from Fort Bridger to Coalville had been 235 to 233 degrees, and from Coalville over the field had been 240 degrees. According to his testimony, Captain Christenson at that time also stated to Captain Morton that he was suspicious of the range and would check further and give his a positive answer.

Immediately after passing the range station at 5:29, Trip 11 reported that he had crossed the station at 5:29 a.m., was proceeding out the south leg, and would return over the cone at 11,000 feet, apparently indicating that he was beginning a standard instrument approach. From the station the

flight turned toward the south in order to intersect the south leg and assumed a heading of 210 degrees. This heading was held until 5:34 a.m., or approximately 5 minutes after passing the Salt Lake cone, which should have placed the airplane well within the southwest or "N" quadrant. Captain Christenson testified that about this time he broke out of the overcast and observed that he was 3 to 4 miles northeast of Bingham Canyon, which point bears from the Salt Lake station about 22 degrees west of the normal south leg and is within the southwest "N" quadrant. At that time he was getting an "A" signal. Here a turn was made and a heading of 30 degrees assumed to a point at which the south leg of the range normally would be. At this point another turn was executed which produced a flight path diagonally across the normal southwest quadrant to the normal position of the west leg at which point another shuttle was completed on the west leg.

The trip then proceeded to the airport, again cutting across the southwest quadrant, and landed at 6:05 a.m. Captain Christenson testified that during his flight from a point which he identified as 3 or 4 miles northeast of Bingham Canyon to the Salt Lake airport, he received "A" signals only, with the exception of an area which he estimated to lie 8 degrees south of the normal west leg in which a "monotone" signal was received. He further stated that there were "A" signals on each side of this area of monotone signal.

Captain Francis A. Norton flew United's Trip 9 of November 3 from Cheyenne, Wyoming, to Salt Lake City. He testified that Trip 9 proceeded without incident until about 5:17 a.m. when he reached a point approximately

10 minutes west of Fort Bridger, Wyoming. He then tuned his range receiver from the Fort Bridger range to the Salt Lake range. He stated that at that location he normally heard a swinging range with both "N's" and "A's" and "on course" signals being received over a period of a short time. However, on this occasion, according to his testimony, he received an "off course A" with practically no background (strong "A" signal). The identification signals were garbled to the extent that he at first thought he was experiencing interference from some other range. He changed the heading of his flight to 270 degrees in an attempt to locate the east leg of the Salt Lake range, which, according to the signals he received, should have been well to the north. At approximately 5:22 a.m., he definitely established his position by ground contact as being slightly north of Evanston, Wyoming, which is well in the northeast or "N" quadrant of the Salt Lake City range. From this point he maintained a heading of 270 degrees, still seeking the east leg according to his testimony, flying for the most part above the overcast until he reached the vicinity of Ogden, Utah, about 5:40 a.m. There he could see through breaks in the overcast the beacon on Promontory Point, several beacons in the valley, and the lights of Salt Lake City. During this entire time, according to Captain Norton's testimony, he received nothing from the Salt Lake range but "off course A" signals with only one identification signal. After passing Ogden he was able to locate himself definitely by reference to the ground. He then changed his heading to approximately 180 degrees which brought him to the vicinity of the emergency field at Grantsville, Utah. Captain Norton stated that at this point he was receiving what he judged to be a fairly close twilight "A" signal but that he could not

say that he did at any time receive an "on course" signal. In the vicinity of Grantsville he lost altitude by spiraling and proceeded by visual contact into the Salt Lake City Airport where he landed at 6:28 a.m.

Captain Stuart D. Baird flew United's Trip 7 of November 4 from Denver, Colorado, to Salt Lake City. The trip departed from Denver at 4:30 a.m. on the morning of November 4 and passed over Evanston, Wyoming, in contact flying conditions about 7:10 a.m. At that point the Salt Lake range was tuned in on the regular beacon receiver and an "A" signal with no background was received. The flight continued toward Salt Lake, making use of the west leg of the Fort Bridger range instead of the east leg of the Salt Lake range since they nearly coincide. Captain Baird stated that normally an "N" signal would be received from Salt Lake when flying on the west leg of the Fort Bridger range. However, during the remainder of the flight to the Salt Lake cone of silence, he checked the Salt Lake range from time to time and received nothing but "A" signals. The flight passed over Salt Lake at 7:31 a.m. and received a normal signal from the positive station location marker. The flight had been above a solid overcast from a point just west of Evanston until after passing over the Salt Lake range, at which time breaks in the overcast became visible in the vicinity of Stansbury Island and a let-down was made in the clear in this vicinity and the trip proceeded on contact to the Salt Lake Airport where a landing was made at 7:59 a.m.

Captain D. R. Petty, Assistant Superintendent of Flight Operations for United, testified concerning a flight test of the Salt Lake range made by

him on the morning of November 4, 1940. Early on the morning of November 4, Captain Petty made a flight for the purpose of searching for Trip 16 and in the course of this flight, made observations concerning the alignment of the Salt Lake range. The airplane used in the flight was a DC-3 belonging to United and the radio equipment was similar to that aboard NC 16086 at the time that airplane crashed. After take-off at 8:25 a.m., which was made to the north on the north-south runway, the range station was circled in a clockwise direction at a radius of approximately one-half mile. Captain Petty testified that he received "A" signals all during this circle except somewhere in the southwest quadrant where he received what resembled an "on course" signal. Captain Petty continued to circle the range in the same direction but increased the radius of the circle to approximately four miles and practically the same signals were received. A turn was then made and the range circled in a counter-clockwise direction one and one-half times with a radius of approximately four miles and again the same signals were received. Captain Petty was unable to locate precisely the area in which he had received an "on course" signal but believed that it might have been approximately 25 degrees south of the published location of the west leg. He described the signals received in this "on course" area as being either "on course" or "twilight A" signals with "A" quadrants on each side. He thought a "few seconds" elapsed while he flew through this area.

At the completion of the last portion of the counter-clockwise circle, the flight proceeded out what would normally be the north leg until it

reached the vicinity of Layton where a procedure turn was made and a heading of 110 degrees was assumed. During the entire flight up to this point, visual contact had been maintained but as the mountains were approached on the 110-degree heading, the flight went between a higher and lower overcast. When the mountains were approached at an altitude of approximately 7,000 feet, signals were received which appeared to be "twilight A" signals and these continued as the flight turned south and flew parallel with the Wasatch Mountains. The flight ran out of the lower overcast in the vicinity of the town of Wood Cross where a pronounced "A" was received instead of the "twilight A" which had been heard up to that time. The flight then proceeded under contact conditions around the 7,000-foot contour line of Black Mountain, which is directly on the normal east leg of the Salt Lake range, and after following this contour line well into the normal southeast quadrant of the range, cut across to the normal position of the south leg of the range and proceeded in a northerly direction into the airport and landed at 9:00 a.m. From Wood Cross until the airplane landed, no signals, according to the testimony given by Captain Petty, were received other than "A" signals.

Captain Paul W. Norman, a United captain, accompanied Captain Petty on the flight of November 4 and his testimony concerning the flight in question agreed, except in minor details, with that given by Captain Petty. Concerning the location of the "A twilights" and "on course" signals which were heard in the southwest quadrant, Captain Norman estimated the location of this signal area as being approximately 20 degrees south of the normal west leg of the Salt Lake range rather than 25 degrees south which was the estimate of Captain Petty. Captain Norman further stated that it seemed to him that this signal area was never a complete "on course"; that at its greatest "on

course" intensity the "A" was still readable. Captain Norman stated that several seconds elapsed while they flew through this area and that it seemed to be wider than a normal "on course" counting the time when he departed from a strong "A" until he arrived again in the strong "A" signal. Concerning the area of "A twilight" in the northeast quadrant which Captain Petty had discussed, it was Captain Norman's impression that this signal area did not extend westward from the mountain range to the extent that Captain Petty had indicated.

Mr. Fred W. Kelly, Chief Pilot for Western Air Express Corporation, testified concerning a flight made on the morning of November 4 during which he observed the alignment of the Salt Lake radio range. The flight was made in a Douglas DST* airplane belonging to Western Air Express and Captain Wooster and First Officer Loffler, both employees of Western Air Express, were aboard.

The flight took off at approximately 9:05 a.m. in a northerly direction and passed approximately 100 to 150 yards east of the range station. Mr. Kelly testified that as the range station was approached, the signals became what appeared to be an "on course" signal, and as the flight continued northward into the northeast quadrant, the signals changed to a "twilight" then faded into a predominant "A" signal. Proceeding for two or three miles in a northerly direction, a turn to the west was made and as the flight approached what would normally be the north leg of the range, the signal assumed the character of a broad "A twilight" and then changed back into a pronounced "A". After having flown in a westerly direction for about five miles, the

* A Douglas DC-3 sleeper airplane.

airplane was turned to the south and somewhere in the vicinity of the published location of the west leg of the range, there was found a broad area of "on course" signal which changed into an "A twilight" as the flight continued southward. Mr. Kelly stated that he tried particularly to notice whether or not he could receive an "N" signal, knowing that the position of the airplane with respect to the range station was such that an "N" signal should be received. However, he failed to receive anything other than an "A" signal. As the flight proceeded southward, a receiver was kept tuned to the Salt Lake station and the Salt Lake signals were received continuously until the airplane was in the vicinity of Tintic, which is about 60 miles south of Salt Lake. During thie entire time "A" signals were being received.

Henry Clay Hollenbeck was captain of Western Air Express Trip 16 of November 4 which departed Salt Lake at 9:10 a.m., November 4. After circling the range towers at a radius of approximately one and one-half miles, the trip proceeded southward toward Las Vegas and Burbank. Captain Hollenbeck testified that during this circle of the range towers he received nothing but "A" signals except for a zone of "twilight" and steady monotone signals which he estimated to be at a bearing of 20 degrees from the station. He did not at any time hear an "N" signal. The signal which he received seemed to be of normal intensity and except for the absence of "N" signals, the signals radiated by the range station appeared to be normal. After making the circle described above, the flight proceeded southward following a flight path lying to the west of the normal location of the south leg of the Salt Lake range.

Condition of Equipment at Range Station.

Mr. Charles E. Givens, Principal Radio Electrician in Charge of Maintenance of the radio and teletype facilities for the Civil Aeronautics Administration at Salt Lake, was called, in accordance with established Civil Aeronautics Administration procedure, to investigate the reported malfunctioning of the Salt Lake range on the morning of November 4, 1940. He was notified at approximately 6:00 a.m. and soon thereafter proceeded to the range station. Upon entering the range building, he noticed that the tape of the Esterline-Angus automatic remote monitor recorder was beginning to pile up, which difficulty he immediately cleared. At the same time, he readjusted the gain of the line amplifier of the automatic recorder so that the trace was returned to mid-scale.* He then read the meters which indicate the current in the coupling units and noted that the "A" reading was 1:10 and the "N" reading 0.60, whereas the normal readings should have been (approximately) "A" 1.35 and "N" 1.30. He operated the dialing mechanism so that the transmitter which was then in operation--Transmitter No. 8--was turned off and the other transmitter--Transmitter No. 7--was started up. Another reading of the meters showed that with Transmitter No. 7 in operation the current in the "A" circuit was 1.05 while the current in the "N" circuit was 0.5. Since these readings did not indicate any transmitter defects, he dialed Transmitter No. 7 off and returned Transmitter No. 8 to operation.

Mr. Givens then inspected the various towers. He found that at the northeast tower the center insulator was bridged across by snow and the corner

*As to the necessity for this adjustment, see page 66.

insulators had snow on the rain shields and around the base, but were not bridged over. At the northwest tower, he found that one corner insulator was bridged. An inspection of the other towers revealed that none of the insulators were bridged by snow.

Mr. Givens then checked the tuning dials in the range building to see that these dials had been properly adjusted and tried tuning the "N" primary while observing the "N" meter deflections. He found that when the dial was turned about 15 degrees to the high-frequency side (of the setting on which it was at that time), the "N" meter deflections were approximately the same as the "A" meter deflections. However, he returned the dial to its original position.

He then proceeded to the northeast tower and, removing the cover from the tuning house, opened the shunt which is normally around the radio frequency ammeter and noticed that there was a definite movement of the needle, but that it was below the first division, i.e., one ampere. He also checked the tuning dials and found that they were in their proper detents. He made the same meter reading at the southwest tower and found that although the current here was slightly more than that in the northeast tower, it was still below the first graduation--and therefore less than one ampere. He noted the setting of the dials and tried tuning the various adjustable elements, but without a noticeable increase in meter deflection.

Convinced that it would be necessary to shut down the range for further testing, Mr. Givens sought and secured authority to do so from the Regional Office in Santa Monica, California. The range was shut down at 10:05 a.m.

Immediately thereafter Mr. Givens, with the help of Mr. Hill, his assistant, proceeded to the northeast tower and removed the lines from the tuning house terminals. These lines were checked for resistance between the lines and from the lines to the ground, and it was found that an infinite resistance was obtained. The towers were then isolated, and a resistance measurement from the tower to ground showed a resistance of 900,000 ohms. The same measurements were made on the southwest tower with a resistance of infinity shown on the transmission lines and a resistance of 950,000 ohms shown between the tower and the ground. Later, at 11:00 a.m., with the help of Mr. Lindsay, impedance measurements were made at the transmission lines leading into each tower. The following values were obtained:

Southwest Tower	131 ohms
Southeast Tower	126 "
Northwest Tower	157 "
Northeast Tower	30 "

At 1:10 p.m., another impedance measurement was made on the northeast tower and a reading of 120 ohms was obtained. At approximately 2:15 p.m., the transmitter was again started and coupling unit current readings were taken, and were "A" - 1.32, and "N" - 1.30, which indicated that the range had returned almost to normal operation.

While he was inspecting the tower insulators, Mr. Givens had wiped them with rags and had examined them closely but could discover no indications of scratches or cracks nor, in his opinion, was there any leakage of water through the rain shields. Also, during this time the three electricians, Givens, Hill and Lindsay, inspected the tuning house at the northeast tower and checked the equipment in this tuning house for defective components.

During one of these inspections, it was noted that the coupling dial was four or five degrees off the detent, which condition was corrected. However, testimony was later presented which indicated that this incorrect adjustment of the coupling dial had been made at a previous inspection by Mr. Givens or one of the other electricians earlier in the morning of November 4 and had no bearing on either the impedance measurements or on the malfunctioning of the range.

The maintenance electricians also removed the plugs from the heater flues* at the base of the northeast tower. It was found that the insides of these flues were wet and no definite source of this moisture was discovered, although the flues could not be examined above the bend inside the concrete base. It is probable that the moisture discovered in these heater flues resulted from condensation due to the change in temperature of the air in the flues and the impossibility of fresh air circulating because of the presence of the flue covers.

Mr. Givens testified that the last inspection he had made of the Salt Lake range was the Friday before the accident on Monday and that his assistant, Mr. Hill, made the inspection on Saturday and Sunday. He further testified that records showed that Mr. Hill did make these inspection and had found a defective tube in one transmitter and had replaced this tube. There was, however, no other equipment reported as operating improperly.

* Heater flues are holes in the concrete bases which support the tower legs. They lead from the outer vertical surface of this base to the upper horizontal surface immediately beneath the insulator on which the tower leg rests. These flues are provided so that heat can be introduced to the insulator for the purpose of drying them out. There is one of these flues at each of the four tower legs.

The Recorder Chart

During Mr. Given's testimony, the chart removed from the Esterline-Angus recording meter was received in evidence as Exhibit No. 111. As previously stated, this meter is connected through a line amplifier to the remote monitor receiver installed on the north leg of the Salt Lake range. Mr. Givens testified that when he entered the transmitter building upon first arriving at the range station the morning of November 4, he noticed that the recorder tape was piled up. He cleared the tape and re-adjusted the trace to mid-scale. About 2:15 p.m., he removed the roll of the recorder chart which, according to his testimony, had been installed by Mr. Hill "in the neighborhood of 6:00 p.m. the day before".

Concerning the condition of the meter and the chart at the time he restored the recording meter to normal operation, Mr. Givens stated that, in his opinion, the chart had started to pile up a short time before he arrived and his inspection showed that it was not damaged thereby. He was certain that the operation of the recorder had not been interfered with prior to the time that the chart had started to pile up.

It is possible to determine in a number of different ways and with a high degree of accuracy not only the period of time covered by a particular recorder chart but also the time at which a particular trace on the chart was made. The chart moves past the recorder pen at the rate of three-quarters of an inch per minute and the electrical motor which actuates the chart is a synchronous motor driven from the same power supply as that used to operate the range station. Thus, should the

commercial power fail, the power to the recording meter would be supplied from the auxiliary power unit which would also supply power to the range station equipment. Such power failures could be identified on the chart and the periods of time during which the actuating motor of the recording meter had been inoperative could also be determined by reference to the other timing elements shown on the chart.

It is the established practice for the maintenance electrician who inserts the new chart roll in the indicating meter to mark in pencil on the chart the exact time opposite a given place on the trace and if no abnormal operation was encountered, the exact time at which any trace is placed on the chart may be determined by measuring the distance between the original mark and the point in question on the trace and computing the elapsed time at the rate of three-quarters of an inch per minute. To determine whether or not abnormal movement of the chart beneath the recorder pen has occurred, it is possible to compute the elapsed time between broadcasts made from the range station which are indicated on the recorder chart by erratic traces, generally of greater amplitude than the trace produced by the "A" and "N" signals of the range. The times at which broadcasts were made may be obtained from the Daily Communication Report prepared at the Communications Station.*

An examination of Exhibit No. 111, the chart made by the recording meter of the remote monitoring system on the north leg of the Salt Lake range, shows that the trace departed from the normal amplitude ratio between the "N" signal and the "A" signal, as indicated by the amplitude of the "N" and "A" identification signals, during the period of 12:40 to 1:00 a.m. of November 4, 1940, and did not return to the normal amplitude

*The Daily Communication Report for the Salt Lake City station for November 4, 1940, was received in evidence as Exhibit No. 105.

ratios for the remainder of the trace covering the period ending at 10:05 a.m. when the range was shut down. Prior to 1:00 a.m. of November 4 the amplitude ratio of the trace showed certain irregularities but, so far as could be discovered, there were no traces which showed a ratio of the amplitudes of the "N" to the "A" of unity, or less. An examination of the trace for the period of assumed normal operation, i.e., prior to 12:40 a.m., indicates that the ratio established by Mr. Givens as the normal ratio which should exist between the "N" signal and the "A" signal (100/90 or 1.11 to 1) is a fair average of the ratio which actually existed, although, as noted before, there are deviations of considerable magnitude in this ratio recorded during this period. Starting at approximately 12:40 a.m., the ratio of the "N" and the "A" signals gradually changed so that by 1:00 a.m., there were traces where the "N" signal and the "A" signal were equal and by 1:10 a.m. the amplitude of the "N" signal was consistently less than that of the "A" signal, with ratios of "N" to "A" in the neighborhood of 0.90 being recorded. By 1:40 A.m. the ratio had decreased to 0.85, at 2:24 a.m. to 0.70, and at 3:10 a.m. to 0.50. From 3:10 a.m. until 5:39 a.m. this ratio varied about the value of .5. For the period of 4:40 a.m. to 4:50 a.m., during which time the accident to airplane NC 16086 occurred, the ratios shown by the chart were as follows:

4:40 a.m.	-	0.43
4:41 a.m.	-	0.48
4:42 a.m.	-	0.54
4:43 a.m.	-	0.54
4:45 a.m.	-	0.55
4:46 a.m.	-	0.55
4:47 a.m.	-	0.50
4:50 a.m.	-	0.52

It is impossible to compute the ratios for 4:44 a.m., 4:48 a.m., and 4:49 a.m. due to the fact that broadcasts were made at those times. The ratio did not show any decided improvement until after Mr. Givens arrived at the range

station and completed the various adjustments he made.

The problem of computing the signal ratios accurately from the chart is complicated somewhat by the change in amplitude of the trace which took place during the period under investigation. When the chart roll was first installed, at approximately 6:00 p.m. on November 3, 1940, Mr. Hill, who made this installation, adjusted the trace so that it was centered, on the average, in the middle of the scale at a value shown on the chart as 2.5. This value of amplitude held, with slight variations, until approximately 5:40 p.m., at which time the amplitude decreased over a period of a few minutes so that the value between 5:43 p.m. and 6:00 p.m. was in the neighborhood of 1.5. Starting at 6:00 p.m. there appears to have been a gradual decrease in amplitude of the trace so that by 6:30 p.m. the value was slightly greater than 1.0 and after a series of broadcasts, starting at 6:38 p.m., and lasting until 6:55 p.m., the amplitude had an average value of approximately 1.0. After the special weather broadcast at 10:08 p.m., the amplitude of the trace was definitely below 1.0 but returned to the value of approximately 1.0 at 10:56 p.m. and at 11:30 p.m. increased in amplitude to approximately 2.5, the amplitude at which the value was originally set by Mr. Hill. However, this amplitude did not remain constant, and again gradually dropped off until at 1:00 a.m., on November 4, 1940, it returned to a value of approximately 1.5. At 2:00 a.m. the amplitude was approximately 1.0 and decreased steadily, until at 2:30 a.m. it was approximately 0.5, and, after some unexplained variations which at times swung the trace off the chart at the top of the scale (a value of 5.0) the amplitude at 3:10 a.m. was approximately 0.25 and remained at this value until the amplifier was readjusted at 7:00 a.m. by Mr. Givens. For the ten-minute period between 4:40 a.m. and 4:50 a.m., the amplitude was slightly less than 0.3 although, due to the fact that the operator set up his broadcasting circuit at 4:41 a.m.

and did not return the circuit to normal until 4:55 a.m., the trace from 4:41 a.m. to 4:50 a.m. had an average amplitude of approximately 0.5. Because of the small amplitude of the trace during this period it is, of course, difficult to determine precisely the "A" to "N" ratios that existed. However, our determination appears to be sufficiently accurate for the purpose of this study.

An attempt was made to determine the condition of the Salt Lake range for the period immediately preceding, during, and immediately following the accident to NC 16086 on the morning of November 4, 1940, by making use of the information given by the recorder chart. Mr. Howard W. McKinley, Radio Engineer for the Civil Aeronautics Administration, Mr. Peter Sandretto, Superintendent of the Communications Laboratory of United, and Mr. Ford Studebaker, radio consultant for the Civil Aeronautics Board, described at the hearing the investigations and tests which were made.

It was decided that additional information concerning the reported malfunctioning of the Salt Lake range might be gained if a sufficiently accurate simulation of the conditions which produced the trace shown on the recorder chart for the period of the accident could be effected. In order to simulate this trace, it was necessary not only to create a condition which would result in the same "N" to "A" ratio being recorded, but also to reduce the amplitude of the trace to that shown for the period in question.

It appeared that on the night of November 3, 1940, the gain (volume) control of the amplifier for the recording meter had been set at a point which was considered normal by the maintenance electricians and which had been marked by a pencil mark on the panel of the line amplifier. No change had been made in the setting of this control during the period in question and it was decided, therefore, that whatever tests were made should be made with the amplifier gain control in this normal position, which decision, of course,

precluded a reduction of the amplitude of the trace by changing the amplification factor of the amplifier by means of the gain control. The most obvious reasons for the change in amplitude would be: First, a variation in the voltage applied to the range station and to the remote monitoring system, and second, a decrease in the signal received by the recorder from the monitor receiver.

In investigating the effect of voltage variations on the recorder trace, it was found that an increase in voltage resulted in a decrease in the amplitude of the recorder trace. By operating the range station and, therefore, the remote monitor system on power supplied by the auxiliary power unit, it was possible to vary the voltage applied to the entire system and, thus, with other factors being equal, to produce a trace similar in amplitude to that of the trace under investigation. In making this calibration, it was discovered that the amplitude was extremely sensitive to voltage changes. For example, with an indicated voltage of 120 volts, a normal trace with an amplitude of approximately 2.5 on the chart was obtained whereas when this voltage was increased to 125 volts, the trace was decreased to 0.5.

A decrease in signal delivered by the receiver to the recording meter amplifier could have resulted either from a decrease in the field strength produced by the range at the receiver location, or a lowered efficiency of the receiver. Considering the fact that there had been a wet snow during the period under investigation, it was thought possible that leakage had occurred across the antenna insulator of the

receiver which resulted in a decreased voltage being applied to the input of the receiver. To determine what value of leakage might have existed a resistance was connected between the receiver antenna and the ground and varied until a trace with an amplitude equal to that which had been made during the period of 4:40 a.m. to 4:50 a.m., November 4, 1940, appeared on the recorder at the range station. All other conditions, such as amplifier gain and line voltage, were maintained at normal values. It was found that a resistance of approximately 170 ohms reduced the amplitude of the trace to the required value.

In order to change the ratio of the "N" to "A" signal from a normal value of approximately 1.1 to a value of approximately 0.5 as shown for the period of 4:40 a.m. to 4:50 a.m. of November 4, 1940, the northeast tower of the range was detuned by connecting a condenser from the tower to the counterpoise. With a capacity of approximately 30 micromicrofarads,* the desired ratio was obtained. It was found that in both the case of the decreased signal from the monitor receiver and the increased voltage, the amount of detuning required on the northeast tower to obtain this ratio was of the same value.

On November 12, 1940, Mr. McKinley, Mr. Sandretto, and Mr. Studebaker adjusted the range and the monitor receiver to simulate the trace under investigation; first, by decreasing the signal input at the receiver and detuning the northeast tower, then by increasing the applied voltage and detuning the northeast tower. The courses of the range were observed by

*A micromicrofarad is a unit used for certain electrical measurements.

means of check flights made during the time the range was operating under these test conditions. Mr. Herbert Hucke, radio consultant for the Civil Aeronautics Board, and Mr. Frederic Stephens, Air Carrier Inspector-Radio for the Civil Aeronautics Administration, were the observers, and the airplane, a Douglas DC-3, was flown by Mr. R. T. Freng and Captain S. T. Wanrick of United. Both of the range receivers installed aboard the airplane were used in conjunction with both of the wire type "belly" antennas to receive the range signals. The signals received, using any combination of these receivers and antennas, were substantially identical; the maximum difference observed between any arrangement was believed to be less than one degree at distances of over four miles from the radio range station. Also, there appeared to be no difference in the alignment of the Salt Lake range under the two conditions of operation which were set up at the range station for the tests.

Under both of the test conditions it was believed that, as closely as could be determined from known land marks, the north course of the Salt Lake range was displaced by approximately 12 degrees to the east of the published alignment. Observations were also made to determine, if possible, the multiple structure of the north leg in the vicinity of Layton. At this point it was found that one multiple lay to the east and one multiple lay to the west of the predominant center position of the north leg. The multiple on the east side of the actual leg was of sufficient magnitude so that the pilot on this test flight, when flying outward from the Salt Lake range, apparently mistaking this multiple

for the true range course, followed the multiple instead of the center of the actual on-course. The total width of the north leg, including the two multiples, was approximately 6 degrees. The airplane during the test flight was also flown from the vicinity of Layton to the scene of the accident and the observers reported a normal increase in "N" signals as soon as the aircraft departed from the twilight of the eastern multiple. This "N" constantly increased in magnitude as the scene of the accident was approached and a clear "N" signal was heard directly over the point where the accident occurred.

The data furnished by the recorder chart were also used in conjunction with the impedance measurements and the tower current measurements (made by the maintenance electricians on the morning of November 4), in an attempt to determine by theoretical consideration the alignment of the Salt Lake City radio range for the period in question. In order to reduce the information given by the recorder chart to usable form, it was necessary to determine, as nearly as possible, the actual field strengths which existed at the remote receiver, since it is the field strengths which determine the comparative intensity of the aural signals heard by a listener. To make this determination the amplifier gain control was placed in the normal position, as indicated by the mark which had been placed on the front panel of the line amplifier by the maintenance electricians, and deflections of the pen of the recorder were noted for varying inputs of radio frequency voltage at the antenna terminals of the remote monitor receiver. Input-output calibrations were also made for

various settings of the amplifier gain control for the purpose of determining the response characteristics of the amplifier and the receiver system.

An examination of the resulting calibration curve for normal gain (Exhibit 125) indicates that a threshold value of approximately 2000 microvolts* exists below which no deflection is indicated by the recording meter. For a short distance above this threshold value, the movement of the recording hand with respect to the impressed signal approaches a variation in proportion to the square of the voltage, but after the impressed voltage rises above this point, the movement of the pen assumes nearly a linear relationship to the voltage. In converting the "N" to "A" ratios of the recorder chart to field strength ratios by means of this calibration curve, the field strength ratios appear to be nearer to unity than the trace ratios, due primarily to the high threshold value of the system. Thus a trace ratio of 0.5 is a field strength ratio of approximately 0.8, as determined from the calibration curve.

Some doubt, of course, exists as to the accuracy of the field strength values as shown by the calibration curve. The fact that the "A" and "N" signals from the radio range are the product of varying percentages of modulation, whereas the values of the calibration curve are produced by a signal of constant modulation—30%—but of varying voltage, would in itself, of course, produce some inaccuracies. Other factors, known to exist but impossible to evaluate, would also impair the degree of accuracy of this calibration. However, it is believed that here as in so much of the

*A microvolt is a unit used for certain electrical measurements.

other statistical evidence introduced, an order of magnitude is indicated.

The maintenance electrician, on the morning of November 4, had made impedance measurements of the lines and of the towers and had also recorded the radio frequency currents in the northeast and southwest towers, although these tower readings were not made with any high degree of accuracy. From the impedance measurements, it was determined that all towers, except the northeast tower, were generally in a normal condition. The northeast tower, however, was definitely defective. The values of radio frequency currents in the northeast-southwest pair of towers confirmed these impedance measurements and also are an indication of the fields which would be created by radiation from these towers. There would be, of course, a reflected condition which would upset the adjustments of all the elements of the radiating system and which would result in fields other than normal being radiated from all the towers. Unfortunately, very little information concerning such a condition was available since no measurements were made of the currents in the northwest and southeast towers. On the other hand, had such measurements been made, there would still be certain essential information lacking concerning the phase shifts which occurred, and without a knowledge of these phase shifts, it would be impossible to determine the field patterns.

Mr. Sandretto, in his testimony, presented certain exhibits which he had prepared and in which he attempted to make use of the factors discussed above. One of these exhibits (Exhibit No. 126) consists of

four polar diagrams constructed upon various assumed values in so far as tower currents and phase shifts are concerned. These polar diagrams show that from a theoretical consideration and making use of the available statistical data, a course shift of almost any value up to 59 degrees could have existed and produced the same trace on the recorder chart. In this connection, of course, it should be noted that no limits were placed on any of the unknown factors.

In reviewing all the available statistical information concerning the condition of the range course on November 4, Mr. McKinley, Mr. Sandretto, and Mr. Studebaker were in agreement that it was impossible for this information to arrive at any definite conclusion as to the amount of displacement of the courses. Also, they agreed that no great reliance could be placed upon the results of tests made on November 12, this conclusion being primarily based on the fact that it was necessary to ignore a great number of variables in making these tests. It was further agreed that there were a number of combinations of factors and conditions which might have existed, each combination of which could have produced a different displacement of the north leg of the range and still have produced a recorder trace similar to that which was produced on the morning of November 4. They all agreed, however, that from the information furnished by the recorder chart, it was possible to conclude definitely that the north leg of the Salt Lake range had deviated to the east from its normal alignment during the early morning of November 4. Mr McKinley expressed the opinion that the deviation might have been as much as 12 degrees to the east, Mr. Sandretto thought that the deviation was approximately 19 degrees to the east, while Mr. Studebaker stated that the leg had probably swung between 7 and 20 degrees to the east.

Analysis of Evidence on the Salt Lake Range

From the evidence based upon the trace on the recorder chart and the data collected by Mr. Givens at the time he inspected the range early on the morning of November 4, 1940, it is impossible for us to come to a definite conclusion as to the precise location of the north leg of that range at the time Captain Fey was using it in his let-down procedure. However, it is clear that between 4:40 a.m. and 4:50 a.m., the range was not functioning normally and that the north leg of the range had deviated to the east from its published course.

Nor are we able to arrive at any definite conclusion as to the location of the north leg from the reports of the pilots who flew the range early on the morning of November 4. Captains Nelson, Garbutt and Dace thought that the range was operating normally at the times they were using it and this testimony coincides with the recorder trace, for if the trace is to be depended upon, the range had deviated very lettle from normal operation at those times. The testimony of Captin Going, who flew the range from 1:26 a.m. until 2:03 a.m., varies to some extent with the evidence provided by the recorder trace. He took loop bearings from time to time while he was using the range and believed that it was functioning normally. The "N" to "A" ratio shown on the recorder trace during the period 1:26 a.m. until 2:0[illegible] a.m. dropped from about unity at 1:26 a.m. to 0.77 at the time Captain Going landed. However, under all the circumstances, it appears that the apparent conflict between Captain Going's experience with the range and the evidence as to the condition of the range provided by the recorder trace may be resolved.

Captain Going was continually on instruments during the time he was observing the alignment of the north leg and the only means he employed to determine the alignment was the use of his direction finder. In his testimony he stated that the bearings taken might have been inaccurate by 5 degrees, plus or minus, and described in some detail the method used in operating his direction finder. It appears from that testimony that the bearing taken by him when he first intersected the north leg at 1:31 a.m. probably was accurate within the tolerance mentioned by him because that bearing was taken with great care. It is probable that the displacement of the north leg at that time was less than 5 degrees, which was the tolerance allowed for the loop bearings.

However, the taking of bearings thereafter appears to have been secondary to other activities incident to the approach and landing and it is unlikely that they resulted in the same degree of accuracy as did the one originally taken. Under these circumstances, Captain Going or his first officer might well have failed to detect a misalignment of the north leg of the order of 6 to 10 degrees.

It is difficult to determine from Captain Christenson's testimony and the portions of the radio log dealing with his flight whether or not the condition of the range as he observed it is inconsistent with that indicated by the recorder trace. He began using the Salt Lake range at 4:35 a.m., crossed the range station, and made two shuttles on the west log, but until after 5:29 a.m. apparently did not detect any abnormality in the functioning of the range sufficient to indicate to him that the range should not be used in a let-down procedure. Thus, at 5:20, on his return to the station during his second shuttle on the west leg, he requested an Airway Traffic Control clearance for a standard instrument approach and, having received

that clearance, apparently began such a let-down-through procedure at 5:29. It was only when he attempted, as a part of this procedure, to descend on the south leg to 11,000 feet that he definitely concluded that the range was functioning abnormally since he was unable to intersect the south leg after having proceeded as far west as Bingham Canyon.

In his testimony, however, he indicated that he became somewhat suspicious of the range prior to this time when, at approximately 5:08, while proceeding westbound on his second shuttle, his course appeared to be substantially south of the normal alignment of the west leg. From his radio reports it appears that his course must have been approximately 25 degrees south of the normal alignment of the west leg since he reported over Garfield, and from his testimony it appears that at that time he was following an "A twilight", which signal would ordinarily be received north of the on course signal of the west leg.

On Captain Christenson's first shuttle on the west leg, he stated that about 2 minutes after having passed over the range station west-bound, he established his position by reference to the ground and it was his impression at that time that the west leg was on its proper alignment. If the west leg were properly aligned at that time (about 4:48) and at 5:08 were at least 25 degrees south of its published bearing, these observations would indeed be inconsistent with the condition of the range as indicated by the recorder trace, for there is no substantial difference between the amplitude ratios during this entire period. However, it is difficult to determine conclusively from the record whether or not Captain Christenson, in making his first shuttle, made careful observations of his position

since he testified that he had not "paid much attention" to the alignment of the leg until during the second shuttle when his suspicions were aroused abo 5:08. Moreover, it is difficult to determine whether, during his first shuttle, he was at all times following the actual on course signal or an "A twilight". Under these circumstances and in view of the extreme unlikelihood of such a rapid change in course alignment having taken place in a period of less than 20 minutes without being reflected in the recorder trace, we conclude that the west leg was displaced substantially to the south at all time Captain Christenson was using it.

Captain Christenson's observations of the operations of the range made after 5:29 are consistent with the evidence provided by the recorder trace.

Captain Morton, who observed the condition of the Salt Lake range from 5:17 a.m. until 6:28 a.m. on the morning of November 4, flew directly across the northeast or "N" quadrant of the range and, according to his testimony, received nothing but "A" signals. From this evidence, it might be concluded that at the time Captain Morton made his observations the north leg of the range had completely disappeared, which condition would not be entirely inconsistent with the recorder trace. However, we cannot immediately proceed to this conclusion solely on the basis of Captain Morton's testimony because, as he indicated, he was operating a scheduled flight and thus was busy with other duties, and it is possible that he might have failed to detect areas where "N" or on course signals existed. On the other hand, we are justified in concluding from Captain Morton's testimony that the range was, at the time he made his observations, substantially misaligned.

Captain Baird's testimony coincides very closely with the probable conditions revealed by the recorder trace. While flying the west leg of the

Fort Bridger range and the normal position of the east leg of the Salt Lake range. Captain Baird received "A" signals. This is a condition which would be expected in view of the fact that the recorder trace would indicate a movement of the east leg of the Salt Lake range to the north and of the west leg to the south.

The data reported by Captain Petty, Captain Kelly, and Captain Hollenbeck does not appear to be inconsistent with the recorder trace. However, neither their observations nor the recorder trace for this period is greatly relied upon in attempting to arrive at a solution of this problem because, prior to the time they made their observations, Mr. Givens had made some adjustments to the equipment at the range station and thus may have changed the conditions which had existed during the period of malfunctioning in which we are particularly interested.

When taken in connection with the evidence obtained from the recorder trace, the reports of the pilots, particularly Captains Christenson and Morton, give some indication as to the probable condition of the on course signals of the Salt Lake range when Captain Fey was using that leg in his let-down procedure. There appears to be little difference between the recorder trace when Captains Christenson and Morton found the range alignment abnormal and that for the period of 4:40 a.m. to 4:50 a.m. When it is considered that Captain Morton found "A" signals all through the northeast "N" quadrant and Captain Christenson found the south leg to be at least 25 degrees west of its published bearing, it leads to the conclusion that in all probability the north leg of the range was, at the time of the accident, displaced to the eastward by an amount which, taken into conjunction with the mountainous terrain immediately to the east of the normal leg, was sufficient to destroy its utility for purposes of instrument approach.

That the Salt Lake range was unstable and that the alignment was sensitive to changes in humidity was clearly evidenced by testimony submitted concerning the history of the performance of the range since modernization. It seems clear that the presence of wet snow on the morning of November 4, 1940, contributed substantially to the condition of the range during that time. This conclusion is supported by the fact that on January 5, 1940, and February 15, 1940, about the same weather conditions existed and, while there is no direct evidence as to the alignment of the north leg at those times, the south leg was at least 20 degrees west of its published bearing, and it would logically follow that the north leg had swung substantially to the east. On the other hand, it appears from the testimony given by Mr. Givens concerning his special study during April of 1940, that high humidity resulted in an increase of the predominance of "N" over "A" rather than in a reversal of that relationship as was the case on the morning of November 4. Thus, from our investigation the reason for this affect of atmospheric conditions upon the functioning of the range is not readily recognizable, nor could the engineers of the Civil Aeronautics Administration, whose responsibility it is to deal with the technical problems arising in the operation and maintenance of the range, offer any information on this matter. Even though the susceptibility of the range to atmospheric conditions had been forcibly demonstrated in the spring of 1940, no action to correct or to discover the reasons for the resulting malfunctioning had been taken, according to Mr. H. W. McKinley, up to the time of the accident.

It does not appear that the general design or installation of the

equipment at the Salt Lake City range was responsible for the malfunctioning of this range. This same equipment with the same general layout is used at other stations with results as satisfactory as the present state of the art permits. Thus, there is no apparent reason why equipment other than that actually installed should have been used at the Salt Lake station.

However, there may be some unusual defect in a particular piece of equipment. Malfunctioning of the Salt Lake range appears to have resulted in most cases in a distorted field pattern, and since this distortion has been accompanied by changes in humidity or snowfalls, it could logically be concluded that these atmospheric conditions affect the radiating system. In view of the fact that these atmospheric conditions apparently do not affect all elements in the radiating system equally, and since all these elements are equally exposed, it would appear that some peculiar defect does exist in particular elements which make them unusually susceptible to changes in atmospheric conditions.

It is believed that intensive research into such matters as the components of the range equipment, the terrain effects, and the atmospheric conditions existing in the Salt Lake Valley should produce evidence sufficient to provide a solution to this problem.

We have reached our conclusion concerning the displacement of the north leg of the range on the basis of the overwhelming weight of the evidence, notwithstanding the fact that the reports and testimony of the operators responsible for monitoring the Salt Lake range indicate no misalignments of the range until 5:37 a.m. when, after having been told by Airways Traffic Control that the range had been reported as malfunctioning, the Salt Lake operator found that he was receiving an "A" instead of an "N" on the remote monitor

receiver. The operator at Plymouth did not discover any abnormality of the range until 6:46 a.m. after he had been requested by the Salt Lake operator to monitor the range. The operator at Tintic found no malfunctioning of the range until 7:03 a.m. and Wendover never did report the range as abnormal. There may be some justification for the operator at Tintic failing to discover the misalignment of the south leg during the early portion of the period of malfunctioning since Tintic is well within the "N" quadrant. It is difficult, however, to understand why he found the range normal at 6:03 a.m. and abnormal at 7:03 a.m. and thereafter when, if reliance is to be placed on the recorder trace, the range was then probably operating more nearly normally than at the time of the former report. Of course, the recorder trace records signals received north of the range station while Tintic is located south of the range station, but from the nature of the radiating system it would appear to be reasonable to conclude that a substantial shift to the east of the north leg would be accompanied by a shift to the west of the south leg, and that a change in either of the legs would be reflected in the recorder trace. This conclusion is supported by Captain Christenson's report of his observations at 5:33 a.m., from which it appears that the south leg had shifted to the west more than 22 degrees. Tintic is 12 degrees west of the published course of the south leg.

The failure of the operator at Wendover to detect the abnormal operations of the range is explainable in view of the fact that the station is located so that a shift of the west leg to the south would be difficult if not impossible to detect since "A" is the normal signal and such a shift would result in placing Wendover in an "A" quadrant.

The failure of the Plymouth operator and the Salt Lake operator who monitored the north leg to detect the deviation of the leg from its normal bearing is much harder to understand. Both the Plymouth station and the remote receiver which is operated by the Salt Lake operator are located in the "N" quadrant of the north leg and both of these receivers are so situated that any appreciable deviation of the leg to the east should be immediately detected. Indeed, Mr. Thomas Bourne, Chief of the Airways Engineering Division under the then Administrator in the Civil Aeronautics Authority advised United in February of 1939 that the Plymouth station would be able to detect a deviation of the north leg of 1-1/2 degrees to the east. There appears to be no room for doubt that the Plymouth operator, at least as early as 3:10 a.m. should have observed the misalignment of the north leg, for at that time the recorded ratio was approximately the same as it was during the period between 4:40 a.m. and 4:50 a.m. at which time, according to the testimony of the radio experts, the north leg had swung at least 7 degrees to the east. Even at 2:46 a.m. the indicated ratio was .69 which was approximately the same value as shown by the recorder trace at 7:46 a.m. However, at 2:46 a.m., Plymouth reported normal operation for the Salt Lake range with a faint "N" being received, whereas at 7:46 he reported abnormal operation with a moderate "A" being received.

As to the Salt Lake station, it should be noted that the Salt Lake operator monitors the north leg through the same receiver which is used with the automatic recorder and that the operator actually listens to the same signals and, therefore, the same signal ratios which actuate the recorder pen which makes the trace. At 4:24 a.m., just before the accident, the operator

entered in his log "Monitored north leg Salt Lake range, faint 'N' aurally, normal". At this time the recorder trace shows a ratio of 0.5, a ratio lower than that which existed for periods after 5:37 a.m. during which another operator reported a light "A" being received, which would indicate definite malfunctioning of the range.

The aural monitoring observations at Salt Lake City and Plymouth were probably made difficult by the presence of static. One of the Salt Lake City operators testified that the static level was equal to the signal level and, although most of the operators insisted that it was possible accurately to determine the signal being received under such conditions, it is doubtful whether an operator could make the fine discrimination between signal intensities required for accurate range monitoring where interfering noises, equal in intensity to the signals being received, are present. In fact, an operator monitoring under such conditions might think that he was hearing the signals he always heard and expected to hear. Testimony would also indicate that a considerable amount of this static to which reference is made is what is known as "snow" static. "Snow" static is a form of precipitation static and has the characteristic of creating a continuous noise in the receiver so that when receiving under these conditions, the operator does not have the opportunity which exists under the conditions of "crash" static to listen to the signals between the bursts of noise. There is also the matter of ear fatigue which under heavy static conditions may be an important factor in the ability of an operator to judge relative intensities of signals--which is the primary requirement for accurate monitoring. This is particularly pertinent in the case of Communications Operator Andrews who, due to Mr. Daley's failure to relieve him, was required to stay on duty for over 13 hours, 9 of which he spent at

the broadcast watch during a period when static was particularly heavy. All of the operators who testified insisted that since a major part of their experience had involved listening to signals, they could monitor more accurately by ear than by the observation of a visual meter but it is believed that while operating experience enables the operator to determine when a signal exists and to form mentally the signals into the groups which signify letters and words, it does not necessarily enable them to make a fine determination of the relative intensities of two signals under severe static conditions.

Considerable thought has been given to the possibility that both the recorder trace and the aural monitoring reports of the Salt Lake operators could have been correct. One difficulty in arriving at this conclusion is that, while the recorder trace shows the same signal predominating throughout the morning of November 4, the monitor reports show one signal predominating prior to 5:37 a.m. and the other signal predominating after 5:37 a.m. This can be explained only by making one of three assumptions: First, that the automatic recorder equipment operated differently during the two periods of time; second, that the aural monitoring equipment operated differently during the two periods of time; or third, that the ear responses of the listeners were different for the two periods of time.

As to the equipment, testimony indicates that both the automatic recorder and the aural monitoring equipment operated the same during the two periods of time. As to the ear response, no exact information is available but the operators who made these monitoring observations testified and, so far as could be judged, their hearing was normal. Such being the case, it would be unreasonable to assume that of two operators listening to the same signal, one

would actually hear a light "N" and the other a moderate "A". Therefore, it may be concluded that the aural monitoring reports at the Salt Lake station were not at all times accurate observations of the signals actually received.

The above discussion applies equally to Plymouth and to Tintic. The operators at these stations, unlike Salt Lake, were not listening to the same voltages which produced the recorder trace, and thus from the recorder trace alone we might be unable to say with certainty what signals should have been received by them. However, the recorder trace indicates the predominance of one signal during the entire morning while the operators at Plymouth and Tintic reported receiving one predominating signal at one period in the morning and another predominating signal at a later period. The only way in which this inconsistency could be explained is to conclude that changes in field pattern would not be reflected by changes in the recorder trace. We have already stated that there are a number of different field patterns which could produce similar traces and for that reason have been unable to determine the exact alignment of the range by the recorder trace alone. On the other hand, it appears reasonable to assume that the trace would indicate any transition from one field pattern to another, even though the first and the final patterns did produce the same trace. Also, the conditions which produced the field pattern existing on the morning of November 4 were in themselves sufficiently stable to cause progressive rather than abrupt changes in the field pattern and it is believed that these changes were, within the limitations of the equipment, faithfully reflected in the recorder trace. For these reasons it follows that the operators at Plymouth and Tintic did not at all times accurately observe the signals actually being received.

In the case of Plymouth, an additional difficulty is presented when an attempt is made to resolve the conflict between the aural monitoring and the recorder trace by the confusing nature of the evidence concerning the activities of the monitoring operator at this station. There is no accurate record of his activities during the period immediately following the accident and the records which do exist, even when corrected in accordance with the testimony given by this operator, still leave discrepancies. Thus, there is no record whatever of monitoring having been accomplished at 5:46. Also, it appears that the routine weather report was not transmitted on the teletype from Plymouth at 4:35 a.m., but that a weather observation was made at 4:45 a.m. The Plymouth station, according to its Range Monitor Report, monitored Locomotive Springs from 4:40 to 4:43 and monitored the Salt Lake static from 4:46 to 4:49, thus making it necessary for the weather report shown for 4:45 to have been made and recorded in three minutes or less. From a description of the activities involved in making a weather report, it would appear to be doubtful whether a complete and accurate weather report can be made in three minutes. This, taken in conjunction with the failure of the operator to make the regular weather report at 4:35 a.m. and the omission of all the entries having to do with the operator's activities for the period of 5:00 to 6:00 a.m., casts doubt upon the accuracy of all station records made by this operator for the morning of November 4.

The testimony at the hearing indicates that the Salt Lake radio range is the most thoroughly monitored range in the country. It is monitored from five receivers and thus, presumably, is checked four times in every hour during the 24 by the outlying stations and the remote receiver and continuously by the local receiver. The special remote monitor on the north leg is the

only one of its kind in the country and it is specially designed to detect slight movements of the north or low approach leg of the Salt Lake range. This elaborate monitoring system was installed because of the known instability of the Salt Lake radio range. However, notwithstanding these extreme efforts, it seems from the experience of November 4 that the effectiveness of the monitoring system provided still leaves much to be desired.

From the testimony it appears that while the monitor operators have been qualified as radio operators, they are not adequately trained with special reference to the work of monitoring a radio range. The responsibility of that work is great and carries with it the corresponding need for careful training. This is particularly true in the case of a range which, like that at Salt Lake City, is unstable and where deviations in course alignments may lead pilots into high terrain. However, no instructions were given to the operators responsible for monitoring the Salt Lake range explaining to them the peculiarities of that range and the effect of particular atmospheric conditions upon its functioning, nor were they given instructions as to any special monitoring procedure to be followed whenever weather conditions at Salt Lake were such as to indicate the possibility that malfunctioning of the range might result.

Moreover, some, at least, of the monitor operators appear to have gained little appreciation of the practical effects of monitoring upon the safety of air transportation. Those who testified had little, if any, knowledge of the way in which radio range courses are used by pilots or realization of the gravity of any abnormality of the operation of the range. Because the teletype circuit connecting the Tintic operator with the Salt Lake station was

out of order, he failed to report the fact that he had found the south leg of the range misaligned at 7:03 a.m. He apparently did not believe the situation sufficiently serious to justify a telephone call to the Salt Lake station although he was sufficiently concerned over his difficulties with the teletype circuit to call the teletype test board at Salt Lake City at 7:10 a.m. in order to determine the cause, and secure the correction, of the trouble with that facility. Nor did it occur to him, apparently, to request the person with whom he was speaking in Salt Lake City to notify the Salt Lake Communications Station of his findings with respect to the operation of the Salt Lake range. The signal received by the Tintic operator indicated either that the south leg had moved considerably more than 12 degrees west, or that the west leg had moved about 78 degrees south, but he testified that he did not know the distance between his station and the south leg of the Salt Lake range or the effect of the abnormal functioning of the Salt Lake range upon the use of that facility for the purpose of air navigation.

The Salt Lake operator who came on duty late, at 5:05 a.m., testified that he did not know that the north leg of the Salt Lake range was the one used for low approaches to the airport despite the fact that it was his duty to monitor that leg. In addition, he testified that when he received an abnormal signal from the range at 5:37 a.m., it did not occur to him that the signal indicated that the north leg had swung to the east toward the mountains. When questioned as to why he had failed to issue a Notice to Airmen notifying pilots of the malfunctioning of the range after he had received a report from a pilot that it was functioning abnormally and the report had been confirmed by his own monitoring, he stated that he did not believe the

malfunctioning of the range was established thereby with sufficient certainty to justify such a notice. While the written instructions under which he was operating appear to be ambiguous as to the action required under the circumstances, a proper realization of the seriousness of the effect of the malfunctioning of the range would undoubtedly have impelled him to resolve his doubts as to the action required by issuing a Notice to Airmen immediately. However, he sought confirmation of his own monitoring from the outlying monitor stations and called Wendover first, then Tintic, and then Plymouth, which latter station he contacted at 6:34 a.m., nearly an hour after he had originally received the abnormal signals. When asked as to why he did not first call Plymouth, the station best located to affirm or disprove his findings, he stated that he was not certain at that time that Plymouth was the outlying station which monitored the north leg.

Mr. Daley's action in seeking confirmation of his own monitoring rather than immediately issuing a Notice to Airmen was concurred in by Mr. Davis, the operator in charge of the station, whom Mr. Daley called about 6:00 a.m. Mr. Davis also apparently regarded the pilot's report of malfunctioning, when taken with the abnormal signals received by Mr. Daley, to be insufficient proof that the range was malfunctioning to justify a Notice to Airmen. In addition, after arriving at the airport at approximately 7:00 a.m., one hour and twenty-three minutes after the range had originally been reported as malfunctioning, and having been advised that the report of malfunctioning had not only been confirmed by the remote monitor receiver but also by the monitor station at Plymouth, Mr. Davis failed even then to issue a Notice to Airmen. Instead, he devoted his time to preparing an emergency warning advising the

various communications stations and others that an airplane was unreported. He finally issued a Notice to Airmen at approximately 8:20 a.m., almost three hours after the range was originally found to be malfunctioning.

The behavior of the various operators subsequent to the accident indicates a lack of appreciation of the importance of monitoring which makes it appear all the more probable that the monitoring reports in the early morning of the 4th, prior to the accident, are unreliable.

CONDUCT OF THE FLIGHT

Having concluded that the Salt Lake City range was operating abnormally at the time the accident occurred, it does not necessarily follow that this condition constituted the cause of the accident. There still remains the necessity for inquiring into the manner in which the flight was conducted by all those who were concerned with it before any conclusion can be reached on this issue.

We have already determined that the airplane was in airworthy condition with its equipment operating normally all during the flight. Also, from the record it appears that the weather reporting and observation in so far as it affected the flight of Trip 16 was efficiently and accurately done. The terminal and airway forecasts upon which the flight depended were substantially accurate and the flight crew was apparently kept fully advised as to the weather conditions existing in Salt Lake City. There also seems to be no question but that the trip was properly dispatched from Oakland to Reno. The trip carried ample fuel and oil and an ample supply of oxygen, was properly loaded, the weather was excellent, and there were no reported failures among

air navigation facilities along the route. While the dispatch from Reno was made to a terminal at which weather conditions fell below minimums from time to time, the trip could not be said to have been improperly dispatched because the ceiling and visibility at Salt Lake City were variable, good weather conditions existed at the designated alternate, and the trip carried sufficient fuel to carry it not only to its designated alternate but for several hours thereafter.

A large amount of evidence taken at the hearing deals with the operation of the flight by the flight crew and by Dispatcher Edson, who was responsible for furnishing Trip 16 with all weather, traffic, and other pertinent information relating to the operation of the trip. On the flight between Elko and Salt Lake City, the only unusual circumstance which can be said to be of consequence here is that because of extremely heavy static, several radio contacts attempted by both Trip 16 and the ground station were not completed. This is clearly shown by the fact that the trip was apparently unable to read the Salt Lake ground station for some time after passing over Wendover and, after passing over the Timpie marker at 3:28 a.m., was apparently unable to descend to 11,000 feet over the Salt Lake City range station in accordance with previous advice to the Salt Lake City ground station. The flight recorder card shows that the trip descended to approximately 12,000 feet after passing over Timpie and some unanticipated condition, presumably heavy static, caused Captain Fey to stop his descent and climb again to 13,000 feet at which altitude he passed over the Salt Lake City station at 3:40 a.m. The trip again reported over the Salt Lake station at 4:03 a.m. at 14,000 feet, apparently having been required to ascend an additional thousand feet in order to stay on top of the clouds where the static was less severe.

It is not clear what course or courses the trip flew between 3:40 a.m. when it first passed over the station, and 4:03 a.m. when it again reported over. However, from the testimony of United pilots, it would appear that the usual practice under the circumstances then existing would have led Captain Fey to shuttle on the west leg of the Salt Lake City range, waiting for more favorable conditions under which to start a let-down procedure. During this period, Mr. Edson made several attempts to communicate with the trip and the flight recorder on the airplane shows that Captain Fey also attempted to contact the Salt Lake City station without success. From 4:03 until 4:26 a.m. when Trip 16 again approached the Salt Lake City range station, it seems probable that Captain Fey again shuttled on the west leg while waiting for the static to clear sufficiently for him to begin his let-down-through procedure. During this period also the flight recorder showed that Trip 16 made numerous attempts to contact the Salt Lake station.

It is evident that by this time Captain Fey had become somewhat doubtful as to whether a landing at Salt Lake City was feasible in view of the heavy static conditions, and was considering the possibility of proceeding to some alternate point. This is clear from his statement to Dispatcher Edson: "Lots of static at times. Fire all over things and can't hear the range. I don't know whether we can get in here or not. Unless we can pick up the field will have to get out of here." It appears that at the time of the conversation, Trip 16 was in the immediate vicinity of the station for Dispatcher Edson testified that just following the conversation he heard the trip just east of the field.

In accordance with Captain Fey's suggestion that he might have to proceed to some other point, Dispatcher Edson then obtained a clearance from Airways Traffic Control for the trip to proceed from Salt Lake City to Elko. However, it appears that shortly after completing the conversation with Dispatcher Edson at 4:26, Captain Fey started his let-down procedure on the north leg because when Dispatcher Edson at 4:37 advised him that it would be desirable for him to go to Elko if he was unable to make an approach, Captain Fey reported that the trip was on the north leg at 9,000 feet, that conditions were much better, and that he believed he could complete his approach and land at Salt Lake City.

Under the approach procedure used by United at Salt Lake City and approved by the Civil Aeronautics Administration, the pilot crosses the range station at a minimum altitude of 11,000 feet and proceeds out the north leg, letting down at the rate of 400 to 500 feet per minute. He maintains this descent long enough to lose approximately half the difference between his initial altitude and 4800 feet, and then a procedure turn to the left is begun continuing the descent. The minimum altitude for this procedure turn is 7,500 feet. The turn consists of a 45-degree change in heading to the left to be held for one minute, then a one-minute 180-degree turn to the right and flight along the reciprocal heading until the leg is intersected. A turn is then made toward the station for the final approach and a steady rate of descent is continued, passing over the range station at 4,800 feet, or approximately 600 feet above the ground.

The question necessarily arises as to the probable flight path followed by Captain Fey from the time he left the vicinity of the Salt Lake station to proceed north and the time he crashed. It appears that the most accurate way

of determining this flight path is to begin at the scene of the accident and work back along the flight path probably followed.

In making this determination, it is assumed that Captain Fey attempted to follow generally the normal let-down-through procedure. The only evidence which might tend to indicate the contrary is Captain Fey's 4:37 a.m. contact. According to the radio log, Captain Fey said to Dispatcher Edson at that time "OK, we are on the north leg at 9,000 feet and there are breaks in the clouds out here. It is quite a bit thinner. Think we can come down out here and follow the lake in if you want us to do it that way." It might be stated that in making the underscored statement, Captain Fey intended to descend in the area in which he was then flying, establish contact, and follow the lake into the Salt Lake Airport. However, there is every reason to believe that he did not have in mind any such operation.

In the first place, at the hearing there was a substantial conflict of opinion as to whether the word "lake", as indicated in the radio logs, was not a mistake in copying by the radio operators and should have been "leg". The United radio operators at Salt Lake City and Oakland logged this conversation and the one at Salt Lake copied the word as "lake" while the one at Oakland copied it as "leg". Representatives of the Board listened to the record of this conversation made by the automatic recorder at Oakland and were unable to determine which word was actually used.

In addition, it seems impossible that Captain Fey, who was familiar with the Salt Lake City area, could have indicated that he was going to follow the lake into the Salt Lake City Airport because, first, south of the Layton fan marker and west almost to Antelope Island, the land, salt flats, and the water

blend to such an extent that it is impossible to distinguish a shore line, and second, even if Captain Fey had been able to find and follow the shore, it would have led him to a point almost as far west of the Salt Lake City Airport as he was north of the airport at the time he made the contact.

In saying "Think we can come down out here", he must have been indicating that he proposed to continue the descent he had begun after 4:26 a.m. following a standard instrument approach. In saying, "If you want us to do it that way", he was undoubtedly referring to Dispatcher Edson's statement made immediately before, "If you are unable to make your approach, we want you to return to Elko. We will have Trip 11 go to Elko and adjust the cargo".

When inquiry was made of Dispatcher Edson at the hearing as to his understanding of Captain Fey's intentions after the 4:37 a.m. contact, he stated that he understood that Captain Fey intended to continue his standard instrument approach to the Salt Lake City Airport and pointed out that he at that time had said "That is OK to continue your approach, Howard. I will keep you advised." Thus, it appears that the only reasonable conclusion which can be reached from a study of this conversation between Captain Fey and Dispatcher Edson is that Captain Fey did not intend at that time to spiral down and come in contact but intended to continue his standard instrument approach procedure to the Salt Lake City Airport.

In seeking to determine Captain Fey's flight path, it is also assumed that the clocks in the airplane and the clock in the Salt Lake radio station, from which the radio operator made his log, were showing the same times. This assumption is based upon the facts that Captain Fey checked the ship's clocks with the clock in the radio station at Oakland before taking off for Salt Lake

City and that the Oakland clock and the Salt Lake clock appear to have been the same because on several occasions both stations copied the same message and logged it as having been received at the same time. Therefore, this assumption seems well founded.

It appears to be well established that the crash occurred at 4:42½ a.m. One of the airplane clocks, which was found to be little damaged, had stopped at that time and this is consistent with the data shown on the flight recorder. It also seems well established that at some time between 4:39½ and 4:40½, Trip 16 was within the area in which the visual signal of the Layton fan marker could be received (See Figure A). At 4:40 a.m., the Salt Lake radio operator logged a message from Captain Fey in which he said "We are over Layton at 8,000 feet now." With respect to this statement, the testimon of United pilots indicates that when a flight reports "over Layton", referenc is made to the Layton fan marker and not to the town of Layton. This testimony also indicates that when such a report is made, reference is made to the visual rather than the aural signal of the Layton fan marker. It appears that the aural signal of the fan marker may be received over an area approximately twice the size of that in which the visual signal may be seen.* The aural signal may be heard as far south as Farmington and extends to the east well into the mountainous terrain and to the west far out over the lake. Thus, we are justified in assuming that at the time he made his 4:40 a.m. report, Captain Fey was observing the visual signal, first, because he would thus be following the established procedure, and second, because due to the extent of

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* The signals of a radio marker are received aboard an airplane in two ways, one, through the earphones as an "aural signal" and the other through the glowing of a lamp in the pilots' compartment as a "visual signal".

the area in which the aural signal of the fan marker may be heard, it would not constitute a sufficiently definite fix to use either in determining his position or in reporting it to Dispatcher Edson. It also seems reasonable to assume that this report was actually received by the Salt Lake radio operator between 4:39½ and 4:40½ since such messages are logged to the nearest minute. Based upon these assumptions, which appear to be well founded, the trip flew from a point at which the visual signal of the Layton marker could be received to the scene of the accident in a maximum of 3 minutes.

It also seems reasonable to assume that at the time Captain Fey reported over Layton at 8,000 feet, he had just completed the 180-degree timed turn portion of the procedure turn. That Captain Fey would make the prescribed procedure turn seems apparent since, to a pilot of Captain Fey's training and experience, in addition to being the prescribed practice, this maneuver would be the most natural and easiest way of making a 180-degree change in course during a let-down-through procedure. That he would have reported to the Salt Lake station upon the completion of the timed turn portion of the procedure turn rather than at some other time seems reasonable since, from pilots' testimony taken at the hearing, it appears to be the established practice for pilots to report at this point during a let-down procedure.

Since an examination of Figure A will show that the shortest distance between the limits of the visual signal of the Layton marker and the scene of the accident is about 8-1/4 miles, Trip 16 must have made good a ground speed of at least 165 miles per hour between the time the report "over Layton" was made and the time the airplane crashed. Moreover, the evidence would indicate that this ground speed is probably the highest ground speed that we could reasonably assume to have been made in the area in which Trip 16 was flying. According to the let-down procedure prescribed by United for Salt Lake City,

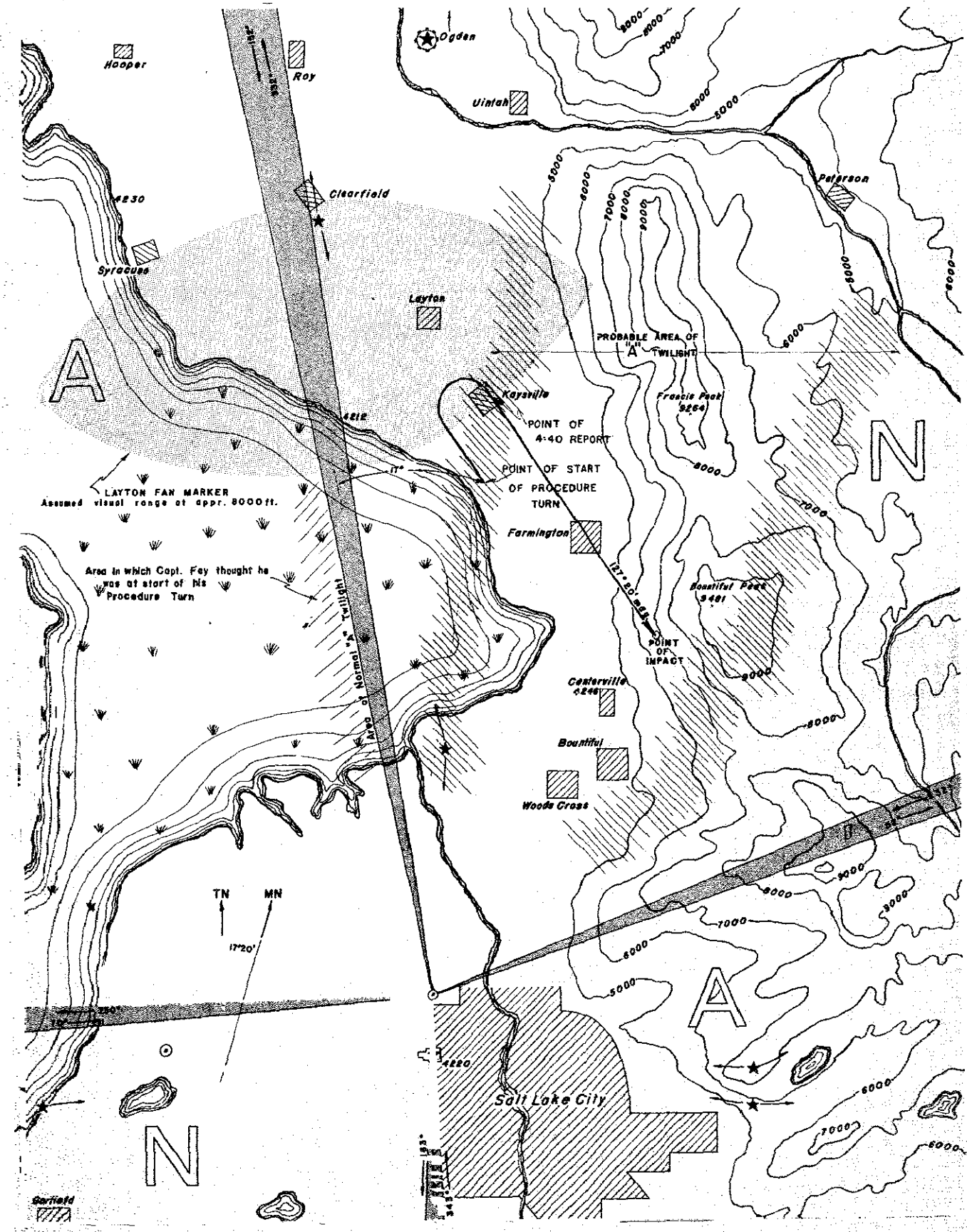

Ogden
Hooper
Roy
Uintah
Clearfield
Peterson
Syracuse
Layton
PROBABLE AREA OF "A" TWILIGHT
Kaysville
Francis Peak 9264
POINT OF 4:40 REPORT
POINT OF START OF PROCEDURE TURN
LAYTON FAN MARKER
Assumed visual range at appr. 8000 ft.
Farmington
Area in which Capt. Fey thought he was at start of his Procedure Turn
Area of Normal "A" Twilight
Bountiful Peak 9481
POINT OF IMPACT
Centerville 4246
Bountiful
Woods Cross
TN
MN
17°20'
Salt Lake City
Garfield
A
N

FIGURE "A"

and which we have already assumed Captain Fey to have been following, the procedure is executed at an indicated air speed of 120 miles per hour. On the basis of the temperature and altitude, this, in the case of Trip 16, would result in a true air speed of 135 miles per hour in the general location, and at the altitudes in which it was flying. Thus, in order to account for a 165-mile-per-hour ground speed, it is necessary to assume a helping wind or wind of northwesterly component of approximately 30 miles per hour. This velocity is higher than is indicated by evidence bearing upon the upper air winds in the Salt Lake Valley for the morning of November 4. Therefore, we would not be justified in concluding that the trip would have encountered a northwest wind of over 30 miles per hour, or that it could have made on this portion of the flight a ground speed of more than 165 miles per hour.

It is next necessary to determine the bearing at which this flight was made. In order for the ship to have flown from the visual signal of the Layton marker to the scene of the accident in 3 minutes at 165 miles per hour, it would have been necessary for the flight to have started from that point within the area of the visual indication of the Layton marker which is closest to the point of impact. A line joining these two points lies along a magnetic bearing of 127 degrees. It appears from the evidence that the airplane struck on a bearing of 127 degrees magnetic. These two factors, taken together, lead to the conclusion that the probable bearing flown by Trip 16 between the time it reported over Layton and the time of the crash was approximately 127 degrees magnetic.

According to prescribed procedure, which we have assumed Captain Fey to have followed, he had just completed a timed 180-degree turn when he made his report over Layton. Also, in accordance with prescribed procedure, this turn would have been begun after a flight of one minute on a heading which was the

reciprocal of the 127 degrees. Under the assumed wind conditions, the timed turn would have been made at an average ground speed of 135 miles per hour and the one minute flight on the reciprocal of 127 degrees would have been made at 105 miles per hour ground speed. These speeds, directions, and time intervals, when plotted on Figure A, indicate the point at which the procedure turn was started, and a measurement of the angle which this point bears from the Salt Lake station gives a figure of approximately 349 degrees magnetic, which is 17 degrees east of the bearing of the north leg away from the station.

In tracing the flight path of Trip 16 from the point at which the procedure turn was started to the point of impact, it has been necessary to deal with factors which are subject to some variations. Thus the precise limits of the visual signal area of the Layton fan marker may not be exactly as we have pictured them, the ground speed of the airplane may have been somewhat less than we have indicated, the time intervals may be subject to a few seconds variation, the bearing of the reciprocal heading may have varied somewhat from the value we have used, and unquestionably the flight path was not as geometrically perfect as we have indicated. However, by giving full play to these variable factors, a variation in angle of only 3 or 4 degrees is introduced and the values we have used are well supported by the evidence and the flight path arrived at by the use of them appears to be the most probable one.

We have no evidence from which we can determine with reasonable accuracy the flight path of Trip 16 prior to the start of the procedure turn. It does seem clear, however, that in arriving at the point where the turn was started, Captain Fey did not follow the on course signal of the north leg. If he had done so, it is difficult to understand why he did not again intersect that

signal while on his reciprocal heading and change his heading so as to follow the on course back to the station. There appear to be only two possible explanations for a failure of this intersection. One of them is that while he was making his procedure turn, the leg suddenly swung well to the east. However, this does not seem possible in view of the fact that the recorder trace does not reflect any violent change in "N" to "A" ratios at this time, which change would necessarily have had to occur in order to cause such a rapid shift in the north leg. The only other explanation of the failure to intersect the leg would have been that the leg was somewhat to the east of Bountiful Peak at the time Captain Fey went out on it and that he began his procedure turn at a point south of Bountiful Peak so that he crashed as he approached the leg at a lower altitude than that at which he had left it. This is completely inconsistent with the evidence, however, because if this procedure had been followed, he could not have come within several miles of the visual signal of the Layton marker and the crash would have occurred several minutes before 4:41 when Captain Fey last spoke to Dispatcher Edson.

The conclusion that Captain Fey did not follow an on course signal away from the station in his let-down procedure is further supported by the fact that it would be extremely unlikely for a pilot, as experienced as Captain Fey in flying in the Salt Lake area, to have failed to detect the misalignment of the range either by taking loop bearings or by observing his compass heading. In addition, it is extremely doubtful that such a pilot would fly for $2\frac{1}{2}$ or 3 minutes directly toward the mountains after completing his timed turn unless his procedure turn had been begun in an "A twilight" area rather than an on course signal.

Having concluded that Captain Fey did not follow an on course signal on his way northbound from the station, the question necessarily arises as to what procedure he did follow in making the probable flight path already set forth. Before starting to let down, he had been flying on the west leg and from the evidence it appears that he was at a point east of the airport at about 4:26 apparently just prior to the time his descent was begun. He reported at 4:26 that due to static interference he could not hear the range. In view of the fact that he made this report near the range station, it is unlikely that he would have experienced any relief from static in the immediate vicinity of the station, particularly if he descended into the overcast at this point. That the trip was still experiencing heavy static after it had proceeded northward from the vicinity of Salt Lake is indicated by entries on the radio log of United's Salt Lake station which show that that station called Trip 16 at 4:31, 4:32, and 4:33, but received no answer. At these times the airplane must have been less than 15 miles from the station and therefore in a location where a high field strength existed. Also, evidence from the station log indicates that the ground station operator was not experiencing static sufficient to interfere with communications and from the flight recorder it appears that the transmitter aboard the airplane was not used during the period of 4:31 to 4:33, nor within several minutes of these times. Furthermore, there is every reason to believe that since Captain Fey was attempting to land at Salt Lake and would therefore desire all possible information concerning conditions at the Salt Lake Airport, he would be on the alert for any call from the Salt Lake station. It would appear from these considerations that the trip was experiencing heavy static from 4:31 a.m. to 4:33 a.m. Since Captain Fey could not hear the range station, it is probable

that he began his descent to the north without having positively fixed his position with respect to the station. He did not report over the station prior to beginning his descent and even though static might have interfered with such a report at the time he was actually over the station, in all probability, if he had known from his radio signals that he had been over the station, he would have reported his time over at the next contact.

After descending to the north from somewhere in the vicinity of the Salt Lake station and reaching an area in which the static interference was reduced, as is indicated by his 4:37 a.m. contact, the first signals he was able to distinguish clearly were, in all probability, "A" signals which indicated to him that he was to the west of the north leg and thus a substantial distance from the mountains. Possibly thinking that he had gone farther into the "A" quadrant than he had at first supposed, Captain Fey assumed easterly headings in an attempt to intersect the north leg, so that at the time the procedure turn was started, his average heading with respect to the Salt Lake range station had been 349 degrees magnetic. When he reached the proper altitude for the beginning of his procedure turn, he was probably receiving a "twilight A" signal which indicated to him that he was in close proximity to the leg. After assuming the reciprocal heading as a part of his procedure turn, he probably attributed the excessive length of time during which he maintained this heading to the fact that he had been farther over in the "A" quadrant when he began his turn than he had anticipated. If the circumstances prevailed as outlined above, the compass heading would not have given Captain Fey any indication that the range was functioning abnormally.

If it had been possible for Captain Fey to take accurate loop bearings, he certainly would have established the fact that his bearing from the station was approximately 349 degrees when, under the circumstances as set out above, he would have expected to find himself on a bearing of less than 332 degrees. However, it is probable under those circumstances that Captain Fey did not take bearings. Company regulations require pilots, while making a let-down-through procedure at Salt Lake City, to take loop bearings "to check the alignment of the north leg" immediately after "getting on course and establishing a heading northbound" and "at completion of procedure turn to return to station". Since this procedure is designed as a check on the alignment of the north leg, and since Captain Fey was not flying on the north leg, he might not have taken loop bearings while in a quadrant but might have waited to do so until he had established himself on the north leg. However, even if he had attempted to take loop bearings, there is a possibility that due to terrain effects and the effects of static or turbulence, he was unable to obtain accurate bearings. Certainly it would have been difficult, if not impossible, for him to have taken loop bearings while in the vicinity of the station because it is clear that he was encountering heavy static there, and while the static was reduced later, it is possible that the turbulence prevailing in that area would affect his ability to take bearings. The weather conditions existing near Salt Lake City while he was attempting to work his let-down procedure were such that considerable turbulence could be expected. In view of the established procedure previously discussed and of the possibility of Captain Fey's having encountered terrain effects, severe static, and turbulence, he might reasonably have failed to determine his position, and thus the misalignment of the north leg of the range, through the taking of bearings.

However, Captain Fey could have discovered the malfunctioning of the Salt Lake radio range if he had refrained from beginning his let-down procedure until he had definitely established his position with respect to the north leg. As is indicated by his radio contacts, he was apparently prevented from doing this by the existence of static in the area surrounding the range station. Under those circumstances, proper radio range technique would have required him to delay his descent until he could locate the north leg definitely or that he proceed to another airport. Moreover, after having found himself north of the station and receiving an "A" signal, as he undoubtedly was, Captain Fey should not have continued his descent while seeking the north leg, but should have climbed to a safe altitude and definitely located himself with respect to that leg or, if it were impossible to so locate himself, he should have gone to another airport.

While Captain Fey was working his let-down procedure he might have discovered the malfunctioning of the Salt Lake range by tuning in the Plymouth range. If this had been done, in all probability the "A" signal, which he would have received from the Plymouth range, would have warned him that he was well to the east of the normal on course signal of the Salt Lake range rather than to the west as he must have thought. It appears, however, from testimony at the hearing, that this practice is not prescribed and is not usually followed by pilots making let-down-through procedures. The on course signal of the Plymouth range was said to be so wide in the vicinity of Salt Lake that it does not constitute an adequate check of the north leg of the Salt Lake range. This is undoubtedly true for small misalignments, but an extensive misalignment of the north leg of the Salt Lake range, such as occurred on the

morning of November 4, could be discovered by checking it against the south leg of the Plymouth range.

The relative alignments of the east leg of the Wendover range and the west leg of the Salt Lake range suggest another means by which Captain Fey might have detected the abnormal functioning of the Salt Lake range. An extension of the on course of the east leg of the Wendover range would place a flight following this course in the normal "N" quadrant of the Salt Lake range. Assuming that the west leg of the Salt Lake range swung south, the extension of the east leg of the Wendover range would probably lead a flight following it into a "twilight A" area of the Salt Lake range instead of the usual "N". Since the east leg of the Wendover range normally leads into an "N" quadrant, it is probable that for this reason the natural practice is for a flight to go north before tuning in the Salt Lake range in order to be more nearly on course. If Captain Fey had done this, he might well have thought, as he tuned in the Salt Lake range, that he had proceeded too far to the north of the on course signal in seeking to intersect it and had gone into the normal "twilight A" signal. Therefore, he may reasonably have believed that he had made a slight error rather than that the Salt Lake range was misaligned. To correct this supposed error, Captain Fey might have made a change in heading toward the south, designed merely to result in an intersection with the west leg close to the Salt Lake station. Such an action would explain why he failed to discover the misalignment of the west leg.

During the 45 minutes Captain Fey was in the vicinity of the Salt Lake station prior to the time he went out on the north leg for his approach, it is unlikely that he was able, due to static conditions which are reported in

the radio log, to make any observations which would indicate to him the misalignment of the Salt Lake range.

All of the procedures followed by Captain Fey while flying in the Salt Lake area and his apparent failure to become at all suspicious of the Salt Lake range when its operation was decidedly abnormal, indicate generally a complete confidence on his part in the functioning of the range. That he probably proceeded into the station from the west in the "twilight A" area rather than definitely locating the west leg; that he was willing to begin a let-down procedure without definitely locating the north leg and to continue this procedure when he found himself in an "A" quadrant; and that he was willing to proceed for 3 minutes directly toward the mountains in search of the north leg in his procedure turn indicate his trust in the correct performance of the radio range.

Captain Fey's confidence in the range was also apparently shared by others. Most of the pilots who testified at the hearing indicated that they relied implicitly on the radio range. When asked how long they would maintain a reciprocal heading in a procedure turn in search of the north leg, they asserted that they would continue to seek the north leg until they found it. Company officials also indicated their reliance on the range. During modernization they established the airport localizer, already described, with which the pilots could monitor the north leg of the range during a let-down procedure. In September, 1940, when this localizer was removed at the request of the United States Army, no attempt was made to institute additional monitoring procedures to compensate for the loss of this facility. In addition, Mr. Hodgson, Flight Supervisor, Western Operating Division of United, states that

they had instructed dispatchers to monitor the north leg of the Salt Lake range from time to time during their watches but that recently that practice had not been followed religiously, apparently with the tacit consent of those supervising dispatching. In fact, Dispatcher Edson stated that he had not monitored the Salt Lake range at any time during his watch.

During his testimony, Mr. Hodgson indicated that this confidence in the Salt Lake City radio range in spite of its history of instability had resulted, in large part, from the receipt of a letter, dated June 26, 1940, from the then Administrator in the Civil Aeronautics Authority as formerly constituted. This letter was addressed to David L. Behncke, President of the Air Line Pilots Association, and had been referred by him to Captain Christenson, apparently as a representative of the pilots operating into and out of Salt Lake City. This letter described a report which had been made a short time before on the functioning of the monitor station on the north course of the Salt Lake range and stated in part as follows:

> ". . . We now have at hand, and have analyzed, complete records for the entire month of April [1940] which have been taken at the Salt Lake station by automatic recorder supplemented by visual and aural observations made by the operating staff.
>
> "Briefly, the records show that the maximum deviation from the established alignment of the monitored course for the 30-day period was not in excess of 2.0 degrees, and that deviations of this order were transitory and of short duration. It is considered that the conditions encountered during April are representative of those which may be expected throughout the year. Furthermore, our experience with vertical radiator type ranges in general shows that random changes in course alignment of more than a degree or so is extremely rare.
>
> "In the development of the radio range to its present state of efficiency, a great deal of effort has been directed toward designing inherent stability into the equipment. This has been successfully accomplished to the point that course shifts do not

occur when the course alignment itself is favorable. Under unfavorable conditions when courses must be bent and squeezed to serve several airways, a certain degree of instability must be introduced."

Mr. Hodgson also mentioned in this connection a letter, dated February 15, 1939, which had been received from the Bureau of Federal Airways under the then Administrator in the Civil Aeronautics Authority. It includes the following statement:

"We appreciate your cooperation in substantiating our claim that the new Salt Lake radio station is equally as usable as the old station before modernization. The monitoring of all of our radio stations is being carried out as efficiently as the relative locations of adjoining stations will permit. At Salt Lake we are particularly fortunate with respect to the north course which is directed on Plymouth, Utah, where as little as 1½ degree change in course alignment can be noted immediately and reported to the Salt Lake station."

Mr. Hodgson testified that having been advised that the range had functioned with but slight deviation during the month of April, 1940, and being aware of the monitoring system which had been established for the Salt Lake City radio range, particularly the north leg, he and his associates had confidence in the monitoring system and believed that in the event the range did deviate from normal alignment, they would be immediately advised of the deviation through monitor observations.

While it appears from the record that United might well have had cause to mistrust the range for some time after its modernization, nevertheless, because of the establishment of the monitoring system, particularly that provided for the north leg, and the correspondence set out above, United had no reason to mistrust this radio range and its monitoring system more than any other range at the time of the accident.

Absolute dependence should not be placed upon any radio range in the present state of the art of radio range transmission, particularly in the case of a range located in a mountainous area where malfunctioning is likel to have disastrous results. However, the let-down procedure prescribed by United and approved by the Civil Aeronautics Administration indicates an ap preciation of these facts. United was not required, in addition to the saf guards provided in the let-down procedure, to establish its own system for monitoring the Salt Lake range. That responsibility is one which must be assumed by the Civil Aeronautics Administration as an incident to the estab lishment and operation of the range.

It also appears that many pilots, like the management of United, did nc especially distrust this range as an aid to air navigation. However, confi dence on the part of a pilot in a radio range is no excuse for deviation fro well established radio range technique which requires the use of all avail able facilities. Safety of operation under conditions of low ceiling and visibility when a radio range must be used depends upon all concerned perfor ing each and every duty with the greatest of care. This was not done on the morning of November 4, 1940.

CONCLUSION

FINDINGS

Upon all of the evidence available to the Board at this time, we find that the probable facts relating to the accident involving aircraft NC 16086 which occurred near Centerville, Utah, on November 4, 1940, are as follows:

(1) The accident, which occurred at approximately 4:42 a.m., November 4, 1940, to United Air Lines Trip 16 of November 3, resulted in major damage to aircraft NC 16086 and the death of the seven passengers and the crew of three.

(2) At the time of the accident United held a currently effective certificate of public convenience and necessity and an air carrier operating certificate authorizing it to conduct the flight.

(3) Captain Fey and First Officer Sandegren were physically qualified, and held proper certificates of competency, to operate as air carrier pilots over the route between Oakland, San Francisco, and Salt Lake City.

(4) Aircraft NC 16086 was currently certificated as airworthy at the time of the accident and had been maintained in accordance with company procedure and applicable maintenance competency letters.

(5) Trip 16 was cleared in accordance with the proper procedure from Oakland, California, to Reno, Nevada, with stops at San Francisco and Sacramento, and from Reno, Nevada, to Salt Lake City, Utah, with a stop at Elko, Nevada.

(6) At the time of departure from Oakland, California, and through all intermediate stops between Oakland and Salt Lake City, the gross weight of the airplane did not exceed the approved gross weight, and its load was

properly distributed with reference to the location of the center of gravity.

(7) At the time of departure from Elko, Nevada, for Salt Lake City, Utah, the airplane carried sufficient fuel to permit flight at normal cruising power to Salt Lake City, and thereafter for about five hours, thus making available to Captain Fey a choice between a number of alternate airports.

(8) Trip 16 first arrived over the Salt Lake radio range station at 3:40 and remained in that vicinity at an altitude of approximately 14,000 feet until shortly after 4:26, when Captain Fey began a let-down-through procedure.

(9) During the period Trip 16 operated in the vicinity of Salt Lake City, two-way radio communication between United's ground station at Salt Lake and the pilots of Trip 16 was made impossible for substantial periods of time due to severe static, and at times such static interfered with reception of radio range signals by the pilots of Trip 16.

(10) During the period Trip 16 operated in the vicinity of Salt Lake City the weather conditions at the Salt Lake City airport were extremely variable with ceilings ranging from 400 feet to 2700 feet and visibility ranging from 5/8 of a mile to 9 miles with light to moderate snow flurries and with variable northwesterly surface winds ranging from 3 to 7 miles per hour.

(11) The weather conditions existing at the Salt Lake City airport, as described in Finding (10), coincided closely with those forecast by the United States Weather Bureau and United's meteorologist.

(12) Shortly after 4:26, Captain Fey proceeded northward from the neighborhood of Salt Lake City and began his descent.

(13) Captain Fey began his descent during a period of time when, because of heavy static, he was unable to hear radio range signals and thus without definitely locating his position with respect to the normal north leg of the Salt Lake City radio range; and after he had emerged from the area of severe static proceeded north receiving "A" or "A twilight" signals.

(14) In so doing, he failed to comply with well-established range procedures designed to permit the execution of let-down-through procedures with maximum safety.

(15) Captain Fey began a standard procedure turn at a point which bears approximately 349 degrees magnetic from the Salt Lake City station or 17 degrees east of the normal position of the north leg of the Salt Lake City range.

(16) He assumed his reciprocal heading at a point near Kaysville, Utah, at which time he was receiving the visual indication of the Layton marker and proceeded on that heading for not more than three minutes until the airplane struck the side of Bountiful Mountain.

(17) At the time of impact, Trip 16 had fuel on board for about four hours of flight at normal cruising power, more than sufficient for the trip to have returned to Elko.

(18) No structural failure, mechanical failure, or malfunctioning of any part of the airplane or its equipment occurred prior to the impact.

(19) During the time Trip 16 was operating in the vicinity of Salt Lake City and for a substantial period prior thereto, the Salt Lake radio range

was functioning abnormally; and, during the period between 4:40 and 4:50, the north course had swung so far to the east as to destroy its usefulness for purposes of let-down-through procedure.

(20) The malfunctioning of the Salt Lake range resulted from the effect of atmospheric conditions upon some defective component of the range equipment.

(21) The monitoring system provided by the Civil Aeronautics Administration to detect any malfunctioning of the Salt Lake range consists of five receivers: one at Tintic, south of Salt Lake City; one at Wendover, west of Salt Lake City; one at Plymouth, north of Salt Lake City; one in the southwest quadrant of the Salt Lake range at the Salt Lake Communications Station; and one located on the north leg of the Salt Lake range and operated by remote control from the Salt Lake Communications Station.

(22) The Salt Lake radio range was malfunctioning to such an extent during the early morning of November 4, 1940, that the monitoring operators at Salt Lake City, Plymouth, and Tintic, notwithstanding intermittent heavy static, could, by the exercise of reasonable diligence, have detected such malfunctioning in time to have permitted the issuance of a general warning prior to the accident since the United ground station was able to contact Captain Fey as late as 4:41 a.m.

(23) The malfunctioning of the Salt Lake City range was not detected by the monitoring operators at Salt Lake City, Plymouth, and Tintic, until 5:37, 6:46, and 7:03 a.m. respectively.

PROBABLE CAUSE

On the basis of the foregoing findings of fact and upon all of the evidence available at this time, we find that the probable cause of the accident to aircraft NC 16086 (United's Trip 16) on November 4, 1940, was the malfunctioning of the Salt Lake radio range and that substantial contributing factors to the accident were:

(1) The failure of the communications operators at Tintic, Plymouth, and Salt Lake City, Utah, whose duty it was to monitor the range, to detect its malfunctioning and immediately notify those concerned; and

(2) The failure of the pilot of Trip 16 to follow to the fullest extent established radio range technique in accordance with the requirements of the procedure established by United and approved by the Civil Aeronautics Administration.

RECOMMENDATIONS

We present the following recommendations pertaining to safety in air navigation with respect to most of which we understand the Administrator of Civil Aeronautics to have already initiated action.

Radio Range Transmission

We recommend that a study be made by the Civil Aeronautics Administration of the components of the Salt Lake City range in order to determine the reason for the demonstrated effects of particular atmospheric conditions upon the functioning of the range; and that the knowledge gained from such study be used to improve the stability of the Salt Lake range and any other range where similar conditions exist.

Radio Range Monitoring System

We recommend that a thorough study be made by the Civil Aeronautics Administration of the existing system for monitoring radio ranges to the end that any malfunctioning of a range will be immediately detected, reported, and the necessary warnings issued. In connection with this study, consideration should be given to the elimination of the present complete dependence upon aural monitoring by providing a substantially reliable visual indicator for monitoring operators. For example, automatic recorders like the one presently installed in the Salt Lake City range station might be installed in communications stations in order that monitoring operators could actually see the signal ratios being received. The possibility of developing an automatic device which would give a clear and immediate warning of the malfunctioning of the range should also be considered. The location of present monitoring stations should be studied with a view to determining whether the location of a particular station with respect to the on course signals of the range monitored is such as to permit effective monitoring. For example, if a particular monitor station is far from the on course signal of the range being monitored and thus is unable to detect substantial deviations in course alignment, it might be found wiser to relieve that station of its monitoring duties and substitute for it a remote receiver, located near an on course signal, similar to the remote monitor system established at Salt Lake City. Moreover, the effectiveness of aural monitoring might be improved if a careful investigation were made of the monitoring equipment installation and the manner in which the monitoring operators use that equipment.

Civil Airways Communications Employees

We recommend that the procedures now established for the training and periodic examination of communications personnel be reviewed, with the objective of securing the maximum possible assurance that such personnel will be properly qualified to undertake and perform efficiently the heavy responsibilities which are imposed upon them. Specifically, we suggest that the adequacy of the training procedure used in familiarizing communications employees with their duties and responsibilities should be re-examined, and that special efforts made to make certain that all such employees are acquainted with the practical relation of their work to the safety of aircraft operation.

We further recommend that efforts be renewed to secure the necessary authority and funds from appropriate governmental agencies to increase the compensation of communications employees, to avoid the present excessive turnover among such employees and to make it possible to secure and keep personnel of high calibre.

Ultra High Frequency Radio Ranges

We recommend that the work now being carried on by the Civil Aeronautics Administration of developing and service-testing ultra high frequency radio ranges be hastened to the greatest extent possible, particularly with respect to the determination of the value of such ranges in mountainous terrain where adequate reception of radio range signals is especially important.

Standardization of Let-Down Procedure

We recommend that the Civil Aeronautics Administration standardize the let-down procedures for each airport authorized for air carrier operation to the end that such procedure will be the same for all aircraft, both civil and

military, to the greatest extent permitted by variations in the inherent characteristics of the aircraft employed and their equipment.

We further recommend that when this is accomplished, the Administrator of Civil Aeronautics so report to the Board in order that we may issue the necessary regulations requiring the use of such standard procedures.

Approval and Certification of Air Navigation Aids owned or operated by Agencies other than the Civil Aeronautics Administration

We recommend that the Civil Aeronautics Administration study the advisability of inspecting, rating, and certificating air navigation aids not owned or operated by that Administration, such as the airport localizer at Salt Lake City, in order that assurance may be had that the quality of the equipment, installation, maintenance, and operation of such facilities meet the minimum standards required for safety of aircraft operation.

POSSIBLE REGULATORY ACTION

The Civil Aeronautics Board has initiated a study of certain provisions of the Civil Air Regulations in order to determine whether there is need for amending the present regulations or promulgating new regulations by reason of facts developed during the course of our investigation of this accident.

Radio Range Reception

Section 61.7720 of the Civil Air Regulations provides as follows:

> "61.7720 Communications failure. In the event of inability to maintain two-way communication with the appropriate communications station or in the event that the pilot does not receive radio range signals sufficient to permit his maintaining an instrument flight on course (see sec. 60.36) to any point cleared to or otherwise specified in an approved flight plan, one of the following procedures shall be observed.

"61.77200 (a) Contact flight. The aircraft may proceed provided that the flight may be made in accordance with contact flight rules as provided for in sec. 60.4.

"61.77201 (b) Landing. Landing shall be made at the nearest suitable airport at which favorable weather conditions exist and where no airway traffic control station is located.

"61.77202 (c) Emergency procedure. In the event weather conditions do not permit the procedures provided for in section 61.77200 or section 61.77201, the pilot shall proceed according to his approved flight plan, including any amending instructions issued and acknowledged en route, with particular attention to maintaining his last acknowledged assigned altitude until the approach time last authorized for him, after which landing may be made. Normal traffic will resume as soon as the aircraft has landed or been accounted for, but, in any event, in not more than 30 minutes after the approach time last authorized for the aircraft."

While a literal reading of this regulation would appear to prohibit the continuance of a let-down procedure, except under emergency conditions, in the event that reception of range signals becomes impossible by reason of heavy static, it is possible that the regulation needs revision in order that such construction may be perfectly clear. The Board is studying the possibility of issuing a new regulation or clarifying the above-quoted one so as clearly to prohibit, except under emergency conditions, the continuance of a let-down procedure through instrument flying conditions whenever radio range reception is such that the range signals cannot be received clearly and continuously.

Dispatch Procedure

Consideration is being given to the promulgation of a regulation which would authorize a dispatcher in charge of a flight to direct it to an alternate or take other indicated action in the event that his judgment leads him to believe that the flight cannot proceed with safety in accordance with its original clearance. This power of the dispatcher would be subject to the

authority which is vested in the pilot to depart from regulation or from company policy when, in his judgment, an emergency then confronting him requires it.

Let-Down-Through Procedure

The Board is also giving consideration to the promulgation of a general regulation requiring pilots during let-down-through procedures to attempt to determine whether the radio range legs they are using are properly aligned by taking bearings on the station either continuously or at brief intervals during the execution of such procedure and by the use of any other means available to them.

THE CIVIL AERONAUTICS BOARD:

/s/ Harllee Branch
Harllee Branch, Chairman

/s/ Edward P. Warner
Edward P. Warner, Vice-Chairman

/s/ Oswald Ryan
Oswald Ryan, Member

/s/ G. Grant Mason, Jr.
G. Grant Mason, Jr., Member

/s/ George P. Baker
George P. Baker, Member

① CAPTAIN

② FIRST OFFICER

③ RIGHT OIL COOLER

④ RIGHT OIL COOLER COWL

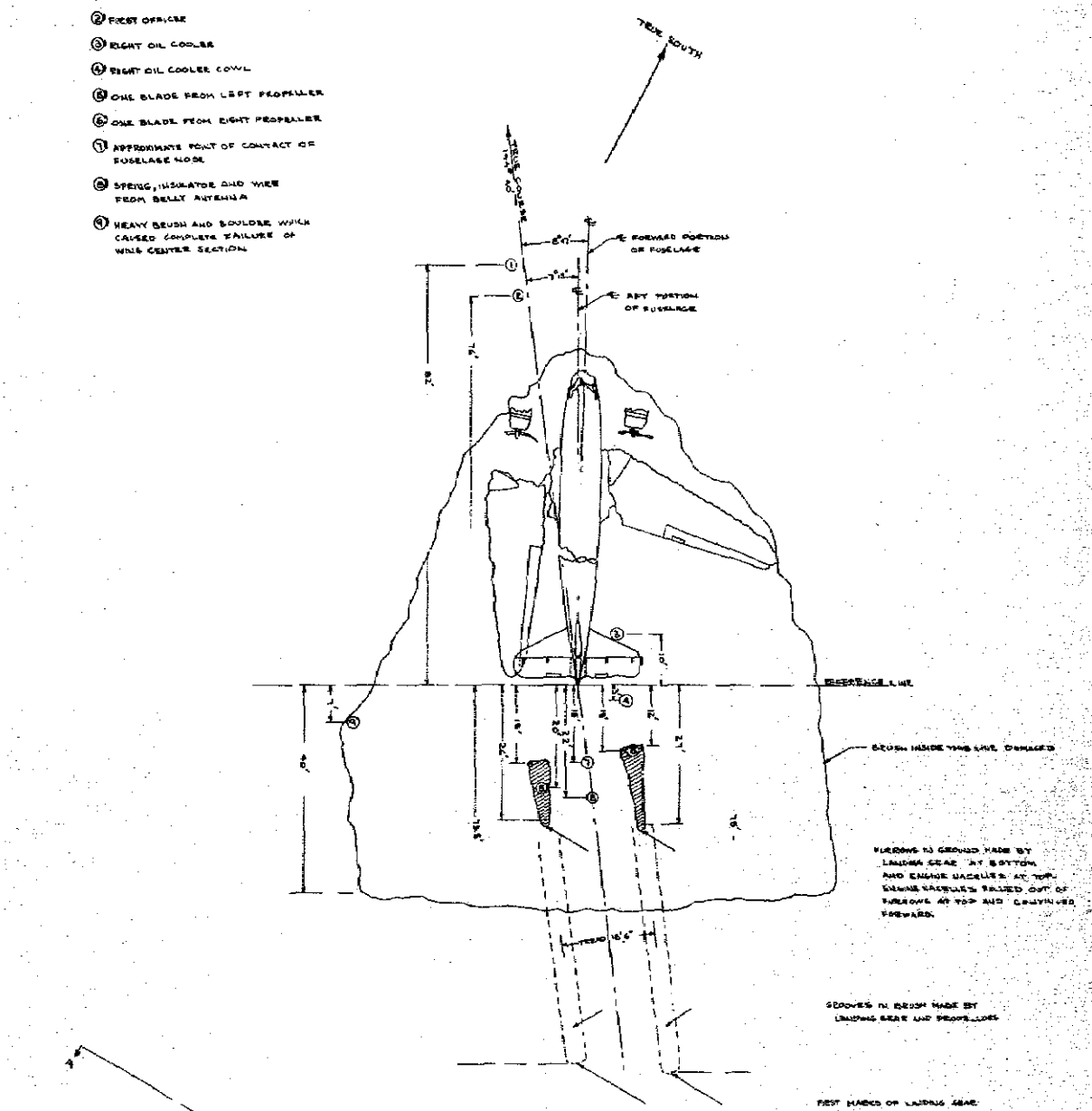
⑤ ONE BLADE FROM LEFT PROPELLER

⑥ ONE BLADE FROM RIGHT PROPELLER

⑦ APPROXIMATE POINT OF CONTACT OF FUSELAGE NOSE

⑧ SPRING, INSULATOR AND WIRE FROM BELLY ANTENNA

⑨ HEAVY BRUSH AND BOULDER WHICH CAUSED COMPLETE FAILURE OF WING CENTER SECTION

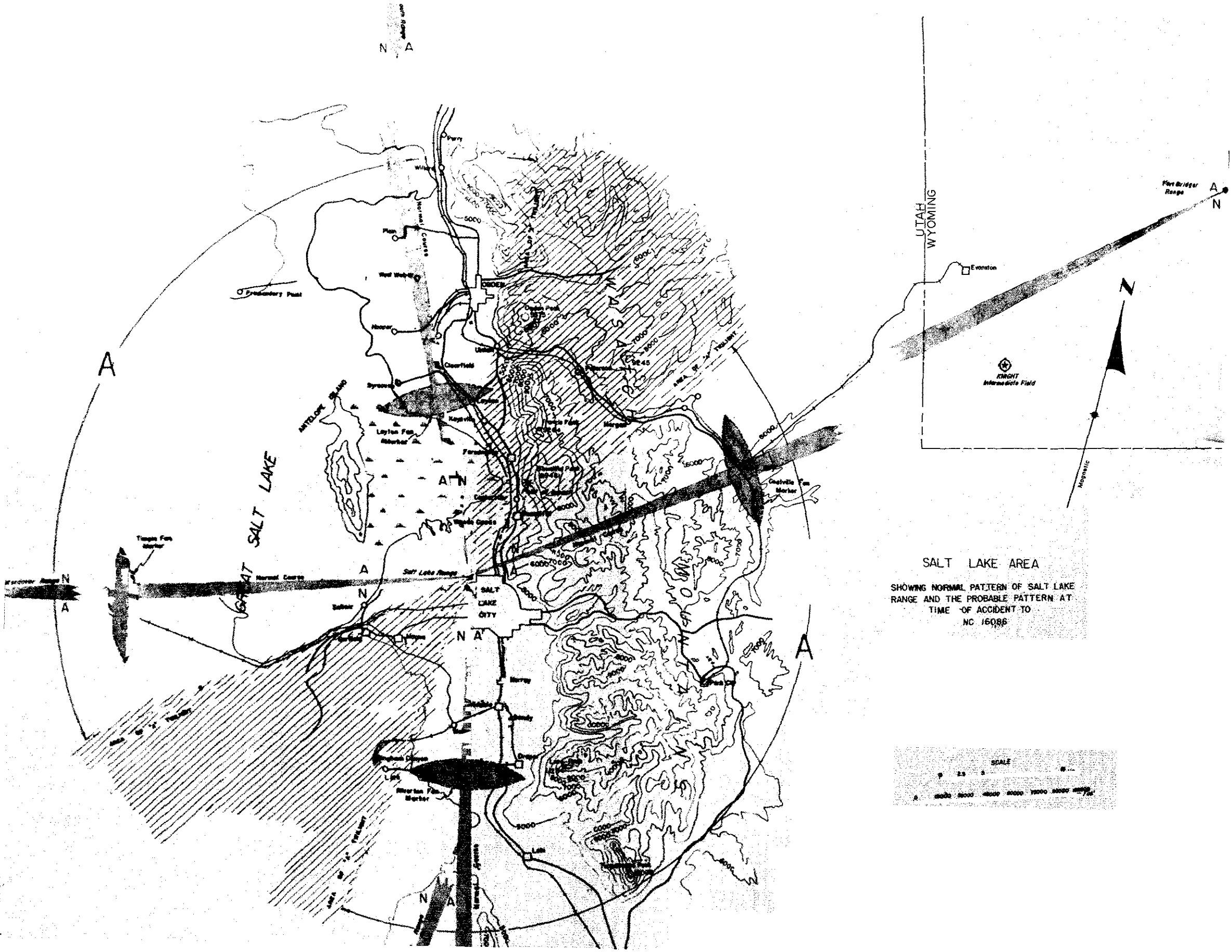


VIEW A-A
ALL DIMENSIONS PARALLEL TO GROUND

SKETCH OF ACCIDENT TO
U.A.L. AIRPLANE NC-16086
NEAR SALT LAKE CITY, UTAH NOVEMBER 4, 1940

UNITED AIR LINES TRANSPORT CORPORATION
PREPARED BY: W. C. Mentzer 11/5/40

CAA-420



SALT LAKE AREA

SHOWING NORMAL PATTERN OF SALT LAKE RANGE AND THE PROBABLE PATTERN AT TIME OF ACCIDENT TO NC 16086