NATIONAL TRANSPORTATION SAFETY BOARD

AIRCRAFT ACCIDENT REPORT

NORTHEAST AIRLINES, INC.
FAIRCHILD HILLER FH-227C, N380NE
NEAR HANOVER, NEW HAMPSHIRE
OCTOBER 25, 1968

NATIONAL TRANSPORTATION SAFETY BOARD
Bureau of Aviation Safety
Washington, D. C. 20591

SA-408 FILE NO. 1-0024

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DEPARTMENT OF TRANSPORTATION
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SYNOPSIS

A Northeast Airlines, Inc., Fairchild Hiller FH-227C, N380NE, crashed at approximately 1817 e.d.t., October 25, 1968, near Hanover, New Hampshire. The aircraft, Flight 946, had been cleared for an approach to the Lebanon Regional Airport, West Lebanon, New Hampshire, at 1808. The aircraft crashed 3.8 nautical miles northeast of the VOR station at an altitude of approximately 2,237 feet m.s.l. At this point in a standard instrument approach, the aircraft should have been no lower than 2,800 feet m.s.l. Witnesses on the ground and survivors of the accident reported that the mountaintop was shrouded in cloud or fog at the time of the accident.

Of the 39 passengers and three crewmembers aboard the aircraft, nine passengers and one crewmember, the stewardess, survived the accident. The aircraft was destroyed by impact and postimpact fire.

The Board determines that the probable cause of this accident was the premature initiation of a descent towards the Minimum Descent Altitude, based on navigational instrument indications of an impending station passage in an area of course roughness. The crew was not able to determine accurately its position at this time because they had performed a nonstandard instrument approach and there were no supplemental navigational aids available for their use.

As a result of the investigation of this accident, the Board forwarded recommendations to the Federal Aviation Administration concerning the operating characteristics of the Lebanon VOR and their relationship with airborne navigation receivers and instrumentation.

The Administrator indicated he had taken or planned actions which were basically in accord with the intent of the Board's recommendations.

1. INVESTIGATION

1.1 History of the Flight

A Northeast Airlines, Inc., Fairchild Hiller FH-227C, N380NE, crashed at approximately 1817 e.d.t., 1/ October 25, 1968, near Hanover, New Hampshire.

The aircraft was being operated in scheduled domestic passenger service as Flight 946 from Boston, Massachusetts, to Montpelier, Vermont, with an en route stop at Lebanon, New Hampshire.

Of the 39 passengers and three crewmembers aboard the aircraft, nine passengers and one crewmember, the stewardess, survived the accident. The aircraft was destroyed by impact and postimpact fire.

Flight 946 departed from Boston at 1742 and was cleared to Lebanon, New Hampshire. The flight was cleared to proceed in accordance with a flight plan which called for a cruising altitude of 8,000 feet m.s.l. and an estimated time en route of 33 minutes at an estimated airspeed of 245 knots. The original scheduled departure time of 1655 was not met due to a delay in getting the aircraft to the gate for passenger loading.

The flight was reported to be normal and routine, and was observed on radar, until it reached a point reported by the radar controller to be 2.5 nautical miles (NM) south-southeast of the Lebanon VOR. The flight was cleared, at 1808, for an approach to the Lebanon Airport to cruise at 5,000 feet and report leaving 6,000 feet. At 1810:45, the controller advised the crew that radar service had been terminated and the flight was cleared to contact the Lebanon Flight Service Station.

At 1811, the crew 2/ contacted the Lebanon Flight Service Station, reported that they were "SIA" (Standard Instrument Approach), and requested the Lebanon weather. They were advised that the Lebanon weather was an estimated ceiling of 2,000 feet overcast; visibility was 10 miles; there were breaks in the overcast; the altimeter setting was 29.55; and the wind was calm. They were also advised that Runway two five was in use and there was no other reported traffic. The crew acknowledged this information and there were no further recorded transmissions from the crew.

1/ All times herein are eastern daylight, expressed on the 24-hour clock, unless otherwise noted.

2/ All voice communications from the flight were identified as having been made by the first officer.

Two surviving passengers stated that they observed the ground and clouds shortly before the first impact. The remainder of the survivors, including the stewardess, either did not look out or could not, because of their positions, see out the cabin windows. One passenger stated that ". . . As we approached Lebanon, the cloud cover had been gradually thinning and before we began our descent, ground had been visible in patches between the clouds for several minutes. On the early part of the descent, the ground continued to be visible. After the turn to the final approach, with the wheels down, we were flying between two nearly vertical cloud banks in the gentle smooth descent which I described in my prior statement. There was no cloud directly below us and the level of the base of the clouds at this point was slightly below the level of the aircraft so that the ground was clearly visible under the cloud to a substantial distance ahead and to the side. I was looking out and observed a pond and that the terrain had very few roads and no houses.

"As we continued our descent, I continued to observe and watched the slope of the ground rising ahead of us at about twenty degrees in the direction of flight. We were so near the ground at this time that I could clearly see the individual trees which appeared fist size and began to look ahead in the direction of flight for airport approach lights as I assumed that we must be very near the touch down point. I observed the rising ground until I suddenly lost all visibility as we had entered a cloud.

"After a few seconds in the cloud, I felt the initial impact which was gentle and seemed no more severe than a normal touch down. I do not remember any severe impact.

"There was no change in course, speed, bank angle, descent angle or engine sound from the time the aircraft completed its turn and started its gradual descent until impact. . . ."

Most of the survivors described the impact as "smooth," "not a crash but more as settling," "a rough landing," etc.

A ground witness, south of the accident site, heard the aircraft approaching. When he looked toward the sound, he saw the "slightly fog covered mountain," but did not see the aircraft until the landing lights appeared in the fog. A few seconds later, the aircraft crashed into the mountain. He reported the accident to the Federal Aviation Administration (FAA) Flight Service Station (FSS) at approximately 1836. Other ground witnesses stated that shortly after the accident, the mountaintop was clearly visible. The accident occurred approximately 1 minute before the end of Civil twilight.

The accident site was located at longitude 72°8'.7 west and latitude 43°43'.3 north, at an elevation of approximately 2,237 feet m.s.l. This location was approximately 3.8 NM northeast of the Lebanon VOR and 8.2 NM northeast of the Lebanon Airport.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	2	30	0
Nonfatal	1	9	0
None	0	0	

1.3 Damage to Aircraft

The aircraft was destroyed by impact and postimpact fire.

1.4 Other Damage

None other than destruction to trees in the accident area.

1.5 Crew Information

The crew was properly certificated and qualified in accordance with the existing FAA regulations. (For details see Appendix B.)

1.6 Aircraft Information

According to the company records, the aircraft was airworthy at the time of departure from Boston and it had been maintained in accordance with the applicable FAA and company regulations. The weight and balance were calculated to have been within limits at both the takeoff and the time of the accident.

The aircraft was fueled with aviation kerosene. (For detailed aircraft information, see Appendix C.)

1.7 Meteorological Information

The accident location was behind a cold front in an area where the weather was characterized by considerable low cloudiness and good surface visibility.

The Lebanon 1757 surface weather observation indicated an estimated overcast ceiling at 2,000 feet, 3/ with breaks in the overcast.

3/ The airport elevation was 580 feet m.s.l.

The surface visibility was reported to be 10 miles. Another observation taken at 1840 reported an estimated ceiling of 2,000 feet and the surface visibility was still 10 miles. In both observations, the altimeter setting was 29.55.

A pilot who departed from Lebanon at 1719 reported a ceiling of 2,800 feet m.s.l. approximately 5 miles southeast of the airport.

Ground witnesses in the accident area reported that the top of the mountain was intermittently shrouded in cloud or fog. Otherwise, their statements indicated that the weather in the accident area was the same as that reported by the Flight Service Station communicator.

A pilot, who flew over the accident area approximately 45 minutes after the accident occurred, reported that a clearing trend was prominent to the north and the sky cover was breaking into large cloud patches. He believed that the cloud bases around the accident site were high because he saw no reflected light from the postcrash fire.

The forecast for Lebanon was prepared by the Weather Bureau Forecast Center at Boston and read in part:

> "1700-2000, 1,200 feet broken, 2,500 feet overcast, visibility 7 miles, broken variable to scattered, occasionally ceiling 400 feet overcast, visibility 2 miles, light rain showers, fog."

The aviation area forecast for the area that included the accident site called in part for:

> ". . .200-500 feet overcast variable to broken, 1,000 feet overcast, visibility 1-3 miles, fog, top 12,000 feet, intermittent drizzle and occasional rain. Hilltops generally obscured . . . condition improving by 1900 to 1,000 feet broken variable to scattered, 2,500 feet overcast, visibility 7 miles, occasionally 1,000 feet overcast, visibility 4 miles light rain showers, fog. . . . Freezing level near 4,000 feet north and west portions of northeastern New York sloping up to 10,000 feet . . . southeastern New Hampshire . . . light icing in clouds above freezing level, occasionally moderate Maine and mountainous sections elsewhere. Turbulence . . . occasional moderate turbulence below 12,000 feet."

The 2000 Albany, New York, and Portland, Maine, radiosonde accents were reviewed and recorded (below 9,000 feet m.s.l.) the following:

> ". . . Albany . . . conditionally unstable air below approximately 2,800 feet m.s.l. stable air from near 2,800 to near 4,600 feet m.s.l. and above approximately 8,600 feet m.s.l. with unconditionally unstable air from near 4,600 to near 8,600 feet m.s.l. generally moist air below 8,600 feet m.s.l., dry air above 8,600 feet m.s.l., and the freezing level was at 5,200 feet m.s.l."
> ". . . Portland . . . conditionally unstable air below approximately 2,600 feet m.s.l., stable air from near 2,600 to near 5,800 feet m.s.l. and above 8,300 feet m.s.l., moist air below approximately 3,000 feet m.s.l. and in a shallow layer near 8,300 feet m.s.l. with relatively dry air at other levels and the freezing level was at 8,300 feet m.s.l."

The winds aloft observation for the same stations at the same times were in part:

Height (Feet) m.s.l.	Direction (Degrees True)	Velocity (Knots)
	ALBANY	
Surface	050°	4
1,000	290°	9
2,000	290°	20
3,000	285°	21
4,000	280°	21
5,000	260°	13
6,000	240°	14
7,000	230°	17
8,000	220°	24
9,000		
	PORTLAND	
Surface	205°	4
1,000	225°	14
2,000	270°	16
3,000	250°	17
4,000	220°	23
6,000	210°	33
7,000	210°	37
8,000	210°	41
9,000	210°	48

The Northeast Airlines dispatcher, on duty at the time the crew of Flight 946 left Boston, stated that the crew did not receive a weather briefing from him. However, copies of the 1600 and 1700 weather reports, as well as applicable forecasts and winds aloft reports, were given to the crew prior to their departure from Boston.

The accident occurred in clouds approximately 1 minute before the end of official Civil twilight.

1.8 Aids to Navigation

The only navigational aid available for an instrument approach to Lebanon was a VOR facility. This facility transmitted on a frequency of 113.7 MHz and was in operation without any reported discrepancies at the time of the accident.

The standard daytime instrument approach, 4/ published and in effect at the time of the accident, required an aircraft to proceed outbound from the VOR station on the 066° radial. The procedure turn was to be made north of the outbound radial and was to be completed within 10 NM of the station. The minimum altitude until inbound from the procedure turn was 4,200 feet m.s.l. Once established on the inbound heading of 246° and within 10 NM of the VOR, the aircraft could descend to an altitude no lower than 2,800 feet m.s.l. until station passage at the VOR occurred. After station passage, the aircraft could descend no lower than 1,880 feet m.s.l. until becoming VFR or the time to fly to the airport had been flown. The minimum visibility for this approach was 2 miles.

Straight-in landings were not authorized from the prescribed instrument approach to the Lebanon Airport. Only circling approaches to land were authorized.

The FSS Facility Log indicated that the No. 2 VOR transmitter was in use and three scheduled and routine monitor checks had shown that the facility was operating normally. There were no monitor alarms reported on the date of the accident.

The VOR had been given a routine ground check and certified for use 5 hours before the accident.

Shortly after the accident, the maintenance technicians assigned to the facility again checked the transmitter in use. They found the equipment operating within the established parameters.

4/ See Appendix G.

FAA flight checks of the facility were conducted at 2330, October 25, and in the early morning of October 26, 1968. These checks indicated that the VOR was operating within the established tolerances.

The instrument approach procedures in effect at Lebanon from the commissioning date to the date of the accident were reviewed. A number of minor changes had been made to the approach during this period. In 1961, the minimum safe altitude for the procedure turn, within 10 NM of the VOR on the south side of the approach radial, was 4,500 feet m.s.l., and the minimum altitude over the VOR station on the final approach was 3,300 feet m.s.l. In January 1966, the procedure turn was moved to the north side of the approach radial and the minimum altitude for the turn was established as 4,200 feet m.s.l. At the same time, the minimum altitude over the VOR on the final approach was reduced to 2,800 feet m.s.l. These latter minima were in effect on the date of the accident.

The procedure turn was moved to the north side of the approach radial so that all the procedures including the holding pattern, the procedure turn, and the missed approach would be on the same side of the radial and make the pilots' workload lighter.

The minimum altitude of the procedure turn was reduced to 4,200 feet because there was, according to the FAA, no obstructing terrain that required a higher altitude.

The minimum altitude, over the VOR on the final approach, was reduced from 3,300 feet to 2,800 feet so that the FAA established maximum approach gradient of 300 feet per mile would not have to be exceeded during an actual instrument approach. With a Minimum Descent Altitude (MDA) of 1,880 feet m.s.l., an approach from 3,300 feet, at the maximum approach gradient, would not allow the pilot to reach the MDA before passing the approach end of the runway. However, from an altitude of 2,800 feet over the VOR, the pilot could, in zero wind conditions, be at the MDA approximately 1-1/4 NM before reaching the approach end of the runway. This would provide him with room to maneuver for a circling approach, the only type of instrument approach authorized at the Lebanon Airport.

A review was made of reports of various flight checks on the Lebanon VOR from the time it was commissioned until approximately 2 months after the accident. Particular attention was paid to the recorded signal strength on the approach radial within 10 NM of the VOR. It was found that there was no reported degradation of signal strength on any of these reports. In all cases, even on flights below the authorized minimum altitude, the signal strength was at least twice as strong as the minimum allowed of 5 microvolts. In most cases, the recorded signal strength was at or above 25 microvolts.

Since the accident, the State of New Hampshire has installed a low frequency nondirectional beacon and a co-located 75 MHz marker beacon 2.2 NM northeast of the Lebanon VOR on the approach radial. The use of these navigational aids has been approved by the FAA and two new approach procedures have been published for use by pilots.

The new VOR No. 1 approach is essentially the same as the approach in effect on the date of the accident. The major difference is that the minimum altitude for the procedure turn has been increased from 4,200 to 4,300 feet m.s.l.

The new VOR No. 2 approach allows the aircraft to descend to 3,000 feet m.s.l., after completing the procedure turn, until passing the "Hanover NDB/FM." After passing Hanover, the aircraft can descend to 2,500 feet m.s.l. rather than being required to maintain 2,800 feet from the procedure turn to the VOR.

In both cases, the minima for instrument approaches are essentially the same as they were at the time of the accident.

1.9 Communications

Radio communication between the flight and the various FAA communicators was without reported discrepancies.

1.10 Aerodrome and Ground Facilities

Not applicable to this accident.

1.11 Flight Recorders

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR).

The installed CVR was a Microdot, Inc. Recorder, serial No. 103. This recorder was recovered from the wreckage approximately 20 hours after the accident. The unit had been mounted in the aft section of the fuselage which was involved in the postimpact ground fire. The exterior surfaces were charred and pitted and the electrical cable had been burned off. There was no evidence of impact damage.

The interior of the recorder was examined and evidence of fire damage was found in the electronic section. When the recording section was opened, the reel of tape was found charred and fused. The portion of the tape lying across the recording head had been destroyed. There was no discernable magnetic recording remaining.

The FDR was a Lockheed Aircraft Service Model 109-D, serial No. 318. The recorder was recovered the morning after the accident from the burned out and still smouldering aft section of the aircraft. The case was still warm to the touch approximately 24 hours after the accident.

The only mechanical damage noted to the recorder case was the absence of the front and rear cover plates. The exterior of the case was discolored and all the paint was missing. Internally, the structure was blackened and the wiring insulation and electronic components were disintegrated. The cassette containing the aluminum foil record was intact and a portion of the foil was visible where it covered the cassette platen. The recorder was cut open to remove the cassette. Prior to removal of the cassette, a visual examination revealed four holes in the foil.

The cassette cover was removed and the foil was found to be intact between the supply and takeup spools. During the removal of the spools, the foil separated beyond the end of the scribed record on the supply spool end of the foil.

Because the layers of foil on the takeup spool were stuck together, the spool was immersed in ethyl alcohol for 24 hours. This loosened the adhesion between layers sufficiently to allow removal of approximately 9 inches of foil which contained the record of the flight from Boston to the time of the accident.

The foil was affixed to a glass plate and examined under high magnification. The foil surface had a coating of aluminum oxide which was sometimes crackled and sometimes flaky in appearance.

All parameter traces, other than the vertical acceleration trace, were readable except in the areas of greatest surface damage. The vertical acceleration trace was too nebulous to be readable. For the most part, the scribed traces were carried on the oxide coating with little or no indenting of the parent metal beneath the oxide.

All readable parameters appeared to be functioning in a normal manner throughout the flight. A data graph was prepared reflecting a time period of 35 minutes and 8 seconds after the indicated lift-off at Boston. This graph contained gaps in the parameter traces which corresponded to the areas of surface damage to the foil due to severe oxidation, gaps in the oxide coating, or holes in the foil. Care was taken to attempt to ascertain the path of each trace on each side of each gap to ensure an accurate graphic presentation of each trace. A large gap appeared in the heading trace between 32:24 minutes and 34:40 minutes, a total of 2:16 minutes. There was no visible east-west heading binary trace during this period and the foil was not damaged in this area. The east-west binary trace did appear at other appropriate times on the recorded portion of the flight, representing the takeoff and departure from Boston.

A review of the graph of this flight indicated that, following the takeoff from Boston, the greater portion of the flight was conducted at an average altitude of 8,100 feet m.s.l. and on headings between 320° and 338° magnetic. At a point approximately 8:44 minutes before the end of the record, the flight initiated a descent from 8,000 feet m.s.l. on a heading of 320° magnetic at an indicated airspeed of 220 knots. Approximately 2 minutes later, the flight was at 6,000 feet m.s.l. on a heading of 340° magnetic and at an indicated airspeed of 220 knots. At 3:14 minutes prior to the end of the record, the flight descended through 5,000 feet m.s.l. on a magnetic heading of 343° at an airspeed of 140 knots. Fourteen seconds later, while the aircraft was descending through 4,800 feet m.s.l. at 145 knots, the heading changed to 356° magnetic. This heading was maintained for 16 seconds, at which point the trace terminated in a hole in the foil. At the time of the disappearance of the heading trace, the flight was descending through 4,500 feet m.s.l. at an indicated airspeed of 150 knots.

Twenty-eight seconds prior to the termination of the recording, the heading trace was discernable at 245° magnetic. The flight was descending through 3,000 feet m.s.l. at an indicated airspeed of 130 knots.

During the period of time that the heading trace was not visible, due to foil damage, no east-west binary trace was visible.

During the last 28 seconds of the record, the heading increased from 245° to 250°, and 250° existed at the time of impact. At the time of impact, the altitude was less than 2,700 feet m.s.l. and the airspeed was approximately 120 knots.

1.12 Wreckage

The accident occurred on the side of a steep, rocky, heavily wooded mountain, the top of which was 2,294 feet above sea level.

The first impact marks found were 57 feet below the summit at 2,237 feet m.s.l., where the aircraft struck a tree. From this point, a swath was cut through the trees, parallel to the east side of the mountain, oriented along a bearing of 230° magnetic and sloping down 8.4°. The slope of the swath, perpendicular to the flightpath, corresponded to a right wing down attitude of 2° to 4°.

The aircraft broke up as it passed through the trees and was almost completely destroyed by impact and fire.

The wreckage was contained in an area approximately 440 feet long and 200 feet wide.

Examination of the wreckage indicated that all the observed fractures were caused by overloads. The flight control system was demolished and its integrity prior to impact could not be determined. The wing flap screwjack positions were measured and were found to correspond to a 16.5° landing flap extension. The right aileron stop horn was jammed in a position that correlated to a small upward deflection of the aileron. The position of the landing gear could not be determined by examination of the wreckage; however, the landing gear handle was in the "down" position. No aircraft components were found outside the main wreckage area, and portions of all the major airframe components, flight controls, trim tabs, and landing flaps were identified in the primary wreckage area. The flap position indicator showed the flaps to be at 16.5° down.

Both engines and propellers were recovered in the primary wreckage area. The propellers were separated from the engines.

Examination of the engines revealed no indication of operating distress or overtemperature. There was rotational scoring on the roots of the turbine blades of both engines.

Shop disassembly of the propellers was accomplished and the blade angles were determined to be 17°. The flight fine setting of this type propeller was 16° and the coarse setting was 28°.

The recovered components of the VOR navigational receivers, the altimeters, the pictorial deviation indicator, the attitude indicator, and the air data computer with the alticoder were taken from the site for laboratory examination. There was no evidence of malfunction of any of these components.

The captain's altimeter was set at 29.54 and the first officer's set at 29.53. The last acknowledged altimeter setting was 29.55. There was no indication of the altitude displayed by the altimeter at the time of impact and the alticoder provided no usable altitude information.

Examination of the Flight Director Indicator showed evidence of an aircraft pitch angle of 0° and a right bank of approximately 8° at impact.

The directional and vertical gyros were examined and they all exhibited evidence of rotational scoring.

The VOR navigational receivers were both tuned to the frequency of the Lebanon VOR.

The impact and fire damage to the navigational and flight instruments was such that little other data were available.

1.13 Fire

No evidence of in-flight fire was found and no in-flight fire was reported by the survivors. A postimpact fire did occur which reduced large portions of the wreckage to a molten state. This fire burned for approximately 18 hours following the accident. Because of the terrain and the isolated location of the accident site, little effective firefighting was performed and the fire burned itself out.

1.14 Survival Aspects

Due to darkness, the remoteness of the accident site, as well as the terrain and heavy ground cover, it was extremely difficult for the rescue groups to get to the scene.

All 10 survivors were seated in the aft end of the cabin. They made their escape from the burning wreckage through the rear cabin service door or through fractures of the fuselage. Their injuries included contusions, abrasions, lacerations, fractured ribs and limbs, two vertebral fractures, and one fractured hip. Seven fatally injured passengers were found away from the area of ground fire and clear of the fuselage. They had all received severe traumatic injuries. An additional 21 passengers were recovered from the fire area just forward of the portion of the fuselage occupied by the survivors.

Autopsies and toxicological studies were conducted on both pilots and selected passengers. There was no evidence of pre-existing disease found in either pilot. No evidence of an elevated carboxyhemoglobin saturation or ethyl alcohol was found. Furthermore, the studies of the pilots revealed no evidence of drugs.

The mobile survivors proceeded downhill away from the aircraft following their escape from the fuselage. Some of them returned and assisted some trapped persons from the wreckage. One of the survivors, who was a physician, directed the first aid actions while the survivor group was awaiting rescue.

1.15 Tests and Research

During the investigation, data was supplied to the Board indicating that the Lebanon VOR facility was unreliable and on occasion caused the airborne navigation equipment to give incorrect navigation indications to flightcrews.

Normally, VOR stations are used to give bearing lines from the station to the aircraft, but they also provide a navigation fix when directly overflown. This fix, or station passage, is indicated on the aircraft's navigation instruments.

Northeast flightcrews reported getting, at times, instrument indications of station passage prior to reaching a position over the Lebanon VOR.

Based on this information, the Board contacted other regular users of the VOR facility to determine their experiences in this matter.

Trans East Airlines and Executive Airlines, scheduled air taxi operators, as well as the local fixed base operator, confirmed erratic instrument indications at times, but none of them had experienced indications of incorrect or false station passage.

During the investigation, eight incidents of partial or complete station passage indications, observed prior to reaching the Lebanon VOR station, were documented. These reports included three incidents reported by Northeast Airlines, Inc., crews. The first incident occurred on November 5, 1961. The second occurred on June 10, 1968, and the third on October 27, 1968.

The avionics investigation group, in addition to reviewing the initial flight checking of the Lebanon VOR facility, conducted extensive ground and flight checks of the facility. The station was checked for power output, transmitting frequency measurement, and monitor operation. All of these checks revealed that the station was operating within the specifications established by the FAA.

Following the ground tests, the Avionics Group outlined an extensive flight test program to check further the facility for accuracy and reliability. Four different aircraft were flown using different VOR receivers with airways monitoring equipment installed: two Flight Inspection DC-3's from the FAA, with Collins and Bendix receivers installed; a Northeast Airlines FH-227, with the standard Wilcox 806A receivers installed; and a Wilcox Electric Company Inc. Cessna 185, with a Wilcox 806A receiver installed. The flight profile flown by these test aircraft was the standard VOR instrument approach procedure to the Lebanon Airport.

Flight Tests

Special flight checks of the Lebanon VOR signal were conducted as indicated above. During these flight checks, all the flight test aircraft displayed indications of approach course roughness on the 066° radial. Course roughness is displayed on the aircraft instruments as a series of ragged, irregular course deviations. These aberrations are usually caused by reflected VOR signals being received in combination with direct VOR signals. The reflected signals can be caused by rough terrain, trees, or other irregular objects. A study of flight inspection recordings and the terrain will often disclose the source of such course aberrations.

When this condition exists, the Course Deviation Indicator (CDI) will rapidly change its indication of left of course, right of course, or on course. The navigational pointer on the Radio Magnetic Indicator (RMI) will alter the indicated bearing angle erratically above and below the correct value, and the TO-FROM indicator, which shows the relationship between the course selected and the relative position of the VOR station, may flutter in its display.

Although all the tested receivers reacted to course roughness, the flight tests showed that the Wilcox 806A receiver caused the greatest fluctuations in the navigation instruments. None of the tested receivers caused the navigation instruments to indicate a station passage, by the required TO-FROM reversal, in the detected areas of roughness.

These tests identified two areas of course roughness on the 066° radial of the Lebanon VOR. One was approximately 8 to 10 NM northeast of the VOR station, the area where the procedure turn inbound to the station would normally be completed. The second area of roughness was located near the accident site.

Because the Wilcox 806A receiver reacted to course roughness (indicated on the CDI as variation of 3° to 10° and "flutter" of the TO-FROM indicator), additional tests were made using a modified Wilcox receiver designated as the 806D. The 806D contained modified circuits which resulted in the receiver being less sensitive to the lower frequencies of course roughness. This receiver provided acceptable, within tolerance, guidance in the previously identified areas of course roughness.

Additional flight tests were made in an effort to define clearly the areas of course roughness on the approach radial at Lebanon.

The first area, in the vicinity of the crash site, was found to be cone-shaped and centered at 20.1° above the horizontal. This zone extended to 2,800 feet m.s.l. at 4.0 NM northeast of the VOR on the approach radial.

The most distant zone originated at a point 9 NM northeast of the VOR at 2,000 feet m.s.l. This zone centered around an angle of 3.7° above the horizontal.

A third area of roughness, or reflected signal, was located between the two zones listed above, 6.5 to 8.5 NM from the VOR on the approach course. It was limited to an altitude of 2,800 feet m.s.l. and lower. The zone appeared to be intermittent in that it was not always available for measurement. Measurements that were obtained indicated it varied somewhat in location, duration, and amplitude.

Radio Interference Measurements

On October 30, 1968, an FAA radio frequency interference measurement vehicle was positioned approximately 300 feet from the Lebanon VOR transmitter site. The VOR frequency band was monitored during the morning and evening hours and no interference was noted. The VOR station, the local TV station, and the Dartmouth College research station were made inoperative, for a period of time, during these tests.

On October 31, radio frequency interference measurements were made near the TV station and then near the base of South Peak ridge. On November 1, 1968, the vehicle was positioned at Reservoir Pond near Smarts Mountain. No interfering signals were detected during these tests.

Other VOR Interference Studies

Interference with the proper reception of navigation signals from the Lebanon VOR could have been caused by the undesired presence of navigation signals from other VOR stations using the same frequency. Such VOR stations are geographically separated to prevent interaction of their signals; however, phenomenon exist that can overcome the effect distance has in reducing the strength of a signal.

Tropospheric and ionospheric refraction, aurora, sun spot activity, and meteors can provide means to alter normal signal paths. A professor at Dartmouth College testified that from a study of conditions in existence at the time of the accident, "F" layer refraction mechanism was very low in probability. Aurora conditions were very quiet at the time of the accident. There were no data to verify sun spot activity. Meteor activity at the time was of very low probability.

Multipath interference can occur between direct and indirect ground-reflected radio waves. The combining of the two signals, while in phase, results in a strengthened signal. When the signals are combined while out of phase, cancellation can result or the signal can become weaker. The strength of the reflected signal depends on the reflection coefficient of the terrain. This coefficient depends on the character of the terrain and the presence or absence of moisture either in the ground or as a surface layer of ice, snow, or water.

This expert stated that interference due to multipath reflections existed at Lebanon, New Hampshire. There were many possible reflectors in this area. These reflectors would vary at times in their ability to reflect, but the time interval for a change would be measured in weeks, not overnight or hourly.

Unusual meteorological conditions and irregular terrain may combine to confine radio energy to thin layers near the earth's surface, resulting in the presence of a stronger than normally expected signal at some distant point. This phenomenon is known as ducting and can occur at altitude as well as near the surface. An expert from the Environmental Science Services Administration stated that such atmospheric ducting was suspected to exist at Lebanon with possible interference from the VOR station at Elmira, New York, which was on the same frequency. After a study of available data, he concluded that the most favorable conditions for ducting between Elmira and Lebanon would not produce an interfering signal at Lebanon.

Tests at Wilcox Electric, Kansas City, Missouri

The Wilcox 806A receiver and other navigation receivers were tested for behavior when subjected to simulated course roughness on a test VOR signal. These induced course roughnesses were applied to the direct VOR signal and the amplitude and frequency of the course roughness were varied.

The relative strengths of the direct and reflected VOR signals were controlled by the percentage of additional modulation applied to the basic VOR signal. The frequency of the roughness (1 to 50 Hz) was fixed during each test run. It was noted that this was not completely realistic, since an aircraft passing through a roughness zone alters the frequency of the roughness by its continuous change in position relative to the VOR station and signal reflector.

For charts illustrating the measurements see Appendix E.

Northeast Airlines Tests

A special study of the performance of the avionics equipment used by Northeast Airlines was conducted for Northeast Airlines, Inc., by a professor of electrical engineering at the Massachusetts Institute of Technology.

The study was designed to isolate spurious electromagnetic-radiation effects which might cause a reversal of the TO-FROM indicator. His report stated that testing of the Wilcox 806A VOR receiver demonstrated several conditions that could give an indication of station passage at a point in space where the aircraft was not actually over the VOR transmitter. These conditions were (a) co-channel interference, which was a signal whose frequency was within the pass band to which the receiver was tuned; (b) off-channel interference, which was a signal whose frequency was outside the pass band to which the receiver was tuned; and (c) sine-wave modulated signals at the co-channel or off-channel frequencies at a modulation frequency of 30 Hz, and at 10 Hz, 20 Hz, and 40 Hz at certain signal frequencies.

The forms such signals could take included an unmodulated RF signal, a second VOR signal on the same frequency, a pulse-modulated RF signal, or a Doppler-type signal.

Illustrative examples of signal sources of the above character would include: an unmodulated transmitter being adjusted or tested; an RF transmitter whose signal was interrupted for code sending purposes; a scattered VOR signal which entered the receiver simultaneously with a direct-wave signal to provide a Doppler effect; or a transmitter that had strayed off frequency into the VOR receiver receiving range.

The study also concluded that there was high probability that an elevated electromagnetic duct existed in the New England region at the time of the accident. The effect of this duct would have been to extend the range of RF signals and thus increase the possibility of interfering signals being present in the accident area.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

Our investigation indicates that the aircraft was airworthy at the time of its departure from Boston and at the time of the accident. There was no evidence of a failure of the airframe or the flight control system. The aircraft was properly configured for the descent and approach to the VOR station inbound to the airport. The landing flaps had been lowered to 16.5° and the landing gear was down and locked. The propeller pitch angles were those which would be expected at a minimal power setting used for descent. Both engines were operating at low power settings upon impact.

There was no indication of a malfunction of any of the aircraft systems and there was no evidence of in-flight fire, explosion, or interference with the crew.

The crew was properly certificated, qualified, and experienced with the approach to the Lebanon Airport.

The weather and light conditions were suitable for the operation in progress. While there may have been light icing in the clouds, there was no indication that it had any effect on the performance of the aircraft or the engines.

The passengers received no warning prior to the accident and noted nothing unusual in the way of sudden power changes or aircraft handling. It would appear, therefore, that the pilots had little if any warning of the proximity of the aircraft to the terrain.

The flight from Boston was normal and routine until the Boston controller cleared the aircraft for an approach to Lebanon. From that point, the flight would be expected to proceed to the VOR station at 5,000 feet m.s.l., to turn outbound 066°, and to execute a procedure turn north of the outbound radial within 10 NM of the VOR, descending no lower than 4,200 feet m.s.l. Upon completion of the procedure turn, the flight should have descended to a minimum altitude of 2,800 feet m.s.l. and proceeded back to the VOR on the 246° track. In this connection, we note that the crew notified the FSS communicator that they were "SIA," which has been interpreted to mean that they were going to perform a standard instrument approach.

However, the record indicates that this was not accomplished. The flight data record showed that the aircraft turned right to a heading of 340°, after leaving its cruising altitude, and continued on that approximate heading for about 3:45 minutes, then turned farther right to a heading of 356°. Sixteen seconds later, the heading trace disappeared in a hole in the recording medium. About 2.5 minutes later, the heading trace reappeared on the other side of the hole indicating a heading of 245°. During the time the heading trace was not visible, there was no east-west binary trace on the recording, which would have appeared had the aircraft heading ever been east of 360°. During the last 28 seconds of recorded flight, the heading increased to 250° -- the heading at impact.

During these maneuvers, the aircraft was in a relatively constant descent and the airspeed was decreasing. The last recorded altitude was just under 2,700 feet m.s.l. and the airspeed was approximately 120 knots.

This indicates that the aircraft was maneuvered to intercept the inbound radial at a point approximately 8 to 10 miles northeast of the VOR station about 3 minutes before impact. Then a left turn was made to cause the aircraft to track inbound on the prescribed course of 246° magnetic. The aircraft was descending at the time of the interception of the inbound track, passing through approximately 4,500 feet m.s.l., and that descent continued until impact. The indicated airspeeds during this portion of the flight were compatible with those normally used in the FH-227 during an instrument approach.

In an effort to determine why the aircraft did not level off at 2,800 feet m.s.l., the minimum altitude inbound to the VOR, the Board considered a number of possibilities. These included crew incapacitation, faulty altimetry, an attempt to remain VFR, and finally, some instrument indication that led the crew to believe that they had passed over the station when, in fact, the station was still well in front of them.

The surviving passenger statements, a review of the flight data record, the results of the autopsies and toxicological studies, taken in conjunction with the medical histories of the pilots, indicate that crew incapacitation was not a factor in this accident.

The flightpath of the aircraft, as recorded by the FDR, is typical of controlled flight up to the time of impact. The configuration, maneuvering, and location relative to the desired inbound track are all indicative of normal aircraft response to crew inputs.

The Board's studies of the altimeters and their associated systems have revealed no abnormalities that could account for an altimeter error of approximately 530 feet. The flight data record shows that where altitude depicted can be compared to desired altitude, the aircraft was at or near the desired altitude.

Because these data were taken from the system that provides altitude information to the first officer's instruments, we believe that his instruments were accurately reflecting the correct altitude of the aircraft throughout the flight. The altitude information provided to the captain's instruments comes from a completely separate pitot static system; however, there is nothing in the record of this flight to indicate that this information was substantially different from that recorded by the FDR. The aircraft maintenance records did not indicate any significant history of altimetry or pitot-static problems. The flightpath of the aircraft, as depicted by the FDR, indicates that the aircraft was being maneuvered by reference to guidance furnished by the VOR receiver and its associated instruments. Furthermore, the positioning of the aircraft on the inbound radial supports this belief.

If the pilot was not sure of his exact position, because he was performing a nonstandard approach, and he received an indication of station passage from his navigation instruments, he would probably descend toward the minimum altitude for his approach.

The definition of station passage as outlined in FAA and pilot training literature was considered to be a complete reversal of the TO-FROM indicator from "TO" to "FROM". There are supplementary indications of oscillation of the CDI and reversal of the RMI/VOR needle that are associated with station passage, but these supplementary indications are not to be used as an indication of station passage.

The navigational system including the aircraft receivers, the aircraft instruments, and the ground station were examined separately, and as a system, in an attempt to find evidence of a problem that may have induced the crew to descend prematurely below the limiting terrain.

The VOR station was tested repeatedly by exercising it through established routines. In addition, many components of the station were examined individually. No malfunction of the transmitter or any of the station components was found, and the signal strength on the approach radial was adequate at the prescribed altitude.

The Board reviewed the actions taken by the FAA to investigate and correct the reported incidents of partial or complete station passage and course roughness at the Lebanon VOR station. This review indicated that, in those cases that had been reported to the FAA, corrective action was taken in accordance with the existing procedures of the FAA. In those cases where a discrepancy was detected by a flight check, appropriate action was taken to correct the discrepancy and the followup flight checks showed that the station was operating within the established tolerances.

The possibility of a signal from a source other than the Lebanon VOR interfering with the Lebanon signal was considered. Special ground radio equipment was used to search the appropriate frequency bands for undesirable signals that would alter the signal transmitted by the Lebanon VOR. Measurements were made adjacent to the VOR transmitter and at several positions in the approach quadrant. Listening samples were taken several times a day at each location over a 1-week period. No signal was detected that would interfere with the navigation signal.

The possibility of interference from a VOR signal from another navigational transmitter on the same frequency was studied. VOR stations with a common frequency are sited geographically so as to prevent this type of interference. In this case the nearest co-frequency VOR station was located at Elmira, New York, at a distance adequate to prevent interference under normal circumstances.

Unusual conditions that might have introduced an interfering signal were then examined. These unusual conditions included atmospheric ducting, troposheric and ionospheric refraction, auroral reflection, sun spot activity, and meteorite scatter propagation.

Testimony at the public hearing indicated that tropospheric or ionospheric refraction were of a very low order of probability, if at all present at the time of the accident. Auroral conditions were found to be attenuated and there was no verified sun spot activity. At the time of the accident, meteor activity was at its lowest level and was given a low order of probability as an effective refracting device.

While the meteorological conditions were such that atmospheric ducting could have occurred, calculations by two Federal agencies indicated that the signal strength of the nearest co-frequency transmitter would be too low to interfere with a normal signal transmitted by the Lebanon VOR station.

Because of the reported history of off-course indications and "false station passage" uncovered by this investigation, a detailed study was made of the combination of direct and reflected signals and their effect in airborne navigational equipment.

Direct and reflected signals can combine to strengthen or weaken a signal detected by the aircraft receiver. When the direct and reflected signals are in phase or out of phase, their combination results in amplitude modulation of the received signal.

A review of the routine flight tests flown before the accident, as well as special flight tests after the accident, indicated that course roughness was detected on the approach course at Lebanon. According to the FAA flight checks, this roughness was less than 3° and within the established tolerances.

This roughness was believed to be a result of reflected signals and there were many possible reflectors existing simultaneously along the approach course. The reflection coefficient of the terrain depends primarily on the nature of the terrain and the moisture content. The reflection coefficient typically persists for weeks or longer and does not change abruptly.

Based on the above, the Board concludes that no method of signal propagation existed at the time of the accident that would have caused the Elmira VOR signal to interfere with the Lebanon VOR signal. The Board also concludes that if false navigational information were presented to the crew of Flight 946, it was caused by an effect of reflected signals combining with direct signals from the Lebanon VOR.

An interfering signal symptom, such as roughness, is measured in the aircraft navigational system as a current flowing through the Course Deviation Instrument. Roughness is defined as a series of irregular course deviations with such a frequency of occurrence that they cannot be followable by an aircraft in flight. The official standards required that this roughness not exceed a course change of plus or minus 3°. As previously stated, the roughness at Lebanon, prior to and after the accident, was within these limits. This type of roughness is not unusual and is found at many VOR stations located in mountainous or rough terrain. At Lebanon, the roughness was attributed to the presence of terrain reflected signals into the same zone as the direct radiated signal.

Flight tests at Lebanon indicated that there were three general zones of roughness along the approach radial.

Proceeding outbound from the VOR transmitter along the 066 radial, the first zone was found at an altitude of 2,800 feet m.s.l., at a range of approximately 4 NM. The second zone was found between 6.5 and 8.5 NM from the transmitter and was limited to 2,800 feet m.s.l. and below. The third, and most distant, zone originated at a range of 9 NM at 3,000 feet m.s.l.

The first and third zones originated at areas designated as South Peak and Winslow Ledge. The patterns of these zones were conical, sloping upward and away from the transmitter along the 066 radial. The middle or second zone was more difficult to locate with respect to point of origin and shape. The area did not appear to exist continuously and was limited to 2,800 feet m.s.l. and below. The measurements to define all three zones were made by aircraft flying the approach course which did not always permit a descent below 2,800 feet m.s.l. The Board believes that this explains the apparent intermittency of the second zone. Our analysis of this zone indicates that North Peak was the most probable reflector.

The navigation intelligence transmitted by a VOR station is contained in two separate 30 Hz modulations. A portion of the signal is frequency modulated (FM) and a portion is amplitude modulated (AM). The electrical phase relationship of the two 30 Hz modulations varies about the circumference of the station, and the magnetic bearing from the station is the electrical phase angle between the two modulated portions.

When a reflected signal joins the direct signal, a mixing results which affects the aircraft receiver detection of the AM signal. This alters the phase relationship between the AM and FM modulations within the receiver and also the bearing information which is derived and presented on the pilots' instruments. The bearing can fluctuate rapidly because of the beating effect between the reflected and direct signals. The beating is a result of the moving receiver changing the path lengths of the reflected and direct signals at a different rate. This produces a differential Doppler shift in the two received signals. The beat frequency combines with the basic 30 Hz frequency producing a complex modulation that effectively changes the angular position of the original AM modulated VOR signal.

Thus, the crew of an aircraft flying through a zone of roughness may see, with some VOR receivers, a fluctuation of the CDI, the VOR needle on the RMI, and sometimes, a flutter of the TO-FROM indicator. Course errors of up to plus or minus 10° will indicate up to full scale deflections, right or left, on the CDI. Greater course errors will not be measurable on the CDI because of instrument limitations. The RMI will indicate the error by an angular change of its pointer equal to the course error. As the error approaches a value of 90°, the TO-FROM indicator will start responding. It was learned that the aircraft equipment requires from 1 to 5 seconds to respond fully to such errors.

The behavior of these instruments resulting from large course errors is the same behavior generally associated with the beginning of passage over a VOR station.

Flight testing by FAA and Northeast Airlines aircraft equipped with VOR receivers manufactured by Bendix, Collins, and Wilcox revealed a variation in receiver susceptibility to the roughness phenomena. During flight in the areas of roughness, the Wilcox receiver (identical to that in the accident aircraft) showed deflections of the CDI of as much as 10° or full scale. At the same time, the standard Collins FAA flight test receiver showed a variation of 3°, the maximum authorized. In one instance, this latter deflection lasted 31 seconds. Special test equipment determined that the frequency of these fluctuations was less than 25 Hz. In the area of the crash site, the reflected signal was of sufficient strength to modulate the direct signal from 50 to 85 percent.

In the areas of roughness, the TO-FROM indicator associated with the Wilcox receiver displayed an intermittent flutter of the "TO" indicator; however, there was no reversal indicative of station passage.

Laboratory tests were conducted to further explore this condition and they confirmed the flight test results.

These tests simulated the mixing of direct and reflected VOR signals. The relative strength of the reflected signal to the direct signal was varied 10 percent to 70 percent and the frequency of roughness from 1 to 50 Hz. By this technique, the behavior of different receivers could be compared. The Wilcox 806A receiver indicated more of a bearing change at lower frequencies of roughness than did other receivers. This bearing change was evident on the CDI, the VOR needle on the RMI, and occasionally on the TO-FROM indicator. This appeared to be due to the filtering circuit in the Wilcox receiver which permitted frequencies of modulation lower than 30 Hz to be more effective than they were in other receivers. In this connection, the Board notes that all the receivers used in these tests were found to be in compliance with the appropriate Technical Standard Orders (TSO's) and had been certificated by the FAA for use in air commerce. The Board also recognizes that laboratory tests do not truly simulate an aircraft's passing through a zone of roughness because fixed frequencies of roughness are difficult to achieve in flight.

An independent study of this problem by the carrier concluded that while recognizing the situation described above, it was more likely that spurious RF signals, entering the aircraft receiver simultaneously with the VOR signal, could cause the aircraft receiver to give indications identical to a normal VOR station passage. The study also concluded that there was a high probability that an elevated electromagnetic duct existed in the New England region at the time of the accident. The effect of such a duct would have been to extend the normal propagation range of RF signals and thus expand the area in which spurious signals could originate.

With regard to this study, the Board has reviewed the available evidence. We agree that conditions favorable to the existence of an atmosphere duct existed. However, there is nothing in the record to support a finding of the presence of spurious signals with the required frequencies, characteristics, and strength to interfere with the Lebanon signal in such a way as to give the crew of Flight 946 an indication of station passage prior to their arrival over the VOR station.

The Board believes that the geometry of the aircraft flightpath combined with the second area of roughness, located 6.5 to 8.5 NM northeast of the VOR station, gave the crew an indication of an impending station passage. Considering the meteorological conditions, with broken cloud cover, it is also possible that the crew might have seen glimpses of the terrain through the breaks in the clouds. There are two rather similar prominent lakes east of the approach radial. One is in the area of the procedure turn and the other is near the VOR station. If, during a nonstandard approach, the captain glimpsed a prominent lake through a break in the clouds and shortly thereafter saw instrument indications of an impending station passage, this might have reinforced his belief that he was at the VOR station and influenced him to start a descent to his minimum descent altitude. It is also possible that the crew might have observed North Peak and might have mistaken it for South Peak, with essentially the same effect as sighting the lake.

The Board believes that the crew, in an attempt to expedite their landing at Lebanon, elected to perform a nonstandard approach to the Lebanon Airport. By using this type of an approach, they were precluded from knowing their exact position over the ground. During the turn inbound to the VOR and while getting established on the inbound radial, they observed navigational instrument indications of impending station passage. These indications were a result of the second area of roughness located on the inbound radial. These indications may have been reinforced by visual observation of some prominent geographical feature which was not correctly identified. In any event, the crew continued the descent through 2,800 feet m.s.l. toward their minimum descent altitude of 1,880 feet m.s.l. Based on the reported weather, the crew would have anticipated breaking out of the clouds at about 2,500 feet m.s.l. and having good visibility below the clouds. The descent was continued without interruption until impact with the trees.

2.2 Conclusions

(a) Findings

(1) The flight was 47 minutes late departing from Boston.

(2) The aircraft was airworthy at the time of departure from Boston and at the time of the accident.

(3) There was no evidence of a failure of the airframe or of the flight control system.

(4) The aircraft was properly configured for a VOR approach. The landing flaps were extended 16.5° and the landing gear was down.

(5) Both powerplants were operating normally.

(6) There was no evidence of a malfunction of any aircraft system.

(7) There was no evidence of an in-flight fire or explosion.

(8) There was no evidence of incapacitation of or interference with the flightcrew.

(9) The flightcrew was properly certificated and qualified.

(10) The weather and light conditions were suitable for a standard instrument approach.

(11) Aside from the existence of the clouds and an inversion aloft, weather was not a factor in this accident.

(12) There were no unusual maneuvers or power application noted by the survivors.

(13) The flight from Boston was normal and routine until radar service was terminated.

(14) The crew of Flight 946 advised the Flight Service Station communicator that they were going to perform a standard instrument approach.

(15) The flight did not perform the published instrument approach procedure.

(16) The flight executed an abbreviated approach by making a right turn from their northwesterly heading and then a left turn back to intercept the inbound radial to the VOR station.

(17) At no time during the approach did the aircraft heading go east of 360°.

(18) The aircraft was positioned approximately on the inbound radial at the time of the accident.

(19) The aircraft intercepted the inbound radial approximately 8 to 10 miles northeast of the VOR station.

(20) From the time of the interception of the inbound course until impact, the aircraft was descending continuously.

(21) No evidence of an abnormality in the pitot static system or the altimeters was found.

(22) No significant discrepancies were found in the aircraft navigational receiver or instruments.

(23) Extensive testing of the VOR ground station revealed no out of tolerance operations.

(24) No evidence could be found of an extraneous signal in the Lebanon area which might have interfered with the VOR signal.

(25) The maximum possible navigational error that could have resulted from a ducted signal from the Elmira, New York, VOR was 1°.

(26) An inversion aloft existed at the time of the accident.

(27) No evidence of a co-frequency signal, effective in the Lebanon area, as a result of an atmospheric duct, was found.

(28) Tropospheric and ionospheric refraction, auroral reflection, sun spot activity, and meteorite scatter propagation cannot be shown to have affected signal propagation in the New England area at the time of the accident.

(29) Three areas of course roughness existed on the approach radial of the Lebanon VOR.

(30) This roughness was measured by the FAA and found to be within tolerance.

(31) The effects of these roughness zones were greater on the Wilcox 806A receiver than on the FAA test receivers.

(32) The greater effect noted on the Wilcox receiver was a result of a filter circuit that passed modulation frequencies of less than 30 Hz and allowed them to have a greater effect on the receiver.

(33) The Wilcox 806A was in compliance with the appropriate TSO's and was certificated for use in air commerce.

(34) Course roughness manifested itself on the Course Deviation Indicator, the VOR needle of the Radio Magnetic Indicator, and the TO-FROM indicator during test flights.

(35) These manifestations did not give a complete reversal of the TO-FROM indicator, the only accepted indication of station passage.

(36) These manifestations did give the appearance of an impending station passage.

(37) The geometry of the nonstandard approach flown by Flight 946 combined with the second area of course roughness in an area 6.5 to 8.5 NM northeast of the VOR station.

(38) This combination gave the crew flight instrument indications of an impending station passage.

(39) Intermittent views of the terrain and prominent geographical features were possible during the approach.

(40) An erroneous identification of such a geographical feature may have reinforced the crew's impression of impending station passage.

(41) The nonstandard approach did not provide the crew with any accurate means of knowing their position in relation to the VOR station.

(42) Having made a decision based on inadequate information, the crew initiated a descent to their minimum descent altitude.

(43) This descent was initiated from 6 to 8 NM northeast of the VOR station.

(44) The descent was continued, uninterrupted, into clouds that masked the presence of South Peak.

(45) The crew had little if any warning of the impending accident.

(46) No corrective action was taken by the crew prior to the initial impact.

(47) The Lebanon VOR had a history of reported false station passage indications and course roughness.

(48) Some of the problems associated with the Lebanon VOR are common to VOR stations located in mountainous terrain.

(49) Some of these problems have been identified with specific aircraft navigational receiver characteristics.

(50) Adherence to good operating practices during the conduct of instrument approaches in mountainous terrain will reduce the magnitude of these problems.

(b) Probable Cause

The Board determines that the probable cause of this accident was the premature initiation of a descent towards the Minimum Descent Altitude, based on navigational instrument indications of an impending station passage in an area of course roughness. The crew was not able to determine accurately its position at this time because they had performed a nonstandard instrument approach and there were no supplemental navigational aids available for their use.

3. RECOMMENDATIONS

On October 29, 1968, the Board submitted a recommendation to the Administrator of the Federal Aviation Administration. The Board recommended that the Administrator take immediate precautionary action to restrict all operations using the Wilcox 806A VOR receiver to visual approaches where radar or DME was not available, and to require visual flight during en route operations where an exact fix requirement was necessary for terrain avoidance, if DME or radar verification was not available.

On November 7, 1968, the Administrator replied that he had sent a telegraphic Operations and Maintenance Alert to all FAA Regions, Area Offices, and Flight Standards Offices on October 29, 1968. This telegram requested that all known users be advised that erratic operation and false reversals had been reported. Owners and operators were requested to (1) restrict the use of these receivers to en route navigation with position confirmed by radar or DME prior to changing altitudes in conformance with ATC clearances and (2) restrict VOR instrument approaches to only those based on DME information or where station passage is confirmed by radar. Finally, the telegram requested that known malfunctions be reported.

A telegram was also sent to Wilcox Electric Company requesting that they alert all known users of the equipment as soon as possible. The en route restrictions of this telegram were lifted on November 5, 1968.

On December 6, 1969, the FAA issued Advisory Circular No. 91-18, Subject: Course Needle Oscillations on VHF Omnidirectional Range (VOR) Receivers.

This circular, in part, advised all operators of aircraft equipped with VHF navigational receivers that pilots might observe brief course needle oscillation and RMI variations (but not reversals) with some flicker (but not reversals) of the TO-FROM indicator similar to the indication of "approaching station." This erratic operation was attributed to interference by reflected VOR signals from various reflecting surfaces and was most likely to occur at low altitudes. Pilots were cautioned to be alert to these vagaries and to use a solid TO-FROM reversal to determine positive station passage. It was noted that a similar caution had been published in the Airman's Information Manual since 1958.

The circular also outlined a laboratory test procedure to determine whether a VOR receiver was susceptible to reflection interference. (See Appendix D.)

Operators of aircraft equipped with VOR receivers that did not pass this test were cautioned to confirm station passage with DME, or ATC radar, when using these receivers for VOR approaches in areas subject to reflection interference.

On January 1, 1969, the Wilcox Electric Company issued a service bulletin which recommended three modifications to the Wilcox 806A receiver to improve the performance of the receiver.

These modifications were to:

(1) Improve the operation of the Bearing Drive Mechanism assembly;

(2) Improve the TO-FROM and flag alarm indication at low subcarrier signal levels; and

(3) Improve the operation of the automatic VOR circuits at low signal levels.

On January 31, 1969, the Wilcox company issued another service bulletin for the 806A and 806C receivers. The expressed purpose of this modification was to reduce the effect of interference by reflected VOR signals from terrain irregularities or ground structures. The bulletin offered a kit containing a bandpass filter to be added to both the manual and automatic VOR audio sections to assure compliance of the Wilcox 806 receiver with the tolerances specified by FAA Advisory Circular 91-18, referred to above. Wilcox recommended that these modifications be installed in all receivers listed by serial number.

On December 13, 1968, the Board forwarded a five-point recommendation to the Administrator, FAA, for his consideration. These recommendations cited the circumstances surrounding the accident and recommended that: (a) the FAA conduct long-term radio frequency monitoring of the Lebanon VOR area for signal interference; (b) priority consideration be given to the installation of dual navigational facilities at those locations where a single facility could exhibit characteristics of the type found during our investigation of the Lebanon accident; (c) a review of the design concept of the Wilcox Model 806A receiver and its compatibility with other airborne instrumentation and ground station navigational equipment to assure standards of airworthiness. Furthermore, this compatibility problem may be general in nature and consideration should be given to reviewing all pertinent standards for compatibility of ground and airborne navigation components; (d) the FAA should provide the leadership in developing and implementing an industrywide operational incident reporting system for an interim period, and that early attention should be given to insuring a wider dissemination of existing operational incident data among the elements of the FAA; and (e) an Advisory Circular, or similar type bulletin, be issued reemphasizing positive station passage indications.

In his reply dated January 14, 1969, the Administrator stated that: (a) his staff had investigated the possibility of radio frequency interference effects at Lebanon from co-channel stations. Based on data derived in coordination with ESSA, U. S. Department of Commerce, considering ducting and superrefraction, there was one chance in fifty that a maximum signal of 10 microvolts could be received in the Lebanon area for a total of 50 minutes a year from the nearest co-channel VOR at Elmira, New York. This signal would be usable only in the absence of the Lebanon VOR, but would be about 20 decibels lower than the Lebanon VOR signal in the flight area in question. This ratio would cause less than 1° of error. The Administrator also indicated he would give further consideration to the need for long-term frequency monitoring recommended by the Board; (b) the FAA has a policy to improve navigation aids when necessitated by unsatisfactory performance. In the case of VOR, this usually involves relocation or conversion to Doppler VOR. In any event, an additional navigation aid such as DME is primarily installed to provide additional operational benefits such as lower landing minima or reduction of flight time, rather than support of facilities having unsatisfactory performance. The Lebanon VOR performed within the flight inspection tolerances specified for VOR facility performance and was considered adequate to support the VOR instrument approach procedures at Lebanon. Therefore, this VOR should not require an additional facility to support the instrument procedure; (c) the Wilcox Electric Company was developing a design change to their equipment to minimize the difficulties experienced during flight checks at Lebanon. When this equipment has been modified, the restrictions on the use of the 806A receivers would be rescinded. The Administrator also issued Advisory Circular 91-18, previously discussed, and an Air Carrier and General Aviation Operations and Maintenance Alert was to be issued on all equipment found to be susceptible to ground-reflected signals. The Administrator believed that this action should provide sufficient safeguards for equipment now in service. He was also planning to amend the Technical Standard Order for VOR receiving equipment, and a new performance requirement and test procedure similar to that in AC 91-18 would be developed for inclusion in TSO-C40A. Other airworthiness requirements, including frequency interference effects and known compatibility problems with navigational aids, would also be reviewed to determine whether additional amendments should be made or new requirements issued; (d) FAR 91.129 requires all pilots to report airborne navigational equipment malfunctions immediately to ATC, and FAR 121.561 requires air carrier pilots to notify an appropriate ground station when an irregularity in a navigation facility is encountered which, in the pilot's opinion, would adversely affect the safety of other flights. The Administrator felt that these requirements were responsive to this problem and saw no need to amend them at that time. He planned to issue an Air Carrier and General Aviation Operations Alert so that appropriate emphasis would be given to these reports. He stated that he believed that the recommended industrywide operational incident reporting system was being accomplished by his system of issuing telegraphic alerts and operations bulletins, at least with respect to those incidents having a significant effect on safety. He also recommended that appropriate revisions be made to the NTSB Safety Investigation Regulations to enhance the effectiveness of the system to capture and utilize the hazard warning potential of operational incidents. The Administrator stated his agency would conduct a complete review of the current incident reporting procedures. An objective of this review was to include assurances that his reporting procedures were adequate, within FAA and industry, to insure accuracy and reliability of ground and airborne equipment; and (e) the Airman's Information Manual provided cautionary information to pilots to use the TO-FROM indicator to determine positive station passage. While the Administrator considered this caution adequate in its existing form, he indicated that future editions of the Airman's Information Manual would have this item set aside as a separate paragraph in bold print. Additionally, the FAA Instrument Flying Handbook and Air Carrier training programs would emphasize that positive station passage is to be determined from the TO-FROM indicator. (For additional details, See Appendix F.)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

April 1, 1970

INVESTIGATION AND HEARING

1. Investigation

The Board received notification of the accident at approximately 1915 eastern daylight time on October 25, 1968, from the Federal Aviation Administration. An investigating team was immediately dispatched to the scene of the accident. Working groups were established for Operations, Air Traffic Control, Weather, Structures, Powerplants, Aircraft Systems, Human Factors, Aircraft Maintenance Records, Flight Data Recorder, Cockpit Voice Recorder, and a special Avionics Group.

Interested Parties included the Federal Aviation Administration; Northeast Airlines, Incorporated; Air Line Pilots Association; Air Line Dispatchers Association; Fairchild Hiller Corporation; Rolls Royce, Limited; Dowty Rotol, Limited; and Wilcox Electric Company, Inc.

The on-scene investigation was completed November 4, 1968.

2. Public Hearing

A public hearing was held at Boston, Massachusetts, April 1-4, 1969. Parties to the Investigation were: Federal Aviation Administration; Northeast Airlines, Inc.; Air Line Pilots Association; and Wilcox Electric Company, Inc.

3. Preliminary Report

A summary of the testimony which was taken at the public hearing was published by the Board on May 6, 1969.

Crew Information

Captain John A. Rapsis, aged 52, was employed by Northeast on March 3, 1957. He held airline transport pilot certificate No. 53660. He also held type ratings in a Douglas DC-3 and Fairchild F-27/227, with commercial privileges in airplane single-engine land and sea and multiengine sea.

Captain Rapsis had satisfactorily completed his most recent line check on July 10, 1968, and his most recent proficiency check on May 5, 1968, in the FH-227 aircraft. His last recurrent training was completed on April 22, 1968. Captain Rapsis' first-class medical certificate was dated May 22, 1968, and listed no limitations.

The following additional pilot data were obtained from Northeast and FAA records:

Total pilot time	14,700:00 hours
Total pilot time in FH-227	1,181:55 hours
Satisfactorily completed ground school training FH-227	November 9, 1966
Satisfactorily passed type-rating check FH-227	December 18, 1966
Satisfactorily passed Proficiency check FH-227	November 28, 1967
Satisfactorily passed line check FH-227	March 11, 1968
Satisfactorily passed line check FH-227	April 18, 1968
Duty time last 24 hours prior to accident	2:25 hours

Captain Rapsis was off duty the 24 hours preceding his reporting for Flight 946 on October 25, 1968. He was also off duty on October 22, 23, and 24, 1968.

First Officer John C. O'Neill, aged 29, was employed by Northeast on May 1, 1967. He held commercial pilot certificate No. 1530989 with airplane single- and multiengine land and instrument ratings.

First Officer O'Neill had satisfactorily completed his most recent proficiency check on July 14, 1968, in the FH-227 aircraft. His last recurrent training was completed on July 8, 1968. First Officer O'Neill's first-class medical certificate was dated November 1, 1969, and listed no limitations.

The following additional pilot data were obtained from Northeast and FAA records:

Total pilot time	2,499:43 hours
Total pilot time in FH-227	281:43 hours
Satisfactorily completed ground school training FH-227	June 5, 1967
Satisfactorily passed initial check out as First Officer FH-227	July 7, 1967
Satisfactorily passed line check FH-227	July 13, 1967
Duty time last 24 hours prior to accident	2:25 hours

First Officer O'Neill was off duty the 24 hours preceding his reporting for Flight 946 on October 25, 1968. He was also off duty on 22, 23, and 24 of October 1968.

Stewardess Betty J. Frail, aged 21, satisfactorily completed her initial stewardess training with Northeast on June 6, 1968. Her last recurrent training was completed on July 24, 1968. Stewardess Frail was off duty the last 24 hours prior to reporting for Flight 946 on October 25, 1968.

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Aircraft Information

The aircraft was a Fairchild Hiller Model FH-227C, N380NE, manufacturer's serial No. 517. The aircraft was manufactured in September 1966, delivered to Northeast Airlines on December 22, 1966, and entered air carrier service on December 27, 1966.

The aircraft had accumulated a total service time of 3,828:15 hours prior to the departure of Flight 946 on October 25, 1968. The last line maintenance inspection was an "A" check, performed 1:29 hours prior to the accident.

The aircraft was powered by two Rolls-Royce RDA532-7 turbo-propeller engines.

The examination of the maintenance records for N380NE indicated that all required inspections had been performed and properly certified in accordance with established procedures of Northeast Airlines and accepted by the Federal Aviation Administration. The records also indicated that the engines and propellers were being operated within their approved overhaul periods.

The following is the maintenance inspection data for the aircraft and the powerplant assemblies:

Total Aircraft Hours	3,828:15
Time since "A" Check	1:29
Time since "B" Check	188:51
Time since "C" Check	438:02

No. 1 Engine Serial No. 13956

	Cold	Hot
Time since overhaul	3,002:49	30.56
Time since inspection	188:51	

No. 2 Engine Serial No. 13933

	Cold	Hot
Time since overhaul	576:52	576:52
Time since inspection	188:51	

<u>No. 1 Propeller Serial No. DRG 79/66 - Model R257/4-30-4/60</u>

Time since overhaul	2,709:12	TT 3,593:01
Time since inspection	188:51	

<u>No. 2 Propeller Serial No. DRG 130/66 - Model R257/4-30-4/60</u>

Time since overhaul	3,295:11	TT 3,298:03
Time since inspection	188:51	

APPENDIX D

AC NO: 91-18

DATE: 12/6/68

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: COURSE NEEDLE OSCILLATIONS ON VHF OMNIDIRECTIONAL RANGE (VOR) RECEIVERS

1. PURPOSE. This advisory circular is issued to advise all operators of aircraft equipped with VHF omnidirectional range (VOR) receivers regarding course needle oscillations.

2. DISCUSSION.

a. On some VORs, pilots may observe brief course needle oscillations and RMI variations (but not reversals) with some flicker (but not reversal) of the "TO-FROM" indicator similar to the indication of "approaching station." This may or may not be associated with "flag alarm" activity. This erratic operation is caused by interference by reflected VOR signals from terrain irregularities or objects such as buildings, powerlines, etc., and is most likely to be encountered at relatively low altitudes. Pilots making VOR approaches in instrument conditions to unfamiliar airports are cautioned to be on the alert for these vagaries and in particular, to use a solid "TO-FROM" reversal indication to determine positive station passage. A similar precautionary statement concerning this effect has appeared in all issues of the Airman's Information Manual published since 1958 under the section titled "Air Navigation Radio Aids."

b. A laboratory test procedure (outlined in para. 3) has been devised to determine whether a VOR receiver is susceptible to reflection interference of the kind described in para. 2.a. Most modern VOR receivers, FAA believes, have been designed to minimize the effect of this interference.

c. Operators of aircraft equipped with VOR receivers that do not pass the laboratory test procedure in para. 3 (or an equivalent test procedure) are cautioned to confirm station passage by DME,

Initiated by: FS-130

or by ATC radar, when using these receivers for VOR instrument approaches in areas subject to reflection interference.

d. This laboratory test procedure may also be useful to equipment manufacturers and to maintenance agencies attempting to confirm pilot reports of erratic VOR receiver performance.

3. TEST PROCEDURE FOR DETERMINING REFLECTION INTERFERENCE

a. Alternatives

In FAA testing, the following equipment and procedure have been found satisfactory. Other equipment and/or procedure, which gives equivalent results, may be used, and may be required to achieve valid results with various receiver designs.

b. Test Equipment

(1) VOR signal generator

(a) Boonton 211A RF
(b) Collins 479 S3 AF

(2) Diode Modulator - Hewlett-Packard 10514A Mixer
(3) Audio Oscillator - WAVETEK 103 Function Generator
(4) 6 DB pad
(5) Vacuum Tube Voltmeter
(6) Milliammeter

c. Procedure

(1) Set up test equipment as shown in Figure 1.

(2) Insert a standard VOR signal, and set 211A attenuator to 400 µv output.

(3) Adjust battery bias to obtain 12 db loss through H-P 10514A mixer. 0.75 m.a. current was necessary in FAA testing.

(4) Using VTVM, measure the level of the 30 Hz variable AM modulation in the 30 Hz channel of the VOR receiver (primary of output transformer).

(5) Turn off 30 Hz variable AM modulation from VOR audio source.

(6) Set audio oscillator output to 1/3 of the value measured in Step (4) to obtain 10 percent modulation. Restore 30 Hz AM.

(7) Vary audio oscillator frequency from 5 to 25 Hz in 1 Hz steps, and from 25 to 100 Hz in 5 Hz steps. Ignore readings at 10, 15, 30, 60, and 90 Hz (± 2 Hz); test at 12 Hz.

(8) At each step, restore 10% modulation as necessary, and measure the amount of deflection by recentering the OBS or VOR audio source bearing selector. This procedure gives the amount of error in the manual channel. Recenter VOR audio source bearing selector to measure error in automatic channel. Consider the average of instrument oscillations.

d. Tolerance.

A VOR receiver is not susceptible to reflection interference of the kind described in para. 2.a. if, using this test procedure, the bearing error is found to be not more than ± 2 degrees in the manual channel and not more than ± 5 degrees in the automatic channel.

K. S. Shiff
acting Director
Flight Standards Service

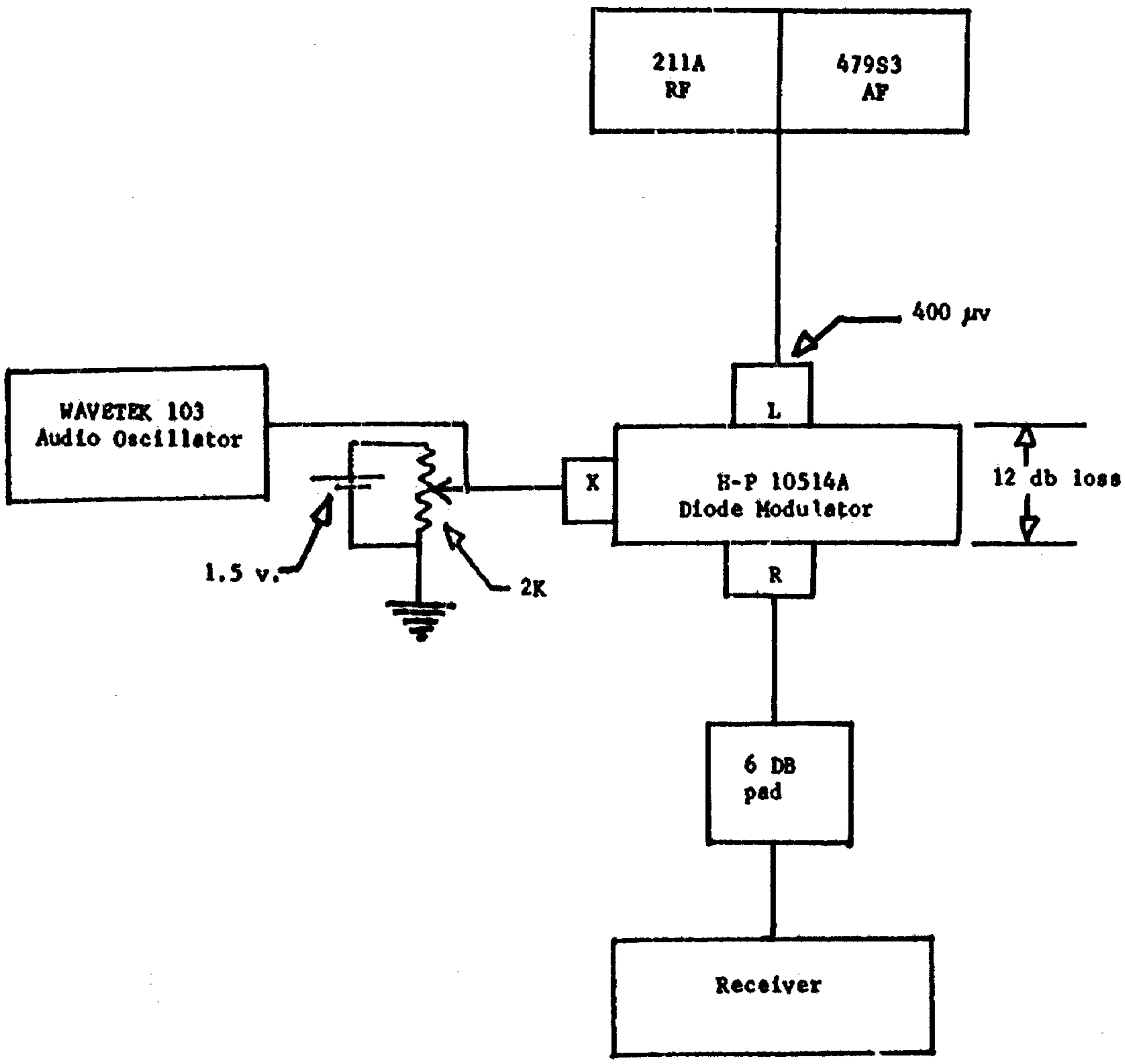
211A
RF
479S3
AF
400 μv
L
WAVETEK 103
Audio Oscillator
X
H-P 10514A
Diode Modulator
12 db loss
1.5 v.
2K
R
6 DB
pad
Receiver

Figure 1

OMNI BEARING INDICATOR

Wilcox 806A

FREQ.	10%	50%	70%
0-1 Hz	0°	356-001°	---
2 Hz	0°	350-000°	350-004°
3 Hz	358°	353°	345°
4 Hz	356°	342°	326°
5 Hz	352°	313-328°	305°
6 Hz	347°	317-322°	302-310°
7 Hz	344°	313°	312°
8 Hz	339°	308°	302°
9 Hz	331°	310°	305°
10 Hz	322-004°	---	256-284°
11 Hz	020°	315°	307°
12 Hz	021°	315°	313°
15 Hz	354-357°	299-310°	296-310°
20-25 Hz	358°	333°	326°
50 Hz	000°	359-002°	358-003°

COURSE DEVIATION INDICATOR

FREQ.	10%	50%	70%	REMARKS
2 Hz	5 ua	60 ua	80 ua	LEFT
3 Hz	21 ua	140 ua	240 ua	LEFT
4 Hz	299 ua	200 ua	185 ua	LEFT
5 Hz	110 ua	325°	160-210 ua	LEFT
6 Hz	150 ua	321°	85-185 ua	LEFT
7 Hz	200 ua	317°	110 ua	LEFT
8 Hz	341°	316°	95 ua	LEFT
9 Hz	337°	316°	316°/80 ua	LEFT
10 Hz	329°-356°	---	*	LEFT
11 Hz	347°	321°	318°/75 ua	LEFT
12 Hz	350°	319°	317°/40-120 ua	LEFT
15 Hz	358°	326°	329°	LEFT
20-25 Hz	000°	329°	331°/75-100 ua	LEFT
50 Hz	000°	000°	000°	

*A continuous change through 360°.

At a value of $\pm$ 150 ua the CDI steer pointer is hard against the stop or travel limit post. This is 10° either side of on course. Bearing values are given as those that would center the CDI.

TO-FROM INDICATOR

FREQ.	10%	50%	70%
2 Hz	225 ua	225 ua	180 ua
3 Hz	225 ua	185 ua	130 ua
4 Hz	230 ua	140 ua	100 ua
5 Hz	230 ua	125 ua	80 ua
6 Hz	235 ua	75-150 ua	50-125 ua
7 Hz	240 ua	110 ua	85 ua
8 Hz	235 ua	110 ua	86 ua
9 Hz	230 ua	110 ua	85 ua
10 Hz	220-250 ua	----	*
11 Hz	235 ua	120 ua	75-125 ua
12 Hz	240 ua	125 ua	75-125 ua
15 Hz	225 ua	75-200 ua	30-190 ua
20-25 Hz	225 ua	180 ua	175 ua
50 Hz	240 ua	205 ua	195 ua

* Indicates TO changing to a peeping FROM.

"TO" CURRENT	FRACTION OF "TO" VISIBLE
50 ua	one-tenth
80 ua	one-fourth
100 ua	one-third
100-130 ua	one-half
185 ua	three-fourths

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NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
WASHINGTON, D.C. 20591

October 29, 1968

Mr. David D. Thomas
Acting Administrator
Federal Aviation Administration
Department of Transportation
Washington, D. C. 20590

Dear Mr. Thomas:

Information received from our accident team investigating the Northeast Airlines accident at Lebanon, New Hampshire, on October 25, 1968, involving an FH227, N380NE, indicates a need for immediate FAA precautionary action directed to all operators of aircraft equipped with Wilcox VOR Model 806A receivers.

Two other Northeast FH227 aircraft, while making approaches to Lebanon Airport on Saturday after the accident, reported false station passage by omni bearing indicator reversals before reaching the VOR station. There was another recorded occurrence of erratic VOR receiver operation on a Northeast aircraft approaching Bermuda earlier this year. TWA, which operates this Wilcox equipment in their DC-9, B-727 and some B-707 equipment, has also reported a number of erratic operation occurrences and two false reversals which were actually observed by two of your FAA inspectors.

In light of this information the Board recommends that the Administrator take immediate precautionary action to restrict all operators using this type of Wilcox VOR receiver equipment to visual approaches where radar or DME is not available and require visual flight during en route operations where an exact fix requirement is necessary for terrain avoidance, if DME or radar verification is not available.

The Board's representatives have discussed the foregoing with your Director and Deputy Director of Flight Standards and also other personnel in Washington, D. C., and Kansas City, Missouri. Our technical staff is available to provide you with further information or assistance as desired.

Sincerely yours,

/s/ Joseph J. O'Connell, Jr.
Chairman

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF THE ADMINISTRATOR

NOV 7 1968

Honorable Joseph J. O'Connell, Jr.
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

Dear Mr. Chairman:

This is in reply to your letter of October 29, 1968, regarding erratic operation and false reversals experienced by users of the Wilcox 806A VOR navigation receiver.

Concurrently, a telegraphic operations and maintenance alert was sent to all regions, area offices, and Flight Standards offices on October 29, 1968, requesting that all known users of this receiver be advised that erratic operation and false reversals have been reported. Restrictions on the use of the 806A receiver for en route operations and VOR instrument approaches were also requested. In addition, the manufacturer was requested by telegram to also alert all known users of the equipment as soon as possible. A copy of our alert notice to the field offices is enclosed.

We believe that the above precautionary action substantially parallels your recommendations.

We intend keeping you advised of further corrective action that may be taken in this regard.

Sincerely,

D. D. Thomas

D. D. Thomas
Acting Administrator

Enclosure

TELEGRAPHIC MESSAGE

NAME OF AGENCY	PRECEDENCE	SECURITY CLASSIFICATION
FEDERAL AVIATION ADMINISTRATION FLIGHT STANDARDS SERVICE WASHINGTON, D. C. 20590	ACTION PRIORITY INFO	
ACCOUNTING CLASSIFICATION	DATE PREPARED 10/29/68	TYPE OF MESSAGE ☐ SINGLE ☐ BOOK ☒ MULTIPLE-ADDRESS
FOR INFORMATION CALL		
NAME James Hemingway / W. H. Sorrell	PHONE NUMBER 25367/ 25331	

THIS SPACE FOR USE OF COMMUNICATION UNIT

MESSAGE TO BE TRANSMITTED (*Use double spacing and all capital letters*)

TO: SERVICE (D) GENOT (NOTE: EU ADDRESSES)
TO: DIRECTORS, ALL REGIONS
DIRECTOR, AERO CENTER, OKLAHOMA CITY

29OCT68 21 572

DATE TIME GROUP

UNCLAS ALDCNS-200, EU-20, EU-700, WE-100, AC-200, ALL AREA OFFICES, ALL FS OFFICES

THIS IS AIR CARRIER AND GENERAL AVIATION OPERATIONS AND MAINTENANCE ALERT [illegible]. AS A RESULT OF SEVERAL RECENT CONFIRMED FALSE DEVIATION INDICATOR, DME AND TO-FROM REVERSALS ON WILCOX ELECTRIC COMPANY MODEL 806A REPEAT 806A RECEIVERS AT MORE THAN ONE VOR FACILITY, ALERT ALL KNOWN USERS OF THIS RECEIVER THAT THIS CONDITION MAY OCCUR. IT IS REQUESTED THAT OWNERS AND OPERATORS OF AIRCRAFT EQUIPPED WITH THIS MODEL RECEIVER ~~[illegible]~~ 1) RESTRICT THE USE OF THESE RECEIVERS TO ENROUTE NAVIGATION WITH POSITION CONFIRMED BY RADAR OR DME PRIOR TO ALTITUDE CHANGES IN CONFORMITY WITH ATC CLEARANCES, AND 2) RESTRICT VOR INSTRUMENT APPROACHES TO ONLY THOSE BASED ON THE INFORMATION OR WHERE STATION PASSAGE IS CONFIRMED BY RADAR. UPON DETERMINATION OF CAUSE AND CORRECTIVE ACTION TO BE TAKEN, THIS ALERT WILL BE REVISED AS APPROPRIATE. REPORT KNOWN MALFUNCTIONS TO NAC CENTER AND CE REGION IN ACCORDANCE WITH 8300.2A CHAPTER II, PARAGRAPH 447 Original signed by
James F. Rudolph
RUDOLPH, FS-1

PAGE NO.	NO. OF PGS.	SECURITY CLASSIFICATION
1	1	

STANDARD FORM 14
REVISED AUGUST 1967
GSA FPMR (41 CFR) 101-35.306

NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
WASHINGTON, D.C. 20591

DEC 13 1968

Honorable David D. Thomas
Acting Administrator
Federal Aviation Administration
Department of Transportation
800 Independence Avenue, S. W.
Washington, D. C. 20590

Dear Mr. Thomas:

Our recent investigation of the Northeast Airlines, Inc., FH-227C, N-380NE accident, near Hanover, New Hampshire, on October 25, 1968, has disclosed several areas where improvements to aviation safety are needed.

Our investigation has indicated that the possibility exists that the Northeast accident flight experienced false indications of station passage while making a VOR approach for landing at the Lebanon Airport. This possibility is predicated, in part, on flightcrew statements from Northeast Airlines, Trans East Airlines, and operators of general aircraft in the Lebanon area. In addition, numerous flight checks conducted during our investigation, using FAA airborne monitoring equipment, revealed that there were several areas of course interference. One area was at a point between the accident site and a commercial TV Station WHBD, 3.8 miles east-northeast of the Lebanon VOR; the other area was 8 to 10 miles east-northeast of the VOR Station, the area where the normal procedure turn inbound is conducted during an instrument approach to the Lebanon Airport. The tests revealed full or partial deflections of the CDI indicators, partial rotation of the RMI's, and some softening of the To-From indicators; however, there was no full reversal of the To-From indicators during any of the flight tests. The flight tests did indicate that the greatest CDI deflections, RMI rotation, and To-From indicator softening occurred to the Wilcox Electric Company Model 806A airborne receivers used by Northeast Airlines.

The use of ground radio frequency interference monitoring equipment disclosed that a direct signal from the Lebanon VOR was detected in the areas where the greatest deviations of the airborne equipment were noted.

Honorable David D. Thomas (2)

During this period, the ground monitoring equipment detected no radio signals from any other radio facility. However, our investigation has revealed instances of radio frequency interference from stations remote from the Lebanon-Hanover areas affecting local radio and law enforcement communication facilities.

1. Signal Interference Effects on the Lebanon VOR Facility

From the fact that the reports from flightcrews concerning the VOR Station deviations do not occur on a regular basis, we would conclude that some radio frequency signals or co-channeling may exist from outside of the Lebanon-Hanover area and these signals do have an effect on the Lebanon VOR signal. We would, therefore, recommend that the FAA conduct long term radio frequency monitoring of the Lebanon VOR area for signal interference.

2. Need For Additional Navigation Facilities at Lebanon

An additional concern to the Board is the use of a single navigational facility for instrument approaches when the facility is subject to environmental factors similar to those which appear to exist at the Lebanon VOR.

We understand that your long range air navigation modernization program provides for the installation of additional navigation aids as well as the upgrading of existing facilities.

Recognizing that there are many airports served by single navigational aids for instrument approaches, the Board recommends that priority consideration be given to the installation of dual navigational facilities at those locations where a single facility could exhibit characteristics of the type found during our investigation of the Lebanon accident.

3. Operating Characteristics of the Wilcox Model 806A Navigation Receiver

The flight tests conducted during our investigation have indicated that the Wilcox Model 806A Receiver is more sensitive to reflected signals and possible frequency interference than navigational receivers of other manufacturers, and this sensitivity can have an effect on the airborne navigation equipment.

Honorable David D. Thomas (3)

The Board recommends that a review be made of the design concept of the Wilcox Model 806A Receiver and its compatibility with other airborne instrumentation and ground station navigational equipment to assure standards of airworthiness. Furthermore, the facts disclosed during our investigation of this accident indicate to us that this compatibility problem may be general in nature and that consideration should be given to reviewing all pertinent standards for compatibility of ground and airborne navigation components.

4. Reporting of Incidents

During the investigation, it was disclosed that prior to the accident a Northeast flightcrew had experienced a false indication of station passage while making an approach to the Lebanon Airport. In this incident, the crew was completing the procedure turn inbound when the CDI needle fluctuated, and the To-From indicators went from "To" to "From," indicating station passage. With these indications, the crew started a descent from 2,800 feet. Upon reaching 2,000 feet, the crew then noticed that the To-From indicators had reversed, indicating a "To." The Captain observed the nearness of the terrain through breaks in the overcast and immediately applied power and climbed back to a safe altitude. This incident was reported to the local FAA maintenance technician who initiated a routine check of the facility which uncovered no irregularity. However, he did not, nor was he required to by your current procedures as we understand them, report this occurrence to any central unit within your organization.

Other Northeast Airlines flightcrews have reported to us that they have experienced previous indications of station signal difficulties. Their reports indicated that full scale CDI deflections and partial rotation of the RMI's have been observed prior to reaching the Lebanon VOR and, in some cases, when they are 5 to 10 miles north of the station.

Our investigation disclosed that there is no evidence to indicate that any of these incidents were reported to the Company for dissemination among their pilots or that they were brought to the attention of the assigned FAA air carrier operation inspectors. We are of the opinion that, had these incidents been reported to proper authorities, a strong possibility exists that the October 25 accident would not have occurred.

Honorable David D. Thomas (4)

We recognize that operational incident reporting is a matter which has received considerable industry attention in past years and that the various proposals suggested have received only limited acceptance. However, until operational performance recorders are installed and regularly monitored, some type of operational reporting system should be devised so that the industry can capture and utilize the hazard warning potential of incidents such as the ones discussed above. In this regard, we believe that the FAA should provide the leadership in developing and implementing an industrywide operational incident reporting system for the interim period. In moving toward this objective, we would hope that you would give early attention to insuring a wider dissemination of existing operational incident data among the elements of your organization.

In connection with the Board's accident prevention responsibilities, our staff is reviewing the general availability and methods of collection of operational incident data within the industry. As this review progresses, we will forward to your staff information of possible interest to you.

5. <u>Positive Station Passage, VOR Instrument Approaches</u>

Our final recommendation concerns the reemphasis of what cockpit indications constitute positive station passage during a VOR instrument approach. The Board is well aware of the warnings to pilots on positive station passage as outlined in the Airmen's Information Manual; however, our investigation at Northeast Airlines and other operators indicated that pilots have different concepts as to what indications constitute true station passage. Some pilots related to our investigators that deflections of the CDI needle were indicative of station passage. Others stated that the rotation of the RMI indicators was indication of station passage; whereas, others did state that they relied on the To-From indicators for positive station passage.

Due to the conflicting opinions by pilots as to what indication should be used to identify positive station passage, we recommend that an Advisory Circular, or similar type bulletin, be issued reemphasizing positive station passage indications.

Honorable David D. Thomas (5)

The areas of our concern were discussed in general with personnel from the Flight Standards Service and Systems Maintenance Service by our Bureau of Aviation Safety staff.

Please feel free to contact us if further information is desired.

Sincerely yours,

Original signed by

Joseph J. O'Connell, Jr.
Joseph J. O'Connell, Jr.
Chairman

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

JAN 14 1969

Honorable Joseph J. O'Connell, Jr.
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

Dear Mr. Chairman:

This is in reply to your letter dated December 13, 1968, concerning your investigation of Northeast Airlines, Inc., FH-227C accident near Hanover, New Hampshire, on October 25, 1968.

As you know, we are aware of the anomalies in the Lebanon VOR signal and of the sensitivity of the Wilcox Electric Company Model 806A receiver to these anomalies. As a matter of fact, the Clarksburg (reflected path signal) effect has been well publicized and has been a part of information disseminated to pilots as far back as 1964. Although numerous flight checks of the facility using the Model 806A and other types of VOR receivers did not reveal any false reversals of To-From indicators and we have received no confirmed reports of any false reversals, as a precautionary measure all known users of the Model 806A receiver were alerted that erratic operation had been reported and requested restrictions on the use of the receiver for VOR instrument approaches where station passage could not be confirmed by DME or radar. You were advised of this action in our letter dated November 7, 1968.

Following are our comments on each of the numbered recommendations in your letter:

1. <u>Signal Interference Effects on the Lebanon VOR Facility</u>. We have investigated the possibility of radio frequency interference effects at Lebanon from co-channel stations. Data derived in coordination with ESSA, U. S. Department of Commerce, shows that, considering ducting and superefraction, there is one chance in fifty that a maximum signal of ten microvolts could be received in the Lebanon area for a total of 50 minutes a year from the nearest co-channel VOR at Elmira, New York. This signal would be usable only in the absence of the Lebanon VOR, but would be about 20 decibel lower than the Lebanon VOR signal in the flight area in question. This ratio would cause less than one degree of error.

Extensive tests conducted at Lebanon indicated the Clarksburg effect to be quite prevalent in the Lebanon area. This effect results from the presence of low-frequency signals (5 Hz to 20 Hz) in the receiver indicating circuits. The signals are the result of the aircraft passing through a region where the VOR direct signal intensity is altered by signals from a reflecting surface. The actual low frequency signals generated by this action is a function of the aircraft's ground speed and its varying angular relationship to the upward reflected signal. Therefore, the irregular occurrence of deviations from the Clarksburg effect is explainable and we cannot conclude that RF interference is indicated. However, we will give further consideration to the need for the recommended long term frequency monitoring. Performance of receivers which exclude the effect by meeting the standard of AC 91-18 will be a factor in this determination.

2. Need for Additional Navigation Facilities at Lebanon. The FAA has a policy to improve navigation aids when necessitated by unsatisfactory performance. In the case of VOR this usually involves relocation or conversion to Doppler VOR. In any event, an additional navigation aid such as DME is primarily installed to provide additional operational benefits, i.e., lower landing minima or reduction of flight time, rather than support of facilities having unsatisfactory performance. The flight inspection tolerances specified for VOR facility performance in the United States Standard Flight Inspection Manual (USSFIM) conform to International Standards and are adequate to support the VOR instrument approach procedures. The Lebanon VOR performs within these tolerances and, therefore, should not require an additional facility to support the instrument procedure. Notwithstanding budgetary constraints, we would like to see a DME located at every VOR site. However, our ultimate objective is to provide vertical guidance, as well as directional, at all air carrier airports.

3. Operating Characteristics of the Wilcox 806A Navigation Receiver. Wilcox Electric Company is now developing a design change to their equipment to minimize the difficulties experienced during flight checks at Lebanon. The restriction discussed above on the Model 806A receiver will be rescinded when the equipment has been modified. We have also issued Advisory Circular AC 91-18, dated December 6, 1968, "Course Needle Oscillations on VHF Omnidirectional Range (VOR) Receivers", which outlines a test procedure to be used to determine susceptibility of VOR receivers to ground reflected signals. Tolerances have been established for tests which equipment should meet. We are planning to request all VOR receiver manufacturers to conduct this test on their equipment and determine its susceptibility to ground reflected signals. An Air Carrier and General Aviation Operations and Maintenance Alert will be issued on all equipment found to be susceptible to ground reflected signals.

The above action should provide sufficient safeguards for equipment now in service. We are also planning to amend the technical standard order for VOR receiving equipment. A new performance requirement and test procedure similar to that in the Advisory Circular will be developed for inclusion in TSO-C40A. Other airworthiness requirements including frequency interference effects and known compatibility problems with navigational aids will also be reviewed to determine whether additional amendments should be made or new requirements issued.

4. Reporting of Incidents. FAR 91.?29 requires all pilots to report malfunctions immediately to ATC and it identifies specific items to be reported. In addition, FAR 121.561 requires air carrier pilots to notify an appropriate ground station when an irregularity in a navigation facility is encountered which, in pilots' opinion, would adversely affect the safety of other flights. We feel that these requirements for pilot reporting are responsive to this problem and see no need at this time to amend them. The Airmen's Information Manual, Part I, page 1-16, also requests pilots who encounter radio interference in flight to report the matter to an FAA facility. However, to preclude the possibility that pilots may not be aware of this important requirement, we plan to issue an Air Carrier and General Aviation Operations Alert so that appropriate emphasis will be given to these reports.

We concur that recorders which have suitable operational parameters appear to offer the best means for obtaining meaningful accident prevention information on operational incidents such as the ones discussed in your letter. In regard to the suggested industrywide operational incident reporting system, this is now being accomplished by our system of issuing telegraphic alerts and operations bulletins - at least with respect to those having a significant effect on safety.

Appropriate revisions to the Board's Safety Investigation Regulations, Part 430, are recommended to enhance the effectiveness of the system to capture and utilize the hazard warning potential of operational incidents. For example, 430.5(a) could be amended to add a new item (6) to require reporting any irregularity of a navigation facility.

We will conduct a complete review of current incident reporting procedures. An objective of this review will include assurances that our reporting procedures are adequate within FAA and industry to insure accuracy and reliability of ground and airborne equipment. We appreciate your offer of information on your own staff's review of the availability and methods of collection of operational incident data. This information could assist in our own efforts along this line.

5. Positive VOR Station Passage. The Airmen's Information Manual, page 1-9, VOR, paragraph b, currently provides cautionary information to pilots to use the "To-From" indicator to determine positive station

passage. While considered adequate in its present form, we are going to set this item aside as a separate paragraph in bold print on future editions of the AIM. In addition, the FAA Instrument Flying Handbook, AC 61-27, and Air Carrier training programs emphasize the positive station passage is to be determined from the "To-From" indicator. The recently issued Advisory Circular AC 91-18 also describes additional instructions for checking VOR receivers including use of DME and radar for receivers which do not pass prescribed tests.

We trust our comments and information in the areas of your concern will be helpful.

Sincerely,

D. D. Thomas

D. D. Thomas
Acting Administrator

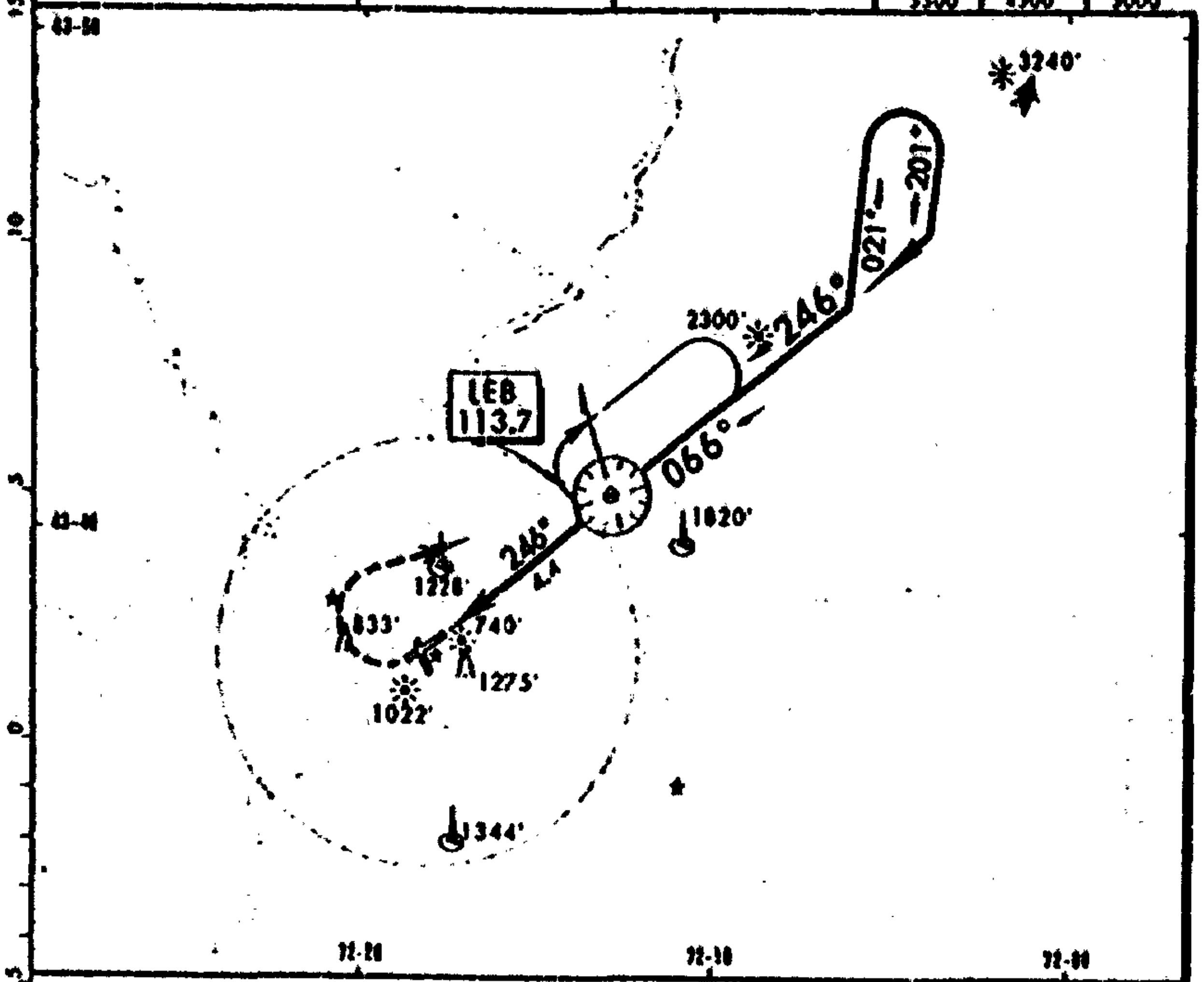
Jeppesen Approach Chart FEB 16-68 (13-1)

LEBANON, N.H.
LEBANON REGIONAL
VOR-1

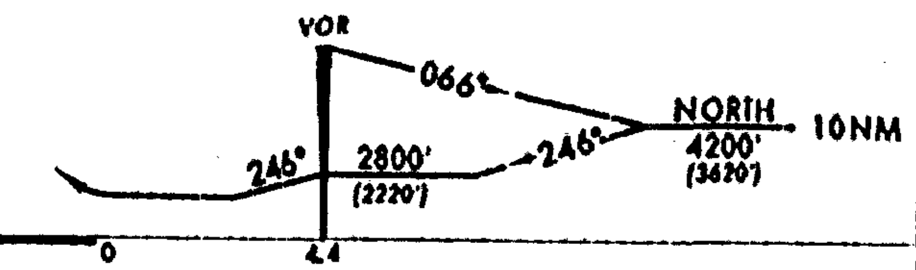
VOR 113.7 LEB

LEBANON Radio 122.1G 122.2 122.6 123.6 255.4		Apt. Elev. 580' Var. 15°W Class BVOR
Approach	Departure	Ground

MSA



CAUTION: High terrain and turbulence all quadrants.



PULL UP STRAIGHT AHEAD to 2000 feet within 5 NM, turn RIGHT to 4200 feet to LEB VOR and hold NORTHEAST.

STRAIGHT-IN LANDING RWY		CIRCLE-TO-LAND		
			DAY	NIGHT
A B C	NA	A B C	1880'(1300')-2	2580'(2000')-2
D	NA	D & 3 Eng Jet	1880'(1300')-2	2580'(2000')-2
All Non Std	NA			

Gnd speed-Kts	60	80	100	120	140	160
VOR to MAP 4.4	4:24	3:18	2:38	2:12	1:53	1:39

CHANGES: Minima format