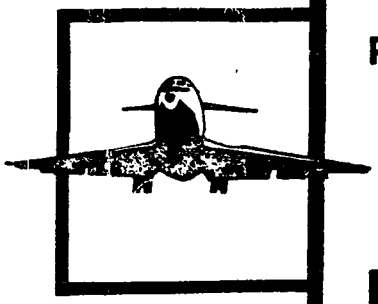

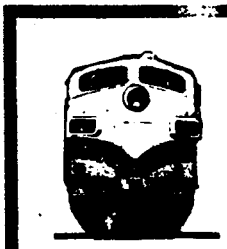

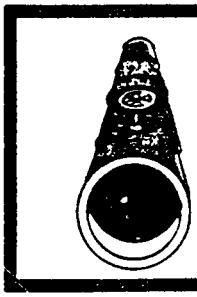

PB85-910403

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

AIR ILLINOIS HAWKER SIDDLEY
HS 748-2A, N748LL
NEAR PINCKNEYVILLE, ILLINOIS
OCTOBER 11, 1983

NTSB/AAR-85/03

UNITED STATES GOVERNMENT

CONTENTS

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AIRCRAFT ACCIDENT REPORT

Adopted: March 5, 1985

AIR ILLINOIS HAWKER SIDDLEY HS 748-2A, N748LL NEAR PINCKNEYVILLE, ILLNOIS OCTOBER 11, 1983

SYNOPSIS

On October 11, 1983, Air Illinois Flight 710 was being operated as a regularly scheduled passenger flight between Capital Airport, Springfield, Illinois and Southern Illinois Airport, Carbondale, Illinois. About 2020 central daylight time, Flight 710 departed Springfield with seven passengers and three crewmembers on board. About 1.5 minutes later, Flight 710 called Springfield departure control and reported that it had experienced a slight electrical problem but that it was continuing to its destination about 40 minutes away.

The cockpit voice recorder (CVR) transcript showed that shortly after takeoff Flight 710's left generator suffered a complete mechanical failure and that in responding to the failure of the left generator, the first officer mistakenly isolated the right generator and the right generator bus bar from the airplane's d.c. electrical distribution system and, thereafter, the right generator disconnected from the right generator bus bar. All subsequent attempts to restore the right generator to the airplane's d.c. electrical distribution system were unsuccessful, and the airplane proceeded toward Carbondale relying solely on its batteries for d.c. electrical power.

The flight toward Carbondale was conducted in instrument meteorological conditions. The cloud bases in the area of the accident were at 2,000 feet m.s.l. with tops at 10,000 feet. Visibility below the cloud bases was 1 mile in rain, and there were scattered thunderstorms in the area.

About 2053, while the airplane was descending from its instrument flight rules (IFR) assigned altitude of 3,000 feet, battery power was depleted. Flight 710 continued to descend, turned about 180°, and crashed in a rural area near Pinckneyville, Illinois, about 22 nmi north northwest of the Southern Illinois Airport. The airplane was destroyed by impact forces, and all 10 persons on board the airplane were killed. There was no postcrash fire.

The National Transportation Safety Board determines that the probable cause of the accident was the captain's decision to continue the flight toward the more distant destination airport after the loss of d.c. electrical power from both airplane generators instead of returning to the nearby departure airport. The captain's decision was adversely affected by self-imposed psychological factors which led him to assess inadequately the airplane's battery endurance after the loss of generator power and the magnitude of the risks involved in continuing to the destination airport. Contributing to the accident was the airline management's failure to provide and the FAA's failure to assure an adequate

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15. Supplementary Notes

16. Abstract On October 11, 1983, Air Illinois Flight 710 was being operated as a regularly scheduled passenger flight between Capital Airport, Springfield, Illinois and Southern Illinois Airport, Carbondale, Illinois. About 2020 central daylight time, Flight 710 departed Springfield with seven passengers and three crewmembers on board. About 1.5 minutes later, Flight 710 called Springfield departure control and reported that it had experienced a slight electrical problem but that it was continuing to its destination about 40 minutes away.

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Loss of d.c. electrical power from both airplane generators; decision to continue flight; inadequate assessment of risks involved in continued flight; self-imposed psychological factors.	This document is available to the public through the National Technical Information Service Springfield, Virginia 22161

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1. FACTUAL INFORMATION

1.1 History of Flight

On October 11, 1983, Air Illinois Flight 710, a Hawker Siddley 748-2A was being operated as a regularly scheduled passenger flight between Chicago, Illinois, and the Southern Illinois Airport, Carbondale, Illinois, with an en route stop at Springfield, Illinois. The flight was about 45 minutes behind schedule when it arrived at Capitol Airport, Springfield, Illinois, about 2005. 1/ The flightcrew remained on board while the airplane was loaded with 300 gallons of jet-A fuel. The flightcrew did not report any mechanical malfunctions to either the Air Illinois controlling dispatcher in Carbondale or to the ramp personnel at Springfield. Air Illinois station personnel gave the flightcrew documents containing the latest Carbondale weather and the airplane load information which had been prepared by the company dispatcher in Carbondale.

At 2011, at the request of Flight 710, the flight service specialist at the Decatur, Illinois Flight Service Station provided the flightcrew with the latest Carbondale weather and the St. Louis, Missouri, winds aloft. The flight service specialist said the reported ceiling and visibility at Carbondale were 2,000 feet overcast and 2 miles, respectively, with light rain and fog. He also provided the flight with the winds aloft at three, six, and nine thousand feet and asked the crew if it wanted the St. Louis weather. The crew replied, "Negative," and the Flight Service Station had no further contact with Flight 710.

The 127-nmi flight to Carbondale was to be flown in accordance with an Instrument Flight Rules (IFR) flight plan stored in the Kansas City, Missouri, Air Route Traffic Control Center (ARTCC) computer. The routing was direct at an altitude of 9,000 feet 2/ and the estimated time en route was 45 minutes. However, at 2011:44, when Flight 710 requested its IFR clearance, it also requested 5,000 feet for its en route altitude. The request was approved.

Flight 710 had been scheduled to depart from Springfield at 1935; however, it was not cleared to taxi from the gate until 2015:14. There were 7 passengers and 3 crewmembers on board Flight 710 when it left the gate. At 2016:00, Flight 710 was cleared to taxi to runway 18 for takeoff. At 2019:40, Springfield tower cleared Flight 710 for takeoff, which occurred about 2020:00, and then, at 2020:43, the tower told the flight to contact Springfield departure control.

At 2021:14, Flight 710 contacted departure control and informed the controller that it was climbing through 1,500 feet. The departure controller advised the flight that he had it in radar contact, cleared it to climb to and maintain 5,000 feet, and cleared it to proceed direct to Carbondale after it received the Carbondale VOR (very high frequency omni directional radio) signal on its navigational radio. Flight 710 acknowledged receipt of the clearance.

1/ All times herein are central daylight time based on the 24-hour clock.
2/ All altitudes herein are mean sea level unless otherwise specified.

At 2021:34, Flight 710 informed the departure controller that it had experienced a "slight electrical problem. . . ." and that it would keep the controller "advised." The controller asked the flight if it was going to return to Springfield, and the flight reported that it did not intend to do so.

At 2022:10, the flight told departure control that "We'd like to stay as low as we can," and then it requested and was cleared to maintain 3,000 feet. The controller asked the flight if he could provide any assistance, and the flight responded, ". . .we're doing okay, thanks."

At 2023:54, the first officer told the captain that "the left (generator) is totally dead, the right (generator) is putting out voltage but I can't get a load on it." At 2024:26, the first officer reported, "zero voltage and amps (amperes) on the left side, the right (generator) is putting out twenty-seven and a half (volts) but I can't get it to come on the line." At 2025:42, he told the captain that the battery power was going down "pretty fast."

At 2026:03, Flight 710 reported to the Kansas City ARTCC and told the center controller that they were at 3,000 feet. Shortly thereafter, the first officer reported that the battery voltage was 22 volts.

At 2027:24, the captain called Kansas City center and stated that he had an "unusual request." He asked clearance to descend to 2,000 feet "even if we have to go VFR [visual flight rules]." He also asked the controller "to keep your eye on us if you can." The controller told the flight that he could not clear it to descend because 2,000 feet was below his "lowest usable altitude." He also told the flight that if it requested VFR and then descended to 2,000 feet he did not believe he would be able to maintain radar contact. The captain thanked the controller and continued to maintain 3,000 feet. During this conversation, the first officer reported that the battery voltage was 22.5 volts.

At 2028:45, the captain said "Beacons off. . .," and, at 2028:46, he said, "Nav (navigation) lights are off." At 2031:04, the first officer reminded the captain that Carbondale had a 2,000-foot ceiling and that the visibility was 2 miles with light rain and fog.

At 2033:07, the flight attendant came forward and the captain asked her if she could work with what she "had back there." The flight attendant reported that the only lights operating in the cabin were the reading lights, the lights by the lavatory, the baggage light, and the entrance lights. The captain instructed her to brief the passengers that he had turned off the excess lights because the airplane had experienced "a bit of an electrical problem. . . ." but that they were going to continue to Carbondale. The flight attendant requested the Carbondale estimated time of arrival (ETA) and the first officer said they would arrive "about on the hour."

At 2038:41, the first officer told the captain, "Well, when we. . . .started losing the left one I reached up and hit the right [isolate button] trying to isolate the right side [be] cause I assumed the problem was the right side but they [the generators] both still went off."

At 2044:59, in response to the captain's request, the first officer reported that the battery voltage was 20 volts. At 2049:23, Kansas City center requested Flight 710 to change radio frequencies. The flight acknowledged the request, which was the last radio communication received from Flight 710.

At 2051:37, the first officer told the captain, "I don't kn[illegible]ve have enough juice to get out of this. At 2052:12, the captain asked the first [illegible] to "Watch my altitude, I'm going to go down to twenty-four hundred (feet)." He [illegible]n asked the first officer if he had a flashlight and to have it ready. At 2053:18, the first officer reported, "We're losing everything, . . .down to about thirteen volts," and, at 2053:28, he told the captain the airplane was at 2,400 feet. At 2054:00, the captain asked the first officer if he had any instruments. The first officer asked him to repeat and, at 2054:16, the captain asked, "Do you have any instruments, do you have a horizon [attitude director indicator] ?"

About 2051, Kansas City center lost radar contact with Flight 710. The last confirmed radar return from Flight 710 occurred near the Centralia, Illinois VORTAC 3/ located about 40 nmi north of the Southern Illinois Airport. The accident occurred during the hours of darkness. The wreckage of the airplane was found in the rural area about 6 nmi northeast of Pinckneyville, Illinois, at 38° 9' north latitude, 89° 19' west longitude. Three crewmembers and seven passengers were killed in the crash.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others	Total
Fatal	3	7	0	10
Serious	0	0	0	0
Minor	0	0	0	0
None	0	0	0	0
Total	3	7	0	10

1.3 Damage to Airplane

The airplane was destroyed.

1.4 Other Damage

None.

1.5 Personnel Information

The flightcrew and flight attendant were qualified in accordance with current regulations.

The captain and first officer had been on duty the preceding day. They had reported to operations at Southern Illinois Airport at 0500, had flown four flights in the Hawker Siddley 748-2A (HS 748-2A) between Southern Illinois Airport, Springfield, and Chicago, and had returned to Southern Illinois Airport at 1754. Both pilots signed off duty about 1809, and both retired about 2200 that night.

On October 11, the captain arose about 0830 and had about 2 cups of coffee with his roommate. According to his roommate, the captain's demeanor seemed normal.

3/ Co-located very high frequency omnidirectional radio and Tactical Air Navigation Aid that provides azimuth and distance information

He left home about 1015 and signed in at operations at 1050. The first officer arose about 0930, skipped breakfast because he was late, left for the airport at 1015, and signed in at operations at 1050.

The captain and first officer were scheduled to "deadhead" to Springfield to pick up the HS 748-2A, N748LL for Flights 709 and 710. They left the Southern Illinois Airport at 1120, arrived at St. Louis about 1200, and remained in St. Louis about 3 hours. The captain and first officer had been scheduled to fly to Springfield on Air Illinois Flight 5; however, Flight 5 was late and they were rerouted. They departed St. Louis on a de Havilland DHC-6, Twin Otter about 1530, arriving at Burlington, Iowa at 1659. They departed Burlington at 1704 on Air Illinois Flight 905, another DHC-6, and arrived in Springfield at 1755.

By the time the captain and first officer arrived in Springfield, the flightcrew that had flown the HS 748-2A on the previous flight had left the airport. The crewmembers of the previous flight said that they did not experience any mechanical malfunctions while they were operating the aircraft. Air Illinois Flight 709 departed Springfield at 1805, 45 minutes behind schedule, and arrived at Meigs Field at 1859.

Flight 710, which originated at Meigs Field, departed Meigs Field at 1915 and arrived in Springfield at 2005.

1.6 Airplane Information

The airplane, a Hawker Siddley HS 748-2A, N748LL, was owned and operated by Air Illinois, Inc., (see appendix C) and was the only HS 748-2A Air Illinois owned and operated. According to Air Illinois' Federal Aviation Administration (FAA) Operating Specifications, N748LL was to be maintained in accordance with an approved continuous maintenance program which incorporated the latest approved British Aerospace maintenance schedule. In addition to several checks and inspections based on either days or hours in service, the program required the carrier to conduct period inspections. The carrier's FAA Operations Specifications stated "Each Period Inspection will be sectionalized into ten (10) consecutively numbered parts. Each part shall be performed at intervals not to exceed 1,000 hours of aircraft time in service from the time of the last correspondingly numbered part of the previous period."

1.6.1 Flight Logbook and Maintenance Discrepancy Form Writeup

The Safety Board's investigation revealed that the Air Illinois HS 748-2A flightcrews had not been entering maintenance discrepancies in the discrepancies section of the airplane logbook 4/ after each flight. Federal Aviation Regulation (FAR), 14 CFR

4/ The airplane logbook, or flight log, is carried on the airplane on all flights and contains the Air Illinois Form 1. The Form 1 contains entry formats for logging flight times, selected performance parameters, maintenance discrepancies, and the action taken by maintenance personnel to correct the discrepancies entered by the pilots. The Form 1 also contains the airplane's airworthiness release which, in accordance with the provisions of 14 CFR 121.709 and the Air Illinois Maintenance Manual, must be signed before flight by an authorized certificated mechanic. Signing the airworthiness release certifies the following: (1) all work was performed in accordance with the requirements of the certificate holder's manual; (2) all items required to be inspected were inspected by an authorized person who determined that the work was satisfactorily completed; (3) no known condition exists that would make the airplane unairworthy; and (4) so far as the work performed is concerned, the airplane is in condition for safe operation.

121.563 requires the pilot in command to "ensure that all mechanical irregularities occurring during flight time are entered into the maintenance log of the airplane at the end of that flight time." Section 5.03(1) of the Air Illinois Operations Manual states, "Maintenance discrepancies discovered by the pilot will be recorded in the flight log." Section 5.03 (2) states, in part, "Maintenance discrepancies may only be cleared by authorized personnel. . . .by entering a brief description of the action taken and the signature of authorized personnel. Action taken will be either repair or removal to the Deferred List. Maintenance personnel only will make the decision to defer items, thus removing them to the Deferred List." Section 5.04 (1) of the Manual states, in part, "In the event a maintenance problem occurs away from home base the Captain will immediately notify Operations/Maintenance. If a determination is made that the airplane must be repaired before further flight. . . ." the company would either send a mechanic to the location of the airplane or contract with an authorized local repair facility to perform the required corrective action. With regard to determining whether the airplane must be repaired before further flight, Section 5.01(6)(b) of the Operations Manual states, in part, "Discrepancies that do not affect the airworthiness of the aircraft may be carried over to the Deferred Maintenance List to the next inspection period. . . ." Section 8.03 of the Manual states, in part, that, before each trip and/or, airplane's origination, the oncoming captain shall review the logbook to assure himself that he is "completely familiar with the mechanical aspects of the aircraft." The section also states that "the captain is responsible for assuring that all items are entered in the Form 1 (flight log)," and that, at the end of the flight, "the captain shall sign his name in the appropriate spot next to the discrepancies signifying his review and approval of all entries on the Form 1."

The investigation also disclosed that only five captains were scheduled to fly the HS 748-2A, that the airplane was returned to the Air Illinois maintenance base at Southern Illinois Airport every night, and that a maintenance debriefing procedure had developed between the captains and the maintenance crews. Instead of entering the maintenance discrepancies or irregularities into the logbook as they occurred, the captains would either record the discrepancy on a separate piece of paper or commit the circumstances of the discrepancy to memory. When they returned to the Southern Illinois Airport, the captains would either deliver the piece of paper to or brief the maintenance crew, on what had occurred, or both.

During the Safety Board's public hearing, the HS 748-2A chief pilot and two other captains who had regularly flown the HS 748-2A testified that, between September 21 and October 2, 1983, the airplane had experienced several generator shutdowns, overvoltage malfunctions, and voltage regulator problems. These malfunctions were not entered in the discrepancy section of the airplane's flightlog. The chief pilot and captains testified that they did not make the entries because the malfunctions were either intermittent in nature, or had subsequently corrected themselves and did not recur, or that maintenance already knew of the problem. They also testified that they personally had briefed maintenance personnel about the nature and extent of the malfunctions. In order to construct a list of the electrical discrepancies involving the airplane's d.c. electrical generating system, it was necessary to review both the airplane logbook and the airplane's maintenance discrepancy forms.

Between May 1983 and September 22, 1983, there were no signficant writeups relating to the d.c. electrical system or generators. Between September 22 and October 5, 1983, the following eight generator discrepancies together with the corrective actions taken were logged on the company's Maintenance Discrepancy Report Forms: 5/

5/ The maintenance discrepancy report form contains formats for entering maintenance discrepancies and the actions taken to correct the discrepancies. This form is used by maintenance personnel only and is not carried on board the airplane.

September 22. The right generator dropped off the line due to an overvoltage condition; the right voltage regulator was replaced.

September 26. Brush check was made on the right generator in order to trouble shoot the generator; no defects were noted and the generator was returned to service.

September 27. The right generator overvoltage relay was changed at the request of the HS 748-2A maintenance manager.

September 28. The left generator overvoltage relay was changed at the request of the HS 748-2A maintenance manager.

September 29. The right overvoltage relay set slightly high; the right overvoltage relay was removed and replaced.

September 30. The right generator voltage regulator was removed due to "very slight voltage fluctuations."

October 2. Right generator voltage 0.4 volt high; voltage adjusted within limits.

October 5. Right and left generators to be inspected per HS 748-2A maintenance manager's request, measure and record generator brush length; inspections and measurements carried out per maintenance manager's request.

Since the generators are operated in parallel during flight, the airplane's electrical load should have divided equally between the two generators. However, a maximum load differential between the generators of not in excess of 40 amperes is allowable. Examination of the performance section of the flight log showed that between September 1 and September 25, 1983, the load differential between the generators was 5 amperes or less. On September 25, 27, 28, 29, and 30, the loads on the left generator exceeded those on the right generator by 40 to 70 amperes; on October 2, the load on the right generator exceeded those on the left generator by 45 amperes. The right generator voltage was adjusted on October 2, 1983, and, thereafter, the load differential between the generators remained within allowable tolerances.

Between October 3 and October 11, 1983, Air Illinois and British Aerospace, Manchester, England, division exchanged eight telex messages concerning the attempts of Air Illinois maintenance personnel to regulate the generators' voltages within the parameters contained in the British Aerospace HS 748-2A Maintenance Manual. According to the maintenance manual, the maintenance tolerance for the generator voltages is 27.5 plus or minus 0.25 volt. During the course of trying to trim the voltage regulators and set the generator voltages within the required parameters, Air Illinois, in response to a request from British Aerospace, also checked the brush length and the condition of commutator bars on both generators. Despite several attempts, Air Illinois was unable to set the generator voltages within the prescribed parameters. On October 10, 1983, Air Illinois informed British Aerospace that, with the engines running at cruise rpm, the voltage and load readings on the left and right generators were 27.9 volts/80 amperes and 27.9 volts/72 amperes, respectively, and asked "is this within voltage limits?"

On October 11, the day of the accident, British Aerospace replied that the voltage was not correct and that, if the prescribed voltage parameters were not obtainable, they "would suspect voltage regulators or test equipment."

According to the airplane manufacturer, the voltage limitation contained in the maintenance manual was established to provide a more efficient and equitable sharing of the loads between the generators during flight, therefore, the excess generator voltage on the accident airplane would not have adversely affected either the generator, the generator switching unit, or the generator's consumer equipment. In addition, the generator manufacturer's specifications showed that the generator was authorized for continuous operation at 30 volts.

1.6.2 Maintenance Organization and Procedures

The Air Illinois maintenance procedures and organization were established in accordance with Subpart L of 14 CFR 121 of the FARs. With regard to maintenance inspection procedures, the regulations contained in Subpart L require the certificate holder to ensure the following: that no person may perform a required inspection unless he is appropriately certificated, properly trained, qualified, and authorized to do so; no person may allow any person to perform a required inspection unless, at the time, the person performing that inspection is under the supervision and control of an inspection unit; and, that no person may perform a required inspection if he performed the item of work required to be inspected.

The FARs also require the certificate holder to organize his maintenance functions so as to separate the required inspection functions from the other maintenance, preventive maintenance, and alternate functions. In addition, the certificate holder is required to put into his maintenance manual a chart or description of the certificate holder's organization.

At the time of the accident, the Air Illinois organization chart that was in effect contained Chief Inspector and Assistant Chief Inspector positions; however no inspectors were assigned to these positions. With regard to the HS 748-2A maintenance organization, the lead mechanics were certificated, trained, and qualified to perform the required inspection items (RII). However, according to the company organization chart, these personnel were assigned to, and reported to, the HS 748-2A maintenance manager. The HS 748-2A manager testified that, when the lead mechanics were acting in their capacity as inspectors, they reported directly to the Chief Inspector and when acting in their capacity as mechanics, they reported to him. A former Air Illinois HS 748-2A lead mechanic, who had left Air Illinois to take a similar position with another carrier, testified that he had received his inspection assignments from both the Chief Inspector and the HS 748-2A maintenance manager. He also testified that he had never been directed to inspect a maintenance task which he had performed himself.

The lead HS 748-2A mechanic at the time of the accident also was qualified to perform RII inspections. He testified that since no one else on his shift could perform an RII, he would direct another mechanic to do the job and then perform the inspection.

Both the former and present HS 748-2A lead mechanics testified that the part inspections contained in the period inspection program were being performed before they became due in order to ease the scheduled maintenance workload and to ensure that the airplane remain available for scheduled operations. Thereafter, the work completed entries were entered on the Maintenance Discrepancy Report Form and signed off on the

date the part inspection was required to have been performed. They also testified that the clipboard containing the dates on which these inspections were required was hidden deliberately when the FAA maintenance inspectors were conducting a surveillance of the Air Illinois maintenance facility to prevent the inspectors from discovering this practice. The HS 748-2A maintenance manager testified that he did not implement this procedure. He said that he knew the mechanics were hiding the clipboard, but that "he did nothing to stop the procedure." He testified that "you cannot complete a part inspection [legally] before it came due" and that "on occasion that would happen. This is something that I didn't want to discuss with the FAA."

The former HS 748-2A lead mechanic testified that the practice of post-dating the maintenance records also included the replacement time of life-limited or hard time change components (a mechanical part, component, or appliance which can only be operated for a specified time). He also said that, with regard to post-dating the replacement times of life-limited parts, this practice had ended several years ago. The HS 748-2A maintenance manager testified that they had overshot time changes that were hard time, however, they had "never ever put [entered] the wrong date [in the maintenance records]." According to the maintenance manager, the last "overshoot" occurred 6 months before the accident when a 5,000-hour life-limited" temperature control valve actuator. . . .exceeded its time by approximately 24 hours."

During the investigation, the Safety Board reviewed the removal and replacement times of the electrical system's life-limited components. All of these components had been removed and replaced within their specified life cycles.

1.6.3 Electrical System Malfunction History

The HS 748 airplane has been in service since April 4, 1962. To date, 370 HS 748 airplanes have been sold to 80 operators throughout the world.

During the investigation, the Safety Board requested the manufacturer, the British Civil Aviation Authority (CAA), and the FAA to provide all available operator occurrence reports relating to the HS 748 series 2 airplane electrical system. Sixty-four occurrence reports, covering a period between 1963 and 1984, were received from the manufacturer and the CAA; 17 reports, covering a period between 1978 and 1983, were received from the FAA.

The combined data contained 81 operator occurrence reports; included therein were 39 reported generator failures, 17 of which were reported double generator failures. The remaining 42 reports concerned other electrical system components. (See appendix C.) None of the 81 operator occurrence reports indicated that the airplanes involved had incurred other damage, and, in all instances, the flightcrews had landed the airplanes safely.

1.7 Meteorological Information

The National Weather Service (NWS) Area Forecast which was was issued by the NWS Advisory Unit in Kansas City, Missouri, at 1940. October 11, 1983, contained, in part, the following data pertinent to the area of the accident: Ceilings 2,000 to 3,000 feet broken layered to 20,000 feet. Ceilings and visibilities occasionally below 1,000 feet and 3 miles in moderate rain and fog. Widely scattered thunderstorms, moderate rain showers, cloud tops 40,000 feet. According to the forecast, the thunderstorms implied severe or greater turbulence, severe icing, and low level windshear.

According to an NWS official, there were no SIGMETS or AIRMET there were no Center Weather advisories pertinent to the route of flight in effe the time of the accident.

Weather Radar Data.--NWS radar was located at Evansville, Indiana, and St. Louis, Missouri. According to an official at the Evansville office, between 2026 and 2028, there were no radar echoes over the accident site.

The 2030 weather radar overlay from the St. Louis radarscope showed a Video Integrator Processor (VIP) 6/ level 2 weather echo over the accident site, and a VIP level 3 echo located about 3 nmi east of the site. The 2130 overlay showed a VIP level 3 echo about 2 nmi west of the accident site. The maximum echo intensity observed within a 20-nmi radius of the accident site on both overlays was a VIP level 3. (According to the FAA, the precipitation intensities and turbulence contained in VIP levels 1, 2, and 3 weather echoes are as follows: VIP levels 1 and 2 contain light to moderate precipitation with light to moderate turbulence possible. VIP level 3 contains heavy precipitation; severe turbulence and lightning are possible.)

A color photograph of the Radar Remote Weather Display System at the Kansas City ARTCC taken at 2103 showed a VIP level 2 weather echo over the accident site and a VIP level 3 weather echo about 2 nmi west of the site. The maximum weather echo intensity within 15 nmi of the accident site was a VIP level 3.

Five witnesses who either heard or saw Flight 710 near the accident site were interviewed on October 12, 1984. The witnesses stated that they did not see any lightning, hear any thunder, or see the effects of any significant winds at the time of the accident, and that it was raining hard. None of the witnesses mentioned the occurrence of hail. Two Air Illinois flights were flying either near or over Cabbi intersection nmi south of the accident site). At 2100, Flight 804 was over Cabbi at 4,000 feet. The captain of Flight 804 said that he experienced light chop and moderate rain showers in the clouds. The base of the overcast was about 2,000 feet and there were scattered clouds about 200 to 300 feet below the base of the overcast.

At 2145, Air Illinois Charter Flight 1010 was near Cabbi. The captain of Flight 1010 said that he experienced light turbulence and light to moderate showery precipitation and that he was able to see the ground at 2,500 feet.

Surface Weather Observations.--The following surface weather observations were taken by observers certified by either the NWS or the United States Air Force:

Southern Illinois Airport Carbondale, Illinois

1945 -- Estimated ceiling--2,000 feet overcast; visibility--2 miles, light rain, fog; temperature--65° F; dewpoint--63° F; wind estimated--150° at 10 knots; altimeter setting--29.87 inHg.

2045 -- Estimated ceiling--2,000 feet overcast; visibility--1 mile, thunderstorm, moderate rain showers; temperature--63° F; dewpoint--61° F; winds estimated--180° at 8 knots; altimeter setting--29.86 inHg; thunderstorm began 2040 northwest moving northeast, occasional lightning in cloud, cloud to cloud.

6/ NWS radar systems are able to determine objectively radar weather echo intensity by the use of VIP equipment. Based on this capability, the NWS has classified six levels of echo intensities and has assigned VIP numbers for each level, the higher numbers indicating more severe conditions.

2110 -- Estimated ceiling--2,000 feet overcast; visibility--1 1/2 miles, light rain, fog; winds estimated 180° at 5 knots; altimeter setting--29.84 inHg; thunderstorm ended 2110, moved northeast.

Springfield, Illinois

1951 -- Measured ceiling--2,800 feet broken, 4,500 feet overcast; visibility--6 miles, haze; temperature--65° F; dew point--61° F; wind--130° at 13 knots; altimeter setting--29.82 inHg.

2052 -- Measured ceiling--2,800 feet broken, 4,500 feet overcast; visibility--6 miles, light rain showers, fog; temperature--65° F; dew point-- 62° F; winds--150° at 12 knots; altimeter setting--29.81 inHg; rain began 2048.

St. Louis International Airport

1945 -- 1,000 feet scattered, estimated ceiling 4,000 feet broken, 9,000 feet broken; visibility--4 miles, fog, haze; winds--140° to 12 knots.

2045 -- 1,000 feet scattered, measured ceiling 3,800 feet broken, 9,000 feet broken; visibility--4 miles, light rain showers, fog, haze; winds--150° at 10 knots.

Scott Air Force Base, Belleville, Illinois

2038 -- 500 feet scattered, measured ceiling 1,000 feet broken, 1,500 feet overcast; visibility--2 miles, thunderstorm, light rain showers, fog; wind--150° at 2 knots.

2055 -- 500 feet scattered, measured ceiling 1,000 feet broken, 1,500 feet overcast; visibility--2 miles, light rainshowers, fog; wind--170° at 4 knots.

Preflight Weather Information.--About 1950, the Air Illinois dispatcher at Carbondale sent an updated weather package to Springfield for Flight 710. The package contained the current Springfield, Cape Girardeau, Missouri (35 nmi south southwest of Carbondale), and Carbondale surface weather observations. The dispatcher checked the Carbondale surface weather observation reported in the weather system to verify that it was the same one that had been received via the telephone moments before from the observer at Carbondale. It was, in fact, the same and reported a 2,000-foot overcast ceiling with 1 mile visibility in rain and fog. The Air Illinois Customer Service Agent at Springfield provided the weather documentation to Flight 710's flightcrew before the flight departed. At 2011, a member of the flightcrew of Flight 710 called the Decatur, Illinois, flight service station by radio and requested the Carbondale weather and the St. Louis winds aloft. The flight service station specialist provided the crew the Carbondale surface weather observation of estimated ceiling--2,000 feet overcast; visibility--2 miles, light rain, fog; temperature--65° F; dew point--63° F; estimated wind--150° at 10 knots; altimeter setting--29.87 inHg. The specialist also provided the St. Louis winds aloft at 3,000, 6,000, and 9,000 feet.

Flight Service Handbook 7110.10G, paragraph 170, states that pertinent Flight Precaution information is to be delivered to pilots during inflight weather briefings. The area forecast issued at 1940, October 11, 1983, contained a Flight Precaution for IFR conditions which was pertinent to Flight 710's route; the preceding area forecast issued at 1340, October 11 also contained a thunderstorm Flight Precaution pertinent to Flight 710's route. Although the later forecast was valid at the time the flight service specialist briefed Flight 710's crew, the Safety Board could not determine if it was available to the flight service specialist at the time he briefed Flight 710's flightcrew. However, the earlier forecast probably was available at that time and the flight service specialist did not provide the flightcrew with either Flight Precaution.

1.8 Aids to Navigation

Not Applicable.

1.9 Communications

There were no known communications difficulties.

1.10 Aerodrome Information

Capital Airport, Springfield, Illinois, elevation 597 feet has three paved runways: 4/22, 12/30, and 18/36. Runway 12/30 is 5,298 feet long and 150 feet wide; runway 18/36 is 5,299 feet long and 150 feet wide; and, runway 4/22 is 7,999 feet long and 150 feet wide. Runways 4/22 are served by Instrument Landing System (ILS) approaches and both runways have approach light systems. All three runways have runway edge lights, and the airport has an approach and departure control facility.

Southern Illinois Airport, Carbondale, Illinois, elevation 411 feet, does not have an approach and departure control facility. The airport has two runways: 18/36 and 6/24. Runway 18/36 is 5,000 feet long and 100 feet wide; runway 6/24 is 4,093 feet long and 100 feet wide. Runway 18 is served by ILS, Very High Frequency Omnidirectional Radio (VOR), and Nondirectional Radio Beacon (NDB) approaches. All runways have runway edge lights and, runway end identifier lights (REIL), and runway 18 also has an approach light system. The airport control tower operates between 0800 and 2000.

The following airports along Flight 710's route of flight between Springfield and the accident site possessed facilities which were adequate to accept a diversionary landing: Centralia, Illinois; Scott Air Force Base (AFB), Belleville, Illinois; and, Lambert-St. Louis International Airport, St. Louis, Missiouri.

1.11 Flight Recorders

The airplane was equipped with a Lockheed 209E digital flight data recorder (DFDR), serial No. 109, and a Fairchild A-100 cockpit voice recorder (CVR), serial No. 3523. The DFDR and CVR were removed from the airplane wreckage and taken to the Safety Board's Washington, D.C., laboratory to be examined and read out.

The DFDR had broken in half. However, the crash survivable portion containing the recording medium retained its integrity. The tape deck was removed, and the recording medium was mounted on the Safety Board's playback station and read out.

A printout of selected parameters was made which included the 36-minute segment from about 2 minutes before takeoff until the recorder stopped operating while the airplane was descending through 2,400 feet. Although the recorder was operating normally, several parameters were invalid; the most noticeable being engine torque (both engines) and vertical acceleration.

Examination of the DFDR's heading, indicated airspeed, and pitch angle parameters showed that Flight 710 started its takeoff roll about 2019:55. The examination also showed that the DFDR experienced two losses of synchronization; at 2022:16, synchronization was lost on all parameters, and at 2048:46, there was a loss of synchronization which affected only a portion of the parameters and lasted less than a second.

During normal operation, the DFDR is turned on when the airplane's rotating beacon switch is turned on. Electrical power from the airplane's center busbar is then supplied through the No. 1 inverter to the DFDR. If the rotating beacon switch is turned off in flight, electrical power is supplied directly from the internal busbars of either the left or right generators to a holding relay and the DFDR will continue to operate. According to the CVR, at 2028:17, the first officer reported that the battery voltage was 22.5 volts. At 2028:45, the captain said, "Beacons off," and the first officer replied, "Okay." The captain then said, "Nav [navigation]) lights are off."

Cockpit Voice Recorder.--The exterior of the CVR was damaged severely, but the crash case had protected the tape which was unharmed. The CVR tape was removed, read out, and a transcript was made of the entire tape. (See appendix D.)

Most of the flightcrew conversations were heard on the CVR's radio/interphone channel. The cockpit area microphone (CAM) channel was operational throughout the entire flight; however, the flightcrew chose to use the interphone for normal conversation. Only two conversations could be heard on the CAM channel; the first occurred at 2032:32, and the second at 2054:16.

The recording speed of the CVR is regulated by the aircraft's 115 volt, 400 Hertz (Hz), a.c. electrical power. From the beginning of the recording at 2023:54 to about 2050:37, the recorder speed was decreasing at a rate equivalent to about 2.5 seconds per minute. This rate was determined by comparing the CVR recording with the ATC transmissions. After 2050:37, the recorder's speed began decreasing at a much faster rate. From 2050:37 to the last statement on the CVR at 2054:16, the recorder was running at about 58 percent of its normal speed.

After the last statement had been recorded, about 280 cm of tape moved past recorder heads without any new information being recorded. According to the manufacturer of the unit, the recording electronics stop working at an input voltage of about 60 volts a.c. The tape drive motor continues to run until the input voltage drops to about 30 to 35 volts a.c.

During the last part of CVR operation, the erase circuitry continued to erase the old information, but the recording circuitry failed to insert any new information. As the voltage continued to fall, the erase circuitry failed and about 80 cm of old information remained on the tape. Thus, the transcript between 2023:54 and 2024:11 contains information which normally would have been erased but was not.

Between 2023:54 and 2050:37, the times on the transcript are accurate to within 0.2 percent. Thereafter, all times are accurate to within 2 percent.

1.12 Wreckage and Impact Information

Flight 710 struck the ground in an open pasture area. The airplane was destroyed and wreckage scattered about 200 feet on either side of a 1/2-mile-long wreckage path. The direction of impact and the wreckage path was about 340° magnetic. The wreckage path traversed two small wooded areas, a pond, and the farthest major piece of wreckage along the path was the diffuser and turbine section of the left engine.

The initial ground scars were shallow, narrow scrape marks which contained partially buried pieces of green colored glass from the right wing tip navigation light. The accident scene was reconstructed by matching ground scars and airplane components. The airplane was in an 8° descending flightpath at impact and in a 33° right-wing-down attitude.

The airplane fuselage had disintegrated and was scattered along the wreckage path. The airplane doors, which separated during the impact sequence, were found along the wreckage path.

The empennage separated from the airplane during the impact sequence and had broken apart. The vertical stabilizer, the left and right horizontal stabilizers, and the tail cone were recovered along the wreckage path. Except for the vertical stabilizer, which had broken into three major pieces, the other empennage components were relatively intact. All of the primary flight controls were found within the wreckage area and had been battered by the impact forces.

The left and right wings were broken extensively and pieces of wing structure were scattered through the wreckage area. A section of outer right wing structure between wing station (WS) 160 and 340 was found with the outboard flap attached and in the fully extended position. In addition, a 2-foot length of the right wing tip was found near the initial impact point; it was crushed upward along the lower side of the leading edge.

The largest portion of the left wing consisted of a 15-foot length of outer wing structure which had one flap track attached along with a small piece of flap structure. The small piece of flap was in the fully extended position.

The right flap was recovered in two pieces. One piece, consisting of the outboard end back to flap station (FS) 140, was relatively intact and was attached in the extended position to the outer structure of the right wing. The flap tab was attached to this portion of the flap, and the tab's upper surface contained a spanwise row of dents. The dents, which extended outboard on the tab from FS 140 to FS 296, were located about 4 to 5 inches forward of the trailing edge of the tab. With the flaps fully retracted, the area where the dents were located would have been below the wing's trailing edge.

The flap signalling unit was relatively intact, but had separated from the flap gear assembly at the bearing tube attachment flange. The measurements of the unit's components showed that their position corresponded to the flap retracted position.

Landing Gear.--The left main landing gear structure, which was intact and attached to a portion of the left wing structure was recovered from the pond. The left gear was in the down and locked position. The landing gear hydraulic actuator had separated from the landing gear cross beam assembly at the attachment pin; however, the base of the actuator was attached to the wing. The actuator rod and rod end were intact within the actuator housing and measured 14.5 inches from the center of the eye of the rod end to the face of the actuator housing. The position of the actuator rod corresponded to the landing gear retracted position. The right main gear had broken apart and was scattered throughout the wreckage site.

The nose gear assembly was relatively intact. The nose gear actuator rod was attached to the outer tube of its housing but had separated from the fuselage structure at the attachment pin. The rod was located toward the gear retracted position and measured about 3 inches between the center of the rod end and the face of the actuator housing.

Hydraulic System.--The hydraulic system was damaged severely by impact. Those hydraulic lines which were identified were crushed and broken. The landing gear normal selector valve, emergency valve, and emergency isolating valve were found and examined. The position of the actuating mechanisms of all three valves indicated that the landing gear was selected to the retracted position at impact.

Engines.--The engines had separated from the wings and had broken apart during the impact sequence. Those engine components which were found were, for the most part, located toward the far end of the wreckage path. The propellers had separated from the engines, and the propeller blades had separated from their respective hubs.

The examination of the engines indicated that the right engine had been damaged more severely by impact forces than the left engine. The examination of both powerplants indicated that they were operating above flight idle power at impact.

Electrical System Components.--Many of the electrical system components were damaged severely and some could not be identified. The components that were recovered from the accident site were examined; no physical evidence of either electrical arcing or short circuiting was observed.

The d.c. power feeder cables and their connectors to other components did not show any evidence of abnormalities. About 10 cells from the 4 nicad batteries were found and examined; no obvious physical abnormalities were observed.

The internal components of one of the two rotary inverters were found. The stator and rotor assemblies were found together; however, the stators had separated from the case and only fragments of the case could be found. The data plate from the No. 2 inverter was attached to one of the case fragments.

The left and right alternators were recovered; both units had minor impact damage. The alternators provide a.c. electrical power for engine, propeller, and windscreen deicing only.

The left d.c. engine driven generator was attached to a portion of the engine accessory gear box. The attached gear case had separated from the airplane structure, and the gear case had broken into at least two pieces. The generator case had received some impact damage.

The right d.c. engine driven generator stator and case assembly had separated from the right engine accessory gear box; the stator and case assembly were intact. Several days later, during the final search of the accident site, the armature and brush assembly of the right generator was found along the wreckage path. They were found about 100 yards ahead of the place where the right generator's stator and case assembly had been found.

The voltage regulators and switching units of both d.c. generators were also found. The voltage regulators were damaged severely, and no valid observations could be made as to their electrical condition. The switching units had been damaged heavily by impact forces.

The major components of the electrical system which were found at the accident site were removed for teardown and more detailed examinations.

1.13 Medical and Pathological Information

A review of the autopsies and toxicological examinations of the flightcrew disclosed no evidence of preexisting physiological conditions which could have affected their performance.

1.14 Fire

There was no evidence of either inflight or postimpact fire.

1.15 Survival

The cockpit and passenger cabin structure of the fuselage had disintegrated during the impact sequence. This accident was non-survivable because the livable volume within the cockpit and passenger cabin was destroyed during the impact sequence and the impact forces exceeded human tolerances.

1.16 Tests and Research

1.16.1 Examination of Airplane Electrical Components

Teardown inspections and metallurgical examinations of the airplane's electrical system components were performed under the supervision of the Safety Board at the following facilities: Trio Aviation and Manufacturing Company, Dallas, Texas; Lucas Aerospace, Inc., Englewood, New Jersey; Flight Components Service Corporation; and, the Safety Board's metallurgy laboratory, Washington, D.C. In addition, a cell recovered from the airplane's batteries was examined at the Royal Aircraft Establishment (RAE), Farnborough, England. This examination was requested by the Safety Board and was conducted under the supervision of the English Accidents Investigation Branch (AIB). The results of these examinations and inspections were as follows:

Nicad Battery Cell.--An SAFT VP 230KH nickel cadmium (nicad) battery cell, bearing serial Nos. 49819 and 40965, was examined at the RAE. The examination showed that the cell was totally discharged when received at the RAE. According to RAE Battery Report No. 304, the cell plates were "in reasonable health and the cell as a whole shows no signs of serious misuse prior to the accident." There was no evidence of internal short circuiting between plates resulting from mechanical damage sustained at the time

of the accident. The RAE report concluded, in part, "The low state of charge of this cell, as received at RAE, is unlikely to have been due to internal damage suffered by the cell as a result of the accident. Damage to the battery, however, could have discharged the cell through an external short circuit to earth (ground) or through the battery box, alternatively the cell could have been discharged by normal electrical load prior to impact." The report stated that since no method of analysis was capable of determining why the cell was in a discharged condition, "it cannot be deduced whether a short circuit, normal load discharge or lack of charging accounted for this condition."

Rotary Inverter.--There were no visible signs of either electrical arcing, pitting, overheating, or excessive wear on either the rotary inverter's d.c. commutator or the a.c. slip rings. The examination of the one of the recovered d.c. brushes disclosed no physical abnormalities; the other d.c. brushes were either broken or missing.

The Left Generator.--The left d.c. generator, Rotax model B3508, serial No. 1720 (see appendix C) was torn down for inspection. The generator spline drive shaft had sheared on the designed shearpoint at the driven end of the shaft. Metallurgical examination of the shear point and the mating surfaces of the shear disclosed that the shear mode was torsion and that the two fractured surfaces were polished. The drive splines on the shaft were normal in appearance.

The generator's air inlet and exhaust ports were damaged severely. The air inlet, exhaust, and brush cover were removed. The brush housing was damaged by impact forces and about one-fourth of the housing had broken away. All four sets of brushes (two brushes per set) were intact and electrical continuity between the brushes and the commutator portion of the armature was observed. There were no obvious signs of either overheating or other type of damage on the brushes.

The retaining nut on the anti-drive end of the armature was intact; however, the nut was finger tight and easily removed. The ball bearing assembly at the anti-drive end of the generator was intact and bottom surface of the bearing race showed signs of rubbing.

The generator field coil assembly contained the field coils and the interpole and compensator winding. The field coils, within which the armature is rotated, were rubbed, scored, and discolored by heat. The area of discoloration was confined for the most part to the vicinity of the cooling air outlet at the drive end of the field coil assembly. The heat discoloration was more pronounced on the interior of the field coils (the surface exposed to the armature) and diminished toward the exterior surface which mates with the stator case. There was no evidence of either overheat or other damage on the interpole windings.

The drive end of the armature had been discolored by heat, and the discolored area corresponded with the discolored area observed on the field coils. The armature exhibited signs of excessive rubbing and scoring.

At the drive end of the armature, the banding wire used to hold the armature windings and assembly in place had come loose and had bound up the armature. (See figure 1.) In the area where the banding wires had come loose, the armature's conductor bars had spread and one of the bars was missing.

The examination of the commutator portion of the armature disclosed that the commutator bars were not chamfered; however, the commutator did not show any signs of either overheating or electrical arcing.

Figure 1.--Left generator armature.

The unwrapped banding wires were examined for solder. One of the banding wires was removed from around the armature drive shaft. The wire broke in two places while it was being removed. It was discolored by heat and was very brittle at the point of the breaks and at other places along the wire. The wire was placed in an acetone bath and then cleaned ultrasonically. A sample was then cut from the wire, placed in the scanning electron microscope (SEM) and chemically analyzed with an X-ray energy dispersive system. No sign of lead was detected; however, noticeable amounts of tin and antimony were found indicating that the banding wire had been soldered with a 95 percent tin/5 percent antimony solder instead of a 95 percent lead/5 percent tin solder. Both types of solder are designed for electrical and mechanical bonding. Reference data showed that the melting points for the tin/lead solder and the tin/antimony solder are 594° F and 464° F, respectively. The reference data also indicated that the tin/antimony solder has a higher fatigue resistance and a higher tensile strength than the lead/tin solder. 7/

7/ American Society For Metals (ASM) Handbook, Volume 6.

The left generator's voltage regulator and switching unit were damaged too severely during the crash sequence to be torn down and examined.

The Right Generator.--The right engine driven d.c. generator, Rotax model B3508, serial No. 1711, was torn down and examined. The armature still was attached to the antidrive end head assembly. The anti-drive head assembly, which contains the brush assembly, was distorted and broken in many places from impact forces.

The brush assembly window strap was removed and all four outboard brushes and one inboard brush were removed from their mounts. The remaining three inboard brushes were restricted in their mounts due to impact damage. Three of the five brushes which were removed were worn to within about 1/16 inch of the grooved wear line, and evidence of heat discoloration was noted on the brushes. The brushes, which had been restricted in their mounts, were then removed and examined. They were similar in appearance to those which had been removed previously, and the examination did not disclose any abnormalities.

The generator exhaust port, which had been crushed severely, was removed. Before removing the field coil assembly from the stator case, the electrical continuity and insulation of the field coil windings were checked. Electrical continuity was present through the windings; however, there was a short circuit between the stator case and the windings.

After the field coil assembly was removed from the stator case, the windings of the four field coils, compensator windings, and interpole windings were examined. There were carbon deposits on the field coil windings; however, the deposits appeared normal for the generator's time in service. (See appendix C.) The insulation on the field coil windings was burned and flaked in spots, and portions of bare copper were present. This condition was indicative of a high current load; however, it could not be determined whether this was the result of a short term high current load or a higher than normal current load over a long period of time. (Under Air Illinois normal operating procedures, the right generator is used to start the airplane's left engine.)

The interpole windings were discolored by heat and their insulation had flaked. The surfaces of the field coil and compensator windings that mate with the stator case were discolored by heat. The heat discoloration on the internal surfaces of these windings (the surface nearest the armature) was minimal. There was no evidence of arcing on any of the components of the field coil assembly.

The ball bearing assemblies were removed from the drive and anti-drive ends of the generator and examined. The outer race of the drive end assembly was cut in half and the bearings removed, and the races and bearings were cleaned. There were four distinct impact marks on the outer race pieces, and there was a deposit similar to corrosion in the center of the race. In the other piece of the outer race, there were vertical score marks which extended across the width of the race. No other deposits or marks were noted. All the bearings were intact; however, score marks and deposits similar to corrosion were noted on the bearing surfaces. The examination of the inner race disclosed equally spaced marks running vertically across the width of the race. There was rust and corrosion on the race, and there were at least four indentations along one edge.

The examination of the anti-drive end bearing assembly disclosed a vertical crack which extended across the width of the outer race of the bearing assembly. The outer race was cut in half diametrically opposite the crack. The fracture face on both

outer race pieces showed signs of corrosion. There were deposits similar to corrosion on one of the outer race pieces as well as a series of faint score marks which ran vertically across the width of the race. There were no deposits on the other piece of the outer race; however, there were at least two diagonal score marks on one edge of the race. The inner race showed some evidence of deposits similar to corrosion, and there were at least three indentations on the one edge of the race. The ball bearings were intact; however, there were varying degrees of scoring and identations on their surfaces.

The bearing races were examined at the Safety Board's metallurgical laboratory. The examination disclosed indentations on the surfaces of the bearing race ways that were consistent with the absence of rotation of the generator at impact.

The armature was removed and examined. The banding wires at both ends of the armature were intact and appeared to be soldered in place properly. There was no evidence of either arcing, open circuits, or short circuiting on the armature. The armature was placed on a spin balancing machine and examined; the examination showed that the armature was bent and was out of balance.

The examination of the commutator portion of the armature showed that the commutator bars were chamfered. There were impact marks on the commutator and brush holders; however, the wear pattern on the commutator appeared normal. A metallurgical examination showed that the impact marks between the normally rotating commutator and the stationary brush holders were consistent with the absence of rotation of the generator at impact.

The generator spline drive shaft was removed. The drive shaft had broken at the designed shear point of the shaft. Metallurgical examination of the shaft disclosed that it had fractured transversely through the 0.375 diameter shear section. Optical and scanning electron imaging of the fracture showed that the surfaces were heavily damaged by rotational smearing typical of ductile torsional overstress. A longitudinal cross section near the circumference of the fracture disclosed grain deformation indicative of clockwise rotation of the aft section of the shaft relative to the forward section when viewed looking forward.

The fractured end of the shaft was discolored blue at the fracture changing to a straw color about 1 inch from the fracture, indicating some heating of the outer diameter surface of the shaft. Hardness measurements were made along the outer diameter of the drive shaft using Rockwell "A" and "C" scales. The recorded outer diameter measurements showed no significant hardness change along the shaft length and the recorded outer diameter values were not significantly different from those measured in the shaft interior.

There was circumferential scoring on the drive shaft near the fracture. No evidence of torsional impact was found on the shaft splines.

The right generator's voltage regulator was badly crushed. The top and end cover of the case were removed and all five printed circuit boards were removed from the case and examined. The circuit boards and printed circuits were broken or crushed. There was no evidence of electrical overheating on any of the boards and their circuits.

The right generator's switching unit was badly damaged and distorted by impact forces. The voltage sensing relay was smashed, and the coil windings were severed in numerous places. The contactor assembly was broken, and the contactor coil measured

197 ohms (170 ohms typical). The contacts were examined; evidence of pitting and arcing typical of that produced by switching the generator on and off were observed. The resistance of the main operating coil measured 48 ohms (50 ohms typical). Diode tubes D1 and MR2 tested normal.

1.16.2 Generator Operational Tests

During the investigation, the Safety Board investigated the load bearing capability of the Rotax generator. The generator, a Rotax B3508, serial No. 1085, which had been operated 2,789.6 hours since its last overhaul, was supplied by Air Illinois. It had been disassembled for shipment by an Air Illinois mechanic and arrived at the test facility without the cooling air intake and exhaust fittings used when the unit is installed on the airplane engine.

The generator was examined before the tests were conducted. The examination showed an insulation breakdown resistance between the field coil assembly and stator case of 0.2 meg ohm; breakdown resistance is normally 2 meg ohms or higher. Evidence of heat discoloration and the wear patterns on the coils, brushes, and armature were noted and documented. Several other abnormalities were noted; however, the Systems Group concluded that they were either correctable or would not interfere with the operational tests.

The generator was fitted with cooling air inlet and outlet hardware which was nonstandard and mounted on a test stand. A standard carbon pile voltage regulator was connected, and the case was grounded to the test fixture; the case is grounded to the airframe when the generator is operating on the airplane. Cooling air was applied to the unit and the output voltage was maintained at 27.5 volts. The generator was spun up to its normal inflight cruise rpm--8,500 rpm--and the test loads were applied. The generator maintained a 300-ampere load for 5 minutes without failure. After a 5-minute cooling period. the generator was again spun up to 8,500 rpm. A 524-ampere load was applied for 15 seconds; thereafter, the load was reduced to 250 amperes and held at that value for 7 minutes. The generator maintained these loads.

The generator was removed and examined after the tests. There were no additional signs of either heat or other abnormal discoloration. There was no evidence of arcing on the brushes or of additional wear on the armature. The insulation breakdown resistance between the field coils and stator case measured about 0.2 meg ohm; after 2 minutes, this reading decreased to a value which was not discernible on the 0-500 meg ohm meter scale. There was no evidence on the interior surfaces of the field coil of additional wear or heating.

1.16.3 Human Performance Information

The Safety Board conducted in-depth interviews with Air Illinois personnel who had flown with the captain and first officer. Eleven captains and first officers were asked to describe their flight experience with the two men.

The Captain.--The captain was single, lived in Carbondale, and had worked for Air Illinois for 4 years 10 months. Except for one or two pilots with whom he shared mutual off-duty interests, he did not associate socially with the majority of Air Illinois pilots.

The captain had flown 3,170 hours in the HS 748. Of the [illegible]ots interviewed, 9 had flown as first officer with the captain for various periods of [illegible] from mid 1981 until about a month before the accident. Two of the nine pilots sta[illegible] that they had a comfortable working relationship with the captain and that they felt free to offer suggestions regarding flight operations. One of these pilots was more experienced in the airplane than the captain and the other was one of those who shared some common interests with the captain.

The remaining seven pilots stated that the captain wanted things done his way. They said that he ran "a one man operation," and they did not feel free to offer suggestions because he generally became angry and "non-communicative" when they did make suggestions. However, one of these pilots stated that after he gained more experience in the HS 748-2A, the captain became more responsive to any suggestions he chose to offer.

There was almost total agreement among all of the pilots concerning the captain's flying skills; they described him as an "average pilot." One of the pilots stated that, "I would use the word over-confident in as much as I think his confidence in his ability, at least as I observed it, exceeded that ability." This pilot stated that the captain had allowed him to land at Meigs Field, Chicago, even though he did not have the required flying time contained in the company operations manual to be allowed to land at Meigs Field. The pilot stated, "He did so, in my opinion, because he felt that he could adequately recover from any difficulty that I could get the airplane in."

Several of the first officers reported that the captain flew too close to or under thunderstorms that were along his route of flight in order to avoid deviating from the route and delaying the flight. There was general concurrence that he was a captain who was "in a hurry" to make schedules. They stated that he would overspeed the a[illegible]lane during descent to save time and when he did this he would order the first officer [illegible]pull the circuit breaker which disabled the overspeed warning horn. Most of the pilots stated that the captain disliked being made late and that he wanted to return to Carbondale at the end of a flying day; one pilot stated that "he [the captain of Flight 710] hated to stay overnight in Springfield." The captain's personnel file contained a Telex commending him for his efforts to maintain the flight schedules.

Most of the pilots described the captain as a "company man" who might not have always agreed with management decisions, but he accepted them because he believed management was doing what had to be done to keep the airline operating. In that respect, several pilots stated that the captain would become angry very easily, especially at Air Illinois flight and ground personnel who did not do things the way he thought they ought to be done or who did not dress according to the standards that he believed company personnel should maintain.

The First Officer.--The first officer had worked for Air Illinois 3 years 8 months. He was single and lived in De Soto, Illinois, which is near Carbondale.

The first officer had flown 1,746 hours in the HS 748. Seven pilots interviewed had flown with the first officer either as his first officer on the Twin Otter airplane or as his captain on the Hawker Siddley. He was described by three Hawker Siddley captains as the best Hawker Siddley first officer on the line. He knew the regulations, he had a vast knowledge of the airplane, and he was "always ahead of the airplane." According to these captains, when a question would come up concerning some detail of the airplane the first officer would research the question and find the answer. One of these captains stated

that he (the first officer) was the most tactful of all the HS 748-2A first officers when offering "suggestions concerning the conduct of the flight" and that he would offer suggestions" as the need arose." All the pilots who had flown with the first officer when he was a Twin Otter captain described him as a good pilot, knowledgeable about the airplane, confident, and safety conscious. He had a pleasant, "laid back" personality and commanded by virtue of his ability and knowledge rather than his position as captain, and they liked to fly with him.

The first officer had flown many flights with the captain of Flight 710. Except for one pilot, none of the pilots interviewed could recall the first officer either discuss or complain about the manner in which the captain flew the airplane. However, one of the pilots had complained to the first officer about her experiences while flying with this captain and had asked the first officer how "he could just sit there and let him do these things. And he [the first officer] said 'I just try to keep a close eye on things. . . . .he definitely pushes everything to the limit and a little beyond. He pushes himself and pushes the airplanes. . . .I just try to monitor the situation and I never let him get into a situation that I don't think I could take control of and rectify it.'"

Company Management.--The pilots who were interviewed were asked if they felt undue pressure to maintain schedules and whether this pressure was placed on them by the company. All of the pilots stated that they did feel pressure to maintain the schedule; however, they all stated that it was a self-imposed pressure. They stated that, as pilots they wanted to complete the flight as scheduled, provided that it could be completed safely and within prescribed company procedures and Federal regulations.

The investigation, however, did disclose several instances where company management personnel had questioned captains concerning their decision to delay a flight. In each case, the captains involved stated that they had explained their reasons for delaying the flight, reaffirmed their decision not to continue the flight until the reason for the delay was corrected, or in the case of a weather-related delay, the weather conditions dictating their decision had either changed or abated. In each case, Air Illinois management accepted the captain's decisions and no further action was taken. In one instance, a captain delayed his departure from Meigs Field, Chicago because of weather and the flight subsequently was cancelled. According to the captain, Air Illinois' principal competitor flying the same route did not delay its departure, and the Air Illinois passengers were transferred to the competing flight. The captain stated that the company management did not question or discuss his decision. Several other captains stated that they had made similar decisions and the company management had neither questioned nor criticized their decisions.

With regard to the actions taken by the captain in order to maintain company schedules, the pilots did not believe that these actions were the result of any management actions. One of the pilots who had flown with the captain stated that he had "got the impression that (the captain) wanted to be a 'good old boy' to get the airplane in on time and to bring it home. It's not that management was pushing him to do it, it's just that it was his own idea."

The factors which can influence a pilot's decision were discussed in a National Aeronautics and Space Administration (NASA) study. 8/ The study states that in order for a pilot to make a decision to select a course of action from a limited number of

alternatives, he first must seek and acquire information from whatever sources are available. He then must make some determination regarding the quantity and the quality of the information gathered. Knowledge previously gathered and contained in his memory (e.g., training and experiences) will influence his decision. Psychological or environmental stress (e.g., get-home-itis and pressure) also could influence his evaluation of the quantity and quality of the information. A large portion of this decision-making process involves the pilot's judgment of probabilities. In fact, he is attempting to make "wise" decisions in the face of uncertainty and other influences. Of course, the pilot also must consider cost and safety tradeoffs. The NASA document concludes that, "There is considerable evidence that all of these factors influence decision-making in aircraft operations."

1.17 Other Information

1.17.1 Hawker Siddley 748-2A Electrical System

The airplane primary electrical system is supplied at 27.5 volts d.c. by two engine driven 9-kilowatt (KW) generators. Between 4,500 and 8,500 rpm, each generator can provide 300 amperes continuous, 400 amperes for 5 minutes, and 600 amperes for 5 seconds. Because of cooling air limitations during ground operations, the following load limitations have been placed on the generators:

> 180 amperes at International Standard Atmosphere (ISA) temperature (+15° C) and
> 150 amperes at ISA + 30° C.

Emergency electrical power and electrical power for internal engine starts are provided by four nicad 24-volt, 22-ampere hour (A.H.) batteries. The four batteries are connected in pairs, two on the left side and two on the right side of the airplane.

The D.C. Control Panel.--A mimic diagram of the airplane's busbar layout and the manual controls for the ground power supply, batteries, and generators are contained on the d.c. control panel which is located on the first officer's overhead control panel. (See figure 2.) The control panel contains the on-off-reset switches for both generators, the on-off switch for both battery pairs, and the on-off switch for ground supply power.

The mimic diagram of the airplane busbar system is depicted below the ground supply, generator, and battery control switches. Seven magnetic (mimic) indicators depict the power status of the generators, batteries, and ground power. A cross-line position of the mimic indicator shows that its associated battery pair or generator is not connected to its associated busbar.

The two-hooded isolate buttons on the bottom left and right side of the d.c. control panel operate the generators' reverse current circuit breakers (RCCB). Depressing either or both isolate buttons opens the associated RCCB, disconnects or isolates the associated generator from the center busbar, and causes the associated mimic indicator to move to the cross-line position.

The control panel also contains an ammeter and voltmeter which are controlled by a five-position rotary switch. Operating the selector switch, as desired, allows the flightcrew to read voltage and load current on either the left or the right

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8/ A method for the Study of Human Factors in Aircraft Operations, NASA TM X-62,472, September 1975.

generator; voltage and either charge or discharge current on either the left or the right battery pair. Placing the selector switch to the center or B/B position connects the voltmeter only to the center busbar. (See figure 2.) Once either one or both generators are connected to the center busbars, neither battery voltage nor discharge current can be read.

Batteries.--Each nicad battery pair is connected to its individual battery busbar and then via contactors to the center busbar which supplies all services essential to flight. (See figure 3.) Turning off either or both battery switches on the d.c. control panel opens the associated battery contactor and disconnects the associated battery pair from the center busbar but does not disconnect them from their associated battery busbars. The battery busbars are alive at all times. Major fault protection between the battery busbars and the center busbar is provided by two RCCB's. Any circuit condition which creates a 500-ampere current flow from the center busbar to a battery busbar will automatically trip the associated RCCB, and the battery RCCB cannot be reset in flight. An inflight trip of a battery RCCB will be shown by a cross-line indication of the associated battery mimic indicator with the battery switch on. The pilot must switch off that battery pair and make no further attempt to switch them back on during the remainder of the flight.

The batteries are recharged from the center busbar by the generators during ground or inflight operation. Since each battery is a 22-ampere hour battery, assuming optimum battery condition, four fully charged batteries should provide 88 amperes to the airplane busbars for 1 hour.

The basic function of a nicad battery is to store energy and to make that energy available during discharge to do work. The output measures of a battery are voltage and capacity. However, during the discharge cycle, the voltage output does not reflect the remaining capacity of the battery. According to a General Electric Corporation engineering handbook, "The nicad battery's voltage remains relatively constant until very nearly all its capacity is discharged, at which point the voltage drops off sharply. The discharge characteristics of all nickel-cadmium cells follow this general trend. . .." 9/ The term "plateau effect" has been used to describe the discharge characteristics of the nicad battery. The British Aerospace electrical design engineer testified that the voltage will remain at a very high output level until almost the end of the battery's duration, and that, therefore, "You can't tell (battery) capacity by voltage."

Generators.--Each engine driven generator is connected to its individual busbar by a switching unit and then via the left and right generator RCCB's to the center busbar. (See figure 3.) When the generator control switch on the d.c. control panel is selected on, the switching unit will, providing the generator voltage is correct, place the generator on line. With both generators serviceable and connected to the center busbar, an equalizing circuit operates to equalize the generator loads. The generator inflight voltage limitations are 27.5 volts plus or minus 0.5 volt.

Major fault protection between the generator busbars and the center busbar is provided by two generator RCCBs. A current flow in excess of 525 amperes from the center busbar toward a generator will automatically trip the RCCB and, in addition, trip the affected generator.

9/ Nickel-Cadmium Battery, General Electric Application Handbook, Second Edition.

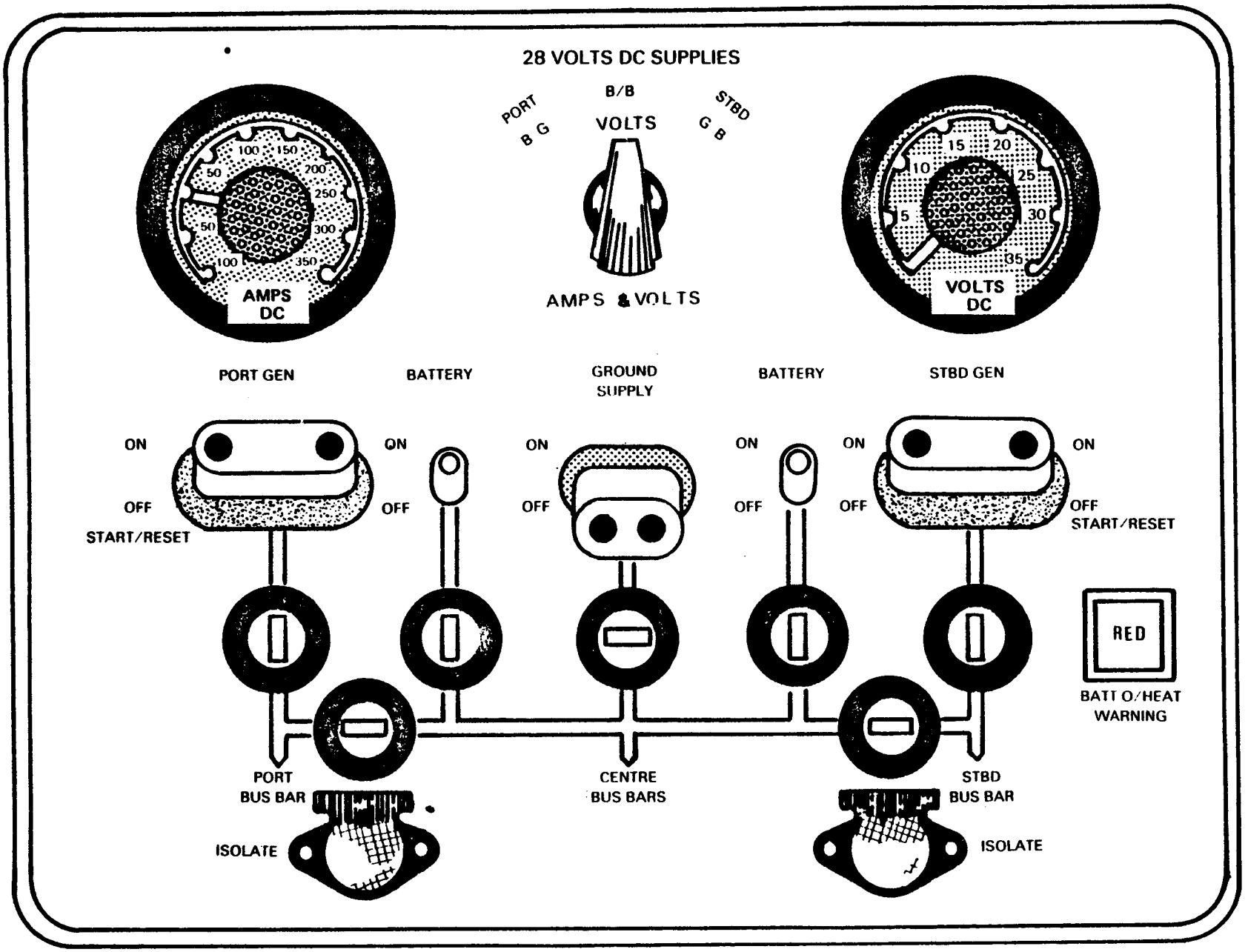

Figure 2.--D.C. control panel. (Figure depicts normal inflight panel configuration. The mimic indicators are on-line to their associated busbars; the left and right generator busbars are connected to the center busbar. Ground power supply is disconnected as shown by the cross-line position of the ground power mimic indicator and ground power supply switch position.)

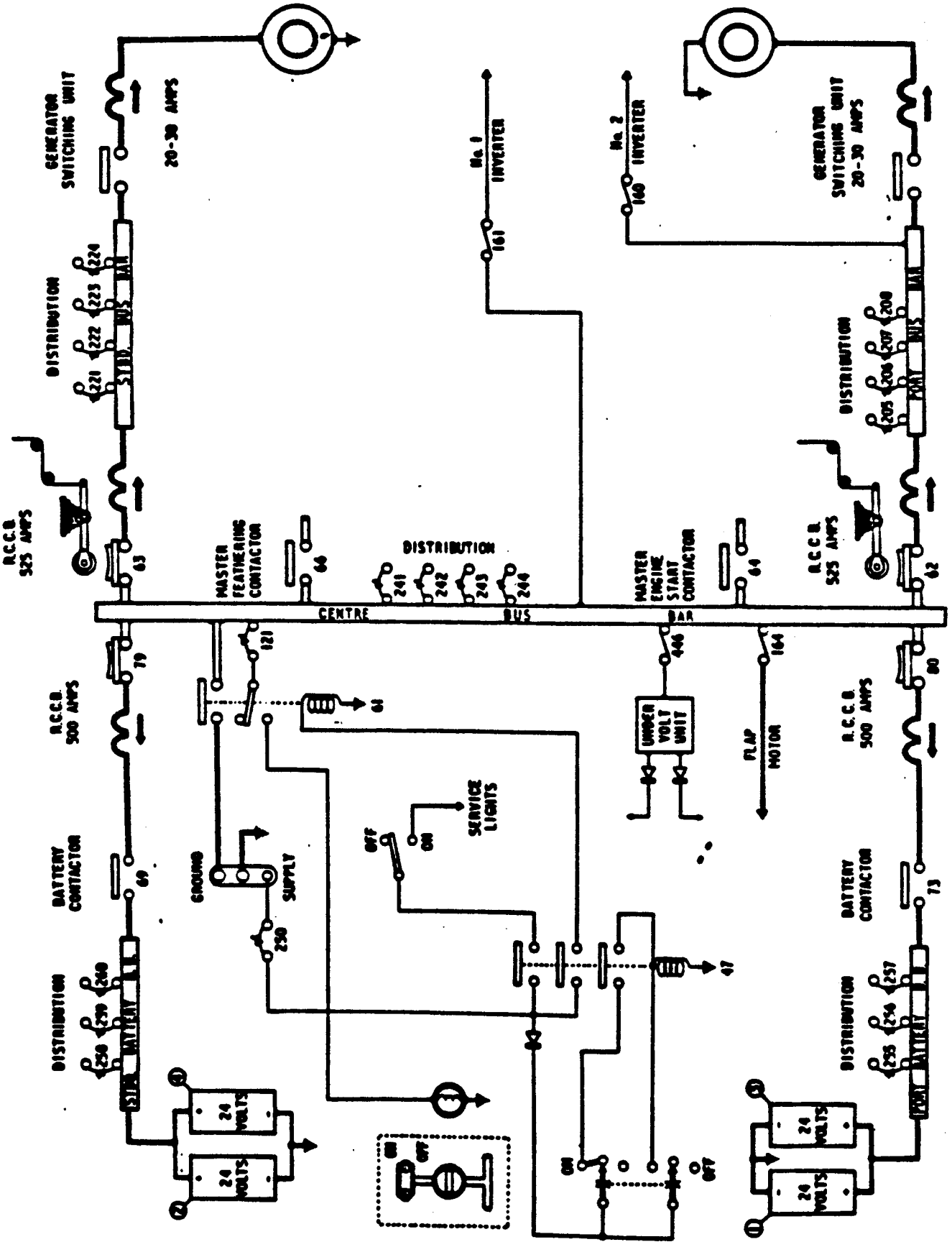

Figure 3.--D.C. electric power distribution system.

The generator RCCBs can be tripped individually by depressing the isolate buttons on the d.c. control panel, which isolates the center busbar without affecting the running generator. In addition, the generator RCCBs can be reset mechanically in flight by pulling up the reset handle which is located on the cockpit floor outboard of the first officer's seat.

The busbar and generator circuits also incorporate both over and undervoltage protection circuitry. Should any single generator output voltage exceed 31 volts, the overvoltage unit will operate and turn the affected generator off.

Undervoltage protection circuitry is incorporated in each generator switching unit and in the center busbar circuitry. With regard to the switching unit, whenever a generator output voltage falls below the voltage of the busbar to which it is connected a current flow will be induced toward the faulty generator and the generator will be disconnected from the busbar by a 20- to 30-ampere reverse current coil inside the switching unit.

The inflight voltage to the center busbar is measured by an electronic sensing unit. Whenever the center busbar voltage drops below 25 volts the undervoltage unit will cause both generator failure lights to illuminate with either one or both generator mimic indicators showing an on-line indication. The left and right generator failure lights are located on the left and right sides, respectively, of the emergency panel below the cockpit glare shield. This system will not operate when the airplane is on the ground and the landing gear "squat switches" are depressed.

D.C. Load Switch.--A toggle switch labeled "D.C. Load -- Normal/Reduce" is located on the lower right hand side of the electrical control panel above the first officer's head. This switch enables certain nonessential electrical loads to be shed quickly from the center busbar. Placing the switch to the reduce position sheds the electrical loads of the galley services, the toilet water heater, and the passenger reading lights.

A.C. Electrical System.--A.c. electrical power is supplied by the left and right engine driven alternators and two 115-volt, 3-phase, 400-Hz, a.c. inverters. The No. 1 inverter is powered by the center busbar; the No. 2 inverter is powered by the right generator bus bar. (See figure 3.) A transfer switch allows the essential a.c. power loads of a failed inverter to be transferred to the operating inverter.

During operation, the inverters will maintain the power output levels required by their consumer equipment. Therefore, if the voltage input to an inverter should decay the inverter will draw more current to maintain the required power output level.

Flight Instruments.--The airplane was equipped with two d.c. electric attitude director indicators (ADI). The captain's and first officer's ADIs were powered by the center and right generator busbars, respectively. The horizontal situation indicators and radio magnetic indicators were powered by the inverters as were the radios and weather radar.

The captain's altimeter was a d.c. electric servo altimeter, which was powered by the center busbar. In the event of a power failure, the altimeter would remain at its last reading and a failure flag would come into view. According to the manufacturer, during a decreasing voltage input, the failure flag will drop completely at 10 volts and the altimeter will continue to read correctly down to 6 volts. The first officer's pressure altimeter, the airspeed indicators, and the vertical velocity indicators received their data inputs from the pitot static system and were not electrically powered.

The airplane also was equipped with two turn and slip (needle and ball) indicators. These instruments operated on d.c. electric power and were located on the captain's and first officer's instrument panels. "Normal" and "alternate" power source selector switches were located below each instrument. Selecting the "alternate" position on the captain's switch would disconnect his turn and slip indicator from the center busbar and connect it to the left live battery busbar; the same action on the first officer's selector switch would remove his instrument from the right generator busbar and connect it to the right live battery busbar.

The Air Illinois Airplane Operating Manual (AOM) did not reflect the fact that both attitude indicators were operated by d.c. electrical power. However, according to the British Aerospace flight safety engineer, this configuration would have been readily apparent to the pilots since both attitude indicators would have begun to function as soon as the battery switches were turned on and would have been fully operational before the inverters were turned on.

With regard to the captain's and first officer's turn and slip indicators, had both selector switches been placed in the alternate position and had the emergency light switch been turned on, the battery switches could have been turned off to obtain the maximum conservation of battery power. In this configuration, except for the emergency cockpit lights and the turn and slip indicators, virtually every electrical component in the airplane would have been turned off. The only instruments available to the pilots to enable them to fly the airplane would have been the turn and slip indicators, airspeed indicators, vertical velocity indicators, and the altimeter.

1.17.2 Generator Normal and Emergency Procedures

The Air Illinois Hawker Siddley 748-2A AOM contains flightcrew procedures relating to the operation of the generators. The procedures relating to the failure of a single generator are contained in the AOM's normal procedure section; those relating to a dual generator failure are contained in the emergency procedure section. In the event of a single generator failure the flightcrew should insure that the load on the remaining generator is reduced to 300 amperes or lower. Thereafter, one attempt only may be made to reset the failed generator using the following procedure:

1.	Failed generator switch	Off
2.	Generator switch	Start and Reset
3.	Generator voltage	27.5 plus or minus 0.5 volts
4.	If all correct, generator switch	On

Figure 4.--Single generator failure procedure

The emergency procedures section of the AOM contains the procedures and checklist to be used in the event of a dual generator failure. Also, a plastic-covered emergency checklist was on board the airplane for use during flight. This checklist contained the following procedure:

FAILURE OF BOTH GENERATORS

Make one attempt to regain the failed generators by separating the generator supplies from each other using the following drill:-

1.	Reverse current circuit breaker (RCCB) switches port and starboard	Press (irrespective of RCCB magnetic doll's eye indicator).
2.	Generator switch, starboard	START AND RE-SET (if de-excited).
3.	Generator voltage, starboard	Check 27–28 Volts.
4.	If all correct, generator switch	ON.
5.	Generator magnetic indicator starboard	IN LINE.
6.	Generator starboard	ON LOAD.
7	Manually reset starboard RCCB as follows:-	
8.	RCCB isolate switch, port	Press and hold.
9.	Manual RCCB reset control	Pull up.
10.	RCCB isolate button, port	Release.
11.	Generator failure warning light starboard	OFF.
12.	Generator switch port	START AND RE-SET (if de-excited).
13.	Generator voltage, port	Check 27–28 Volts.
14.	If all correct, generator switch	ON.
15.	Generator failure warning light, port	OFF.
16.	Generator magnetic indicator port	In line.
17.	Check generator loads	

Note . . .

1. Load shedding action must take place immediately if unable to regain generators.
2. If unable to regain or connect the starboard generator reverse the procedure to the port generator.
3. Make no attempt to couple both generators to the centre bus bar.

TOTAL D C FAILURE

Switch off both batteries.

Operate RCCB buttons.

Make one attempt to reset a generator that has tripped off line. Do not reset the reverse current bus bar isolation contactors Do not switch on the batteries (since these may become discharged, prejudicing the operation of the emergency services) See Flight Manual Section II, Part C, Page 92 for details of services affected by loss of one or more of the bus bars.

Figure 5.--Failure of Both Generators emergency checklist.

Though slightly different in format, the dual generator failure procedure in the checklist was identical in content to the procedure contained in the AOM. However, the AOM further amplifies the flightcrew duties. The AOM explains that in the event both generators remain disconnected, the airplane's electrical loads will be supplied by the batteries; therefore, as noted in the checklist, electrical load shedding should begin immediately.

The initial action required by the emergency procedure--depress the left and right isolate buttons--sheds from the batteries the non-essential electrical loads of the left and right generator busbars. According to the British Aerospace flight safety engineer, the total electrical load on the center busbar is "only about 70 or 75 amps (amperes)." Thereafter, all that remains to be done is to shed from the center busbar any electrical loads that the captain decides are not essential to flight. For example, placing the d.c. load switch on the overhead instrument panel to the "reduce" position sheds the electrical loads of the galley, the toilet water heater, and the passenger reading lights from the center busbar.

The initial checklist action also places each generator on its own busbar. Steps 2 through 6 of the checklist contain the procedures for restoring the right generator; these procedures are identical to the normal generator start procedures used by the flightcrew in daily operations. If the generator is restored to its busbar, steps 7 through 11 contain the procedures that simultaneously restore the right generator and the right generator busbar to the center busbar and keep the center busbar isolated from the left generator busbar. Steps 12 through 17 contain procedures similar to those contained in steps 2 through 6 for restoring the left generator to its busbar. If both generators have been restored, no attempt should be made to couple both generators to the center busbar.

The Air Illinois AOM contains another emergency procedure which is designed to reduce electrical loads. The HS 748-2A has four electric fuel booster pumps which are normally on during flight. The emergency procedure states, in part, that in the event the booster pumps are lost because of a complete generator failure, the flightcrew should follow the emergency procedures for restoring generator power. Thereafter, "If generator power cannot be restored, or if for any other reason (e.g. load shedding) it is necessary to fly in emergency without booster pumps, commence a descent to 7,000 feet, or to minimum en route altitude." The procedure also states "Note: Under these conditions the engines will continue running but there is a risk of cavitation of the engine-driven fuel pumps." The British Aerospace flight safety engineer testified that once below 7,000 feet "the engines are very secure. . .no problems in gravity feed to the engine driven (fuel) pump."

The emergency procedures section of the Air Illinois AOM contains charts showing the electrical loads carried on each busbar. The charts are displayed under another type of emergency, but the discussion in the generator failure section refers the flightcrew to these charts. The charts, however, do not contain the amperage values of the electrical loads and the text of the AOM does not specify a minimum amperage to which the flightcrew should try to reduce the load and the expected endurance time of the batteries at that minimum electrical load. With regard to battery endurance, the Air Illinois AOM states, "The battery time available is dependent on the charge state of the batteries at the time and the essential loads required for flight conditions."

Finally, the "Total DC Failure" procedure contained in the plastic covered emergency checklist carried in the airplane contained an erroneous reference. The procedure, which relates to a grounding and subsequent total failure of the center busbar, is discussed in Section 3 of the AOM; however, the cockpit checklist refers the flightcrew to Section 2 of the AOM. This error was not detected by either Air Illinois flightcrew or training personnel or by FAA inspectors until it was pointed out to them by Safety Board personnel after the accident.

1.17.3 Flightcrew Training

Between October 13 and 24, 1978, Air Illinois' personnel records showed that the captain completed an initial Hawker Siddley 748-2B ground school course conducted by a British Aerospace ground school instructor. The records showed that the captain received passing grades on all airplane systems.

The instructor who had taught the course testified that the difference between the HS 748-2B and the HS 748-2A electrical system was very slight. The HS 748-2B, a later model airplane, had slightly different warning lights, and, in the event of an undervoltage condition on the center busbar, the HS 748-2B's RCCBs were tripped automatically, whereas on the HS 748-2A the flightcrew performed this action manually by depressing the "isolate" buttons on the d.c. panel. According to the instructor, both airplanes had the same batteries and the endurance time of the batteries after the failure of both generators would be the same. In addition, since the pilots attending the course were going to fly both the HS 748-2A and -2B airplanes, the course included the differences between electrical systems.

The instructor testified that the electrical system ground school course covered all emergencies, including the failure of both generators. The pilots were taught that if both generators failed and could not be restored to the center busbar, the

flightcrew should reduce the electrical load on the center busbar to 35 amperes for each battery pair (70 amperes total), and that, based on a 70-ampere total load, a minimum battery endurance of 30 minutes was available.

During both the Safety Boards' public hearing and the human performance group interviews, the Air Illinois HS 748-2A flightcrew personnel were questioned about the training they had received on the airplane electrical system. All the pilots either stated or testified that they had received training on electrical system emergencies and that the training included single and dual generator failures. They stated or testified that the initial and recurrent training curricula included simulated generator failures in the airplane; however, given the nature of the emergency and the fact that no HS 748-2A flight simulator was available, the failure of both generators was demonstrated only while the airplane was on the ground. All of the pilots said that they received "hands on" training with the RCCB reset handle and that they had actually been required to operate the handle.

Five of the eleven pilots interviewed by the Safety Board were flying the HS 748-2A schedules at the time of the accident. These five pilots, one of whom was the HS 748-2A chief pilot, were asked what the endurance time of the airplane batteries would have been after a dual generator failure. Three said that it was 30 minutes; two of these three stated that the 30-minute endurance time could only be obtained if the normal airplane electrical loads were reduced. The fourth pilot stated that "you would have to reduce the electrical load to 35 amperes per battery pair and then the endurance time of the batteries would probably be less than an hour." The chief pilot who supervised the company's training program said that he could not give a figure and that the available time would depend on the state of charge of the batteries and the electrical loads required by flight conditions.

During the public hearing, an HS 748-2A captain testified that the Failure of Both Generators emergency checklist (see figure 5) was improperly constructed and that Note 1, should be moved and inserted as the first action in the emergency checklist. He said that after the October 11 accident, he investigated the time required to complete the Failure of Both Generators emergency checklist and that "if you are doing it properly and if you have no major problems completing it, it should take you about seven or eight minutes to complete the (check) list. In an emergency situation, only. . . .after you have completed the (check) list, (do) you theoretically get down to the note 'Load shedding must take place immediately if unable to regain the generators.' " The captain testified that the batteries would be powering all the loads on the center busbar during the 7 to 8 minutes required to complete the emergency checklist, and therefore, if Note 1 were placed at the head of the emergency checklist "I would be load shedding immediately before I went to the checklist."

The HS 748-2A chief pilot testified that Air Illinois had been operating the aircraft for 10 years and that he had flown it for 3 years. He said that during recurrent training, the HS 748-2A flightcrews were required to "run" the Failure of Both Generators checklist and to discuss this emergency. He also said that he believed 6 to 8 minutes would be required to complete the checklist actions and that the emergency checklist was inadequate. The chief pilot testified that, "after reviewing the incidents that led to the accident and listening to the cockpit voice recorder it became very apparent that some of these (checklist) actions were not in the proper order they should have been. . . " and that the emergency checklist "assumes that as each item is accomplished you. . .see what happened on the checklist. If you do not get exactly what this checklist says you are going to get in the response portion, there is no alternative action. It does not tell you where to go from that point."

Flightcrew Inflight Actions.--The CVR contains numerous conversations concerning the actions of the flightcrew after d.c. electrical power from the generators was lost. At 2024:24, the captain asked the first officer, "What did you do, anything?" The first officer replied, "Naw, reset the RCCBs, I tried to select each side, isolate the side. . ."

At 2026:21, after he had told the captain that the battery power was going down "pretty fast," the first officer reported that the battery voltage was 22 volts. At 2026:31, the first officer said "There's the right one." The captain answered "Okay," and then directed the first officer to "turn load shedding back on so they [passengers] can use the reading [lights] back there and turn off the lights, main lights." The captain repeated his instructions and his reasons for turning the d.c. load switch to normal at 2026:59. At 2028:12, the captain asked "How are our bats [batteries] there?" The first officer replied, "Ah, twenty-two and a half [volts]."

At 2028:45, the captain instructed the first officer to turn off the rotating beacons and the first officer replied "Okay." The captain then said that the navigation lights were off.

At 2029:07, the first officer began a discussion concerning the generators, and stated "Both generator failures . . .see here." He then said, "I am going to try something here. . .I'm going to try and isolate both sides and see what happens." At 2029:39, he then asked the captain, "Want me to go to emergency so you can get some. . .get your Grimes lights." The captain replied, "No, I want it back the way it was." The captain then explained. "You see, you're shutting off all electricity to the back end that way, lighting and everything." At 2030:10, the first officer asked, "You want me to leave it the way it is then?" The captain replied, "Yeah, that will be good, keep an eye on those boost pumps though."

At 2031:04, the first officer told the captain that the ceiling at Carbondale was 2,000 feet overcast, the visibility was 2 miles, and the surface winds were 150° at 10 knots. At 2031:09, the first officer asked "Do you want to kill the pitot heat or anything?" The captain told the first officer to leave the pitot heaters on unless "you see that thing really depleting, which I don't believe it is. Is it really bad, really [depleting] rapidly?" The first officer replied, "No not too bad."

At 2031:43, the first officer told the captain, "Those inverters take a lot of power." The captain agreed but did not direct that first officer to take any action with regard to the inverters. Thereafter, the CVR conversation indicated that one navigation radio, the transponder, and one radio cooling fan were on. The conversation also indicated that the DME and weather radar had been turned off.

At 2036:06, the captain asked about the status of the batteries, and the first officer replied, "Still pretty good. . . .twenty-one and a half (volts)." Between 2036:23 and 2039:33 the flightcrew discussed turning on the airplane's weather radar. At 2036:23, the captain said, "I want to use this briefly." The first officer answered, "Take a while to warm up." At 2037:22, the first officer said "It's gonna take a few minutes to warm up, I think." At 2039:20, the first officer said, "Hey its working now, that looks like Carlyle there, either or it's a . . .of a shadow." The captain answered, "Yeah that's it. . . .We're right on course. . . ." And, at 2039:33, the first officer said, "Better stay away from them shadows, Frank."

At 2038:41, the first officer said, "Well when we. . . .started losing the left one I reached up and hit the right RCCB trying to isolate the right side because I assume

the problem was the right side, but they both still went off." The captain replied, ". . .when you were doing that. . . .I was losing my lighting here and I was losing lighting in the cabin and it was going pitch dark back there. . .(I) don't want to scare . . . . the people."

1.17.4 Electrical Load Analysis

During the accident investigation, the Safety Board requested British Aerospace to provide an analysis of the electrical loads drawn by various electrical components on the HS 748-2A airplane. The analysis shows that during a night takeoff--a period of 5 minutes--the average electrical load required is 302.5 amperes. During a 1-hour night cruise, the average electrical load is 211.2 amperes. (See appendix E.)

The inflight loads can be monitored at any time during flight or ground operations. The meters and selector switches on the d.c. control panel enable the flightcrew to read the load current supplied by any generator or any battery pair.

The airplane batteries are used to start the right engine and, thereafter, the right generator is used to assist the left engine start. During the unassisted engine start, the initial load current drawn from the batteries is 1,400 amperes. The load current then drops almost immediately to 650 amperes and then, over the next 15 seconds, decays to about 200 amperes. Based on these data, the Safety Board estimates that an engine start reduces battery capacity by about 2 ampere hours.

1.17.5 FAA Surveillance

On February 1, 1983, Air Illinois was issued Air Carrier Operating Certificate No. AGL-655, authorizing the company to operate as a scheduled air carrier in accordance with the applicable regulations of 14 CFR 121 (Part 121). Air Illinois also conducted commuter operations in accordance with the regulations contained in 14 CFR 135 (Part 135). The Air Illinois operating certificates were held by the FAA General Aviation District Office No. 19 (GADO-19). GADO-19's surveillance responsibility over the Air Illinois' Parts 121 and 135 operations was exercised by two principal maintenance inspectors (PMI) and one principal operations inspector (POI).

FAA Order 8320.12, "Air Carrier Airworthiness Inspector's Handbook" provides FAA Airworthiness Inspectors "with information to assist them in performing the duties associated with the surveillance of aircraft, airmen, and air carriers. . ." The order states that the purpose of "surveillance is to ascertain if a pertinent activity has been or is being accomplished in an acceptable manner. Surveillance may take the form of observing the actions of an individual or a group and comparing their actions to prescibed instructions or standards. In other cases, the inspection of a finished job may suffice. Surveillance may be applied to aircraft and components, to use of tools or equipment, aircraft records, etc."

Paragraph 665 of the FAA Order 8320.12 states, in part, that air carrier maintenance inspectors are responsible "to conduct periodic inspections to determine that the air carriers for which they have inspectional assignments are conducting their activities in accordance with the FAR's (Federal Aviation Regulations) and good operating practices."

FAA Order 8320.12, outlines the areas that should be inspected during various types of surveillance inspections, the forms to be inspected during the visits, and the

items that should be included on the various forms. However, the order does not contain specific instructions to field inspectors to cross-check various forms against other forms to verify the information contained on the forms.

Inspectors conduct various types of inspections in the course of their duties, often concurrently. These include, but are not limited to, the following:

> Spot Inspection--The inspection is conducted at the carrier's maintenance base and can be unannounced. The airplane is generally undergoing maintenance during the inspection and therefore is open for examination by the inspector. The inspection includes all available forms.
>
> Ramp Inspection--This inspection is generally unannounced and can be conducted at any station used by the carrier. The inspection includes the interior and exterior of the airplane and any documents and forms normally carried on board the airplane.
>
> En Route Inspection--The inspection is conducted during one of the carrier's route segments flights. The inspection includes the airplane's appearance and condition and any documents and forms normally carried on board the airplane. When conducted by an operations inspector, the inspection also includes flightcrew procedures and proficiency; this also often is an unannounced inspection.
>
> Facility Inspection--This inspection includes any of the physical facilities used by the carrier throughout its route structure. It generally is limited to the condition, appearance, and cleanliness of the facility being inspected. However, it can, at the option of the inspector, include forms and documents he deems appropriate to the inspection.

FAA Order 8430.6C "Air Carrier Operations Inspector's Handbook" directs the activities of the Operations Inspectors who are responsible for the inspection, certification, supervision, and surveillance of air carrier and certain other operators who conduct their operations in accordance with Part 121 of the Federal Aviation Regulation (FAR). With regard to the Operations Inspector's duties and responsibilities, the Order states, in part, "To a large degree, the safety and success of air transportation rests on the ability and integrity of the FAA principal inspectors. . . The Principal Operation Inspector must periodically review and sample all phases of the certificate holders operations to determine if the operator is in compliance with all certification requirements."

Principal Maintenance Inspector (PMI) for Avionics.--The avionics PMI had completed the FAA's Air Carrier Electronics Indoctrination Course on August 31, 1971, before he was assigned to Air Illinois in 1973. Air Illinois was the only Part 121 operator assigned to him: however, he had had previous experience with eight other Part 121 operators. In addition to his Air Illinois duties, the avionics PMI also had surveillance responsibilities over 43 air taxi operators, 14 repair stations, and 19 supplemental weather reporting stations.

The inspector testified that during June 1983, he had undergone knee surgery and had been incapacitated, and that consequently, his last inspection of Air Illinois' operations was made during June 1983. Before the surgery, he had conducted 10

inspections of Air Illinois' Part 121 operation. These inspections included Air Illinois' British Aircraft 1-11 (BAC 1-11) based in Evansville, Indiana, and the HS 748-2A based in Carbondale.

According to the inspector, he normally visited Carbondale about once a month. He testified that he knew about the test equipment used to calibrate the HS 748-2A's voltage regulators, but that he had never inspected the equipment or observed the equipment being operated. However, he did check to ensure that the test equipment was being calibrated at the prescribed intervals. He also testified that he did not know about the verbal briefing procedures between the HS 748-2A captains and maintenance personnel until he heard about them at the Safety Board's public hearing.

The inspector also testified that he had conducted ramp inspections of Air Illinois' Part 121 airplanes. These were usually conducted when the airplanes landed at Springfield. He testified that during these inspections he checked the airplane flight log, but that he never noted any difference between the entries made by the HS 748-2A captains and the corrective actions taken by the maintenance personnel. Also, he checked to ensure that inoperative avionics components which were being carried as deferred maintenance items in the airplane flight log were properly placarded. He could not recall conducting any unannounced or surprise inspections other than spot inspections.

The avionics inspector testified that the principal airworthiness inspector had been assigned to perform his duties while he was incapacitated. However, the air-worthiness inspector testified that he was neither trained nor qualified to perform avionic inspections and that he did not perform the avionics inspector's duties. The airworthiness inspector testified further that he did not know if anyone else had performed the avionics inspector's duties. With regard to workload, the avionics inspector testified that he did not "feel particularly overloaded."

Principal Maintenance Inspector for Airworthiness.--The airworthiness PMI had completed the FAA's 2 week Air Carrier mini-indoctrination course on February 11, 1983; however, he had never served as a Part 121 inspector before he was assigned to Air Illinois on August 8, 1981. In addition to Air Illinois, the airworthiness PMI had surveillance responsibility for 12 on-demand air taxi operators, 17 executive operators, 3 air agencies, 18 agricultural operators, 8 repair stations, and 1 mechanics school.

From October 1982 to the date of the accident, the airworthiness PMI had performed ramp checks, spot checks, facility inspections, and en route inspections of the Air Illinois Part 121 operation. During an en route inspection, the PMI would fly the airplane's assigned route, inspect the airplane and its flight log, and inspect the maintenance procedures being used by maintenance personnel at the Air Illinois stations at which the airplane landed. He testified that he did not notice anything "out of the ordinary" during these inspections.

The airworthiness PMI testified that he had been told by maintenance personnel of a shortage of parts. He verified the shortage during his inspection of the stockroom. Although this shortage should have been noted on his official report forms, he testified that he did not remember if he had made appropriate entries. He testified also that Air Illinois had remedied the situation and that the stockroom had a sufficient spare parts inventory to perform its maintenance tasks properly.

The airworthiness PMI did not know about the verbal briefing procedures being used by the HS 748-2A captains and the maintenance personnel. He testified that he did not detect the procedure because he had no reason "to suspect it was done." He also

testified that he did not know that the part inspections contained in the period inspection program were being performed improperly and that there was no way that he could have discovered that the clipboard was being hidden during his ramp inspections at Carbondale.

The airworthiness PMI testified that he knew that the Air Illinois maintenance organization chart in effect at the time of the accident did not comply with the required separation of maintenance and inspection functions contained in the applicable provisions of 14 CFR 121. He testified that the chart did not reflect the maintenance organization accurately, and that he had confirmed that these functions were separate during his inspections by observing the way the maintenance and maintenance inspections were performed and by conversation with the Air Illinois vice president for maintenance. Personnel had been assigned to the chief and alternate inspector position; however, the airworthiness inspector "could not recall their names." He also testified that he never had required Air Illinois to correct the chart and that that "was an oversight on my part."

After the accident, Air Illinois submitted a new chart which set out a maintenance organization which complied with the functional separation requirements of 14 CFR 121.

Principal Operations Inspector.--The Principal Operations Inspector (POI) completed the FAA's Air Carrier Operations Indoctrination Course on August 13, 1968, and he served as an Assistant POI for Allegheny Airlines during 1968 and 1969. He then served 3 years as a flight and ground training instructor in the Air Carrier Training Section at the FAA Academy in Oklahoma City during which time he taught in the Air Carrier Operations Indoctrination Course. He was assigned as POI to Air Illinois in September 1980. However, he had not performed as a Part 121 POI since 1969, and he did not receive any retraining before assuming his Air Illinois duties. In addition to his Air Illinois surveillance responsibilities, the POI was responsible for five Part 135 operators and one Part 141 flying school (Southern Illinois University). The POI also was responsible for administering airman qualification and proficiency checks required in 14 CFR 61 and 121.

According to FAA Order No. 8430.6B, "Air Carrier Inspection and Surveillance Procedures," the purpose of the surveillance and inspection program is to insure that a carrier's training program conforms with the "regulatory requirements and that it is effective in qualifying crew members for the type of operation conducted." The regulatory requirements for the flightcrew initial and recurrent training programs are contained in Subpart N and Appendixes E and F of 49 CFR 121. The POI was responsible for monitoring and ensuring the adequacy of the Air Illinois Part 121 flightcrew training program.

The POI testified that his inspections and surveillance activities were directed toward insuring that Air Illinois complied with all applicable regulatory requirements. He also testified and the curricula of the initial and recurrent training programs outlined in the company manuals complied with regulatory requirements contained in Part 121.

With regard to dual generator failures, the POI testified that the Air Illinois HS 748-2A initial flightcrew training course included a presentation on this emergency. He also testified that, although the dual generator failure was not listed, per se, in the recurrent training program curriculum, the emergency would have been presented to the flightcrews since the curriculum outline indicated that emergency procedures were to be presented and a dual generator failure was an emergency procedure. The POI could not recall whether or not he had observed the dual generator failure emergency being taught during recurrent training.

Although 14 CFR 121.417(b)(4) requires that each crewmember review and discuss previous aircraft accidents and incidents pertaining to actual emergency situations, Air Illinois did not have a formal presentation of this material for their personnel. The POI testified that during emergency training they "got around to that, but I don't believe there was a formal course in that." He also testified that he was not aware of the fact that HS 748-2A captains were not entering maintenance malfunctions in the airplane flight log.

On September 28, 1983, the POI had observed a 6-month airman's proficiency flight check conducted by the HS 748-2A chief pilot on the accident airplane. During the preceding flight that day, the flightcrew had recorded an out-of-tolerance division of generator loads in the performance section of the airplane flight logbook; however, the captain of the flight had not recorded this malfunction in the discrepancies section of the logbook page as required. The POI testified that he did not detect this because he did not review the flight logbook during the flight. He said that he would have reviewed the logbook if he had been performing either a ramp or en route check; however, in this case, since he had only boarded the airplane to observe the chief pilot's performance of his check airman's duties and the examinee captain's performance, he did not examine the flight logbook.

His last inspection visit to Carbondale occurred on September 22, 1983, at which time he inspected the company's training records and noted discrepancies in the training records. The POI stated that he had attended the training in question, that the training was accomplished properly; however, the information concerning the personnel who had attended the course had not been entered in the company training records.

Pre-Accident Surveillance.--Between January 1, 1983, and October 11, 1983, the Principal Avionics and Maintenance Inspectors performed 40 surveillance inspections of the Air Illinois Part 121 operation. The records showed that they had performed 10 en route inspections; 7 facility inspections; 14 ramp inspections; 1 record surveillance inspection; and 8 spot inspections. Examination of the official forms containing the results of these inspections disclosed that the principal inspectors had inspected and documented, among other items, the condition and status of Air Illinois' physical facilities and ground equipment; refueling procedures; and operational, training, and maintenance records to determine whether the company was entering required data properly and that the information contained therein denoted that the required maintenance procedures and operational training and flight checks were being performed and were completed within required time limits. The examination of these records also disclosed that they did not contain any serious deficiencies of the type discovered by the Safety Board during the investigation of the accident or by the FAA after the accident.

During the same period, the POI performed 107 surveillance inspections of the Air Illinois Parts 121 and 135 operations. The inspections included 24 ramp inspections, 13 facility inspections, 3 airman proficiency flight checks, 54 en route inspections, and 13 miscellaneous inspections. The miscellaneous inspections included observing initial and 6-month flight checks, first officer qualification checks, dispatcher training, HS 748-2A training, and attending the Air Illinois HS 748-2A 8-hour recurrent training program. With regard to the recurrent training, the POI stated that the course material was "covered thoroughly." The records showed also that the POI had monitored the captain of Flight 710's last HS 748-2A Airman's Proficiency Check. The check was given by the chief pilot on July 7, 1983; the captain received a "satisfactory" grade for the oral examination and all required maneuvers, and the POI commented that the chief pilot's "performance (was) very good."

The official forms prepared by the POI contained instances where he had detected improper emergency procedure training on a Part 135 airplane, poor passenger briefing procedures, and faulty weight and balance procedures. The forms showed that, the POI had instituted followup action on these discrepancies and that the followup action was completed satisfactorily.

The POI's records showed that 8 of the 24 ramp inspections were performed on the HS 748-2A and that he had examined the airplane flight logbook during these inspections. Except for one inspection which occurred on the 13th day of the month, all ramp inspections were conducted after the 15th day of each month. Therefore, at least 13 days of flight logbook pages were available to the POI to inspect pilot writeups of maintenance discrepancies and the corrective action writeups entered by maintenance personnel. Even though these forms were available and were inspected, the POI did not draw any inference from the fact that the HS 748-2A captains had not entered any maintenance malfunctions in the logbook for lengthy periods.

Temporary Manager of GADO-19.--The temporary manager of GADO-19 testified that he assumed his position during May 1983. As of October 11, 1983, in addition to Air Illinois, the GADO was responsible for the surveillance of 1 commuter operator and 48 Part 135 operators. Six inspectors were assigned to the GADO, and the manager testified that he believed his staffing was adequate. He testified also that, since Air Illinois was the only scheduled air carrier assigned to GADO-19, its inspections were given the highest priority. Thereafter, "we do all we can for the other operators." The acting manager also testified that, as a result of the accident, he was going to recommend "that every effort be made to have people assigned full-time to Air Illinois because I feel that they have reached a complexity that they need full time inspectors."

The manager testified that the procedures used by the Air Illinois HS 748-2A captains with regard to entering maintenance malfunctions in the flight log would have been difficult, but not impossible for his inspectors to detect during their surveillance inspections.

An Air carrier operations specialist from the FAA's Great Lakes Regional Office 10/ testified on the task of maintaining surveillance over the growing numbers of Parts 121 and 135 operators. With regard to the reason the Air Illinois Part 121 certificate was not transferred to an Air Carrier District Office (ACDO), he testified that, as a rule, if the Part 121 operation is an outgrowth of a Part 135 operation which is already resident in a GADO and the Part 121 operation is composed of a small fleet of aircraft, the surveillance of the Part 121 operations will be kept in the GADO.

With regard to the Great Lakes Region, he testified that between 1980 and 1983, the number of Part 121 operators increased from 11 to 25, whereas the Part 135 operators remained constant at 18; however, several of these Part 135 operators were using large airplanes. He also testified that between 1980 and 1983, the number of inspectors in the Great Lakes Region had decreased from 249 to 207. With regard to training inspectors to perform Part 121 duties, he testified that the region now requires that any inspector who is assigned to do air carrier work attend the full air carrier indoctrination course at the FAA Academy in Oklahoma City before assuming his new assignment.

10/ GADO-19 operates under the jurisdiction of the FAA's Great Lakes Regional Office.

Postaccident Inspections.--After the accident, three [illegible]spection teams conducted surveillance inspections of Air Illinois. Between Octob[illegible]nd November 1, 1983, a five-member inspection team conducted a surveillance insp[illegible]on of Air Illinois' operational and maintenance procedures; between December 2 and 4, 1983, a second inspection team conducted a maintenance surveillance; and, between December 7 and 13, 1983, an 11-member Special Inspection Team inspected all aspects of the Air Illinois operation. Neither of the first two teams issued formal reports of their findings. Commenting on the work of the three teams, the chief of the first inspection team stated that, "A major point is that the FAA conducted only one inspection. There were recognizable phases to the inspection which accounts for a possible misperception that two or three separate inspections occurred." He stated that his team's "preliminary findings were reported to the (FAA's) Great Lakes Regional Director, the Flight Standards Division Manager, and Regional Counsel." The conclusion was that, "while the findings were serious, we had insuffucient data to support emergency suspension or revocation action." Furthermore, the chief of the first inspection team also had told a member of the Safety Board's investigation team that his team's negative findings were "nickle and dime" type findings and that nothing had been discovered to warrant recommending emergency suspension action against Air Illinois' operating certificate.

Following the initial inspection, the FAA began, according to the team chief, a review of the surveillance and inspection history regarding Air Illinois and also started developing an enforcement action, including an assessment of additional inspections that might be appropriate. In addition, FAA personnel were "detailed to attend the Safety Board's hearing in Carbondale (see appendix A) in order to be able to recommend appropriate action should any new information be revealed."

The chief of the first inspection team stated further that "As it turned out, our concerns were heightened during the early part of the [Safety Board's] hearin[illegible] The [Flight Standards] Division Manager responded by ordering maintenance surveill[illegible] as an interim measure until a large enough group of inspectors were assembled to continue the inspection efforts in greater depth and detail. The results of all phases associated with the Air Illinois inspection were reported in the Special Inspection, Air Illinois, Inc., dated December 7-13, 1984." On December 2, 1983, while the Safety Board's public hearing at Carbondale was in progress, the FAA announced that it was placing Air Illinois under a 100 percent surveillance inspection.

The 11-man special inspection team which conducted the in-depth inspection of Air Illinois consisted primarily of personnel from FAA Flight Standards Headquarters and the FAA Great Lakes Region. The inspection included, but was not limited to operational procedures, flightcrew training, airplane flight manuals, maintenance procedures, training of maintenance personnel, and maintenance manuals. The special investigation began on December 7, 1983, 4 days after the Safety Board's public hearing recessed, and ended December 13, 1983.

According to the report of the special inspection team, the investigation of the HS 748-2A accident at Pickneyville "and the evidence gained during the increased surveillance inspections of the Carrier's operation prompted the decision to establish this special inspection. The mandate issued to the team was to determine if the incidents were indicative of, or symptomatic of, a general compromise of aviation safety standards within the company."

Before beginning its on-site activities, the special inspection team reviewed the information gathered during the October and December surveillance inspections of the Air Illinois operation. The team decided that these data "would be used as information

only and that our report would be based on the results of a separate and independent evaluation." The team's inspection report identified several "major safety deficiencies affecting the overall operation of Air Illinois, Inc." Among these deficiencies were the fact that Air Illinois did not have an effective flight training program for its personnel; that operating manuals contained out-of-date material and did not meet the requirements of the applicable Federal Aviation Regulations; that maintenance items were carried on the deferred list for 10 months or longer; and, that "Air Illinois has operated a BAC 1-11 since July 14, 1982, without an approved [inspection] program." The report stated further that, "It was the unanimous agreement of the Inspection Team that the significant and widespread non-compliance with the Federal Aviation Regulations warranted a recommendation for immediate action as follows:

> That the Air Illinois, Inc., Operating certificate be revoked, with a waiver of the one-year waiting period, to permit a complete recertification process to be initiated. The waiver of the one-year waiting period was proposed so as not to impose any specific time limitations which would affect the complete and comprehensive re-certification action to be accomplished.
>
> That the responsibility for the administration of the Air Illinois' Operating Certificate be transferred from the Springfield, Illinois General Aviation District Office to an Air Carrier District Office."

On December 14, 1983, Air Illinois voluntarily surrendered its Parts 121 and 135 Operating Certificates to the FAA. On January 13, 1984, Air Illinois was recertified for Part 121 operations and resumed scheduled flights with their BAC 1-11 airplanes. Their Part 135 Operating Certificate was reissued on March 9, 1984. Shortly thereafter, Air Illinois filed for bankruptcy and suspended scheduled service on April 17, 1984.

1.17.6 Other FAA Actions

As a result of the Safety Board's accident investigation and the report of the FAA's special inspection team, the Department of Transportation (DOT) and the FAA have implemented programs designed to enhance the efficiency of the FAA's surveillance. On February 13, 1984, the DOT directed the FAA to restore the air carrier inspector work force to its 1981 level. The FAA began implementation of the directive in March 1984, and action was completed on September 9, 1984. During this period, the FAA hired 166 air carrier field inspectors bringing the work force to 647 inspectors. In addition to increasing the work force, the FAA has started training programs to enhance the quality of surveillance inspections.

The FAA has instituted a new Principal Operations Inspectors Course at the FAA Academy. All new POIs and old POIs will be required to attend this course. Present projections call for 60 inspectors to complete this course during the first year it is offered.

The FAA also plans to begin a POI Recurrent Job Functions Course. All inspectors assigned for duties with Part 121 operators will be required to attend this course at recurring intervals; however, no beginning date for this course has been set.

With respect to airworthiness, the FAA is presenting a series of 4-day Airworthiness Training Seminars. The seminar's curriculum is designed to correct deficiencies discovered by the FAA during the National Air Transportation

Inspection (NATI) 11/ and various special investigations. The subject matter presented in the seminar covers maintenance organization, maintenance manuals and records, deferred maintenance and minimum list compliance, continuing analysis and surveillance systems, reliability programs, and contractual arrangements for maintenance.

The FAA plans to give this seminar to all their airworthiness inspectors and they encourage all office managers to attend. The 4-day course will be given at various locations throughout the country. As of the end of 1984, eight seminars already have been held. Between January 1 and March 29, 1985, the FAA plans to conduct 12 additional seminars.

1.17.7 Airplane Flightpath

Flight 710's ground track was reconstructed from data retrieved from the airplane's recorders (CVR and DFDR), the ATC radio communication transcript, and radar data from the FAA National Track Analysis computer printout. (See appendix F.)

The radar data included both primary (a directly reflected radar return) and secondary (a transponder beacon) signals. The secondary radar returns began at 2023:23 and ended at 2048:51. Six primary radar returns, between 2049:11 and 2051:43, were used in the reconstruction.

According to the recorded radar data and DFDR information, Flight 710 was flying along the flight plan route at 3,000 feet at 220 KIAS until about 2.5 nmi before reaching the impact position, when Flight 710 began to descend. The integrated DFDR flightpath showed that Flight 710 continued about 3.5 nmi past the position of impact before the DFDR ceased operating at 2053:42. At that time, Flight 710's true airspeed, magnetic heading, and altitude were 216 knots, 175°; and 2,575 feet, respectively. No further DFDR or radar data was recorded and, thereafter, Flight 710 continued descending, turned, and crashed on a magnetic heading of 340°.

2. ANALYSIS

The Safety Board's investigation disclosed that the d.c. electrical power from the airplane's two engine driven generators was lost within about 2 minutes after takeoff from Capitol Airport, Springfield, Illinois. Despite the fact that the weather at Capitol Airport was above VFR minimums, the fact that the estimated time en route to his destination at Southern Illinois Airport, Carbondale, Illinois, was 45 minutes, and the fact that the flightcrew knew that the reported weather at Southern Illinois Airport was below VFR minimums, the captain elected to continue to his destination. Therefore, the Safety Board's investigation and analysis placed special emphasis on identifying and analyzing the factors which led to the captain's decision to continue the flight. In addition, it sought to identify the generator failure modes and to identify and analyze the emergency and other procedures used by the flightcrew to conserve d.c. electrical power during the ensuing flight.

The investigation also disclosed maintenance procedures which did not comply fully with either applicable FAR or Air Illinois procedures. Consequently, the Safety

11/ The NATI inspection was conducted between March 4 and June 5, 1984, at the direction of the Secretary of Transportation. The inspection included all Part 121 air carriers and Part 135 commuter carriers. It did not include Part 135 on-demand carriers and all-cargo carriers.

Board attempted to determine if these deviations from the prescribed maintenance procedures contributed to the accident. The Safety Board also examined FAA surveillance inspection procedures to determine if they were adequate and whether they contributed to the accident.

2.1 Generator Failures

At 2021:34, about 1.5 minutes after takeoff, Flight 710 told Springfield departure control that it had "a slight electrical problem," but that it did not intend to return to Springfield. Subsequent CVR conversations which began at 2023:54 and at 2038:41 showed that the left generator had failed and that the right generator output was 27.5 volts. However, the first officer was not able to reconnect the right generator to the busbars. The conversations showed that during the failure sequence of the left generator the first officer had depressed the right generator isolate button on the d.c. control panel instead of the left isolate button because he had assumed the "problem was on the right side, but they both still went off." The fact that the airplane maintenance records and flight logbook contained numerous writeups describing problems with the right generator may have led the first officer to anticipate an electrical problem with the right generator or its circuitry. Although the first officer's initial action should only have disconnected the right generator busbar from the center busbar, his description of the right generator's voltage output and his inability to "get it [the generator] on the line" showed that the right generator also had been disconnected from the right generator busbar. Based on these data, the Safety Board concluded that Flight 710 lost all d.c. generator power. The Safety Board then sought to determine the cause and the timing of these failures.

The Left Generator.--The examination of the left generator showed that one of the banding wires which hold the conductor bars in their mounts around the armature had failed. Thereafter, the unrestrained conductor bars were lifted from their mounts by the centrifugal force of the rotating armature and contacted the field coil around the armature. The armature rotation became restricted and caused the drive shaft to shear at the design shear point of the shaft. The highly polished fracture surfaces on the drive shaft and drive coupling showed that the drive coupling end of the shaft continued to rotate and rub the fracture surfaces, thus, indicating that the shaft had sheared early in the flight.

The examination of the failed banding wire indicated that the solder used to hold the band in place had melted. Centrifugal forces had thrown the melted solder from the band and the banding wire had unwrapped. The likely sources of heat sufficient to melt the solder were mechanical overheating, electrical overheating, or an insufficient flow of cooling air through the generator. There was evidence of localized heating of the armature and a corresponding area of the field coil assembly at the air outlet end of the generator; however, there was no physical evidence of either mechanical binding or seizures within the generator's rotating components which could have provided a source of mechanical heating of sufficient intensity to melt the solder. Electrical overheating due to a high current flow would have produced a more uniform heat pattern over the entire armature and field coil assembly rather than the localized pattern described above. An insufficient flow of cooling air through the generator could cause localized overheating within the generator, particularly at the air outlet end where the exiting air would be the hottest, and the Safety Board believes that insufficient flow of cooling air was the most likely cause of the overheat condition. However, there was not enough evidence available to specifically identify the cause of the insufficient air flow.

The Safety Board could not determine if the type of solder used on the banding wire contributed to the wire failure. Since the melting point of the tin/antimony solder

used on the banding wires was 130° F lower than the more commonly used lead/tin solder, there might not have been a failure if the highest temperature within the generator was between the melting points of the two solders; however, the Safety Board could not determine the exact temperature which existed within the generator.

The Right Generator.--The examination of the right generator showed that the field coil windings, particularly the compensator windings, had been exposed to high heat. The insulation had flaked off in places and had exposed the bare compensator windings to the generator case. The continuity check disclosed an insulation breakdown as evidenced by a very low resistance between the windings and the generator case. However, these windings are on the negative or low potential side of the generator and a low resistance to the case would not have prevented the generator from producing power. The exemplar generator supplied by Air Illinois for the generator capability checks also exhibited a similar low resistance to the generator case. However, during the operational tests, this unit was able to deliver its rated voltage and current.

Under Air Illinois procedures, the right generator routinely is used in conjunction with the airplane batteries to assist the start of the airplane's left engine. The right generator installed on the airplane had accumulated about 1,453 hours since its last overhaul. Consequently, it is probable that the heat discoloration resulted from engine starting procedures during the time it had been installed on the airplane. Based on these factors and the physical evidence, the Safety Board concludes that the right generator was capable of producing power throughout the accident flight.

The right generator spline drive shaft had sheared at its design shear point at the drive coupling end of the shaft. The shaft also exhibited some bluing, indicating high heat over a small area around the sheared end of the shaft. The metallurgical analysis of the shear indicated that the generator continued to run until it overran the engine that was driving it, i.e. the engine speed decreased relative to the generator speed. The metallurgical analysis further indicated that the shaft heating was minor and that it may have been the result of the scoring on the shaft. The damage noted on the rotating components of the generator was indicative of both rotational and nonrotational impact damage.

The ground scars at the accident site showed that the airplane struck the ground in a right wing down attitude and that the right engine propeller contacted the ground during the initial impact sequence. Thereafter, the airplane became airborne again and major structural breakup did not occur until later in the crash sequence. Since the generator is mounted on top of the engine, the Safety Board believes that the generator overran the engine and the shaft sheared during the initial impact sequence when the right engine propeller struck the ground. Thereafter, the armature came to a stop and was damaged further during the final stages of the impact sequence as evidenced by the nonrotational type impact damage observed on the commutator, ball bearings, and ball bearing races. In addition, since the left generator failed shortly after takeoff and since the rotating beacons were turned off about 9 minutes after takeoff, the sole remaining source of power to the DFDR's holding relay was the internal busbar of the right generator. The fact that the DFDR continued to operate until battery power to the inverter was lost further indicates that the generator ran until initial impact. Therefore, the Safety Board concludes that the right generator was running when the airplane struck the ground.

The evidence indicated that the first officer never was able to restore the right generator to the right generator busbar. Although the generator was producing 27.5 volts, the first officer never observed a load current on the generator. There are

many high load drawing components powered from the right busbar, such as the No. 2 inverter and the right pitot head heater. Had the first officer been able to place the right generator on the right busbar, the load current would have been readily apparent on the ammeter. The only component of the airplane electrical system which could have failed in a manner that would allow the generator to produce voltage but not supply power to its busbar was the generator switching unit which connects the power terminals of the right generator, through the use of a contactor, to the right busbar. Because the voltmeter on the d.c. control panel is connected directly to the power terminals of the generator, the voltage output of the generator would be shown on the voltmeter even if the switching unit contactor had failed open; however, the generator could not have been placed on the right busbar. Under these conditions, when the first officer positioned the rotary selector switch on the d.c. control panel to the right generator position, the voltage and load current readings would have been 27.5 volts and zero, respectively.

The Safety Board could not determine precisely how the right generator disconnected from its busbar during the failure sequence of the left generator. The right generator switching unit was examined for evidence of a malfunction. However, the unit had been damaged so badly that it could not be tested functionally. Although the description of the condition of the right generator gleaned from the CVR indicates that the first officer's inability to restore the right generator to service probably was caused by a switching unit malfunction, the Safety Board, based on its examination of the physical evidence available, could not determine if the switching unit was operating properly during the flight.

Finally, the captain reported the electrical difficulty to ATC at 2021:34. At 2022:16, sychronization was lost on the DFDR indicating a momentary loss or interruption of the recorder's power supply, and, at 2023:54, the first officer reported that the left generator was "dead, the right one [generator]) is putting out voltage but I can't get a load on it." This indicates that both generators were no longer supplying power to the airplane's busbars. Given the timing of these three events, the Safety Board concludes that the airplane lost the power output of the generators at 2022:16, about 2 minutes after takeoff.

2.2 Operational and Human Performance Factors

The CVR recording begins at 2023:54, or about 3.5 minutes after Flight 710 departed Springfield. During that 3.5 minutes, the flight had reported to ATC that it had experienced a "slight electrical problem," but that it was not returning to Springfield. The CVR transcript showed that between 2023:54 and 2025:42, the first officer had briefed the captain on the loss of and the status of the two generators, that he had been unable to restore the apparently functional right generator to the airplane busbars, and that the battery power was going down "pretty fast." Flight 710 continued toward Carbondale.

At 2026:31, the first officer told the captain, "There's the right one," and the captain then directed the first officer to turn the d.c. load switch to normal and restore the passenger's reading lights and to turn off the main cabin lights. Based on this statement and the captain's order to restore the passenger reading lights it was hypothesized initially that the right generator had been restored to the airplane's busbars. Since the generator has a continuous rated 300-ampere capacity, which would have easily supported the airplane's electrical load throughout the rest of the flight to Carbondale, it was further hypothesized that the captain's decision to continue was based on this fact. However, several actions taken by the flightcrew during this portion of the flight are inconsistent with these hypotheses.

First, between 2026:31 and 2028:17, the captain had re ed clearance to descend to 2,000 feet even if "we have to go VFR." This course of ac would have been unnecessary had the right generator been restored to the airplane's busbars.

Second, although it was after sunset, the captain had turned off the airplane's navigation, or position lights. Since 14 CFR 91.73 requires these lights to be turned on after sunset, the captain's decision to turn them off could only be justified under his emergency authority contained on 14 CFR 91.3(b). Under these circumstances, turning the position lights off was totally inconsistent with a hypothesis that the right generator was operating.

Third, the CVR ran at a continuously reducing speed throughout the entire flight. Had generator power been restored, the CVR would have resumed its design speed at least for the period of time that the generator remained connected to the airplane's busbars.

Fourth, at 2028:12, the captain asked, "How are our batts [batteries] there?" The first officer answered, "Ah, ah, about twenty-two and a half." Had the generator been restored to the center busbar, there would have been no need to monitor battery voltage since the generator would have been charging the batteries. Since it is impossible to read battery voltage with a generator connected to the center busbar, the voltage reading would have been 27.5 volts had the right generator been on-line. Moreover, the Safety Board believes that neither the captain nor first officer would have disconnected the right generator from the center busbar just to monitor the status of the batteries. Not only would this action have been unnecessary, but it would have interrupted any needed battery charging and it would have incurred the unnecessary risk of not being able to restore the right generator to the center busbar. Consequently, the Safety Board concludes that the right generator was never restored to the center busbar after had been disconnected from that busbar by the first officer.

The Safety Board believes that by 2025:42 it should have been obvious to the captain that he had to rely solely on the airplane's batteries for electrical power. At 2025:42, Flight 710 was about 6 minutes from Springfield and about 39 minutes from Carbondale. Based on the reported weather observations at Springfield and Scott AFB, and the flight's request to descend to 2,000 feet "even if we have to go VFR," the Safety Board believes that Flight 710 was either flying within the clouds, through the bases of the clouds, or just below the bases of the clouds. Given the reported weather observation at Carbondale, the Safety Board believes also that the captain had to know that there was little chance that he could conduct the entire remaining portion of the flight below the cloud base or that he could land at Southern Illinois Airport without the use of electrically powered radio navigation aids. Nevertheless, the captain elected to continue to Carbondale.

The accident data showed that Flight 710's batteries depleted about 2053. Since, at 2025:42, the ceilings and visibilities at Capitol Airport, Springfield, Illinois, were well above VFR minima, had the captain elected to turn back he would have been able to land without difficulty at Capitol Airport before the batteries depleted. Based on the situation which existed at this time, the Safety Board concludes that the captain's decision to continue toward Carbondale was the major causal factor in the accident sequence, and, therefore, the factors which led the captain to make the decision to continue must be analyzed.

Two factors concerning the airplane's d.c. electrical system were critical to both the captain's decision and the accident. First, the captain needed to know if the

endurance time of the batteries was sufficient to allow Flight 710 to fly to and land at Carbondale and second, having decided that sufficient time was available, he had to manage the airplane's electrical loads properly to insure that he was able to extract the maximum endurance from the batteries. Therefore, in order to determine the captain's knowledge of the electrical system and his ability to manage the airplane's electrical loads, it was necessary for the Safety Board to analyze in depth the manner in which the flight toward Carbondale was conducted.

The Air Illinois' AOM stated only that the available battery time was dependent on "the charge state of the batteries and the essential loads required for flight conditions." However, additional data concerning battery endurance had been presented to the captain during his initial ground school training. The British Aerospace ground school instructor testified that he had taught the pilots who had attended his course that with fully charged batteries, if the total load on the batteries was reduced to 70 amperes, a minimum of 30 minutes battery time was available. The captain had attended that class and, therefore, he had been taught that, provided the batteries were fully charged and the electrical loads were reduced properly, at least 30 minutes of power was available on the battery. Four HS 748-2A flightcrew personnel also testified to their understanding that the minimum time available on the batteries was 30 minutes.

The ability of the batteries to deliver a minimum of 30 minutes power was dependent on their state of charge. When the airplane was stopped at the gate in Springfield, the batteries could be expected to have been about 90 percent charged to about a 79.2 ampere hour capacity. Since Flight 710 activated its ATC clearance at 2011:44, the Safety Board assumed that engine start procedures began about 2012. During the 7 minutes before engine start, the batteries would have been supplying the cabin lights (18 amperes) and cockpit lights (7.3 amperes). Also, the No. 1 inverter (31 amperes) would have been on for about 2 minutes while the airplane was being refueled. These loads would have reduced the battery capacity by about 4 ampere hours.

Engine start would have required about 3 minutes, during which time the No. 1 inverter would have been running; however, all other loads should have been reduced. The battery start of the right engine reduced the battery capacity by 2 ampere hours. In addition, during this 3-minute period while the airplane was being configured for taxiing, the inverter plus other miscellaneous electrical loads would have drawn about 65 amperes and would have reduced the battery capacity another 3.5 ampere hours. Thus, at the conclusion of the engine starts, the battery capacity was about 69.9 ampere hours.

Since the first officer said that he isolated the right generator during the flight, the Safety Board concludes that both generators had been placed on line when the airplane was cleared to taxi at 2015:14. Therefore, the Safety Board assumes that battery charging at a 30-ampere charge current began at 2015. Since the flight reported that it had experienced an electrical problem at 2021:34, the Safety Board concludes that the batteries were charged at the 30-ampere rate for at least 6 minutes, or 180 ampere minutes. Consequently, the batteries received a 3-ampere hour charge which brought their total capacity to about 72.9 ampere hours when the charging process ceased.

According to the CVR, the flightcrew was estimating Carbondale "about on the hour," or 38 minutes after the generators failed. Since the minimum available time on the batteries was at least 30 minutes, it might have been possible for Flight 710 to reach Carbondale and land provided the generator failure emergency procedures were accomplished properly, and provided the airplane's electrical loads were reduced promptly to or below 70 amperes. The captain's and first officer's ability to accomplish these two tasks were dependent on their training and knowledge of the airplane's electrical system.

Since an HS 748-2A flight simulator was not available to Air Illinois for its recurrent training program and since replicating a failure of both generators in flight, even on a training flight, would be hazardous, training in this emergency procedure, if given during recurrent training, was undertaken only after the airplane had landed. The chief pilot, who was in charge of the recurrent training program, testified that the company considered the failure of both generators to be an extremely rare possibility; therefore, this emergency was rarely demonstrated on the airplane or discussed during recurrent training. The testimony of Air Illinois HS 748-2A pilot personnel indicated that generator failure simulation was generally limited to the failure and recovery of a single generator. With regard to the load reduction procedures required after generator failures, the chief pilot and another Air Illinois HS 748-2A captain testified that they believed that the AOM was inadequate because the busbar load distribution charts contained in the AOM did not contain the amperage values of the listed components.

The CVR transcript indicated that the procedures used by the flightcrew during the emergency did not insure that the airplane electrical loads were reduced to the minimums needed to provide 30 minutes of battery time. The first step in the emergency checklist for a failure of both generators is to depress both generator isolate buttons which opens both RCCBs and disconnects the left and right generator busbars and their nonessential loads from the batteries. Thereafter, unless a generator is restored to service, these RCCBs must remain open. The CVR indicated that this was not done; accordingly, numerous non-vital electrical loads were not shed from the batteries. For example, the airplane navigation lights, anti-collision rotating beacons, interior cabin lights, and cockpit lights all are powered by the left and right generator buses. Had the RCCB's been opened and left open, these lights would have been out. However, conversations on the CVR at 2026:42, 2028:45, 2028:46, 2029:39, and 2030:00 indicated that these lights were on.

In addition, at 2038:41 and 2039:01, the captain and first officer discussed the actions taken by the first officer at the inception of the emergency. The first officer said that when the emergency began he had opened the right RCCB and isolated the right generator busbar from the center busbar. The captain said that when the first officer opened the right RCCB his instrument lights began to dim and that passenger cabin lighting was lost. The captain's instrument lights and half of the cabin lights are powered by the right generator bus and this confirmed that the right busbar had been isolated. Since the first officer's instrument lights did not appear to have been affected, the left RCCB still must have been closed when the left generator failed and the battery began powering the left generator bus. Since the CVR conversations also revealed that the captain's instrument lights and the cabin lights were restored, it also appeared that the right RCCB was closed at some subsequent time.

The first indication that the initial action required in the event of a dual generator failure was taken occurred about 7 minutes after electrical power from the generators was lost. At 2029:25, the first officer said, "I am going to try something here. . .I'm going to try to isolate both sides and see what happens." In addition to informing the captain of his intentions, the first officer's statement confirms that, up until this time, both generator RCCBs had not been opened simultaneously as required by the emergency checklist. At 2029:39, the first officer asked the captain if he wanted the emergency light switch turned on. Since only the center busbar would have been powered after the RCCBs were opened, almost all the cockpit lighting would have been shutdown; turning the emergency light switch on would have placed the cockpit overhead lights on the live battery busbar and would have restored them to service. However, the captain answered, "No, I want it back the way it was." He then told the first officer, "You see, you're shutting off all the electricity to the back end that way, the lighting and

everything." At 2030:10, the first officer asked, "You want me to leave it the way it is then," indicating that the RCCBs had been reset. Based on this conversation, the Safety Board concludes that, except for about 35 seconds between 2029:25 and 2030, the left and right generator busbars were never disconnected concurrently from the center busbar. In addition, except for very small time intervals early in the flight when the first officer was attempting to restore generator power to the busbars, the batteries were carrying the electrical loads of all three busbars.

The CVR conversations also contained numerous references to battery voltage. At 2025:42, the first officer reported that the batteries were going down pretty fast. Thereafter, the first officer noted the following battery voltages: at 2026:21--22 volts; at 2028:17--22.5 volts; at 2036:14--21.5 volts; and at 2044:53, when the captain asked him if he was "Still doing alright up there," the first officer answered "Yeah it's at 20 volts." At 2050:37, the first officer said, "I don't know if we have enough juice to get out of this," and, at 2053:18 he told the captain, "We're losing everything, down to about 13 volts."

The CVR conversations also showed that the captain and first officer apparently were reassured during the early portion of the flight by the fact that the battery voltages were holding quite steadily within 2 to 3 volts of their rated output of 24 volts. However, one of the inherent characteristics of the nicad battery is the fact that it will maintain voltage very close to its rated output until the battery cells are nearly depleted. Thereafter, the battery output voltage decreases at a very rapid non-linear rate as evidenced by the performance of the batteries on board Flight 710. The fact that the captain and first officer were reassured by the constant battery voltage and the captain's remark at 2031:36 concerning whether or not the battery's voltage was depleting rapidly seem to indicate that neither the captain nor the first officer were either aware of this characteristic or considered it during their inflight appraisals of their electrical power situation.

The CVR conversations showed that the flightcrew attempted to reduce the airplane's electrical loads. Unnecessary radio equipment, one of the two radio cooling fans, the main cabin lights, the navigation lights, and rotating beacons eventually were turned off. However, there was no indication that the first officer ever used the ammeter on the d.c. control panel to assess the results of these actions or that the captain requested that he do so. Although the Air Illinois AOM abnormal and emergency procedures relating to generator failures state that the loads must be reduced and the remaining loads must be checked to insure that the remaining functional components are not overloaded, there is no reference on the entire CVR transcript to the load current being drawn from the battery.

The Safety Board recognizes the fact that the Air Illinois AOM did not contain an expressed estimate of the endurance time of the batteries after complete generator failure. However, the information contained in the AOM provided the pilots with information to estimate this value. Since the ammeter on the d.c. control panel allowed the flightcrew to ascertain the total electrical load being drawn by the airplane, the flightcrew after performing the desired load shedding, could easily have ascertained the results of their actions and compared the resultant load with the total ampere hour capacity of the batteries.

As stated earlier, the generator RCCBs were closed during most of the flight and, therefore, the batteries were powering all three busbars. While it was possible, based on the CVR conversation, to determine some of the electrical components which were turned off by the flightcrew, the Safety Board cannot be certain that it identified all the

components that were turned off. However, based on the busbar configuration and the CVR conversations, the Safety Board believes that at least the following components were still being powered by the batteries during the flight: both inverters, the passenger reading lights, the cockpit instrument lights, two fuel booster pumps, the pitot heaters, one radio cooling fan, one very high frequency (VHF) radio, one navigation radio receiver, and the cockpit interphone system. In addition, the weather radar was turned on at 2036:23 and remained on until about 2044:59. The estimated load requirements of these components, based on the British Aerospace Load Analysis, was about 110 amperes. Since, it was 2053:18, before the first officer said "We're losing everything, down to about 13 volts," the data indicated that, even though the total load was not reduced to, or below 70 amperes, the batteries, in fact, powered the airplane for about 31 minutes. This evidence also indicates that had the total load on the batteries been reduced to 70 amperes, the useful battery life would have been extended and the airplane might possibly have been able to reach Carbondale and land.

Because the d.c. control panel was located almost directly over the first officer's head, he had to perform all the required emergency actions. By the time the CVR recording begins, the first officer had completed these actions, and other than his summation at 2038:41 of what he had done, the Safety Board could not reconstruct what had occurred in the cockpit between takeoff and 2023:54 when the CVR recording begins, or determine what suggestions, if any, the first officer might have made to the captain concerning the endurance time of the batteries or the advisability of continuing the flight. During the remainder of the flight, the first officer made several suggestions relating to turning off airplane and cabin lighting. Although the captain did turn off the airplane's navigation lights, rotating beacons, and cabin lights, he did not turn off the passenger reading lights. The captain explained that he did not wish to turn off the reading lights because it would alarm the passengers.

As stated earlier, the first officer made no attempt to configure the d.c. control panel to monitor the airplane load current, which considering the emergency, was the most important feature of the electrical system to monitor, and the captain did not request him to do this. At 2029:25, the first officer said "I'm going to try and isolate both sides and see what happens." Since this was the first, and probably, with regard to load shedding, the most important step in the emergency procedure, this should have been accomplished almost immediately after the initial malfunction occurred. After the first officer had erroneously isolated the right generator, he should have, if he had not done so before, either isolated or insured that the left generator busbar was isolated from the center busbar. Had this been done, a major portion of the airplane's electrical load would have been shed. When the captain explained why he did not want the first officer to do this, the first officer did not point out to the captain that the actions were required by the emergency procedure checklist, nor did he point out that the actions would have shed a major portion of the electrical loads from the batteries or try to justify or explain why he believed it should be done.

Finally, there were other high current loads which could have been shed without affecting the airplane's safe flight capability. At 2031:29, the first officer suggested that they turn off the pitot heat; the captain disagreed and the first officer did not pursue the subject. At 2031:43, both pilots agreed that the inverters "take a lot of current." One of the inverters could have been turned off; however, the first officer did not suggest that this be done and the captain did not order it done. Also, both pilots knew that two fuel booster pumps were still running. Since the airplane was flying below 7,000 feet, in accordance with Air Illinois' emergency procedures, the pumps should have been turned off. Given the fact that the first officer never presented the captain with the consequence of his failure to reduce the electrical loads, the fact that he did not

emphasize the need to isolate the center busbar from the left and right generator busbars by reminding the captain that the procedure was required by the emergency checklist, the fact that neither he nor the captain knew that the fuel booster pumps should have been turned off, and, the fact that, after 2023:54, the first officer neither apprised the captain of the minimum endurance time of the batteries nor did he compare this endurance time with Flight 710's estimated time of arrival at Carbondale, the Safety Board concludes that the first officer never challenged the captain's mismanagement of the electrical loads and that both pilots' knowledge of the airplane's electrical system was incomplete.

At 2052:12, the captain said watch my altitude, "I'm going down to 2,400 feet." At 2053:18, the first officer said that the battery voltage was down to 13 volts and that they were "losing everything." When the descent began, the airplane was at 3,000 feet on a southerly heading, and, based on the meteorological analysis, pilot reports, and witness statements, it was flying in the clouds. With the loss of all battery power, all the flight instruments were inoperative, except for the first officer's altimeter, the magnetic compass, airspeed indicators, and vertical velocity indicators. The airplane struck the ground in a right wing-down attitude on a magnetic heading of 340°.

The left main landing gear was recovered in the extended position. However, it most likely extended during the airplane breakup as the gear emergency release cable was stretched and the uplock released which allowed the gear to swing to the down and locked position. The left gear actuator which had separated from the strut was toward the retracted position.

A section of right flap, which still was attached to the wing structure, was recovered in the extended position; however, the flap section was broken from its drive mechanism and was free to move. A more reliable indication of flap position was provided by the flap signalling unit, which was recovered partially intact and was in the fully retracted position.

Based on its examination of the components of the landing gear and flap system, the Safety Board concludes that the landing gear and flaps were fully retracted at impact. The evidence showed that the airplane descended through the captain's target altitude of 2,400 feet, that during the descent it turned almost 180°, that it struck the ground on on a 8° descending flightpath, and that it was in a 33° right wing-down attitude when it struck the ground. Based on the extensive disintegration of the wreckage and the large distance of the wreckage scatter, the Safety Board concludes that the airplane's airspeed at initial impact exceeded 200 KIAS. Given these facts and the fact that the attitude and directional indicating flight instruments were inoperative, the Safety Board concludes that the airplane was not in controlled flight at impact.

The Captain's Decision.--The accident occurred because the captain elected to continue to Carbondale after he knew both airplane generators had failed and the airplane was totally reliant on emergency, or backup, d.c. electrical power from its batteries. The Safety Board believes that it should have been apparent to the captain by 2025:42 that the airplane was dependent solely on its batteries for electrical power, at which time, Flight 710 was about 6 minutes from Springfield and 39 minutes from Carbondale. Even though the weather at Springfield was well above IFR minimums, the captain decided to use the emergency electric power to continue toward the more distant destination airport instead of returning to Springfield. If, at 2025:42, the captain had returned to Springfield, Flight 710 could have returned and landed safely relying solely on battery power.

At 2025:42, two options were available: the captain could return to Springfield or continue to Carbondale. According to the 1975 NASA study, the following factors would have influenced the captain's choice between options: training and experience, psychological or environmental stress "(e.g., get-home-itis and pressure)," and "cost and safety" considerations. With regard to training and experience, a pilot's decision to continue or discontinue a flight after his airplane has experienced a mechanical emergency would be based on many factors among which would be: his estimate of the airplane's capability based on his knowledge of the airplane's systems and performance; his estimate of his ability to fly the airplane and to cope with the conditions created by the mechanical malfunction; and, finally, his assessment of other factors, such as weather, which would affect his route of flight. Since the Safety Board must assume that no competent airline pilot would knowingly continue a flight to a destination he knew his airplane was either incapable of reaching or which could only be reached by placing the lives of his crew and passengers in jeopardy, the Safety Board concludes that the captain's decision to continue was based on his belief that the airplane was capable of reaching Carbondale and that he was capable of flying the airplane in a manner which would insure that it could reach Carbondale safely. However, the Safety Board also believes that the captain's evaluation of both his and his airplane's capabilities were affected by other factors, which led him to assess inaccurately the risks to himself and his passengers in deciding to continue the flight.

The description of the captain's flying habits provided by his peers indicated that he placed a high priority on maintaining flight schedules. Those pilots who knew the captain stated that he was extremely diligent in trying to maintain schedules to the extent that he was very critical of ground personnel who he believed were delaying his flight; he would disable the airplane's aural overspeed warning horn to gain time during the descent by exceeding the airplane's maximum operating speed limitation; and he would fly too close to or under thunderstorms to avoid time consuming deviations from the flight plan route. During the investigation, the Safety Board tried to determine if these practices were self-induced or the result of undue pressures placed by the company on the captain and other line pilots. The Safety Board, however, could not find any evidence that company management had ever threatened or took personnel action against a captain who had delayed a flight because of marginal weather or justifiable mechanical malfunctions. All of the Air Illinois pilots that were interviewed either stated or testified that pressure to keep to a schedule were self-imposed and a matter of pride in themselves to do the job they were paid to do properly. Those that knew or had flown with the captain were virtually unanimous in stating that the pressures the captain placed on himself to maintain schedules were self-imposed. A first officer who had flown with the captain stated, "I got the impression that he wanted to be a good old boy to get the airplane in on time and bring it home. It's not that management was pushing him to do it, it's just that [it] was his own idea." Although the captain would compromise safe flying procedures to maintain the company's schedules, the statements and testimony of the captain's peers showed that the captain's motivation to resort to these practices was self-induced.

The evidence indicated also that the captain possessed a high degree of confidence in his knowledge of the airplane systems and capabilities, his ability to operate the airplane to its limits, and his skill as a pilot. The fact that he disabled the aural overspeed warning and opted to fly the airplane at airspeeds above the published maximum operating airspeed showed that he was willing to accept the risk of decreasing the safety margins contained in the AOM, and that he believed that he possessed the ability to fly safely within the narrowed limits. His actions in permitting an unqualified first officer to land at Meigs Field, Chicago, also showed that the captain had sufficient confidence in his ability to recover the airplane in a timely manner from any unusual attitude that an inexperienced first officer might get into during the approach and

landing. It also showed that the captain had sufficient confidence in his ability to believe he could accept the risks of operating in contravention of the provisions of the company's operating manual. His acceptance of risks was further corroborated by his flying too close to or under thunderstorms to avoid time consuming deviations from flight plan routes. The Safety Board believes that these unsafe acts demonstrated that the captain's confidence in his ability and knowledge led him to believe that he could accept safely the risks involved in operating his airplane near to and below thunderstorms and outside the constraints of the company operating manual and the airplane operating manuals. The publication "Safety Management—A Human Approach" 12/ discusses why employees perform an unsafe act. The publication states, in part, that "the unsafe act has been learned and is maintained because it has been (and continues to be) reinforced by satisfying events. . .The advantages to be gained may seem greater than the disadvantages. . .The unsafe act 'make real sense' to the person, because it gives the employee personal satisfaction. . .The worker may perceive his unsafe act as having definite job related advantages." The investigation did not disclose any evidence to indicate that Air Illinois management had ever rewarded or knowingly condoned unsafe in-flight actions or decisions. The description of the captain provided by the other Air Illinois pilots showed that his drive to maintain schedules was self-induced; therefore, the performance of these unsafe acts can only be attributed to the fact that they allowed the captain to derive personal satisfaction by enabling him to maintain schedules and avoid diverting to alternate airports.

The captain had been on duty about 9 hours 30 minutes when the emergency occurred, and his duty period included time spent "deadheading" to Springfield via a circuitous route to assume his command duties. In addition, the flight was 45 minutes behind schedule, a circumstance which, according to his peers, tended to irritate the captain. When the emergency occurred, he was within 40 minutes flight time from Carbondale where maintenance facilities were available to repair the airplane. If he returned to Springfield, company maintenance facilities were not available, the airplane would be grounded until it could be repaired, and the captain most probably would have been required to stay in Springfield, which according to one of his peers, the captain "hated to stay overnight" in Springfield. These circumstances could have affected the captain's assessment of the hazards of continuing on battery power only.

With regard to the decision to continue to Carbondale, it should have been apparent to the captain by 2025:42 that he could not conclude with any degree of certainty that he could fly below the clouds and maintain visual contact with the ground all the way to Carbondale. Based on the reported weather at Carbondale, it also should have been apparent that he would need electrical power to operate his radio navigation instruments on arrival since he most probably would have to execute an instrument approach to land. Therefore, to insure that he could complete the 39-minute flight to Carbondale, all unnecessary electrical loads would have to be shed in order to have residual electrical power. In addition, there was no way the captain could determine the exact charge state of the batteries when the generators failed; therefore, even with proper load shedding procedures, the captain could not have been sure that battery power would last longer than 30 minutes. Given the two options available to the captain when the generators failed, the risks involved in continuing to Carbondale were such that this option should have been rejected summarily. However, the Safety Board believes that the evidence describing the captain's flying practices points to the presence of several decision-influencing factors described in the 1975 NASA study. The evidence developed during this investigation described conduct which showed that the captain's decisions were affected by psychological pressures, albeit self-induced pressures to compromise safe flying procedures, and that the circumstances of the accident demonstrated that these

12/ Petersen, D.; Safety Management--A Human Approach, 1975.

factors influenced the captain's decision. The Board believes that the captain's decision to continue was based on his reluctance to remain overnight in Springfield, his self-imposed determination to adhere to schedule, his demonstrated willingness to assume what he believed to be reasonable risks to adhere to schedule, and, in this case, a misplaced confidence in his knowledge of the airplane and his flying capabilities. Based on these factors, the captain did not evaluate properly the risks involved in continuing to Carbondale, and the Safety Board concludes further that his decision to continue not only was imprudent, but was improper.

Although the Safety Board concludes that the captain's decision to continue to Carbondale exposed the airplane to a needless risk, the Safety Board also has examined in detail the flightcrew's mismanagement of the airplane's electrical system during the flight toward Carbondale. Although the evidence indicated that the airplane might have reached Carbondale had its electrical system been managed correctly, the purpose of the Board's examination was not to establish whether this was so, but to determine if flightcrew training was a contributory factor to the accident. Statements and testimony given after the accident by Air Illinois HS 748-2A flightcrew personnel indicated that the Air Illinois recurrent training program had addressed, to some extent, the procedures for coping with dual generator failures, the endurance time of the batteries, and the necessity for reducing battery loads to attain the minimum 30-minute battery endurance time. However, the testimony of one HS 748-2A captain and the HS 748-2A chief pilot at the Safety Board's public hearing and the performance of the accident crew indicated that the training provided by Air Illinois during recurrent training was not adequate.

At the public hearing, an HS 748-2A captain testified that, after the accident, he had discovered that it required 7 to 8 minutes to complete the Failure of Both Generators emergency checklist. He also testified that he believed the footnote requiring the pilot to begin load shedding procedures immediately should be moved to the head of the checklist. According to the captain, if this were done "I would be load shedding immediately before I went to the checklist." The HS 748-2A chief pilot, who was responsible for training all HS 748-2A flight personnel, concurred with the captain's testimony concerning the time required to complete the emergency checklist. The chief pilot also testified that some of the actions on the emergency checklist were not in the proper order because the checklist assumes that "as each item is accomplished you see . . . what happened on the checklist. If you do not get exactly what the checklist says you are going to get in the response portion, there is no alternative action. It does not tell you where to go from that point."

The Failure of Both Generators emergency checklist contains 17 actions; however, since 10 of these actions are the same actions used every day by the flightcrew during a normal generator start, the Safety Board believes that trained and competent HS 748-2A pilots could complete the checklist in well below 8 minutes. In addition, there are only two options to be considered on the emergency checklist; either the generators are restored on-line, or they are not. If one generator cannot be placed on-line, the pilot merely proceeds to the second generator and tries to start it and place it on line. If both generators cannot be placed on-line, except for initiating further load shedding actions, no further checklist actions are required.

Regardless of the precise amount of time required to complete the Failure of Both Generators emergency checklist, the testimony of the HS 748-2A captain and the chief pilot indicated that the Air Illinois electrical system recurrent training curriculum was deficient. Since neither captain knew how long it would take to complete the emergency checklist actions until after the accident, their testimony indicated that

neither captain had either practiced or reviewed the checklist procedure recently. Of greater significance was the fact that neither captain knew that the first action on the emergency checklist--press the left and right isolate buttons--accomplished a major portion of the required electrical load shedding. Since the chief pilot also was a designated FAA check airman and, thus, was responsible for emergency procedures training both in the airplane and in the classroom, his lack of familiarity with the emergency checklist and the consequences of the checklist actions indicated that the emergency procedure training which was provided to the Air Illinois HS 748-2A flightcrews during recurrent training was inadequate to cope with the failure of both generators.

The performance of the flightcrew of Flight 710 reflected a similar lack of knowledge of the Failure of Both Generators emergency checklist and load shedding procedures. Although the testimony and statements of the majority of the Air Illinois HS 748-2A flight personnel indicated that they had been trained adequately in these areas, these statements and testimony were given after the circumstances of the accident and relevant portions of the CVR were made known to them, and after they had had an opportunity to review the AOM. The testimony of the chief pilot and the HS 748-2A pilot at the public hearing concerning inadequacies of the emergency procedures checklist, together with the performance of the captain of Flight 710 showed that three of the five captains regularly flying the HS 748-2A were unfamiliar with the procedures and reflects more adequately the quality and completeness of the company's electrical system emergency training. In addition, since one of these three captains was the chief pilot and was responsible for the scope, depth, and quality of the Air Illinois training program, the Safety Board concludes that the weight of the evidence showed that the recurrent training curriculum concerning electrical system emergencies was not adequate.

Most, if not all, pilots are motivated to complete their flights as scheduled; however, when the successful continuation of the flight is threatened by either environmental conditions, a mechanical malfunction, or both, the motivational drive must be tempered by good judgment. The major tempering factor is the pilot's knowledge of the environmental conditions along his route and the capabilities of the airplane's damaged system or systems. Based on this knowledge, the pilot must decide to either continue to his destination or to divert to an alternate airport. Training provides pilots with knowledge to choose the course of action which will expose airplanes and passengers to the least risk. When the captain of Flight 710 knew that he had lost power from the airplane's generators, he knew, based on his initial training, that he probably could expect a minimum of 30 minutes of power from the airplanes batteries. To reach Carbondale, which was about 39 minutes away he would have to extend the minimum endurance time of the batteries at least 9 minutes. Had the captain's proficiency flight checks and recurrent training emphasized that the purpose of the first emergency checklist action was to decrease the electrical loads on the battery so as to provide the minimum battery 30 minutes of endurance time, he would have known that follow-on load shedding actions would be required in order to try to extend the endurance time of the batteries beyond 30 minutes. The risks involved in trying to extend the endurance time of the batteries might have been more apparent to the captain had he known that the loads shed during the initial emergency checklist action included the power supplies to one inverter and the weather radar system, and that, in addition to depriving the passengers of galley services, cabin, and reading lights and turning off the fuel booster pumps, the follow-on load shedding actions might possibly require him to turn off the remaining inverter even through this action would result in the loss of the airplane's heading systems.

The Safety Board believes that, had the captain of Flight 710 been totally knowledgeable of the hazards involved in trying to extend the minimum endurance time of

the batteries, it would have provided further weight against continuing to Carbondale and that his lack knowledge of these factors contributed to his decision to continue. The Safety Board believes that the captain's mismanagement of the airplane's electrical system during the attempt to reach Carbondale corroborates its conclusion that the Air Illinois recurrent training program was deficient. The Board also concludes that this inadequate training contributed to the captain's imprudent and improper decision.

2.3 Maintenance Procedures

Title 14 CFR 121.365(c) states, in part, that each person performing required inspections in addition to other maintenance shall organize the performance of those functions so as to separate the required inspection function from other maintenance. The investigation showed that all required inspections on the airplane were performed by properly qualified mechanics. However, the investigation also showed that the HS 748-2A lead mechanic often would direct the work of the other mechanics, and thereafter he would exercise his inspector authority and perform a required inspection item on the work that had been performed under his supervision. The lead mechanic, according to his testimony, reported to two supervisors; as lead mechanic he reported to the HS 748-2A maintenance manager, and as an inspector he reported to the Chief Inspector. The investigation showed also that in cases where the lead mechanic had performed the maintenance he had delegated a properly certificated mechanic working under him to perform the required inspection. In this case, the lead mechanic testified, that while performing in his inspection capacity, the mechanic reported to the Chief Inspector and not to him. Regardless of the putative change in reporting channels for required inspection items, the Safety Board believes that the evidence indicated that the total responsibility for any inspection work appeared to come under the direct authority of the lead mechanic on duty and he, in turn, was under the authority of the HS 748-2A maintenance manager.

In addition, 14 CFR 121.371(b) states that no person may allow another person to perform a required inspection unless the person performing that inspection is under the supervision and control of an inspection unit. The Safety Board believes that, with regard to the HS 748-2A maintenance program, this requirement was not being followed since all the mechanics and assigned inspectors were under the direct control of the HS 748-2A maintenance manager. Therefore, the Safety Board concludes that the intent of the Federal regulations, with regard to separation of the maintenance and inspection functions was not met.

The Safety Board's investigation disclosed that, in order to ease maintenance workloads and to insure the availability of the airplane for scheduled operations, the part inspections contained in the period inspection program were not performed at the required time intervals. Although the inspections were performed, they were usually performed before they became due; therefore, the prescribed time intervals between the repetitive part inspections were either compressed or extended. Since the purpose of the program is to insure that each part of the airplane is inspected within a specified time interval, this practice did not comply with the purposes and requirements of the period inspection program.

The Safety Board's investigation also showed that the Air Illinois HS 748-2A captains did not always enter the mechanical irregularities and malfunctions into the airplane flight logbook as required by Federal regulations and company procedures. According to company procedures, any maintenance discrepancy entered in the logbook had to be cleared by maintenance personnel before further flight, or a determination must

be made whether the airplane could be flown with the defect. If the airplane was cleared to continue, then authorized maintenance personnel could remove the logbook writeup to the Deferred List. Since any maintenance writeup entered in the logbook while the airplane was en route could either ground the airplane or require a delay in order to determine if the airplane could be cleared for further flight, the Safety Board concludes that the major reason the maintenance discrepancies were not entered in the airplane flight logbook in a timely manner was to avoid either an en route delay or grounding of the airplane.

While the investigation disclosed that maintenance malfunctions were not entered in the flight logbook, it also showed that these malfunctions were reported to maintenance and that action was taken to correct the malfunction. Regardless of the fact that corrective action was taken, the Board believes that this practice endangered the operation of the airplane. One of the preflight actions required of a captain is to inspect the logbook and ascertain the condition of the airplane. Therefore, he is required to inspect the logbook's maintenance discrepancy section to determine the condition of the airplane after the previous flight and what actions have been taken by maintenance to clear the writeups, if any, which were entered by the previous captain. In addition, the oncoming captain should inspect the Deferred List to ascertain what maintenance has been carried over for future corrective action. Thus, in failing to maintain the airplane logbook as required by Federal regulations and company procedures the Air Illinois captains did not provide an accurate description of the airplane's condition to the flightcrews which operated the airplane after them. However, given the fact that the generator malfunctions had been reported to maintenance and that maintenance had taken action to correct them; the fact that the generators on the accident airplane had been operating within inflight tolerances since October 2, 1983; and, the fact that the preceding flightcrew stated that they did not experience any mechanical malfunctions while operating the airplane the evidence did not indicate that this practice contributed to the accident.

The evidence showed that airworthiness releases had been issued on several occasions for N748LL when the generator voltages were not within the specified 27.5 volt plus or minus 0.25 volt contained in the airplane maintenance manual. Although the generators were slightly above the 0.25-volt tolerance, given the 30-volt continuous output capability of the generator, the Safety Board believes that this out of tolerance condition did not contribute in any way to the accident.

Given the discrepancies found in the HS 748-2A maintenance program, the Safety Board cannot conclude that the airplane was maintained in accordance with prescribed Federal regulations and company procedures. While the investigation did not disclose any evidence that indicated that these maintenance practices contributed directly to the accident, the Safety Board believes that these practices probably contributed to the use of an airplane that technically was not airworthy.

In conclusion, the mechanical failure of the left generator and subsequent mismanagement and loss of the right generator precipitated the chain of events which led to the accident. However, the loss of the generators was too remote from the cause of the accident to be considered a contributory factor. The design of the airplane's electrical system was such that the loss of the generators had no effect on the flight characteristics of the airplane. The airplane could be flown as safely after they failed as before they failed. The only limiting factor was the endurance of the batteries. Had the generators failed at a point in the flight where the flight time required to reach a suitable airport was near the the endurance limits of the batteries, the generator failure might have to be considered contributory to an accident. In this accident, this was not the case.

2.4 FAA Surveillance

The surveillance inspection guidelines for FAA maintenance and operations inspectors are contained in FAA Orders 8320.12 and 8430.6, respectively. Based on the two orders, the inspectors are responsible to determine that the carrier or carriers assigned to them are conducting their activities in accordance with the FARs, good operating practices, and with all certification requirements. It is left to the inspector to establish the type, scope, and frequency of surveillance inspections he believes is required "to determine" that the operator he is responsible for has complied with the FARs, good operating practices, and all certification requirements. Neither order contains any specific instruction which either requires or prohibits the inspector to cross check the information on one or more forms against that contained in other forms to verify the accuracy of the entries.

During the year preceding the accident, the three assigned inspectors conducted numerous inspections of both Air Illinois' Part 121 and Part 135 operations. The ramp inspections and the en route line checks conducted by the POI were, for the most part, unannounced inspections. Although the inspectors testified that they inspected the available pages of the airplane flight log, they did not detect that the HS 748-2A captains were not entering inflight maintenance malfunctions in the flight log as required by company procedures and Federal regulations.

Although numerous inspections were conducted at Carbondale where all the airplane maintenance documents and flight logs were available for comparison type examination, the PMIs conducting these inspections did not detect that proper pilot entries were not being made in the airplane flight log; they did not detect that the part inspections of the period inspections program were not performed within the required time intervals; and they did not detect that life-limited airplane components were not removed and replaced within specified time limits. The evidence indicated that the PMI's did not conduct this type of comparison examination of the documents during their visits to Carbondale and, thus did not detect departures from prescribed maintenance procedures.

The investigation disclosed additional examples of inadequate surveillance. The chart which portrayed the Air Illinois maintenance organization did not display the separation of the maintenance and inspection functions required by Federal regulation. Although the airworthiness PMI knew of this error, he had not taken action to require Air Illinois to correct the chart.

The POI, while observing a 6-month airman proficiency flight check, did not review the flight logbook and did not detect the failure of the preceding captain to record a generator malfunction in the discrepancy section of the logbook. Despite the fact that the POI was not performing a type of surveillance check which would have required a full review of all the available logbook pages, the Safety Board believes that the performance of his inspector duties require him to inspect all available information at every given opportunity. In this instance, since the logbook entries made during the preceding flight must be inspected by the oncoming captain to assure himself that the airplane is airworthy, the POI should have observed that the oncoming captain performed this inspection. To insure that the oncoming captain had evaluated the information on the flight logbook page correctly, the Safety Board believes that the POI at least should have inspected all the entries made by the preceding flightcrew.

The POI's surveillance activities were concentrated, for the most part, in insuring that the Air Illinois' flightcrew training programs and procedures complied with the regulatory requirements of Parts 121 and 135. In the course of his duties, the POI performed en route line checks to monitor flightcrew competency and compliance with applicable regulations and good operating procedures. He either administered or monitored 6-month proficiency and airplane qualification flight checks to check the competency of the Air Illinois FAA desiginated check airmen and the adequacy and quality of the flight check given to the examinee pilot. In order to insure that the Air Illinois ground training program complied with Parts 121 and 135 requirements, he had either audited or attended the company's initial and recurrent airplane ground training courses.

The POI had been assigned to Air Illinois since September 1980 and, therefore, had been responsible for the surveillance of the HS 748-2A program for 3 years. During that time as a check airman, he had either monitored or given airplane qualification or 6-month proficiency flight checks. Both of these type checks require the examinee to pass an oral or written examination demonstrating his or her knowledge of the airplane, airplane systems, and emergency checklist procedures. One of the 6-month proficiency checks monitored by the POI was given to the captain of Flight 710 on July 24, 1983, by the Air Illinois chief pilot. According to the official record, the flight check included an oral examination which the captain had passed.

The POI's official records showed that he had observed an HS 748-2A recurrent training session, and that he had attended the 8-hour recurrent HS 748-2A recurrent ground training program on April 21 and 22, 1983, respectively. Although the POI had attended these ground training courses and had monitored and administered pilot qualification and 6-month pilot proficiency flight checks throughout his 3-year tenure as principal inspector, he testified that he could not recall observing the Failure of Both Generators emergency checklist being taught or demonstrated. In addition, even though his check airman responsibilities required him to know the contents of the emergency procedures checklist, he did not detect the error in "Total D. C. Failure" procedure on the HS 748-2A emergency procedure checklist. Given the length of the Failure of Both Generators emergency checklist, the Safety Board believes that had this procedure been demonstrated, taught, or discussed even on only a few of the flight checks, oral examinations, and recurrent ground training programs he had observed, the POI would have certainly been able to recall observing it. The Board believes that the evidence, as stated earlier, showed that the Air Illinois recurrent training program did not either address or reemphasize this emergency. The failure of the POI to detect this omission during his surveillance inspections and to take action to correct this omission contributed to this deficiency in the Air Illinois training program.

Although neither the inspectors nor the GADO manager felt that they were either "overloaded," or, in the case of the GADO, "understaffed," each inspector as well as the GADO as a whole were responsible for supervising many organizations, some of which were not located in Springfield. Given the travel involved and the number of supervisory visits required to fulfill their surveillance responsibilities, the Safety Board believes that it would have been difficult for any of the inspectors to allot sufficient time to investigate in depth the training and maintenance programs of each organization assigned to him, particularly a Part 121 scheduled air carrier. However, without regard to these difficulties, the evidence showed that many of the pre-accident inspections were not performed in an agressive manner. The inspections did not include a review of all the documents and records which were available to the inspectors for examination. Records and documents were not cross-checked against other records and documents to ascertain if the information therein was accurate. Therefore, the Safety Board concludes that the

FAA pre-accident surveillance inspections of the Air Illinois Part 121 operation were not conducted in sufficient depth to detect the areas of noncompliance with company procedures and Federal regulations.

The major safety deficiencies cited in the report of the FAA Special Inspection Team were based, for the most part, on deficiencies which existed before the accident occurred. These deficiencies, which included, in part, inadequate company manuals, a non-effective flight training program, and the operation of the BAC 1-11 since July 14, 1982, without an FAA approved inspection program were not discovered by the inspectors assigned to Air Illinois during any of their pre-accident ramp inspections, spot inspections, or visits to either of the company's maintenance bases at Carbondale or the BAC 1-11 maintenance base at Evansville, Indiana. Given the fact that the pre-accident surveillance inspections did not detect these deficiencies, the Safety Board concludes that the report provides additional evidence showing that the FAA surveillance inspections conducted before the accident were inadequate.

The postaccident surveillance which led to the recommendation to revoke the Air Illinois operating certificate began October 22, 1983, ended December 13, 1983, and was conducted by three inspection teams. During this period, the Safety Board conducted its 5-day public hearing at Carbondale (November 29-December 3, 1983).

Since only the Special Inspection Team issued a formal report of findings, and, since the report stated that the findings of the previous two inspection teams had been used as information by the Special Inspection Team, the Safety Board could not determine which of the report's findings had been made independently by the Special Inspection Team and which were merely iterations of data discovered by the preceding teams. Except for the discrepancies discovered on the flight checks conducted between December 7-13, 1983, the majority of the evidence examined during the postaccident surveillance had been available to all three teams.

The first, or increased surveillance inspection team, ended its on-scene inspections on November 1, 1983. The FAA's decision to reimpose the surveillance of Air Illinois occurred 1 month later and during the latter stages of the Safety Board's public hearing. Given the timing of the decision and based on the statement of the chief of the first inspection team, the Safety Board concludes that the evidence disclosed at its public hearing was a large catalyst in the FAA's decision to reimpose surveillance.

The recommendation to revoke Air Illinois' operating certificate was based on the final phase of the FAA's inspection which ended December 13, 1983. The recommendation was based on evidence which was, for the most part, available to the first, or increased surveillance team. The fact that the increased surveillance inspection team was unable to discover sufficient evidence to either support a similar conclusion or, at the least, support an immediate decision to conduct an in-depth surveillance of Air Illinois leads the Safety Board to conclude that the first phase of the FAA's postaccident surveillance was inadequate.

The Safety Board notes also that the FAA has instituted, as a result of its investigations and Safety Board recommendations, a program to improve the quality of FAA surveillance of air carrier, commuter, and air taxi operators. As a result of this program, the inspector work force has been increased and additional training courses and seminars have also been implemented. The Safety Board believes that this program, properly implemented and supervised, should enhance the quality of FAA surveillance.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew was properly certificated and qualified to fly the flight.

2. The airplane was not maintained in accordance with applicable Federal regulations and company procedures. However, noncompliance with Federal regulations and company procedures did not contribute to the accident.

3. FAA pre-accident surveillance inspections were inadequate and did not detect the deficiencies in the Air Illinois maintenance program.

4. The left generator's spline drive shaft sheared shortly after takeoff.

5. The first officer erroneously isolated the right generator from the airplane electrical distribution system when the left generator failed.

6. Power from both generators was lost about 2 minutes after takeoff from Springfield.

7. The right generator was capable of producing electrical power throughout the flight. However, the first officer was unable to restore it on the airplane's electrical distribution system.

8. The right generator's spline drive shaft sheared when the airplane crashed.

9. The captain elected to continue to Carbondale rather than return to Springfield. The time required to fly to Carbondale was about 39 minutes and to Springfield, 6 minutes.

10. The captain's decision to continue was affected by self-imposed psychological factors which led him to an inaccurate assessment of the airplane's performance capability without generator power and the risks involved in continuing the flight to the more distant destination airport.

11. The flightcrew did not use proper procedures to cope with the electrical emergency.

12. The flightcrew did not reduce the load on the batteries to the lowest possible value. Despite this, the batteries produced electrical power for about 31 minutes.

13. The procedures for coping with and the consequences arising out of the failure of both generators were not covered adequately in the Air Illinois recurrent training program. This inadequacy was not detected during FAA surveillance inspections.

14. The first two FAA's postaccident surveillance inspections were inadequate.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the captain's decision to continue the flight toward the more distant destination airport after the loss of d.c. electrical power from both airplane generators instead of returning to the nearby departure airport. The captain's decision was adversely affected by self-imposed psychological factors which led him to assess inadequately the airplane's battery endurance after the loss of generator power and the magnitude of the risks involved in continuing to the destination airport. Contributing to the accident was the airline management's failure to provide and the FAA's failure to assure an adequate company recurrent flightcrew training program which contributed to the captain's inability to assess properly the battery endurance of the airplane before making the decision to continue, and led to the inability of the captain and the first officer to cope promptly and correctly with the airplane's electrical malfunction.

4. RECOMMENDATIONS

On March 14, 1984, the Safety Board issued Safety Recommendations A-84-14 and A-84-15 based the preliminary findings of maintenance and inspection control deficiencies during the on-scene phase of the Air Illinois accident investigation. These recommendations asked the FAA to:

— A-84-14

Issue an air carrier maintenance bulletin to emphasize: (1) the need for air carrier airworthiness inspectors to require during the certification process that the air carrier's manuals and maintenance organizational structure conform to regulatory requirements regarding the separation of maintenance and inspection functions, and (2) the need to conduct surveillance in a manner that will verify that the air carrier is performing maintenance/inspections functions and duties in accordance with requirements.

— A-84-15

Issue air carrier maintenance and operations bulletins to emphasize to air carrier airworthiness and operations inspectors the regulatory requirements related to the recording of mechanical irregularities in aircraft maintenance logs and the need for the proper surveillance to confirm conformity with the requirements, including scrutiny of aircraft maintenance logs and other maintenance records to verify that applicable maintenance corrective actions correlate to mechanical irregularities recorded by flightcrews in the aircraft maintenance logs.

Status: On June 12, 1984, the FAA responded that a notice would be issued to reemphasize the Federal Regulations regarding maintenance and inspection organization and the importance of maintenance logbook and records inspections. Also, an Air Carrier Operations Bulletin is to be issued in response to A-84-15. These recommendations have been classified as "Open—Acceptable Action" pending the issuance of the notice and the bulletin.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

PATRICIA A. GOLDMAN, Vice Chairman, filed the following concurring/dissenting statement:

While the accident report correctly identifies training and surveillance, I believe that inclusion of these items in the probable cause statement obscures and detracts from the basic reason the accident occurred and the attendant safety lesson. The pilot should never have continued the flight to the destination airport, but should have returned to the nearby airport on realizing that electrical d. c. power had been lost.

/s/ PATRICIA A. GOLDMAN
Vice Chairman

March 5, 1985

5. APPENDIXES

APPENDIX A

INVESTIGATION AND PUBLIC HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident about 2300 e.d.t. on October 11, 1983, and immediately dispatched an investigative team to the scene from its Washington, D.C., headquarters. Investigative groups were formed for operations/witnesses, air traffic control, meteorology, human factors, structures, powerplants, systems, flight data recorder, maintenance records, cockpit voice recorder, airplane performance, and human performance.

Parties to the investigation were the Federal Aviation Administration and Air Illinois. The Accidents Investigation Branch of the United Kingdom appointed an accredited representative to assist the Safety Board during the investigation. The accredited representative was assisted by advisors from the United Kingdom's Civil Aviation Authority, British Aerospace Incorporated, and Rolls Royce, Limited.

2. Public Hearing

A 5-day public hearing was held in Carbondale, Illinois, beginning November 29, 1983. Parties represented at the hearing were the Federal Aviation Administration, Air Illinois, and British Aerospace.

APPENDIX B

PERSONNEL INFORMATION

Captain Smith

Captain Lester R. Smith, 32, was hired by Air Illinois, Inc., on December 12, 1978. He held Airline Transport Pilot Certificate No. 1938649 with an airplane multiengine land rating and commercial privileges in airplane single engine land. He was type rated in the Hawker Siddley 748. His last first class medical certificate was issued July 1, 1983, and contained no limitations.

Captain Smith qualified as captain of the Hawker Siddley 748 on December 18, 1980. He passed his last proficiency check on July 24, 1983; and he completed recurrent training on February 26, 1983. The captain had flown about 5,891 hours, 3,170 of which were in the Hawker Siddley 748. During the last 90 days, 30 days, and 24 hours before the accident he had flown 261.4 hours, 81.2 hours, and 2.3 hours, respectively. The captain had been off duty about 17 hours before reporting for duty on the day of the accident. At the time of the accident, the captain had been on duty 10 hours 10 minutes, 2 hours 18 minutes of which was flight time.

First Officer Tudor

First Officer Frank S. Tudor, 28, was hired by Air Illinois Inc., on February 18, 1980. He held Airline Transport Pilot Certificate No. 381484275 with an airplane multiengine land rating and commercial privileges in airplane single engine land. His last first class medical certificate was issued November 12, 1983, and he was required to "wear corrective lenses while exercising the privileges of his airman certificate."

First Officer Tudor qualified as first officer in the Hawker Siddley 748 on September 22, 1981. He passed his last proficiency check on October 26, 1982; and he completed recurrency training on February 26, 1983. The first officer had flown about 5,119 hours, of which 1,746 hours were in the Hawker Siddley 748. During the last 90 days, 30 days, and 24 hours before the accident he had flown 246.5 hours, 74.9 hours, and 2.3 hours, respectively. At the time of the accident, the first officer's rest time and duty hours were the same as the captain's.

APPENDIX C

AIRPLANE INFORMATION

Hawker Siddley 748-2A, N748LL

The airplane, manufacturer's serial No. 1716, was delivered to Air Illinois January 9, 1973. Its FAA Airworthiness Certificate was issued October 10, 1973, and it had been operated by Air Illinois since that date. The airplane had flown 21,182 hours and it had made 32,350 landings.

Powerplants

The airplane was powered by two Rolls Royce Dart model RDA-7, MK 535-2, turboprop engines which were equipped with four-bladed Dowty Rotol, hydraulically operated, full feathering, constant speed propellers. The following data are pertinent:

Engine	No. 1	No. 2
Serial No.	19260	15134
Date of Installation	July 8, 1983	September 18, 1983
Total Hours	12,285	7,182

Generator

The generators, Rotax model B3508 were manufactured by Lucas Aerospace. According to Air Illinois FAA Operating Specifications, the generators must be overhauled at 2,800-hour intervals at a certificated FAA repair station. The Air Illinois maintenance records showed that the generators were overhauled within specified intervals at Approved Aircraft Accessories, Romulus, Michigan. Approved Aircraft Accessories is a certified FAA repair station. The following data are pertinent:

Generators	Left	Right
Serial No.	1720	1711
Date of Installation	September 8, 1983	May 7, 1983
Hour Since Installation	216	1,072
Hours Since Overhaul	232	1,453

HS 748 Series 2 Airplane Electrical System Malfunction History

The HS 748 airplane was introduced into service on April 4, 1962. To date, 370 HS 748 airplanes have been sold to 80 operators throughout the world.

Data concerning HS 748 electrical system malfunctions were provided by the United Kingdom CAA, the airplane manufacturer, and the FAA. The CAA's computer printout, which covered the period between October 6, 1976 and May 19, 1983, included mandatory and voluntary operator occurrence reports and contained 43 occurrence reports. The 21 reports provided by the airplane manufacturer either were submitted mainly by foreign operators, or were based on data gathered in the field by the manufacturer's field service representatives.

Twenty of these sixty-four reports related to malfunctions involving wiring faults, inverters, alternators, and propeller feathering pumps and had no relevance to the d.c. electrical generating system. Another three reports related to faults in a voltage regulation system that was installed in the HS 748 Series-1 airplanes only.

Of the remaining 41 occurrence reports, 13 concerned reported double generator failures, 16 concerned reported single generator failures, and 12 concerned malfunctions of other components of the d.c. electrical generating system and included such items as defective wiring, loose connections, and incorrect adjustments of relays.

The period of time covered by CAA and airplane manufacturer's reports covers about 3,550,000 HS 748 Series-2 airplane flight hours.

The FAA's computer readout covered the period between January 1978 and October 1983 and contained 17 occurrence reports; 10 of these reports related to components of the d.c. electrical generating system.

All of the 10 reports concerning the d.c. electrical generating system related to generator malfunctions, i.e., worn brushes, raised armature commutator bars, generator field relay failures, and voltage regulator malfunctions. During this period there were 4 reported double generator failures.

None of the occurrence reports provided by the CAA, the airplane manufacturer, and the FAA indicated that the airplanes involved had suffered other damage; in all instances, the flightcrew landed the airplane safely.

APPENDIX D

COCKPIT VOICE RECORDER

TRANSCRIPT OF A FAIRCHILD COCKPIT VOICE RECORDER S/N 3523 REMOVED FROM THE AIR ILLINOIS HAWKER SIDDLEY 748 WHICH WAS INVOLVED IN AN ACCIDENT AT PINKNEYVILLE, ILLINOIS, ON OCTOBER 11, 1983

LEGEND

CAM	Cockpit area microphone voice or sound source
INT	Intercom
RDO	Radio transmission from accident aircraft
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Flight Attendant
-?	Voice unidentified
DEP	Springfield, Illinois Departure Control
KCC	Kansas City Center
TWA	Trans World Airlines Flight 579
N58AU	Aircraft N58AU
AKY	Air Kentucky Flight 1836
*	Unintelligible word
#	Nonpertinent word
( )	Questionable text
(( ))	Editorial insertion
---	Pause
Note:	All times expressed in local central daylight savings time.

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:23:54 INT-2	Well the left one is totally dead, the right one is putting out voltage but I can't get a load on it		
20:23:59 INT-1	Well okay Frank		
20:24:02 INT-2	What are we going to do * * *		
20:24:03 INT-1	Ah let's concentrate on the in side here		
INT-1	(And ah * * *)		
20:24:11 INT-2	Ah I got the switch on		
20:24:24 INT-1	What did you do anything?		
20:24:26 INT-2	Naw reset the RCCB's ah I tried to ah select each side, isolate the side ah		
INT-1	Yeah		
20:24:34 INT-2	Zero voltage and amps on the left side --- the right one is putting out twenty seven and a half but I can't get it to come on the line		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
INT-1	Okay
208:25:18 CAM	((Sound similar to altitude alert))
20:25:42 INT-2	Ah battery power is going down pretty fast --- (we got ah)
20:26:21 INT-2	Ah ya got ah twenty two volts
20:26:31 INT-2	There's the right one
INT-1	Okay
20:26:42 INT-1	Ah --- turn the load shedding back on so they can use the reading back there and turn off the lights, main lights

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:25:13 DEP	Illinois seven ten contact Kansas City Center one two four point three
20:25:16 RDO-2	Twenty four point three good night
DEP	Good night
20:26:03 RDO-2	Kansas City Illinois seven ten three thousand
20:26:09 KCC	Illinois seven ten Kansas City Center roger.

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:26:48			
INT-2	Turn off the wing lights (is that what you said?)		
INT-1	(Turn)		
INT-2	I didn't hear you		
20:26:54			
INT-1	Naw I said I turned the load shedding switch back on so ah ---		
INT-2	Oh		
20:26:59			
INT-1	She can use the reading lights only back there		
INT-2	Okay		
20:27:09			
INT-2	Still working with Kansas City here		
INT-1	All right --- I'll talk to the man here		
		20:27:19	
		RDO-1	Kansas City Illinois seven ten
		20:27:22	
		KCC	Illinois seven ten go ahead

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:28:12 INT-1	How are our bats there?
20:28:17 INT-2	Ah ah twenty two and a half
INT-1	Okay

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:27:24 RDO-1	Ah we are kinda having a unusual request here ah we would like to go to two thousand feet and ah if we have to go VFR that's fine but ah like to ah like you to keep your ah eye on us if you can
20:27:39 KCC	Ah Illinois seven ten I can't clear you down to two thousand 'em I don't even think I can keep you radar if I, if I had to if you went down that far
20:27:59 RDO-1	Ah all right fine thank you
20:28:25 KCC	Ah Illinois seven ten did you copy that?
20:28:29 RDO-1	I am sorry I missed that

INTRA-COCKPIT	
TIME & SOURCE	CONTENT
20:28:45 INT-1	Beacons off ---
20:28:46 INT-2	Okay
INT-1	Nav lights are off
20:28:57 INT-1	Are you using these lights here?
INT-2	Ah I'll get that one down ---
20:29:07 INT-2	Both generator failures --- see here ---
20:29:25 INT-2	I am going to try something here --- I'm going to try to isolate both sides and see what happens
CAM	((Sound of switches))
20:29:39 INT-2	Want me to go to emergency so you can get some --- get your grimes lights

AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT
20:28:32 KCC	Illinois seven ten I won't be able to clear you down to two thousand ah it's ah below the altitude ah lowest useable altitude I can give you and if you went down there VFR I doubt I can keep you in radar
20:28:43 RDO-1	Okay fine thank you

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
INT-1	No I --- I want it back the way it was ---		
INT-2	Ah		
20:29:45 INT-1	If it does reset		
20:30:00 INT-1	You see --- you're shutin' off all the electricity to the back end that way lighting and everything		
INT-2	Yeah		
INT-1	All right		
20:30:10 INT-2	You want me to leave it the way it is then?		
20:30:11 INT-1	Yeah uh huh yeah that will be good keep an eye on these boost pumps though		
INT-2	Okay		
		2030:46 KCC	TWA five seventy nine everybody has been deviating around the north side of Kubik starting about Vandalia and going around the north side for weather, I really haven't had any ride complaints

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:30:52	
INT-2	Are you going to try to do it separately?
INT-1	No I just leave it the way they are Frank
INT-2	Ah
INT-1	They'll be fine
INT-2	Roger that
20:31:04	
INT-2	Carbondale is ah two thousand over two light rain fog ---
INT-1	Okay
20:31:09	
INT-2	Winds are one fifty at ten
INT-1	Okay got it
	•
20:34:29	
INT-2	Do you want me to kill any pitot heat or anything?
20:31:32	
INT-1	I would leave pitot heat on it will be all right

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2031:10	
KCC	TWA five seventy nine roger deviation north around the weather is approved

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
INT-2	All right		
20:31:36 INT-1	Unless you see that thing really depletin', which I don't believe it is. Is it really bad, really rapidly?		
INT-2	No not too bad		
20:31:43 INT-2	Those inverters take a lot of power		
INT-1	Yeah		
20:31:51 INT-2	All I got ah on here is the transponder and one nav that all I got on		
INT-1	Okay, swell (DME) we don't need that		
20:32:00 INT-2	Radar's off --- only got one fan on		
INT-1	Okay		
20:32:28 CAM-1	Are you going to be able to operate all right now on what you have back there?		
20:32:32 CAM-3	* * people want to know * *		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:32:34	
CAM-1	They want to? --- We have a little bit of an electrical problem here but we're going to continue to Carbondale we had to shut off all excess lights
20:32:50	
CAM-3	I've only got the reading lights the front light by the bathroom and the baggage light, and the ah entrance light
CAM-1	Okay
CAM-3	And one light by the John
20:33:07	
CAM-3	What time do we get there? Is that rain?
20:33:22	
INT-1	What time did we lift off?
20:33:37	
CAM-2	There about on the hour
CAM-3	Okay

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
2033:35	
N58AU	Yes sir I'm back with you, I wonder if we could ah descend down to seven thousand, I believe we could get below the base of the clouds we're in and out at one zero thousand at this time

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:33:56 INT-1	Do you want to use the DME?
INT-2	All right
20:34:30 INT-1	Oh on that checklist other than those RCCB's then did ah has been reviewed then okay
20:34:36 INT-2	Well let's see here ah RCCB's port and starboard, says trip those --- * * --- that's about it you know, switch, just switch both of those off and attempt to ah reset
20:35:19 INT-1	Okay
INT-2	Which I've already done

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:33:43 KCC	Five eight alpha uniform roger descend and maintain niner thousand for now
30:33:48 N58AU	Okay if you don't mind I'll stay at one zero until you can clear me to seven
20:33:52 KCC	Five eight alpha uniform roger maintain one zero thousand
20:33:56 N58AU	All right

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:36:03 INT-2	This is just not been our day Les
20:36:06 INT-1	No that's six of one, half dozen of another --- how are we doing on them volts now?
20:36:14 INT-2	Still pretty good twenty --- twenty one and a half
20:36:20 INT-1	All right ah ---
INT-2	(* should) last to Carbondale
INT-1	I want to use this ((simultaneous with above))
20:36:23 INT-1	I want to use this use this here briefly
20:36:28 INT-1	As a matter of fact, could you ah --- tune ---
INT-2	Take a while to warm up
20:36:32 INT-1	Tune that in for us there ah there was some old guys were complaining over there around Kubik, I think we're below it altogether here

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:37:04 RDO-1	Kansas City Illinois seven ten

INTRA-COCKPIT

TIME & SOURCE	CONTENT
INT-1	Well ---
20:37:22 INT-2	It's gonna take a few minutes to warm up I think
INT-1	Okay
20:37:26 INT-2	I got it
20:37:27 INT-1	Need a, would like him to give us a vector I mean if he's got us okay we want a vector direct to the marker
INT-2	Okay

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:37:08 KCC	Illinois seven ten contact Kansas Center one two seven point seven
20:37:12 RDO-1	Okay
20:37:34 RDO-2	Kansas City Illinois seven ten three thousand
20:37:38 KCC	Illinois seven ten Kansas City Center roger maintain three thousand altimeter at Scott twenty nine eighty three
20:37:45 RDO-2	Twenty nine eight three ah if you are able ah vectors direct Cabbie

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:38:41 INT-2	Well when we lost ah started loosing the left one I reached up and hit the right RCCB trying to isolate the right side cause I assumed the problem was the right side but they both still went off
20:39:01 INT-1	Well --- ah also too when you were doing that you see I was losing my lighting here
INT-2	Yeah
20:39:06 INT-1	And I was losing lighting in the cabin and it was going pitch dark back there don't want to scare the # out of the people
20:39:13 INT-2	Yeah that's for sure
20:39:20 INT-2	Hey it's working now that looks like Carlyle there either that or it's a # of a shadow
20:39:23 INT-1	Yeah that's it --- we're right on course unbelievable

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:37:49 KCC	Illinois seven ten Kansas City Center roger present heading looks good
20:37:55 RDO-2	All right thank you

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:39:33 INT-1	Better stay away from them shadows Frank		
20:39:42 INT-1	I suspect the circuit breaker tripped --- in the belly		
20:39:50 INT-2	Yeah I was thinking the same thing somethin' popped		
20:40:38 INT-1	Whatever you do to don't if you would don't say anything to dispatch		
20:40:43 INT-1	Don't say a # thing to them		
INT-2	Roger that		
INT-1	Not nothing		
INT-2	You can plan on that that's for sure		
20:40:53 INT-2	The less you tell them about anything the better off you are		
INT-1	That's right		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:42:15 INT-1	May I have the ILS for Carbondale please?
INT-2	Roger that

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:41:21 KCC	Air Kentucky eighteen thirty six Kansas City Center roger pilot's discretion, maintain four thousand and ah let me see if I've got any Mount Vernon weather, just a minute
20:41:33 AKY	Yes sir eighteen thirty six out of five
20:41:36 KCC	Air Kentucky eighteen thirty six roger maintain four thousand and Mount Vernon is reporting ah one hour old, estimated ceiling three thousand five hundred broken, five thousand overcast, visibility six in haze, wind calm, altimeter two nine niner zero, what type of approach do you want?
20:41:58 AKY	Eighteen thirty six ah we'll see if we can't get a contact approach out of it but, if not we'll take an ILS
20:42:04 KCC	Air Kentucky eighteen thirty six roger [illegible] advise and I'll have lower ah, oh about [illegible]lia

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:44:53 INT-1	Still doing okay up there Frank?
INT-2	Say again
20:44:58 INT-1	You doing all right up there?
20:44:59 INT-2	Yeah it's at ah twenty volts
INT-1	Turn this thing off now
INT-2	Okay
20:46:12 INT-2	Well the boost pumps (going now)
20:47:08 INT-2	The localizer should at least be doing something, getting anything at all over there?
20:47:14 INT-1	Ah I got the needle but ah little bit away too far away for the flag
INT-2	Yeah
20:47:28 INT-2	Want me to tune in Cabbie real quick?

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:45:48 KCC	Illinois seven ten five degrees to the right until receiving Cabbie
20:45:54 RDO-2	Seven ten roger five right (to Cabbie)

INTRA-COCKPIT

TIME & SOURCE	CONTENT
INT-1	Sure
INT-2	To get a bearing on it
INT-1	It's not going to use that much power
INT-2	Here we go
20:47:46 INT-1	Is that lightning off to your right side?
20:47:49 INT-2	Say again
20:47:50 INT-1	Most of that lightning is off your right side is it not?
20:47:51 INT-2	Yeah
INT-2	It's on number two
INT-1	All right

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:47:38 RDO	((Sound of Cabbie LOM identification))
RDO	((Sound of Cabbie LOM identification goes off))
20:49:23 KCC	Air Illinois seven ten contact Kansas City Center on frequency one two five point three

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:50:37 INT-2	I don't know if we got enough juice to get out of this
INT-1	(How come)
20:50:57 INT-1	Squawk your ah radio failure
20:51:06 INT-1	Know your radio failure code
20:51:27 INT-1	Frank remember your radio failure ---
INT-2	Yeah I got it
INT-1	Squawk

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:49:27 RDO-2	Twenty five three roger Air Illinois seven ten
20:49:30 KCC	Good night
20:51:00 KCC	Illinois seven ten I've lost radar contact
20:51:12 KCC	Seven ten Kansas City
20:51:17 KCC	--- four Kansas City
20:51:20 KCC	Illinois eight oh four what's estimate for Carbondale

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:51:31 INT-2	Yeah		
		20:51:45 KCC	Illinois seven ten Kansas City do you read
20:52:12 INT-1	Watch my altitude I'm going to go down to twenty four hundred		
		20:51:56 KCC	Illinois --- ah seven ten is what I show over two ten I got you at eight thousand I'm looking for your company southbound there north of ah Carbondale
20:52:15 INT-2	Okay		
		20:52:18 KCC	TWA one twenty one ah roger
20:52:24 INT-1	You got a flash light?		
20:52:27 INT-2	Yeah		
		20:52:29 KCC	Illinois eight zero four ah Kansas City maintain ah four thousand over
20:52:33 INT-1	Here we go --- do you want to shine it up here		
20:52:35 INT-2	What do you need		
20:52:36 INT-1	Be ready for it		
20:52:37 INT-2	What do you need?		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
20:52:39	
INT-1	Just have it in your hand if you will
INT-2	Oh
20:53:18	
INT-2	Ah -- we're losing everything --- down to about thirteen volts
20:53:22	
INT-1	Okay
20:53:24	
INT-1	Watch my altitude Frank
20:53:25	
INT-2	Okay
20:53:28	
INT-2	Twenty four hundred
20:54:00	
CAM-1	Do you have any instruments
20:54:03	
INT-2	Say again
20:54:16	
CAM-1	Do you have any instruments, do you have a horizon?

((The tape recorder electronics ceases to operate for an undeterminable amount of time. Further timing is not possible))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
20:52:41	
KCC	Illinois eight oh four no I got your company seven ten inbound from the north at ah three thousand also we've lost him on radar he does have electrical problems I don't know what extent but ah I can't talk to him now so ah Illinois eight zero four ah maintain four thousand and a I am going to have some holding instructions for you shortly proceed to Cabbie

APPENDIX E

HS 748-2A ELECTRICAL LOAD ANALYSIS

HAWKER SIDDELEY AVIATION LTD. AVRO WHITWORTH DIVISION MANCHESTER

D.C. GENERATORS

SUMMARY OF AVERAGE LOADS

L.S.A. (NIGHT) CONDITIONS

DWG. NO. V14457 SHEET NO. 2

SERVICE	NORMAL				EMERGENCY		
	TAXI (20 MINS.)	TAKE-OFF (5 MINS.)	CRUISE (60 MINS.)	LAND (5 MINS.)	CRUISE (PRIOR TO LOAD SHEDDING) (5 MINS.)	CRUISE (AFTER LOAD SHEDDING) (60 MINS.)	LAND (5 MINS.)
Fuel Pumps	14.0	28.0	14.0	28.0	14.0	14.0	28.0
Pressure Head Heaters	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Relays Indicators etc.	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Windscreen Wipers	15.0	15.0	OFF	15.0	OFF	OFF	15.0
Flap Motor	0.5	2.0	OFF	2.0	OFF	OFF	2.0
Prop Feathering	OFF	4.0	OFF	OFF	4.0	OFF	OFF
Navigation Lights	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Anti Collision Lights	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Landing Lights	42.0	42.0	OFF	42.0	OFF	OFF	42.0
Flight Deck Lights	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Instrument Lights	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Cabin Roof Lights	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Passenger Signs	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Passenger Reading Lights	OFF	OFF	9.6	9.6	9.6	OFF	OFF
Battery Charging Port	15.0	15.0	2.5	1.0	2.5	2.5	1.0
Battery Charging Starboard	15.0	15.0	2.5	1.0	2.5	2.5	1.0
Water Methanol Pumps	OFF	24.0	OFF	24.0	OFF	OFF	24.0
Radio Crate Fans	16.0	16.0	16.0	16.0	16.0	16.0	16.0
No.1 Inverter	27.5	27.5	27.5	27.5	27.5	27.5	27.5
No.2 Inverter	21.0	21.0	21.0	21.0	21.0	21.0	21.0
No.3 Inverter	OFF	OFF	35.5	35.5	35.5	35.5	35.5
No.4 Inverter	3.7	OFF	37.0	37.0	37.0	37.0	37.0
No.1 VHF Tx	1.1	1.1	1.1	1.1	1.1	1.1	1.1
No.1 VHF Rx	2.1	2.1	2.1	2.1	2.1	2.1	2.1
No.2 VHF Tx	OFF	OFF	OFF	OFF	OFF	OFF	OFF
No.2 VHF Rx	2.1	2.1	2.1	2.1	2.1	2.1	2.1
H.F.	11.2	6.5	11.2	6.5	11.2	11.2	6.5
Static Inverter (H.F)	6.2	6.2	6.2	6.2	6.2	6.2	6.2
No.1 VOR/ILS	OFF	3.3	3.3	3.3	3.3	3.3	3.3
No.2 VOR/ILS	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Weather Radar	OFF	OFF	1.1	1.1	1.1	1.1	1.1
Twin ADF	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Passenger Address	0.8	0.2	0.8	0.2	0.8	0.8	0.2
Interphone	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Single Marker	OFF	0.5	0.5	0.5	0.5	0.5	0.5
Ground Cooling Fan	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Pitots Heater Mats	6.5	6.5	6.5	6.5	6.5	6.5	6.5
TOTAL AVERAGE LOADS	266.4	304.7	267.2	355.9	271.2	247.6	346.3
MAXIMUM PERMITTED LOADS	340	400	400	400	400	300	400

TITLE:- H.S.748 ELECTRICAL LOAD ANALYSIS MODEL FAA FERRY

ISSUE NO.	1			
B.O.I. NO.	31/25/22			
DRAWN	JM			
DATE	20-2-73			

APPENDIX F

AIRPLANE GROUND TRACK