AIRCRAFT ACCIDENT REPORT

Adopted: August 27, 1969

TRANS WORLD AIRLINES, INC.

CONVAIR 880, N821TW

CONSTANCE, KENTUCKY

NOVEMBER 20, 1967

SA-402 File 1-0033

AIRCRAFT ACCIDENT REPORT

Adopted: August 27, 1969

TRANS WORLD AIRLINES, INC.

CONVAIR 880, N821TW

CONSTANCE, KENTUCKY

NOVEMBER 20, 1967

NATIONAL TRANSPORTATION SAFETY BOARD

DEPARTMENT OF TRANSPORTATION

WASHINGTON D.C. 20591

For sale by Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va. 22151. Annual subscription price $12.00 Domestic; $15.00 Foreign; Single copy $3.00; Microfiche $0.65. Order Number NTSB-AAR-69-5

TRANS WORLD AIRLINES, INC.
CONVAIR 880, N821TW
CONSTANCE, KENTUCKY
NOVEMBER 20, 1967

TABLE OF CONTENTS

SA-402 File No. 1-0033

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C. 20591
AIRCRAFT ACCIDENT REPORT

Adopted: August 27, 1969

TRANS WORLD AIRLINES, INC.
CONVAIR 880, N821TW
CONSTANCE, KENTUCKY
NOVEMBER 20, 1967

SYNOPSIS

A Trans World Airlines, Inc., Convair 880, N821TW, Flight 128, crashed on the final approach to landing on Runway 18 at Greater Cincinnati Airport, Covington, Kentucky, at 2057 e.s.t., November 20, 1967. Of the 75 passengers and seven crewmembers aboard, 10 passengers and two crewmembers survived. The aircraft was destroyed by impact and fire.

The flight was en route from Los Angeles, California, to Boston, Massachusetts, with scheduled stops at Cincinnati, Ohio, and Pittsburgh, Pennsylvania. The flight had been cleared for an ILS approach to Runway 18 and, after reporting over the outer marker beacon, had been cleared to land.

The ILS localizer was operational but the ILS glide slope, runway approach lights, and the middle marker beacon were inoperative due to runway construction. The crew was aware of these conditions.

The published minimums for this approach were 400 feet ceiling and 1 mile visibility. The official reported weather at the airport, just prior to the accident, was ceiling 1,000 feet obscured, visibility 1½ miles in light snow. The airport elevation was 890 feet m.s.l. and the altimeter setting 30.08.

The aircraft first struck trees at an elevation of approximately 875 feet m.s.l., 9,357 feet short of the approach end of Runway 18 and 429 feet right of the extended runway centerline. After several more impacts with trees and the ground, the aircraft came to rest approximately 6,878 feet from the runway and 442 feet right of the extended runway centerline.

The Board determines that the probable cause of this accident was an attempt by the crew to conduct a night, visual, no-glide-slope approach during deteriorating weather conditions without adequate altimeter cross-reference. The approach was conducted using visual reference to partially lighted irregular terrain which may have been conducive to producing an illusionary sense of adequate terrain clearance.

1. INVESTIGATION

1.1 History of Flight

Flight 128, a Trans World Airlines, Inc., Convair 880, N821TW, departed from Los Angeles International Airport, Los Angeles, California, at 1737 e.s.t. 1/ for Greater Cincinnati Airport, Covington, Kentucky. The flight was cleared for a descent and ILS approach to Greater Cincinnati Airport. The crew reported over the outer marker at 2056 and was cleared to land, straight in, on Runway 18. The crew initiated the final descent, extended 50° flaps, and performed the final landing checklist. The prescribed minimum altitude over the outer marker beacon, 4.0 miles from the approach end of the runway, was 1,973 feet m.s.l. The middle marker beacon and the runway approach lights were inoperative. A minimum altitude of 1,290 feet m.s.l. was published for the conditions that existed for this approach. This altitude was discussed by the crew as they left the outer marker and was properly stated by the captain.

The aircraft first contacted small tree limbs, at a point approximately 9,357 feet from the approach end of the runway, 429 feet right of the extended centerline, at an elevation of approximately 875 feet m.s.l. A surviving stewardess stated that the first noticeable impact felt like a hard landing. This was followed by a series of bumps and final impact. None of the survivors recalled any increase of engine power or felt any rotation of the aircraft.

The aircraft came to rest 6,878 feet short of the runway and 442 feet right of the extended runway centerline, virtually disintegrated and enveloped in flames.

The accident occurred during darkness in an area where snow was falling.

Three witnesses observed the aircraft crossing the Ohio River Valley just prior to the impact. One witness stated that other aircraft she had observed were "always higher" by comparison than Flight 128 was at this point in the flight. She described the aircraft as "Lowering himself faster--steeper descent than usual--attitude approximately 10 degrees nose-down." Another witness stated that, "It appeared that the aircraft was coming down at a steep angle. I called this to my wife's attention. About that time, it started to level off and I saw it fly level until it was across the river." The wife of this witness stated that she: "Thought my husband was mistaken about it being too low." She further stated that the "aircraft appeared to be nose-diving into River Road. It wasn't an abrupt cutoff, it just leveled off naturally and I was sure then that it wasn't too low, that it would make it across the river okay. From the time it leveled off, I imagined that only a few seconds passed before the explosion."

1/ All times hereinafter are reported as eastern standard time on the 24-hour clock unless otherwise noted.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	5	65	0
Nonfatal	2	10	0
None	0	0	

1.3 Damage to Aircraft

The aircraft was destroyed by impact and fire.

1.4 Other Damage

Trees and pastureland were damaged by the impact and post-impact fire.

1.5 Crew Information

All crewmembers were properly certificated and qualified for their respective assignments. (See Appendix A for details.)

A first officer, who flew nine trips with the captain of Flight 128 during the month of October 1967, testified that they had conducted approximately 60 approaches and landings during those trips. Four of those approaches were performed under instrument flight conditions, including one ADF approach to Runway 09 at Cincinnati. Several of the approaches were made using an ILS. The witness stated that the captain was very precise in intercepting the glide slope at the published altitude and that the rate of descent was normally 600 to 700 feet per minute. The witness also testified that the captain normally extended the landing flaps at the placarded airspeeds.

Statements were taken from seven other first officers who had recently flown with the captain. In summary, they stated that he flew the CV-880 at all times in accordance with the TWA Flight Manual. They also stated that during their flights with the captain, he extended the landing flaps in accordance with the placarded airspeeds and maintained a rate of descent on the final approach of less than 1,000 feet per minute. All of them classified him as a smooth, competent pilot.

In the year preceding the accident, the captain had landed at Cincinnati 59 times, including five landings in the preceding 60 days. Three of the five landings were conducted at night on Runway 18.

Several designated check airmen and training officers from TWA testified regarding the CV-880 training given to the captain of Flight 128.

During his transition and preparation for release as a captain, he always received satisfactory grades. He was, however, returned for further instruction and practice on level off and landing technique in the CV-880 before being released for line flying. He took one additional training trip and then completed the second check ride.

On November 9, 1967, the captain was given a Category II check which qualified him to make instrument approaches and landings at specially equipped airports which had lower weather minimums than those specified for a normal ILS approach and landing. The minima used for Category II are: decision altitude 110 feet above ground; and Runway Visual Range (RVR) of 1,200 or more. During this check, the captain made eight ILS approaches, four of which terminated in landings and four of which were terminated by intentional missed approaches. The captain had no difficulty in passing this check ride and was the first TWA pilot at his domicile to complete this training and receive the Category II rating in the CV-880.

It was also reported that the captain, during his training in the CV-880, had accomplished at least two back course ILS approaches which were performed without benefit of an ILS glide slope. His grades on these maneuvers were satisfactory.

1.6 Aircraft Information

The aircraft records and pilot reports indicate that the aircraft was airworthy at the time of its departure from Los Angeles. There was no evidence of any occurrence en route which affected the airworthiness of the aircraft. The aircraft was properly certificated and equipped for the flight it was performing and, according to the maintenance records, was maintained in accordance with existing company and FAA criteria.

The weight and balance were calculated to have been within limits at takeoff and at the time of the accident. The aircraft was fueled with 71,000 pounds of aviation kerosene at the time of takeoff from Los Angeles and had approximately 29,600 pounds of fuel aboard at the time of the accident.

A review of the aircraft's maintenance records did not disclose any recurrent writeups or discrepancies that appear to be connected with this accident. The history of the pitot static system and the pitot static instruments of both N821TW and TWA's CV-880 fleet was reviewed. Occasional malfunctions of individual instruments had occurred but, in those cases, the duplicate installed instruments continued to operate in a satisfactory manner. There was no evidence in these records of any malfunctioning of the system or instruments that would introduce significant errors to all the pitot static instruments at the same time.

The aircraft records indicate that all of the installed components were being operated within their prescribed overhaul time and there were no uncompleted Airworthiness Directives assigned to the aircraft.

In order to be able to use a common fitting on static system test equipment, the center hole in each static port on TWA's CV-880's was enlarged from an original size of 0.047 inches to 0.125 inches. This modification was accomplished on N821TW on September 20, 1967. Following the modification, the static ports consisted of six holes arranged in a circle around a center hole which had been enlarged to 0.125 inch diameter. The six outer holes were 0.047 inch diameter.

On October 19, 1967, the flight data recorder in N821TW was moved from its original location in the hydraulic compartment of the aircraft to a new position in the aft end of the aircraft. This move was performed in accordance with an FAA requirement to install all flight data recorders in the aft end of transport category aircraft. As part of this move, correlation studies were performed to assure that the flight data recorder and the flight instruments read essentially the same under certain conditions. Tests were also performed to determine what amount of lag might have been introduced into the flight data recorder by this relocation. These tests revealed no significant lag in the new system. (See Appendix B for aircraft data.)

1.7 Meteorological Information

The surface weather observation taken at the Greater Cincinnati Airport at 1955 reported 600 feet scattered clouds, ceiling 4,500 feet overcast, visibility 6 miles in haze, temperature 34°, dew point 29°, wind 080° at 4 knots, and the altimeter setting was 30.06. A check observation was made at 2040 which reported 600 feet scattered clouds, an estimated ceiling of 3,000 feet overcast, visibility 5 miles in light snow and haze, wind from 120° at 6 knots, and the altimeter was 30.07.

At 2049, the tower reported to the Weather Bureau observer that the visibility had reduced to 1½ miles. Responsibility for official visibility observations was assumed by the tower personnel at that time and this responsibility was retained by the tower personnel for the rest of the evening. At 2055, a record special observation was made by the Weather Bureau which reported an indefinite ceiling at 1,000 feet, sky obscured, surface and tower visibility 1½ miles in light snow, temperature 34°, dew point 30°, wind from 110° at 7 knots, and the altimeter setting was 30.08. The snow had begun at 2001 and the RVR on Runway 18 was reported to be more than 6,000 feet.

Because of the accident, a local observation was taken at 2104 which reported an indefinite ceiling at 1,000 feet, sky obscured, surface and tower visibility $1\frac{1}{2}$ miles in light snow, temperature 34°, dew point 30°, with the wind from 090° at 8 knots, altimeter 30.07. The RVR on Runway 18 was more than 6,000 feet.

The surface weather observations taken at Lunken Field, approximately 12 miles east of the final approach path to the Greater Cincinnati Airport, were:

1955, measured 4,000 overcast, 7 miles visibility, temperature 36°, dew point 31°, wind from 120° at an estimated 2 knots, and the altimeter was 30.07.

2055, estimated 5,000 overcast, visibility 7 miles, temperature 36°, dew point 31°, wind from 120° at an estimated 2 knots, and the altimeter was 30.09.

2130, check observation, estimated 2,000 overcast, surface and tower visibility 3 miles in light snow, the wind was from 080° at 4 knots, and the altimeter was 30.09. The snow began at 2102.

The method of determining the visibility at the Greater Cincinnati Airport during the hours of darkness was examined. The Weather Bureau determines and reports the visibility when it is 4 miles or more. When the visibility is less than 4 miles, the responsibility for observing and reporting the official visibility is transferred to Weather Bureau-certificated FAA air traffic control personnel stationed in the airport control tower. A transmissometer is located at approximately the touchdown point on both Runways 18 and 36. Information from these transmissometers is used to determine and report the RVR.

Both the Weather Bureau office and the control tower are equipped with charts showing the range and bearing to various prominent objects and lights around the airport for use in determining the visibility. At night, the observer determines the visibility by searching for these lights and, applying his experience and judgment regarding which lights he can see and how clearly he can see them, arrives at a visibility which is reported as the official visibility.

The variability of the visibility surrounding the Greater Cincinnati Airport was evidenced by the statements of the FAA controllers, the Weather Bureau observer, and the witnesses in the accident area. The local controller commented on the intercom at 2039:42 that "Good vis to the north it's, uh, restricted to the south." The controller who was working the ground control position stated "At approximately 2048 e.s.t. I observed a slight increase in the snowfall. At this time I glanced towards our 2-mile visibility checkpoint to the southwest of the airport and was unable to see it. At this time, the local controller said the visibility is coming down. The flight data processor also made a remark concerning the reduction of visibility. The local controller, flight data processor and I agreed the prevailing visibility was a mile and a half." The $1\frac{1}{2}$-mile visibility report was transmitted to Flight 128 at 2049:22.

The precipitation in the Cincinnati area on the night of the accident was moving from the west to east. The duty forecaster in his analysis assumed a weather movement from the west or west-southwest, while the radar meteorologist stated that the cells in the area were moving from 290° at about 20 knots.

There was a dearth of nighttime visibility references surrounding the Greater Cincinnati Airport. The lack of nighttime visibility reference lights was particularly acute along the approach path which Flight 128 was following. For example, once beyond the $\frac{1}{2}$-mile range from the observation site at the airport, there were only two lighted markers north-northeast of the airport. One of these markers was located at a distance of 3 miles and was reported to be relatively unreliable. The other marker, north-northeast of the airport, was a beacon 6 nautical miles from the airport.

One-hundredth of an inch of precipitation in the form of light snow 2/ was recorded at the airport between 2000 and 2100 and the same amount fell between 2100 and 2200.

The Weather Bureau observing and electronic recording equipment was checked after the accident and was certified as operating in a satisfactory manner.

Ground witnesses and survivors stated it was snowing in the accident area at the time of the accident.

2/ Light snow is defined by the Weather Bureau as when the visibility is 5/8 statute mile or more. When another obstruction to visibility exists, such as haze, the intensity of snow is based on relative apparent rate of fall or accumulation on a surface recently free of precipitation.

A radar weather observation, recorded at 2040 on the Cincinnati weather radar log, reported Cincinnati to be in a broken area of radar echoes described as: snow showers of unknown intensity, moderate rain showers, light rain showers, and the picture had not changed in the last hour. The area reported was 100 miles wide with cells moving from 290° at 20 knots. The top of detectable moisture was reported to be 20,000 feet.

At 2104, a special radar weather observation was taken because of the accident and showed essentially the same picture as the 2040 observation except that the top of visible moisture was noted as 15,000 feet, north of Cincinnati, and the area was 115 miles wide. An overlay made of the radarscope showed moderate precipitation occurring in an area extending from west to south to south-southeast of the airport.

The crew of another air carrier flight inbound to Cincinnati was interviewed regarding their observations of the weather in the area of the airport. They reported that, as they approached the airport area from the southwest, the descent was accomplished in snow. No turbulence was noted and no icing was detected. The flight arrived over the outer marker beacon at approximately 2100 at an altitude of 3,000 feet m.s.l. They were directed to enter a holding pattern at that point and maintained 3,000 feet throughout their operation in the Cincinnati area.

At 3,000 feet, they were "Under the overcast in light snow and some scattered clouds below. The slant visibility was variable going as low as 1-2 miles and up to 15 plus miles, being much better to the north of our location than to the south."

A short time after entering the holding pattern, this crew was requested to fly toward the airport and to see if they could see any sign of TWA Flight 128. As the aircraft left the outer marker inbound toward the airport, the crew noted that the intensity of the snow had decreased. They could see the ground by looking straight down but could not see anything ahead of them looking through the windshield. When they arrived over the position of the middle marker, 0.5 miles from the end of Runway 18, they could see approximately one-half of the runway lights. After spotting and reporting the fire associated with the accident, the flight returned to the outer marker and resumed the holding pattern. At 2140, they were able to see all of the airport from a position over the beacon. A short time later the flight was diverted to an alternate airport and did not approach or land at Cincinnati.

It was calculated that the freezing level in the area of the airport was 1,000 to 2,000 feet above the surface. The forecast for the area predicted occasional moderate rime icing in clouds, briefly moderate mixed icing in clouds, and precipitation above the freezing level. It was also calculated that the air over the Cincinnati area was saturated, or nearly so, from approximately 5,000 feet up to the top of the clouds.

The crew of Flight 128 was provided with the latest available weather prior to their departure from Los Angeles. Updated weather information was available to them through FAA and TWA communication facilities throughout the flight, including their descent and landing approach.

1.8 Aids to Navigation

The navigational aids available to this flight included a surveillance radar, an ILS localizer, an outer marker beacon, a nondirectional low frequency radio beacon, and the CVG (Covington, Kentucky) VORTAC. These facilities were flight-checked within 3 hours after the accident and were found to be operating within established tolerances. The ILS glide slope, the high-intensity approach lights, and the middle marker beacon were inoperative due to the construction of an extension to the runway at the approach end of Runway 18. This construction necessitated the relocation of the approach lights and middle marker transmitter, and grading around the glide slope transmitter building.

The ILS approach for Runway 18 prescribed an initial approach at 2,000 feet m.s.l. and an interception of the glide slope at the outer marker beacon at 1,973 feet m.s.l. The inbound heading to the runway was published as 180° from the outer marker beacon which was 4.0 nautical miles from the approach end of the runway. The inoperative middle marker beacon was located 0.5 nautical miles from the end of the runway. The standard minimums for an ILS approach in a four-engine commercial jet aircraft, with all the ground system and aircraft components operational, were 300 feet ceiling and visibility 3/4 mile. With the glide slope, approach lights, and middle marker inoperative, as was the case in this approach, the minimums were 400 feet and 1 mile.

In a situation where no glide slope was available, the TWA flight procedures advised pilots to arrive over the final fix (outer marker) with the landing gear down, landing flaps set at 40°, the minimum airspeed was reference plus 10, and to start the final checklist. The descent was initiated to the minimum altitude or the final approach "slot." The rate of descent in this type of approach could be higher than normal at the pilot's discretion. The final approach "slot" was defined as that point in the approach where the pilot determined that he could safely accomplish his approach and landing.

The aircraft should have either descended to the minimum altitude, 1,290 feet m.s.l., or the approach "slot." If the runway was not in sight at the minimum altitude, the aircraft should have leveled off and flown the rest of the calculated time toward the end of the runway. If the runway was not seen, a missed approach would be made in accordance with the published procedure. If, during the descent, the pilot determined the he was in the "slot," he would have extended 50° of flaps and continued his descent to landing.

A summary of NOTAM's was issued by TWA on November 20, 1967, erroneously indicating that the ILS glide slope for Runway 18 at Cincinnati was available. This information was given to the crew before departure from Los Angeles. However, the crew was informed by the FAA Approach Controller of the inoperative condition of the ILS components, including the glide slope, prior to their commencing the approach.

The approach terrain clearance for Runway 18 was examined and found to provide standard terrain clearance and, in the case of no-glide-slope approaches, provided 100 feet more terrain clearance than was provided for a full system ILS approach with the glide slope operational. The 400-foot minimum thus provided 325 feet clearance over high-tension lines in the approach zone.

These high-tension lines on the approach to Runway 18 were reported to be too far from the glide slope transmitter to have any effect on the glide slope when it was operating. These lines had no known effect on the localizer beam in use during the accident. Numerous flight checks were made before and after the accident with no reported discrepancies caused by these high-tension lines.

Special test flights were conducted to establish the operational characteristics of the outer marker beacon transmitter and it was found to be operating within established tolerances.

A series of flight tests was conducted during which the marker beacon receiver audio signals were timed. These tests were performed with a marker beacon receiver taken from N821TW, a shop-calibrated receiver taken from TWA shelf stock, and a receiver installed in an FAA flight check aircraft which is regularly used to perform such checks. One heat damaged diode was replaced in the accident receiver prior to the tests.

The first tests involving all three receivers were made in an FAA aircraft at the outer marker beacon at Cincinnati. The second test was made using the two TWA receivers and was performed in a TWA CV-880 at Kansas City, Missouri. The third series of tests was performed at West Palm Beach, Florida, using only the receiver from N821TW.

A series of calculations was prepared using ground speeds from 179 knots to 250 knots and an audible signal time of 5.9 seconds, as taken from the cockpit voice recorder tape of N821TW. Based on these calculations, and assuming that the aircraft passed through the minor axis of the marker beacon radiation pattern, the test indicated that Flight 128 was between 1,945 and 2,145 feet m.s.l. when it passed over the marker beacon just prior to the accident. At this point the flight recorder indicated 2,340 feet m.s.l. The minor axis of the marker beacon was measured by the FAA shortly after the accident and found to be 2,835 feet wide at 2,000 feet m.s.l.

1.9 Communications

Radio communications between the crew and the air traffic control facilities were normal and without known interruption.

1.10 Aerodrome and Ground Facilities

Greater Cincinnati Airport had two runways available for use by air carrier aircraft. They were Runway 18-36 which was 8,600 feet long and 150 feet wide, and Runway 9R-27L which was the same width but 5,499 feet long. Runway 18-36 was normally equipped with U.S. Standard A approach lights; however, at the time of the accident, these lights had been removed from the approach to Runway 18 but were still installed and operational on Runway 36. Runway 18-36 had high-intensity runway lights installed and these lights were operating at their highest brilliancy setting at the time of the accident. Both Runways 18-36 and 9R-27L were painted with all-weather markings.

A runway extension 900 feet long had been constructed at the approach end of Runway 18; however, it had not been opened for use at the time of the accident.

There were an operational control tower and radar approach control (airport surveillance radar) on the airport and they were in operation at the time of the accident. The flight was observed on radar throughout the approach and the controller stated that it did not deviate significantly from the extended centerline of the runway until the target disappeared from the radarscope. The approach control radar provided range and azimuth information only and had no height finding capability.

The Greater Cincinnati Airport was designated as a medium hub airport served by six scheduled air carriers and one nonscheduled carrier.

The average annual number of scheduled operations was 19,925. Additionally, an annual average of 1,850 military operations, 33,647 local operations, and 51,290 itinerant operations was reported. The calculated total number of operations was 106,712 for a 12-month period ending June 5, 1967. These operations included aircraft ranging in size and capability from small single-engine general aviation aircraft to four-engine turbine-powered air transports.

1.11 Flight Recorders

The aircraft was equipped with a Lockheed 109CR flight data recorder (FDR) and a Fairchild cockpit voice recorder (CVR). Both recording units were installed in the aft end of the aircraft and were recovered from the wreckage in good condition.

The FDR made a record of indicated heading, vertical acceleration, indicated airspeed, and, based on a barometric setting of 29.92, indicated altitude. It received its airspeed and pressure altitude information from the pitot head and static source that provided these inputs for the first officer's flight instruments.

The CVR recorded, on four tracks simultaneously, audio inputs from a cockpit area microphone, the captain's radio channel, the first officer's radio channel, and the third crewmember's radio channel.

The FDR recording medium was examined and a complete chart of the recorded data was prepared. An expanded chart of the last 3 minutes of the flight was also prepared. The expanded chart indicated that the flight arrived over the outer marker at 2,340 feet m.s.l. 3/ and at an indicated airspeed of 200 knots. After the aircraft passed the outer marker, the rate of descent then increased to and stabilized at approximately 1,800 f.p.m. until approximately 20 seconds prior to initial impact. 4/ The rate then increased to approximately 3,000 f.p.m. for about 5 seconds and then decreased to 1,800 f.p.m. The rate of 1,800 f.p.m. was held until approximately 5 seconds before initial contact. Prior to initial contact, the aircraft was rotated to virtually a level attitude. The approximate indicated airspeed at the time of the impact was 191 knots and the indicated altitude was 900 feet m.s.l.

A transcription of the cockpit area microphone channel of the cockpit voice recorder was prepared covering the period from approximately 13 minutes prior to the accident up to the time of impact.

3/ The indicated altitude on this chart was corrected for a barometric pressure of 30.07 in. Hg.

4/ The Board believes this contact with the small branches of a tree was not recorded by the CVR.

This transcription began when the aircraft was at about 19,000 feet in its descent. The first recorded discussion concerned aircraft depressurization and a determination was made that there would be sufficient flying time remaining to have cabin pressure reduced to ground level before landing. The crew then read and acknowledged all items on the preliminary landing cockpit checklist, including the altimeter settings (setting used 30.06).

Appropriate settings were then applied to the radio navigation equipment (frequency and course selection) for the ILS approach to Runway 18. The existing weather report was discussed with regard to the minimums for the approach and it was determined that there was a more than adequate margin between them. There were then some crew remarks about the snow being encountered. The crew then reset the altimeters to the then-current altimeter setting (30.07) as heard in the tower's transmission to another aircraft. Appropriate flap settings were requested consistent with the aircraft's flight regime, and the landing gear was lowered. The aircraft passed over the ILS outer marker at 2056:00, from which point the following relevant exchanges took place in the cockpit:

2056:00	A/C over the center of the Outer Marker
2056:09	Capt: "Okay, and we gotta go down to, ah, four hundred, that would be, ah, (Copilot: Twelve ninety) (Capt: Twelve ninety.)" Capt: "Flaps 50 please." Copilot: "Flaps 50."
2056:25	Final checklist being read. All items covered
2056:37	including "Altimeters set, cross checked on zero seven." Flight Engr: "No Smoking." Capt: "It's on." Unidentified voice: "Nothing to it." Flight Engr: "Yaw damper check." Unidentified voice: "Okay" (very faint)
2056:46	Capt: "What's that . . . say, what you say, twelve ninety?" Copilot: "Ten ninety."
2056:49	Capt: "Come on, you" (last voice intelligence on voice recorder)
2056:49.5	Sound of Impact Begins 5/
2056:55	Recorder ceased operation

5/ The Board believes this sound was recorded upon impact with large trees approximately 1,300 to 1,400 feet after initial contact.

The TWA Flight Operations Policy Manual specified certain procedures to be followed by the crew during the descent and approach for landing.

The crew of Flight 128 followed the prescribed procedures until after crossing the outer marker, according to the cockpit voice recorder transcriptions. In this case, the first officer should have called "airspeed" when the indicated airspeed was more than 5 knots different from the target airspeed, called "sink rate" if the rate of descent exceeded 1,000 feet per minute, called the elevation above the field in feet m.s.l. (1,390 feet m.s.l.) when 500 feet above airport elevation and reported no warning flags on the instruments, called out each 100 feet of altitude change below 500 feet above field elevation until reaching the minimum altitude (1,290 feet m.s.l.), and called "runway in sight" or "minimums--no runway," as appropriate, when the aircraft reached the prescribed minimum altitude.

According to the flight data recorder, the airspeed, sink rate, and indicated altitudes were such as to warrant warning calls but none were recorded on the CVR transcriptions. There is no record of the first officer's calling the altitude at 500 feet above the field elevation (1,390) nor is there any call for the 100 feet increments between that altitude and the altitude at which the aircraft first struck the trees. The first officer did not call when the aircraft appeared to have arrived at the minimum approach altitude.

Several TWA training pilots and management pilots testified at the public hearing regarding the company's position on the use of checklists and the proper performance of a glide slope out ILS approach. In summary, their testimony indicated that the use of the checklist and callouts of variations from prescribed parameters on the final approach were desirable but were also backup procedures. If other duties involving the flying of the aircraft, radio contacts, etc., interfered with the performance of these callouts, they did not believe it would adversely affect the operation of the aircraft. In this testimony, the term final approach "slot" was defined as a point where the pilot-in-command felt that he was set up for a glidepath angle or approach descent angle which would carry him from his present position to the touchdown zone on the runway. It was also indicated that the rate of descent was faster in a no-glide-slope approach than it would be in a full ILS procedure.

The Board examined the possibility that the extension of the static and pressure lines to serve the flight data recorder, in its new location in the aft end of the aircraft, might have introduced an error into the recording, either due to lag associated with the length of the line runs, the restrictions incorporated in the new lines, or the bending of the lines required to make them conform to the fuselage as they passed aft from the cockpit area to the tail section of the aircraft.

Bench tests were performed of the new installation and demonstrated that there was no appreciable lag in the system due to the changes caused by moving the recorder. In addition, theoretical studies performed showed no basis for an increase in lag error in the information sensed by the recorder.

1.12 Wreckage

The aircraft initially struck a tree at an approximate measured elevation of 875 feet m.s.l., at a point 9,378 feet short of the threshold of Runway 18. This tree was 429 feet right of the extended runway centerline. It was computed that the aircraft was wings level, heading 180° magnetic, in a near level attitude at the time of the initial impact. The primary wreckage area, 2,500 feet from the initial impact point, contained the bulk of the aircraft and was approximately 500 feet long and 200 feet wide, with its center 6,878 feet from the runway threshold.

No part of the aircraft was found outside the wreckage path or the primary wreckage area, and portions of all parts of the aircraft were found in those areas.

There was no evidence of preimpact failure of the airframe, flight controls, or the powerplants. There was no evidence of in-flight fire found on any recovered wreckage. All fractures observed were of the overload type. The landing gear was down and locked, the landing flaps were extended 50°, the spoilers were retracted, and the outboard landing lights were retracted at the time of impact. The horizontal stabilizer jackscrew extension was measured and found to be in a position equivalent to a 5° nose-up stabilizer setting.

The crew's flight instruments disclosed no usable information. Examinations of the Kollsman Integrated Flight System (KIFIS) components were conducted and electrial readings of altitude and airspeed were obtained. The captain's scale error corrector module was found at the electrical equivalent of an altitude of 856 feet and the first officer's at 899 feet.

An extensive examination of the pitot static system was conducted. This was a dual, balanced, self-draining system with separate pitot heads and static ports powering the instruments on each side of the cockpit. The static system was balanced so that an interference to one static source would have a minimum effect on any of the flight instruments by averaging out the static pressure in the system. The pitot heads were provided with electrical anti-icing devices but the fuselage-mounted, flush-installed, static ports were not protected against ice accretion. The right pitot head served the first officer's instruments and the flight data recorder.

The static source which served the first officer's instruments also provided data to the FDR. The captain's pitot static system served his flight instruments only. A separate static source was provided for the autopilot, the pressurization system, and the air conditioning.

The pitot head anti-icing systems were operational and the CVR indicated the crew had turned them on. Both pitot heads had been plugged with wood and torn from the aircraft as it passed through the various trees it struck.

The left static port assembly was removed from the aircraft and examined. Inside the static plate, burnt residue and granulated ash were found. The static port assemblies from other TWA CV-880 aircraft were examined and it was found that, in some cases, the sealant compound used to make an airtight seal had extruded into the chamber behind the port assembly. In some cases, the static holes had been drilled through the plate and then through the extruded sealant material. The static ports were originally drilled in the plate as a circle of six holes, each being 0.047 in diameter, and a seventh hole of the same diameter centered in the circle. As previously noted, TWA had, shortly before the accident, drilled the center holes to 0.125 inch diameter to accommodate a common fitting on static test equipment. There is no evidence that this modification had any effect on the static system.

Extensive examination of the KIFIS components, including the test circuitry, did not reveal any discrepancies.

The recovered navigational instruments, navigational radios, and communication radios were properly tuned for an ILS approach to Runway 18. According to the CVR transcript and the Air Traffic Control transcript all of the required aircraft navigational equipment, flight instruments, and communications equipment were functioning in a manner that appeared normal to the crew until just before the first impact.

1.13 Fire

There was no evidence of in-flight fire. The aircraft did burn after it came to rest and witnesses reported several explosions after the crash.

Firefighting equipment responded from the airport and surrounding communities, and the fires were contained and extinguished by them.

1.14 Survival Aspects

Of the 82 occupants of the aircraft at the time of the accident, 60 persons were killed outright, 22 were removed to local hospitals where 10 subsequently died. Of the 12 survivors, two cabin attendants and four adult passengers were interviewed shortly after the accident. The physical condition of the remainder precluded interviews at that time but all of the adults have subsequently received questionnaires. Only one person, a passenger, has been able to give a clear, sequential report of his escape. This man read the emergency information card as instructed and had his seat belt tight. At the first unusual sounds he put his head between his knees and remained in that position until the aircraft movement stopped. Being in a window seat, he was able to crawl out through the fractured fuselage beside his seat and escape serious injury.

1.15 Test and Research

In an effort to resolve some apparent anomalies indicated by a comparison between the flight data recorder record and the prescribed flightpath of the aircraft, the Board performed a number of special studies and flight tests.

A test flight program was designed to resolve apparent differences between CV-880 drag data (based on an aircraft in the landing configuration) furnished to the Board by the manufacturer and other CV-880 drag data provided for simulator purposes furnished to NASA at an earlier time.

The Board requested TWA to conduct a special test flight, observed by Board investigators, to attempt to determine which of these drag data was correct. A recently overhauled TWA CV-880 was used for the test and, prior to the test, all of the pertinent instruments were calibrated and the landing flap positions were checked for conformity to prescribed tolerances. The test plan was prepared by Convair personnel and reviewed by the Board's investigators.

The test was performed with a takeoff gross weight of approximately 173,000 pounds and a center of gravity 22 percent MAC. This c.g. was maintained throughout the flight.

Because there was conformance between the drag data sets referenced above for an aircraft in a relatively clean configuration, a series of runs was made with the aircraft in the cruise configuration to ascertain if there was any substantial deviation in engine thrust from the manufacturer's predicted nominal values. Next, a series of runs was made with the landing gear down and the landing flaps set at 50° to establish the aircraft drag in the landing configuration at the lower lift coefficients. All of the test runs were initiated at pressure altitudes between 8,000 and 10,000 feet and, in a majority of the cases, duplicate runs were made on reciprocal headings. During each of the test runs, a cockpit-mounted camera was used to take a sequence of pictures of the first officer's instrument panel, and the pertinent data was extracted from these photographs.

The runs made in the landing configuration were flown with the engine power set at 1.4 EPR and the calibrated airspeeds varied between 159 and 191 knots, corresponding to lift coefficients ranging from 0.98 to 0.59, respectively. Several runs were also made with the engines at idle thrust, approximately 1.0 EPR, in the landing configuration, and the airspeeds controlled between 180 and 185 knots.

In the clean configuration, EPR values ranged from about 1.0 to 1.6, with airspeeds ranging from 155 to 309 knots. The respective lift coefficients varied from 0.83 to 0.21.

Drag coefficients were calculated for all of the above runs and a reasonable correlation appears to exist for both the clean as well as the landing configurations when test data were compared to predicted values.

The drag of the accident aircraft was computed by revising the drag of the test aircraft to account for applicable variations in induced drag (caused by the difference in lift required between a 135,000-pound aircraft and the actual weight of the test aircraft). The resultant drag values were plotted on a curve of drag versus equivalent airspeed, and good correlation was achieved with the manufacturer's predicted values.

In an effort to determine engine power used during the latter stages of the flight of N821TW, the original CVR tape was provided to the engine manufacturer for an analysis of engine-generated sound spectral frequency relationships.

Several prominent resonances were detected on the accident CVR tape. To define and identify further these prominent resonances and resultant frequencies in terms of rotating engine components, the Board, in a coordinated effort with the Aircraft Engine Group of General Electric Company, continued this study and examination of the original CVR accident tape.

These rotating engine components were identified in terms of sound pressure (energy) levels and frequencies. It was determined that the most prominent resonance noted corresponded to the first-stage compressor blade passing fundamental frequency. Other, less discernible, fundamental passing frequencies that were identified, included the second- and third-stage compressor blades.

These frequencies were at a mechanically fixed constant relationship to each other and were functions of the number of compressor blades and the physical engine rotor speed. These frequencies were in constant relationship with engine speed, thus allowing interpretation on a continuous flight time versus engine speed management basis.

A total flight profile time of 8 minutes prior to the first impact sound was studied and interpreted by General Electric in terms of engine speed management. Their interpretation of engine speed management was made by independently determining engine speed from the first- and second-stage compressor frequencies and then averaging these values. Deviation of these averages was approximately 0.1 percent. Individual engine speeds were also determined by this method. Based on the manufacturer's interpretation of the engine sound spectrum, it was calculated that the following flight profile versus engine power management schedule was conducted by the flightcrew:

> At the start of the 8-minute period, it was calculated that two engines were at flight idle and two engines were at approximately 78 percent of engine r.p.m. These settings remained constant for 3:56 minutes and then the two engines at flight idle were accelerated up to approximately 78 percent, followed by a slow acceleration of all four engines to approximately 84.1 percent. These accelerations took about 18 seconds. This speed setting remained constant for 41 seconds and then the engines were accelerated to 86.1 percent in a 3-second period. This engine speed remained constant for 1:20 minutes when the r.p.m. was reduced to 85.0 percent in a 1-second time period. The engines remained at 85.0 percent for 1:18 minutes and then were reduced to 82.5 percent in 2 seconds. This latter engine speed existed until approximately 0.8 seconds before the first impact sound detected on the CVR. During the last 0.8 seconds the engine speed of all four engines increased to approximately 86.5 percent.

The engine speeds calculated by this method were then correlated with the altitude and indicated airspeed data recorded on the FDR, and the ambient temperature as calculated from the Dayton, Ohio, weather observations, translated to pass through the recorded Cincinnati surface temperature. These correlations were then used to compute total net thrust generated and the nominal percentage of the physical rotor speed, as a function of flight time prior to impact. Engine performance data were corrected for a 30-horsepower extraction for accessory drive loss and a 4-pound-per-second air bleed extraction.

Since net thrust accuracy is dependent primarily upon the speed/airflow relationship and the compressor stator schedule tolerance on thrust, these points were presented as a thrust band. This thrust band was generally equivalent to $\pm$ 2 percent of engine speed at approach power settings. (See Appendix C.)

Based on this study, average total net thrust values were calculated. At 2:57 minutes before the first sound of impact, the net thrust was approximately 8,200 pounds. It increased to slightly over 11,000 pounds in about 3 seconds and then decreased to 10,600 pounds over a period of about 1:20 minutes. The thrust was then reduced to 9,000 pounds in a 1-second interval and then increased to 10,400 pounds over a 1:18-minute period. The thrust was reduced to 7,000 pounds during a 2-second period, then increased to 7,200 pounds during an 11-second period. Finally, the total thrust increased to a value of approximately 13,400 pounds at the first recorded sound of impact.

Prior to initiation of the sound spectral analysis to determine engine generated thrust, the Board calculated the total aircraft thrust required based upon drag data submitted by the manufacturer and an energy analysis of the performance data from the flight data recorder readout. The calculated values were intended to reflect the dynamic character of the aircraft motions, since account was taken of the energy balance requirements for an ascending or descending, accelerating or decelerating aircraft. This latter effort was subject to considerably more interpretation than the spectral study since it required "fairing" both the altitude and airspeed curves. The general magnitude of the calculated thrust-required values did, however, appear reasonably consistent with the thrust values derived from the spectral analysis.

The average thrust required for the time interval between approximately 3 minutes and 50 seconds prior to impact was estimated as between 8,000 and 10,000 pounds. From 3 minutes through 1 minute and 30 seconds before impact, the average thrust required was estimated as approximately 12,000 pounds, and from this latter point through 15 seconds before impact, the average required thrust value was calculated as between 12,000 and 14,000 pounds. Between 15 seconds and 10 seconds before impact, the thrust required dropped to between 6,000 and 8,000 pounds and then subsequently increased, at about the time of impact, to about 20,000 pounds. It should be noted that although the discrete data points on Appendix C are connected in sequence, this graphical artifact is not intended to serve as a means of portraying thrust-time gradients, since this information would have required either an accurate knowledge of engine rotor speeds or an inordinately large number of data points.

The engine manufacturer's calculated thrust values were correlated and applied to an aircraft estimated to weigh 135,356 pounds performing an approach at Cincinnati under the ambient conditions believed to exist at that time. With the landing gear down and the landing flaps extended 40°, the aircraft would have required 21,200 pounds of thrust to maintain level flight at 195 knots. At 45 seconds before the impact, the net thrust indicated by the sound spectral analysis was approximately 10,000 pounds. Two ways this difference of 11,200 pounds of thrust could be made up were either by increasing the thrust output of the engines or by placing the aircraft in a descent. When an aircraft is placed in a descent, a vertical component of the aircraft's weight is resolved into effective thrust along the aircraft's flightpath. If an aircraft were to descend vertically, its total weight would become added thrust, or if the aircraft maintained level flight, there would be no effective thrust due to the aircraft weight.

A series of calculations was then performed in which the approach was divided into segments. These calculations considered only the 45-second time period between the outer marker and the point of the first impact.

The first segment was considered with the flaps at 40°, airspeed 195 knots, landing gear down, thrust required 21,200 pounds, net thrust generated 10,000 pounds, and a gross weight of 135,356 pounds for 30 seconds. This calculation indicated that the aircraft would have had to descend at a 4.75° angle to achieve a balance between thrust required and thrust generated.

The second segment was for a period of 5 seconds, aircraft weight unchanged, gear down, airspeed still 195 knots, the landing flaps extended to 50°, the thrust required increased to 24,000 pounds and the thrust generated increased to 10,400 pounds. This calculation indicated that the descent angle required was 5.76°.

The configuration for the third segment was the same as the second. The thrust generated was reduced to 7,000 pounds while thrust required was 24,000 pounds, and the time element was 11 seconds. This segment required a 7.15° angle of descent.

Resolving these angles to altitude indicates that the difference in altitude between the first and second segments was 795 feet; between the second and third points, 165 feet; and between the third point and the impact area on the first tree, 453 feet. The total, 1,413 feet added to the altitude of the first impact, 890 feet, resulted in a necessary total altitude over the outer marker of 2,303 feet m.s.l. In this connection, the FDR indicated an altitude of 2,340 feet m.s.l. at that point in the flight.

TWA conducted a series of laboratory tests of various static port configurations to attempt to learn whether it was possible for static ports to ingest water and cause errors in the altimeters. In these laboratory conditions, they found it was possible to ingest water, and errors did occur in both the altimeters and vertical speed instruments. The results obtained during these laboratory tests are not relatable, at this time, to an actual flight regime under meteorological conditions similar to those which existed at the time of the accident.

The Douglas Aircraft Company has conducted in-flight water ingestion tests relative to the static system on their DC-9 aircraft. Although water was ingested, such ingestion was readily discernible on the instruments and the excursions were not of appreciable magnitude.

The Board expresses appreciation for the extensive test program which TWA has conducted, both on our behalf and on their own initiative, in an effort to explore possible altimetry problems in conjunction with this investigation.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

In analyzing this accident, the Board has carefully reviewed and investigated all the theories postulated in this matter, and it is our belief that the preponderance of evidence supports the findings as stated in our probable cause.

In our review of this accident, the Board has been able to eliminate a number of causal areas.

The autopsy reports, a review of the medical records of the flightcrew, the toxicological examinations, and an evaluation of the cockpit voice recorder transcription revealed no evidence of any flightcrew incapacitation. The crewmembers were all performing their duties and conversing in normal tones until just before the accident occurred.

Insofar as an aircraft control system malfunction is concerned, there was no physical evidence, nor did the cockpit voice recorder transcription reveal any evidence, to support such a conclusion. We believe that any unusual flight control action or lack of control would have been commented on by the crew. Further, the flight data recorder indicated that the aircraft's recorded flight was indicative of normal flight control response. We have calculated that approximately 1.4 "g" would have been required to accomplish the roundout recorded just prior to the first recorded impact sound. This amount of "g" was recorded at the appropriate time on the FDR trace. Finally, our examination of the wreckage has revealed no evidence of any preimpact malfunction or failure of the flight control system. Therefore, we believe the aircraft was responding normally to the control inputs of the flightcrew until the first impact with the trees.

The evidence indicates that the flight of N821TW was routine and without notable comment until sometime during the descent to Cincinnati. The departure from Los Angeles was delayed due to an equipment change but the assigned aircraft was airworthy at the time of departure. The only carryover discrepancy was an inoperative generator which was not a safety of flight problem and had no bearing on this accident.

The descent into the Cincinnati area from cruising altitude was delayed due to conflicting traffic and was initiated closer to the destination than normal. This should not have caused any problem to the crew or affected the safety of the flight. It did require the crew to conduct the descent with a higher than normal rate toward the initial approach fix. The crew discussed the technique they were using to increase the rate of descent, and the cockpit voice recorder indicated that they were relaxed, unworried, and operating within the established operating limits of the aircraft. This operation was verified by the flight data recorder readout.

A review of the flight data recorder record for this section of the flight indicates that the parameters that could be checked were in good agreement with known benchmarks such as heading, turns, and altitude.

As the flight reported leaving 15,500 feet, a member of the flight-crew remarked to others in the cockpit about the rapidity of the descent, and the following remark was made in the cockpit, apparently with reference to the underlying cloud conditions, "Hope that is still a thin layer." In connection with the rapid descent, we noted that the winds at 14,000 feet and above were in excess of 50 knots from a westerly direction. The remark about the "thin layer" was consistent with the observations of the radar meteorologist at Cincinnati, who described the tops of the clouds to the north of Cincinnati as being approximately 15,000 feet. One of the survivors of the crash advised that "It was real clear and we could see the moon before the approach."

The CVR indicated that the crew checked the anti-icing equipment and conversations after that time indicated that the crew was not aware of any discrepancies regarding that system. Icing would have been light from 20,000 feet to about 16,000 feet, becoming moderate to 12,000 feet. Heavy icing may have occurred from 12,000 down to 6,000 feet. From 6,000 feet down to the surface, any icing encountered should have again been moderate. Turbulence should have been light, with occasional moderate turbulence in convective activity during the descent and approach. The only record of turbulence, during the descent and approach, was depicted on the flight data recorder trace of the aircraft's descent from 16,000 to 9,000 feet.

The air traffic control of the flight was without remarkable incident until the flight was turned over to the approach controller, and that controller failed to provide the crew with the current altimeter setting of 30.07. The crew had previously been given a setting of 30.06. However, the CVR indicated that shortly after the flight came under the control of the approach controller, the crew intercepted a transmission containing the current altimeter setting of 30.07 when it was transmitted to another flight in the area. The CVR also indicated that they set and cross-checked that setting on their altimeters. Examination of the altimeters to verify these settings was not possible due to the damage they received.

Throughout the descent, the first officer called out the appropriate warnings to the captain as the aircraft approached assigned altitudes and apparently performed all of his assigned duties without prompting by the captain. The CVR indicated that the crew coordination was very good during this portion of the flight.

The weather conditions in the Cincinnati area were such that the air-crew should have established visual contact with the ground by the time they reached 3,000 to 4,000 feet during the descent. This conclusion is based upon the following considerations. The last reported official weather observation at Greater Cincinnati Airport prior to the 2055 Record Special observation was a check observation taken at 2040. At that time, scattered clouds were reported at 600 feet, the estimated height of the overcast ceiling was 3,000 feet, and the visibility was 5 miles in light snow and haze. The last measured ceiling at Greater Cincinnati Airport, prior to the accident, was taken at 1941. At that time, the measured height was 4,800 feet overcast. The first measured ceiling subsequent to the accident was taken at 2125. At that time, the ceiling was measured as 4,200 feet overcast. At Lunken Airport, Cincinnati, the ceiling at 2035 and 2055 was reported to be 5,000 feet and the visibility was 7 miles. Lunken Airport was approximately 12 miles east of the approach path to Runway 18 at Greater Cincinnati Airport where that approach path crosses the north bank of the Ohio River.

As the flight approached the final fix, approximately 7 minutes before the accident, the crew was given the latest reported weather which indicated that the ceiling was approximately 1,000 feet and the visibility was $1\frac{1}{2}$ miles in snow and haze. Approximately 1 minute later they were reminded that the ILS glide slope was out of service, as was the middle marker beacon and the approach lights. The crew acknowledged receipt of this information and the CVR indicated that they planned their approach to the proper minimum altitude, 400 feet above the ground, to allow for these outages.

From this point in the approach until passing over the outer marker, the flight data recorder readout showed that the aircraft altitudes and headings were in general agreement with announced altitudes from the aircrew and the headings they were instructed to fly. The CVR also indicated, through this portion of the flight, a normal operation of the aircraft. The proper configuration was established for the approach to the outer marker in accordance with the company's operating instructions for this portion of the flight.

When the crew reported over the outer marker, they were cleared to land on Runway 18 and advised that the wind was blowing from 090° at 8 knots and the RVR was more than 6,000 feet.

The sound of the marker beacon, on the low sensitivity setting, was heard from 2055:58 to 2056:03. The center of this time span, 2056, was used as the time of outer marker passage for all calculations relating to the latter portion of the flight from the outer marker to the first recorded sound of impact.

At this time, the first officer reported to the captain that they were past the marker and that there was no glide slope. The captain acknowledged this comment and stated " ... we gotta go down to, ah, four hundred, that would be, ah." At this point, the first officer supplied the information "twelve ninety" and the captain repeated "twelve ninety."

The flight arrived at the outer marker with the landing gear down, the flaps set at 40° down, the altitude was approximately 2,340 feet, and the airspeed was approximately 200 knots.

The flight data recorder shows that, after the aircraft passed the outer marker, a rate of descent of 1,800 f.p.m. was established at an airspeed of about 190 knots. In this connection, it should be noted that these values are above those recommended by the company for instrument approaches. However, an examination of previous flight records indicates that the captain had, on previous occasions, when operating under visual conditions exceeded the recommended values. This rate of descent was nearly constant until approximately 20 seconds before the first recorded sound of impact. At that time the rate increased to approximately 3,000 f.p.m., coincident with a request for 50° flaps, and a decrease in thrust, and then decreased to about 1,800 f.p.m. until about 5 seconds before the initial contact. Prior to initial contact, the aircraft was rotated to a virtually level attitude, the rate of descent was decreasing, the airspeed was about 191 knots, and the indicated altitude was about 900 feet m.s.l.

The altitude readings obtained from the KIFIS components, 856 feet on the captain's side and 899 feet on the first officer's side, compare quite closely to the indicated altitude of 900 feet and the measured altitude of 875 feet at the point of first impact. The pitot static system examination revealed that any blockage or partial blockage of the static system which might affect the flight recorder would likewise affect the first officer's instrumentation.

The activities of the flightcrew as reflected in their recorded conversation indicated that, during the greater part of the time between the outer marker and the crash, the first officer and the flight engineer were involved in accomplishing the final landing checklist. The captain's request for 50° of flaps and the recorded sounds of the engines changing power were the only indications we have of the captain's activities during this period. If we assume that the flight instruments were accurately reflecting the operation of the aircraft, it appears that the captain knew he was high at the time of the arrival over the outer marker. In line with the company practice of getting down to the designated minimum altitude as soon as possible during a no-glide-slope ILS approach, he initiated a rate of descent higher than that required for a normal ILS approach. The possibility exists, however, that the captain's attention was divided between attempting to locate the runway ahead of him, and flying the aircraft by partial reference to his instruments and partial reference to ground lights or other objects outside of the aircraft.

Up to the time the aircraft reached the river bank, we believe the aircraft was being operated in essentially a VFR flight condition. However, in the vicinity of the river, the flight would have encountered the snow shower which reduced visibility. In these circumstances, the captain may have been faced with the problem of reorienting himself with the flight instruments. It is approximately at this point in the flight where the ground witnesses described the aircraft as descending steeply, nose down, being lower than normal, leveling off, and disappearing in heavy snow. These observations were terminated by the crash which they noted by the flash of light.

Because of the circumstances surrounding this accident, the Board has expended considerable time and effort, as have several of the parties to the investigation, in an attempt to find some evidence that would indicate a malfunction of the pitot static system.

Calculations performed by the Board, based on test flights and special studies, indicate that the aircraft was in an altitude envelope over the outer marker which includes the altitude recorded by the flight data recorder.

An evaluation of the total thrust required during the final approach, versus the thrust generated, was made. The thrust generated, based on the study and interpretation of the sound spectral analysis of the CVR-recorded engine sounds and the FDR data, by the engines very closely approximated the thrust required to perform the flight as depicted by the FDR.

Considering the above factors, we have two, separately obtained, verifiable cross-checks of the data recorded by the FDR. Additionally, the data recovered from the KIFIS system as regards the altitude of the aircraft at impact support this finding.

Our investigation of the CV-880 fleet and this aircraft's history of pitot static system malfunctions reveals no evidence to support a finding of a multiple malfunction or failure of the instruments on both sides of the aircraft. If, as in this case, we believe that the copilot's instruments were accurately reflecting the flight as flown, we must assume that they were either not observed or the indications on them were ignored for some reason. They were used at times during the descent, as prescribed by the operator, to cross-check the captain's instrument indications.

The special studies conducted by the carrier suggest that in flight in heavy precipitation, water ingestion can occur and lead to erroneous readings on the altimeter and the vertical speed indicator. So far as the record of this investigation indicates, there was no precipitation other than snow in the operational area of the aircraft. There was rain in the Cincinnati area but we cannot connect its location with the flight-path of the aircraft. According to our calculations, the freezing level in the approach area was just above the surface, probably no higher than 1,000 feet above ground level (1,890 m.s.l.), so that any precipitation that occurred above that altitude should have been in a solid form such as snow. Were there any water droplets impinging on the aircraft with its supercooled skin, we would expect them to freeze into ice if they adhered to the structure. Under these circumstances, we cannot conceive of any mechanism that would cause a flow of water rivulets across the static ports so as to cause fluid ingestion. Furthermore, the static ports are located in a nonicing area of the aircraft and there are no known cases in which the static ports on these aircraft have been blocked by ice or snow.

The record of this investigation indicates that the flightcrew checked the anti-icing systems during the descent and we believe that they were operating throughout the descent and approach. There are no recorded comments on the CVR to indicate that the crew detected any ice or any malfunction of these anti-icing systems. We have, therefore, discounted icing as a problem in this case.

Following the public hearing held as a part of this investigation, recommendations as to the conclusions that should be drawn from the evidence submitted at the public hearing were offered by Trans World Airlines, Inc. These recommendations were supplemented by additional recommendations following additional tests and research by the carrier.

The initial recommendations postulated that the flight data recorder did not properly depict the flight profile of the aircraft during the final approach. Based on this thesis, TWA also questioned the validity of the information presented on the aircraft flight instruments for use by the crew during the approach.

The carrier supported the inaccurate depiction of the flight profile be referring to the testimony of the ground witnesses near the river and the witnesses who were located north of the outer marker. TWA also pointed out that, in their opinion, the flight recorder did not reflect the necessary pullup "g" load required to level out at the end of the high rate of descent below 2,000 feet. The testimony of the survivors that they did not recall any excessive "g" or noticeable change in noise level (engine) was also noted.

TWA stated that, based on the CVR transcription and the testimony of other TWA pilots who had flown with Captain Cochrane, it is inconceivable that he would have flown the latter portion of the flight as depicted by the FDR. TWA also considered that the airspeed shown by the

FDR was not consistent with a time-distance calculation for the flight from the outer marker to the impact point. They believed that the lack of calls regarding sink rate, altitude, and airspeed indicated that the flight instruments were not providing proper information to the crew.

TWA concluded that the time interval of recorded marker beacon signal passage did not necessarily indicate the altitude at which the aircraft crossed the marker beacon.

Based in the original sound spectral analysis, they concluded that the power level developed by the engines did not change through the initial approach, descent, and level-off.

The carrier discussed the flight test work they performed, based on the original sound spectral analysis and the FDR. They concluded that it was not possible to reproduce the flightpath depicted by the FDR, using the power settings based on this sound spectral analysis. They supplemented this conclusion by reference to the Thrust Required Chart prepared by the Board. In this connection, they noted the wide disparity between the thrust required and the thrust generated.

Finally, they noted that the "heavy wet" snow observed by ground witnesses, and near freezing temperatures, may have had some influence on the aircraft air-data instrumentation. They pointed out that a partial obstruction of the static system could cause a lag in the instrument readings. This lag would have caused the pilot to believe he was at an altitude higher than actual, with an airspeed higher than actual, and a rate of descent that was less than indicated.

In conclusion, TWA recommended that further study and testing in the areas of static port ingestion and simulation of the accident aircraft performance be made.

Several months later, TWA submitted their supplemental recommendations. In these supplemental recommendations, they pointed out again that the flight as depicted on the FDR was not that which would be expected of the crew under the circumstances that existed in this case. TWA reported that they had reexamined the FDR readout and compared the FDR readout, the new sound spectral analysis, and the thrust required data considering the confirmed drag data obtained by test flights. After reviewing these data, the carrier believed that there were significant discrepancies between the thrust required and the thrust generated, based on the engine r.p.m. indicated by the sound spectral analysis. They also pointed out that they could not resolve these differences when they reviewed the FDR profile of the flight from 11,000 to 3,000 feet. They reiterated that in their earlier test flights they could not reproduce the FDR-depicted flight profile using power settings between 86.2 percent and 89.7 percent r.p.m., particularly with regard to indicated airspeed.

They analyzed these discrepancies as being the result of ice or water intermittently blocking or being ingested by the static ports on both sides of the aircraft at the same time. As a result of this analysis, TWA prepared a technical paper outlining a research program on Flush Static Port Water Ingestion.

Both of the recommendations, with their supporting documentation, have been entered into the public record of this investigation, served on the Parties to the Investigation, and considered by the Board during the preparation of this accident report.

No recommendations have been submitted by any other Party to the Investigation of this accident.

Taking TWA's comments in the order presented, the Board offers the following remarks:

We believe that the flight recorder accurately depicted the profile of the flight. We would point out that the recorder was designed to reflect the recorded parameters of a flight with approximately a $\pm$ 2 percent degree of accuracy. It is essentially a trend instrument rather than an infallible point reading instrument. Using the chart attached to the report as Appendix E, 6/ we believe that we have accurately depicted the sequence of events from the outer marker to the point of impact. The test work described in the factual portion of this report indicates to us that the aircraft was capable of performing the latter portion of the flight as recorded by the FDR. Within the accuracy of the information available, we see no indication of support for a theory of erroneous information being generated by the air-data system and presented to either the flightcrew or the FDR. In fact, the record of this investigation indicates that, historically, there is no record of any failure or malfunction of the pitot static system that has affected all the flight instruments aboard an aircraft. Additionally, to accept this theory, the Board would have to believe that the FDR and the flight instruments agreed when the aircraft was at 3,500 feet and at impact, but that a malfunction existed between those two points which affected all the instruments but was not reflected on the FDR. Finally, this theoretical malfunction was not detected by the flightcrew.

The Board cannot place any credence on calculations based on the ground witnesses' statements because either the statements contained no specific information or the information was not precise enough to allow

6/ Appendix E is a chart on which are depicted a flightpath based on the FDR readout, a terrain profile, and CVR comments all keyed to time.

us to perform exact calculations leading to meaningful conclusions. Our evaluation of these statements provided an envelope of altitudes within which the aircraft could have been operating. The altitudes indicated by the FDR are within or near this envelope of altitude.

Our interpretation of the FDR shows a +1.4 "g" pullup at the appropriate place in the flight profile to reflect the level-off pullup.

The testimony of the survivors which reflects no recall of excessive "g" or noticeable change in noise level is, we believe, not unusual in light of the events which followed the pullup and increase in power. However, the FDR and the CVR clearly reflect these actions on the part of the aircrew.

The time-distance calculations performed by TWA are based on time from the outer marker to the first recorded sound of impact. They assigned that sound to the impact with the first tree struck by the aircraft. We do not believe that impact was recorded by the CVR but that the later impact, 1,300 to 1,400 feet closer to the runway, was the sound recorded by the CVR.

As previously stated, we believe the flight instruments were accurately reflecting the aircraft's operation.

We agree that the recorded outer marker signal did not necessarily indicate the altitude at which the aircraft crossed the beacon. However, our calculations in this area developed an altitude envelope that was in reasonable agreement with the FDR-depicted altitude.

There is no documented, actual experience available to the Board that will support a malfunction of the complete pitot static system caused by ingestion or partial blockage, without detection by the flightcrew or the FDR. When problems of this nature have been detected in the past by crewmembers, they have been indicated by the erratic operation of flight instruments. This erratic operation is also reflected by the FDR. There is no evidence of such a malfunction on the FDR record of this flight. Also, under the circumstances hypothesized by TWA in this case, the pilot should have been concerned about, and made some effort to correct, a higher-than-normal airspeed. This type of action by the pilot was not reflected by either the FDR or the CVR.

With reference to TWA's supplemental recommendation, they stated that they could not explain discrepancies between the thrust required and thrust generated. We do not see the discrepancies to be as large as TWA does, and it is our opinion that the differences between thrust required and thrust generated are explained by the rates of descent on the final approach.

In summary, we can find no evidence in the record of this investigation which will suport a finding of fluid ingestion or some form of partial blockage of the static ports as a causal factor in this accident.

After consideration of all the above-cited data, the Board believes that the following sequence best describes the events that occurred between the outer marker and ground impact.

The outer marker was passed at 2,340 feet m.s.l. (1,550 feet above the airport) at 2056:00. Three seconds later, the first officer stated that the flight was "by the marker and no glide slope." This was acknowledged by the captain who then said "we gotta go down to, ah, four hundred, that would be, ah, ... twelve ninety." At this time the aircraft configuration was landing gear down, and landing flaps set at 40°. A descent was initiated and stabilized at approximately 1,800 f.p.m. at an airspeed of 195 knots.

At 2056:21, the flight engineer asked "Want the final checklist?" and the first officer said "You bet." According to TWA procedures, the call for the final landing checklist is made by the captain to acknowledge the landing gear being down and locked. Apparently, in the absence of this call by the captain, the flight engineer initiated a reminder regarding the checklist. Almost simultaneously with the first officer's response, the captain requested "Flaps 50 please." This flap selection is, according to TWA's procedures, normally accomplished as the aircraft intercepts the final approach "slot." The slot is that portion of the approach where the pilot determines that he can successfully complete the approach and landing. During the next 11 seconds the final landing checklist was completed, including a cross-check of the altimeters.

At 2056:34.5, approximately 3 seconds before completing the last item on the checklist, a power reduction was recorded on the CVR, followed 1 second later by an unidentified crewman's remark "Nothing to it." At this time the aircraft was at an altitude of approximately 1,275 feet m.s.l., approximately $2\frac{1}{2}$ statute miles from the approach end of the runway. At this point, the aircraft was about 400 feet above the airport elevation but was also nearly 800 feet above the river valley with its associated lights. During this portion of the flight, the weather on the approach path was such that the Board believes the captain was able to establish visual reference to the lights in the river valley and, possibly, the glow of lights, associated with the airport. In this connection, the Board notes that the reported visibility at the airport was never less than $1\frac{1}{2}$ miles and was reported to be "better to the north" several times. The sighting of the lights mentioned above may have elicited the "nothing to it" comment.

It was noted during the investigation, that the profile of this particular terrain along the approach path from the outer marker to the airport may have provided the crew with an illusion of having adequate terrain clearance on their approach (see Appendix E). The Ohio River Valley is approximately 400 feet lower than the airport mesa terrain and is separated from higher ground by a steeply rising unlighted hillside.

The Board, in studying this terrain, believes there are two methods whereby an illusionary effect might be induced. At night, under lowering visibility conditions, it is possible that the lights in the river valley could be associated with airport terrain elevation and, if used for altitude reference, would provide an illusion of adequate altitude for terrain clearance. It is also possible, since there are no lights which would provide terrain definition (unlighted slope), that the lights in the valley associated with the lights on the airport terrain would provide a condition of a lighted upslope terrain illusion as described in Boeing studies on Night Visual Approaches to Lighted Sloping Terrain. In these studies, it was demonstrated that pilots making approaches to airports, in or adjacent to a lighted upsloping city, received visual cues that produced sensations of being much higher than their actual altitudes.

The Board believes the pilot used the lights in the river valley (400 feet below the airport elevation) as a visual reference to establish his final approach altitude. In this connection, the Board noted that there have been two prior accidents within 1,000 feet of the point where Flight 128 made initial contact with the trees. Both of those aircraft were operating at night in conditions of limited visibility. The record of investigation of those two accidents indicates that in each case, the crew saw or believed they saw, the runway lights shortly before they crashed into terrain lower than the airport elevation. Flight 128 leveled off at about 875 feet m.s.l. (15 feet below the airport elevation) but 400 feet above the river valley.

The cockpit crew conversations reflect a relaxed atmosphere in the cockpit until the last few seconds prior to impact. The recorded cockpit conversations also indicate that the captain may not have had the applicable minimum altitude of 1,290 feet fixed clearly in his mind. When the first officer reported: "By the marker and no glide slope," the captain acknowledged and started some mental arithmetic: "We gotta go down to, ah, four hundred, that would be ah ...." Before he could complete this thought process, the first officer provided the answer: "Twelve ninety" and the captain repeated the answer.

Initial tree contact occurred 3 seconds after level-off commenced and the captain exclaimed: "What's that - say what you say twelve ninety?" Had the captain been referring to his altimeters during the start of level-off, he certainly would not have been asking for a minimum altitude verification 3 or 4 seconds later in such an apparently rhetorical manner. We believe that he was surprised to see his altimeter displaying an altitude far below his target altitude of 1,290 feet.

The captain then initiated a pullup and exclaimed: "Come on,you." Destructive impact occurred about one-half second later and was recorded on the CVR at 2056:49.5. (See Appendix E.)

This crew had flown together enough to have established a rapport between the pilots. The uneventful flight and reported weather well above minimums may have paved the way for complacency on the part of the crew. Each of the pilots knew the other could do his job without being monitored and each probably felt he could count on that performance. The testimony at the public hearing indicates that the monitoring of the pilot flying the aircraft by the other pilot was a backup procedure and was not, in the view of the company, a mandatory procedure, at the time of the accident.

If the flight was, as we believe, operating in an area clear of clouds and precipitation inbound to the marker beacon, the pilot flying the aircraft may have divided his attention between the visible ground lights and the flight instruments. Knowing the glide slope was inoperative and the middle marker beacon and the approach lights were out, but with a reported visibility of $1\frac{1}{2}$ miles and an RVR of more than 6,000 feet, the captain may have devoted a part of his attention to attempting to pick up the runway lights. TWA procedures allowed a higher-than-normal rate of descent to get down to the minimum approach altitude in cases where the glide slope is not operating. With the visibility more than 1 mile, the captain may have decided to descend to his minimum altitude as quickly as possible so when the runway lights came into sight he would be in a position to establish his final landing approach without having so much altitude to dissipate. This operating procedure may not have been noticed by the first officer and the engineer because they were involved in preparing the aircraft for the landing and performing the final pre-landing checklist.

Two reasons are suggested for this possible breakdown of the cross-checks between the pilots. One is the possibility that the first officer was so involved with the performance of the final landing check that he did not observe his flight instruments. The second possibility is that the first officer may have observed the instrument indications but was not concerned because of his confidence in the captain.

The copilot had made all the required altitude callouts on descent and particularily told the pilot when passing through 3,500 feet for the assigned level out altitude of 3,000 feet. The flight recorder and the copilot's instruments agreed at 3,000 feet when he called that they were "out of three." It is thus believed that the main reason that the copilot made no further calls was that he felt the captain was making satisfactory visual approach. Since the copilot was looking at the same values of airspeed and altitude as the flight recorder, he should have called out high approach speed, high sink rate, 100 feet above intended level-out (500 feet), and minimums if the captain were making the approach on instruments, but, if he believed that they were in visual conditions and the captain was using visual ground reference to make the approach, none of these would necessarily be made.

After careful consideration of all the available information in this investigation, the Board believes that this is the most likely explanation for the sequence of events that led to this accident.

2.2 Conclusions

(a) Findings

1. The weather was suitable for the operation comtemplated and should not have affected the safe operation of the aircraft.

2. The aircraft probably operated clear of clouds and precipitation from a point 3,000 to 4,000 feet above the ground in the descent, until the aircraft approached the river. At that time, the aircraft encountered a snow shower which reduced the visibility to $1\frac{1}{2}$ to 2 miles.

3. The visibility during the final approach phase was such as to have permitted the crew to have visual reference to ground lights in the river valley and possibly to the glow of lights associated with the airport.

4. The powerplants were capable of and were delivering power to the aircraft without interruption and without recorded difficulty until the time of the crash.

5. The airframe and flight control systems were intact and capable of normal response until the time of the initial impact.

6. There is no evidence of an in-flight fire either inside or outside the aircraft.

7. There was no deficiency of the flight control system or structure that caused the aircraft to descend below its minimum altitude.

8. There was no in-flight separation of any major aircraft component.

9. There is no evidence of a bird strike which could have been in causal relationship to this accident.

10. The aircraft initially struck a tree at an altitude of approximately 875 feet m.s.l., in a virtually level attitude, with the landing gear down, and the landing flaps set at 50°. The aircraft continued to fly, striking trees along its flightpath, until it was not capable of further sustained flight.

11. Initial impact was 9,378 feet short of the approach end of Runway 18 and 429 feet west of the extended runway centerline.

12. The captain's altimeter was indicating 856 feet m.s.l., and the first officer's altimeter was indicating 899 feet when the electrical power to the KIFIS system was terminated.

13. There is no evidence of a failure or malfunction of any aircraft system.

14. There is no physical evidence of any malfunction or failure of the pitot static system.

15. There is no evidence that the crew detected any malfunction in the aircraft or its system.

16. The weight and center of gravity were within limits at the time of the accident.

17. The functioning ground navigational facilities were operating within their established parameters without reported discrepancies.

18. With the exception of the failure to provide the crew of Flight 128 with the current altimeter setting on initial contact, the air traffic control of this flight was routine and without reported discrepancy. The crew intercepted the current altimeter setting before they began the approach and the CVR indicates it was set and cross-checked.

19. The ILS glide slope, middle marker beacon, and high-intensity approach lights were inoperative. The crew was advised of these conditions and planned their approach accordingly.

20. There is no evidence that indicates the enlargement of the center hole in the static ports of the CV-880 in any way contributed to the accident.

21. Bench tests and independent calculations indicate that the relocation of the flight data recorder in the aft end of the aircraft did not affect the accuracy or timeliness of the flight data record.

22. The available night visibility checkpoints at the Cincinnati Airport were not adequate to determine visibility properly in all four quadrants when there were restrictions that reduced visibility below 5 miles.

23. There was a snow shower moving across the airport and the approach path of the aircraft during the descent from the outer marker.

24. The approach minimums which applied in this case provided FAA-required terrain clearance.

25. The aircraft was at approximately 2,340 feet m.s.l., when it passed the outer marker, as indicated by the flight data recorder.

26. The airport was equipped with surveillance radar which was used to observe the flight of the aircraft; however, this radar had no height information available and the controller could not have provided any warning to the crew regarding a descent below the established minimums.

27. The CVR transcription reveals that the flight operated in accordance with noraml operating procedures including crew coordination until about the time of passing the outer marker. There are no comments on the tape which indicate that any crewmember detected any deviation from a normal operation until the initial tree contact.

28. The captain's exclamation regarding altitude "twelve ninety" and the first officer's reply of "ten ninety" is the first indication that the Board finds which could be construed as the detection of a problem by the crew.

29. The first officer did not call out any deviation from localizer centerline, airspeed, altitude, or rate of descent.

30. During the time the required calls should have been made, the first officer and the flight engineer were carrying out the final landing checklist. This took about 11 seconds, and all required items including altimeters were checked off. This activity, combined with the first officer's confidence in the captain, probably lead to the omission of these calls.

31. The captain did not have the applicable minimum altitude of 1,290 feet fixed clearly in his mind and endeavored to conduct his approach partially by visual reference to ground lights in the river area. He leveled off at the airport elevation (400 feet above the river) rather than 1,290 feet (400 feet above the airport elevation).

32. The extruded sealant found in the left static port was not a causal factor in this accident.

(b) Probable Cause

The Board determines that the probable cause of this accident was an attempt by the crew to conduct a night, visual, no-glide-slope approach during deteriorating weather conditions without adequate altimeter cross-reference. The approach was conducted using visual reference to partially lighted irregular terrain which may have been conducive to producing an illusionary sense of adequate terrain clearance.

3. RECOMMENDATIONS

This accident was one of a series of landing approach accidents that have occurred in recent years. These accidents are generally typified by a non-precision approach conducted at night in restricted visibility over irregular terrain.

In light of these circumstances, the Board believes that recent studies which have been conducted relative to illusionary effects associated with approaches to lighted, sloping terrain should be expanded to encompass approaches similar to the one involved in this accident.

Concerned with the recurring nature of these accidents, the Board forwarded a letter of recommendation to the FAA regarding the need for operational improvements, research in altimetry, and in the development of approach and landing aids. (See Appendix D.) Additionally, the

Board's personnel have engaged in a series of meetings with Government and industry personnel directly concerned with the problems involved in this type of accident. These groups have included: the National Aeronautics and Space Administration; the Federal Aviation Administration; the Air Line Pilots Association; the Air Transport Association; the Aircraft Owners and Pilots Association; the Aircraft Industries Association; the National Business Aircraft Association; and the manufacturers of aircraft instruments. A number of these organizations have begun various programs of tests and studies in an attempt to isolate and identify the areas where corrective actions could be applied to prevent this type of accident.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

CREW INFORMATION

Captain Charles L. Cochran, aged 45, possessed Airline Transport Pilot Certificate No. 445006 with aircraft multiengine and single-engine land ratings and type ratings in Lockheed Constellation CV-880/990 aircraft and a flight instructor's certificate for Constellations. His most recent first-class medical certificate was issued October 18, 1967, with no limitations or waivers. The captain had 12,895 flying time including 1,390 hours in CV-880 aircraft. He had flown 169 hours in the last 90 days and 57 hours in the last 30 days. His last line check was completed May 20, 1967, and his last proficiency check was November 8, 1967. He had been on duty 4:20 hours, including 3:20 of flight time when the accident occurred. His rest period prior to reporting for duty was 14:23 hours.

First Officer Robert P. Moyers, aged 33, possessed commercial pilot's certificate No. 1394932 with aircraft single-engine and multiengine land, instrument, and Boeing 377 ratings. His first-class medical certificate was issued May 19, 1967, with no limitations or waivers. He had approximately 2,647 hours total flying time including 447 in CV-880 aircraft. He had flown 192 hours in the last 90 days and 66 hours in the last 30 days. His last proficiency check was completed February 13, 1967. His rest time and duty time were the same as the captain's.

Flight Engineer Jerry L. Roades, aged 29, possessed flight engineer certificate No. 1743383, issued March 1, 1967, with a turbojet rating, and commercial pilot's certificate No. 1544014, issued September 21, 1966, with airplane single-multiengine land and instrument ratings. The flight engineer had 3,479 pilot hours, none of which were in the CV-880, and 288 hours as a flight engineer in the CV-880. His most recent first-class medical certificate was issued May 25, 1967, with no limitations or waivers.

The four stewardesses were regularly employed by TWA for this duty and their training was current.

Aircraft Information

Convair 880, N821TW, the property of Trans World Airlines, Inc., received an airworthiness certificate January 8, 1961, and the certificate was still valid at the time of the accident.

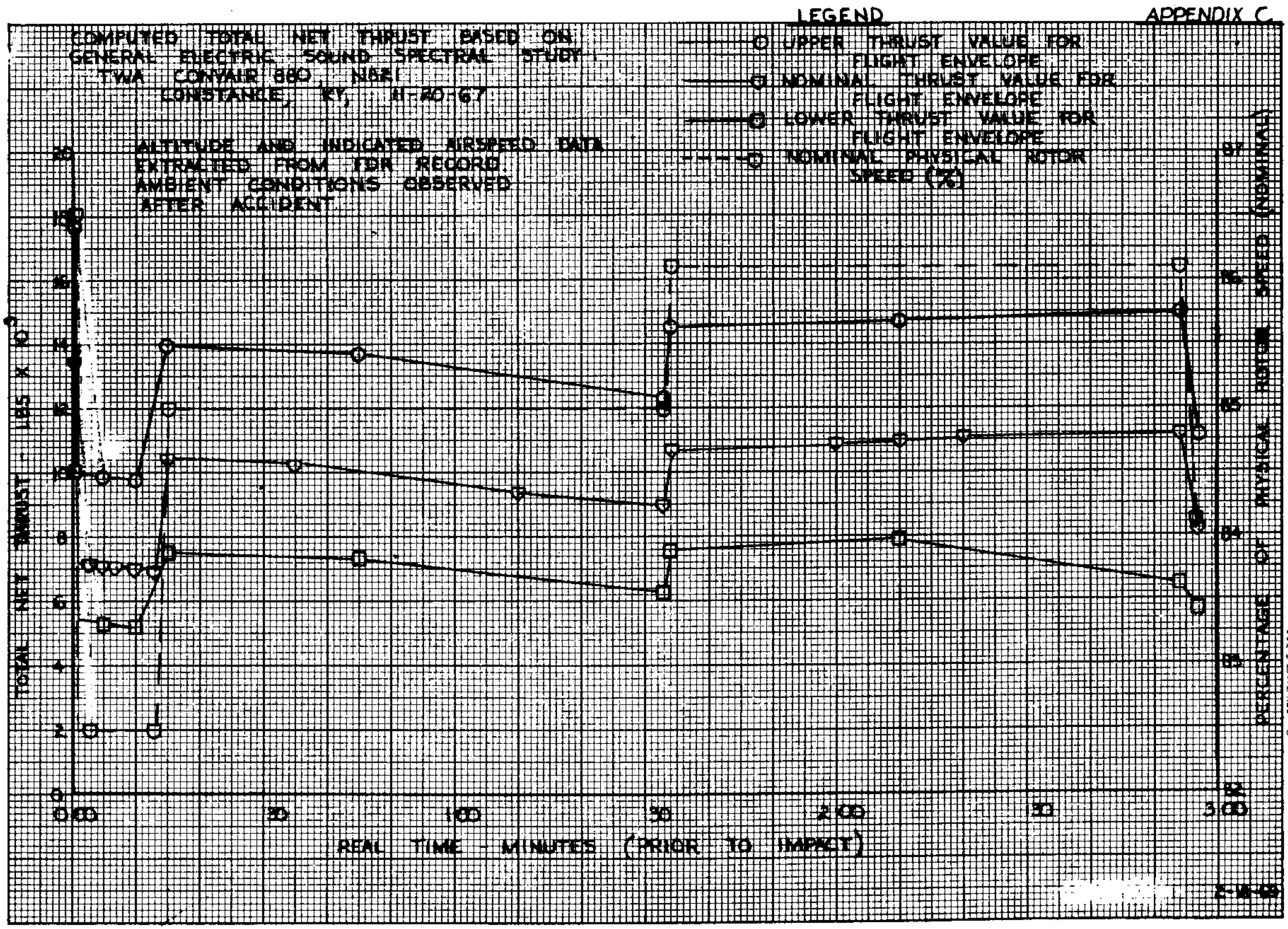
The aircraft records show that the aircraft was manufactured December 20, 1960, and was placed in service by TWA January 12, 1961. The aircraft had a total airframe time of 18,850 hours 1/ and received a Base Overhaul 5,640 hours before the accident. The only known maintenance discrepancy of the aircraft at the time of its departure from Los Angeles was an inoperative No. 1 generator, which was caused by a malfunctioning Constant Speed Drive unit, and the CSD was disconnected by TWA maintenance personnel. A Time Controlled Service Check was completed on the aircraft November 19, 1967, 10 hours before the accident, and no significant pitot static system writeups were noted.

There had been a number of maintenance writeups regarding discrepancies with various components of the flight instruments; however, the records indicate that these writeups had been cleared in accordance with the existing maintenance procedures. In no case reported were both the captain's and first officer's altimeters malfunctioning at the same time.

The aircraft was equipped with four General Electric CJ-805-3A engines:

Position	Total Time (Hours)	T.S.O.
1	14,679	4,076
2	12,355	620
3	13,612	4,127
4	15,379	1,751

1/ All times reported to the nearest hour.


APPENDIX C
COMPUTED TOTAL NET THRUST BASED ON
GENERAL ELECTRIC SOUND SPECTRAL STUDY
TWA CONVAIR 880, N821
CONSTANCE, KY, 11-20-67
ALTITUDE AND INDICATED AIRSPEED DATA
EXTRACTED FROM FDR RECORD
AMBIENT CONDITIONS OBSERVED
AFTER ACCIDENT
LEGEND
UPPER THRUST VALUE FOR FLIGHT ENVELOPE
NOMINAL THRUST VALUE FOR FLIGHT ENVELOPE
LOWER THRUST VALUE FOR FLIGHT ENVELOPE
NOMINAL PHYSICAL ROTOR SPEED (%)
TOTAL NET THRUST - LBS x 10
0
2
4
6
8
10
12
14
16
18
20
PERCENTAGE OF PHYSICAL ROTOR SPEED (NOMINAL)
82
83
84
85
86
87
0:00
:30
1:00
:30
2:00
:30
3:00
REAL TIME - MINUTES (PRIOR TO IMPACT)

C
O
P
Y

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

January 17, 1969

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

Dear Mr. Thomas:

Accidents which occur during the approach and landing phase of flight continue to be among the most numerous. They are again highlighted by some of the events of the past month that have aroused nationwide interest in air safety. Most approach and landing accidents have been attributed to improper operational procedures, techniques, distractions, and flight management. In many cases vertical/horizontal wind shear, forms of turbulence, and altimetry difficulties were, or could have been contributing factors. The phenomenon of breaking out into visual flight conditions and subsequently becoming involved in patches of fog, haze, rain, blowing snow and snow showers and other visibility obscuring forms of precipitation seems to be fairly common occurrence. The sensory illusion problem associated with night approaches over unlighted terrain or water is another likely factor about which more is being learned daily.

Other related factors are the handling characteristics of our transport type aircraft in day-to-day operations, the absence or outage of glide slope facilities, cockpit procedures, possible effects of snow or rain on dual static port systems as they could affect altimetry accuracy, and altitude awareness. These are all factors which may exist singularly or in combination. The inability to detect or obtain positive evidence, particularly such evidence as ice accretion or moisture which becomes lost in wreckage, makes it difficult, if not impossible, in many cases to reach conclusions based upon substantial evidence. It is clear that had all ground and airborne navigational systems been operating accurately and had the flight crews been piloting with meticulous reference to properly indicating flight instruments, these accidents would not have occurred.

In this light, and with the number and frequency of approach and landing phase accidents under similar weather and operating environments, we believe that certain immediate accident prevention measures need to be taken. We believe that preliminary to the successful completion of our investigations into the factors and causes of the recent rash of accidents, renewed attention to, and emphasis on recognized good practices will tend to reduce the possibilities of future accidents.

Pilots, operators and the regulatory agencies should renew emphasis on -- and improve wherever possible -- cockpit procedures, crew discipline, and flight management. It is recommended that both the air carrier industry and the FAA review policies, procedures, practices, and training toward increasing crew efficiency and reducing distractions and nonessential crew functions during the approach and landing phase of the flight. It is specifically recommended that crew functions not directly related to the approach and landing, be reduced or eliminated, especially during the last 1000 feet of descent. Accomplishment of the in-range and landing check lists as far as possible in advance of the last 1,000-foot descent will allow for more intense and perhaps more accurate cross checking and monitoring of the descent through these critical altitudes.

It is also recommended that during the final approach one pilot maintain continuous vigilance of flight instruments - inside the cockpit - until positive visual reference is established.

In order to induce a renewed altitude awareness during approaches where less than full precision facilities exist, it is recommended that there be a requirement that during the last 1000' of final approach the pilot not flying call out altitudes in 100-foot decrements above airport elevation (in addition to airspeed and rate-of-descent). To further enhance altitude awareness within the cockpit, it is recommended that there be a requirement to report indicated altitude to Air Traffic Control at various points in the approach procedure such as the outbound procedure turn and at the outer marker position.

Consistent with and in support of the concept inherent in your Notice of Proposed Rulemaking No. 67-53, the Board urges the aviation community to consider expediting development and installation of audible and visible altitude warning devices and the implementation of procedures for their use. Additional improvements, although desirable now, are attainable only through continued research and development.

The reassessment of altimetry systems with particular regard to their susceptibility to insidious interference by forms of precipitation needs to be the subject of attention by the highest level of aeronautical research facilities and personnel. Toward this end, we are meeting with members of your staff, the National Aeronautics and Space Administration and various segments of the aviation community to initiate an assessment of possible failure modes and effects within the static system.

The possibility of development of additional altitude warning systems - external to the aircraft -needs to be explored by the aviation community. One such possibility would be a high intensity visual warning red light beam - projected up along and slightly below the desired approach glide slope - to warn of flight below the desired path.

Likewise, development is needed in the fields of radio/radar, and inertial altimetry and CRT/microwave pictorial display approach aids as possible improved replacement of the barometric altimetry system in the near future.

Modified use of existing approach radar should be further studied with regard to its adaptability as a surveillance--accident prevention--tool for nonprecision instrument approach.

During the time that we press for answers as to the causes of a number of these recent accidents, the Board urges increased surveillance, more frequent and more rigorous inspection and maintenance of altimetry systems by both the air carrier operators and the FAA; and urges also that the FAA reexamine certification requirements and procedures to determine if there is a possibility of a single failure mode of nominally dual systems which, when combined with an already existent passive failure or inadequate cockpit procedures, can invalidate dual failure protection features.

Whereas these problems have been highlighted by air carrier accidents, they should not be construed as being unique to air carrier aviation. The Safety Board considers that they are applicable to all forms of air transportation.

We know that your Administration, as well as other responsible segments of the aviation community, have been working extensively in all of these areas.

We appreciate your continuing emphasis on the safety of air carrier operations as evidenced by recent communications with your inspectors and airline management.

Your views regarding the implementation of our suggestions will be welcome.

Sincerely yours,

Joseph J. O'Connell, Jr.
Chairman

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF THE ADMINISTRATOR

FEB 6 1969

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

Dear Mr. Chairman:

I have your letter of January 17, 1969, which contained suggestions and recommendations for the prevention of accidents during the approach and landing phase of flight.

My letter of January 28, 1969, commented on a number of the items covered in your January 17 letter. Therefore, I will not repeat them here, except to reiterate that our immediate concern and followup actions are directed to the areas of adherence to established procedures, altitude awareness, winter operating procedures, and cockpit discipline and vigilance.

Our comments concerning the matters discussed in your letter are as follows:

1. Reduce distractions and non-essential crew functions during approach and landing. Instructions to our inspectors require them to review on a continuing basis cockpit check lists and procedures to assure that minimum checking will be done during the more critical periods of flight such as departures, approaches, and landings.

2. Use of in-range and landing check lists. We believe the airlines require all cockpit check procedures, particularly the in-range check list, to be completed well before the last 1,000 feet of descent. However, we will request our inspectors to doublecheck and take action where warranted.

3. Cockpit vigilance. The instructions to our inspectors referred to in item 1 above also require them to assure that cockpit check procedures are arranged so that the pilot flying devotes full attention to flight instruments. As stated in my letter of January 28, 1969, crew vigilance and cockpit discipline is one of the areas stressed in my wire to the airline presidents.

4. Altitude awareness. Over two and one-half (2½) years ago, instructions were issued to our inspectors to be sure the airlines emphasized in training and included in company manuals altitude awareness procedures to be used during climbs, descents, and instrument approaches. This is one of the areas on which we asked our inspectors to place emphasis during the accelerated inspections mentioned in my January 28 letter.

Your letter recommended that during the last 1,000 feet of the final approach the pilot not flying be required to call out altitudes in 100 foot increments. The altitude awareness procedures that we have asked the carriers to adopt require the pilot not flying to call out, during the final 1,000 feet of the approach, 500 feet above field elevation, 100 feet above minimums, and minimums. We believe this procedure is preferable, since it serves to keep cockpit conversation to a minimum and at the same time, assures pilot altitude awareness. This procedure also reduces pilot workload.

5. Pilot reports to ATC of altitudes during instrument approaches. Adoption of this suggestion would significantly increase frequency congestion and increase crew and controller workload. We believe our efforts in the areas of pilot training and education will prove to be the most beneficial course of action.

6. Altitude alerting devices. I appreciate your support of the rule which became effective on September 28, 1968, which will require by February 28, 1971, both visual and aural altitude alerting signals to warn pilots of jet aircraft when approaching selected altitudes during climbs, descents, and instrument approaches.

7. Altimetry systems. With respect to your suggestion that an assessment be made of possible failure modes of altimeter static systems, we plan to participate with NASA and the aviation industry to assist in such a program. Development and testing to validate such improvements will be required. At this time, we know of no practical replacement for the barometric altimeter.

8. Additional altitude warning systems. Your suggestion concerning visual glide path warning would not provide complete information concerning the optimum glide path as does the Visual Approach Slope Indicator (VASI) systems which are installed at many runways throughout the country. We plan to continue to install these systems in accordance with current criteria within the limits of funds appropriated for this purpose.

9. Development to replace barometric altimeter systems. The use of inertial altimetry could be investigated, but must be considered as a long range R&D program. CRT/microwave pictorial display (radar mapping) has been evaluated by the military as an additional approach aid monitor. The FAA as yet does not have detailed information, since this equipment, until recently, was classified. However, we plan to obtain additional information and will look into the matter further.

10. Modified use of existing approach radar. I would appreciate receiving from you additional details on the modified use you had in mind, so that we can more properly evaluate and respond to your suggestion.

11. Inspection and maintenance of altimeter systems. On January 29, 1969, representatives of our Flight Standards Service met with ATA's Engineering and Maintenance Advisory Committee to review and discuss altimetry problems. The airlines are monitoring the operation of these systems and reviewing their maintenance procedures. ATA advised us at this meeting that few troubles are being experienced or reported by the flight crews. This is confirmed by our analysis of the MRR reports. Nevertheless, ATA has agreed to reactivate its Altimetry and Static System Maintenance Subcommittee to further explore this area and intends to review and update material previously published on this subject.

12. Certification of altimeter systems. On August 16, 1968, we issued a Notice of Proposed Rule Making proposing revisions to Part 25 of the Federal Aviation Regulations to require in systems design means to assure continued safe operation following any single failure or combination of failures not shown to be extremely improbable. Industry comments are now being reviewed and analyzed.

Your interest in these problems is appreciated and I can assure you we will continue to press for solutions to them.

Sincerely,

D. D. Thomas

D. D. Thomas
Acting Administrator

AIR LINE PILOTS ASSOCIATION
MUNSEY BUILDING, 1329 "E" STREET, N.W.
WASHINGTON, D.C. 20004
(202) 347-2211
AFFILIATED WITH A.F.L.-C.I.O.

January 27, 1969

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

Dear Mr. O'Connell:

We have read your January 17th letter to Mr. D.D. Thomas with a great deal of interest. We would like to comment both favorably and unfavorably.

We were very pleased that on page two third paragraph from the bottom refers to a "Reassessment of Altimetry Systems". The entire contents of this paragraph has our complete approval and appreciation. Altimetry development and reliability is a subject which the Association has been stressing as in urgent need of attention.

We are also pleased to see NTSB urging the developing and installation of "Audible and Visual Altitude Warning Devices", since we have been on record for many years in regard to pointing out a demonstrated need exists for such devices.

We continue to be greatly concerned that the type of accidents continuing to occur all too frequently during an approach to a landing are apparently no different than those that have been occurring for many years due to the lack of the best available equipment and landing aids both in the airplanes and guidance from ground installed electronic landing aid equipment.

The Association we believe is justifiably concerned to any inference such as contained in the NTSB letter quoted as follows:

> "Had the flight crew been piloting with meticulous reference to properly indicating flight instruments, these accidents would not have occurred."

All pilots be they private, military or airline, fly their airplanes with meticulous care while making an instrument approach toward a landing for obvious reasons. Since instrument flying occurs without any visual reference to the ground the success of an instrument flight is dependent upon the "Properly Indicating Flight Instruments". We believe the choice of wording with regard to a pilot not using meticulous reference to properly indicating flight instruments can be inadvertently misleading to the public by infering carelessness or negligence.

We are also concerned that the NTSB letter infers that there is not sufficient emphasis in using recognized good operating practices. We refer to the paragraph that follows:

> "In this light, and with the number and frequency of approach and landing phase accidents under similar weather and operating environments, we believe that certain immediate accident prevention measures need to be taken. We believe that preliminary to the successful completion of our investigation into the factors and causes of the recent rash of accidents, renewed attention to, and emphasis on recognized good practices will tend to reduce the possibilities of future accidents."

Our comments to the above are that we believe neither the carriers nor the pilots overlook using any "Recognized Good Practices". Here again, there is an inference which is misleading to the lay public and airline passengers.

In our view the most tangible means that would immediately "tend to reduce the possibility of future accidents" is a program for expediting installation of improved landing aids and getting on with the long delayed need for updating our airports so that the new airline transports are not squeezed into obstruction-bound short runways. Overcoming airport obsolescent requires the same ruthless program that is used to make such remarkable progress in overcoming highway obsolescence.

The Association points out that there are approximately 6 million takeoffs and landings annually by airline pilots and thereby indicating a high degree of professional airmanship and also indicating that when accidents do occur in the vicinity or on an airport the incident or accident should be carefully investigated with particular emphasis on the possibility of instrumentation reliability, lack of landing aids, or lack of airport safety standards, such as inadequate runway length, runways surrounded by obstructions and a lack of sufficient numbers of runways to minimize the hazards associated with take offs and landings on slippery runways when strong crosswinds occur.

Again we commend the NTSB for bringing forth several items requiring immediate attention which will enhance air safety. We also point out that while we favor providing the public with information regarding the cause of airline accidents we respectfully recommend that the NTSB would do well to coordinate with other segments of the airline industry such as the ATA and ALPA. This would enable obtaining the view points of other aviation organizations vitally interested in air safety for consideration by the NTSB when providing information for the public relating to airline accident causes.

Rest assured of our interest and appreciation for your continued cooperation in our mutual efforts to increase air safety.

Sincerely yours,

AIR LINE PILOTS ASSOCIATION

Theo. G. Linnert

Theo. G. Linnert, Director
Engineering & Air Safety Dept.

TGL/bk

cc: C.H. Ruby

COPY

January 31, 1969

Mr. Theo. G. Linnert, Director
Engineering & Air Safety Department
Air Line Pilots Association
Munsey Building
1329 E Street, N. W.
Washington, D. C. 20004

Dear Mr. Linnert:

I have your letter of January 27, 1969, commenting "both favorably and unfavorably" on our safety recommendation of January 17, 1969, addressed to David D. Thomas, FAA Acting Administrator.

I can readily understand that ALPA would be sensitive to anything that might impute less than meticulous attention to his task by any ALPA flight crewmember. Such was not, of course, our intention or the thrust of our letter, although I am sure you would agree, on reflection, that such inattention can occur, however rarely.

I might suggest that the quotation in your letter, taken out of context as it was, creates precisely the impression you avow a desire to avoid, and to correct any misapprehension your letter may have created I quote what we actually said in this connection:

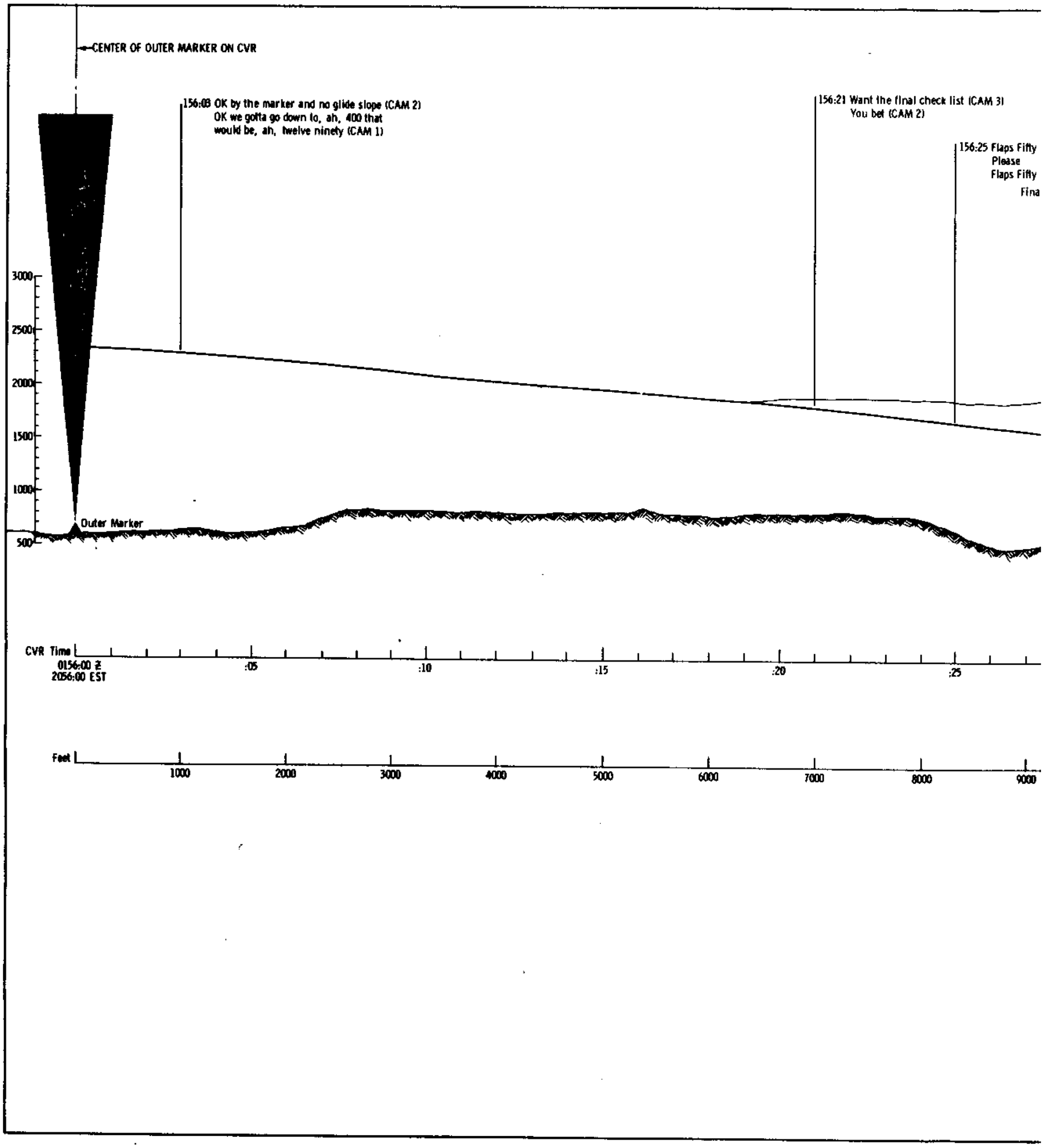
> "It is clear that had all ground and airborne navigational systems been operating accurately and had the flight crews been piloting with meticulous reference to properly indicating flight instruments, these accidents would not have occurred."

The underlined part is what your letter quoted and obviously tends to pervert both what we said and what we meant.

Sincerely,

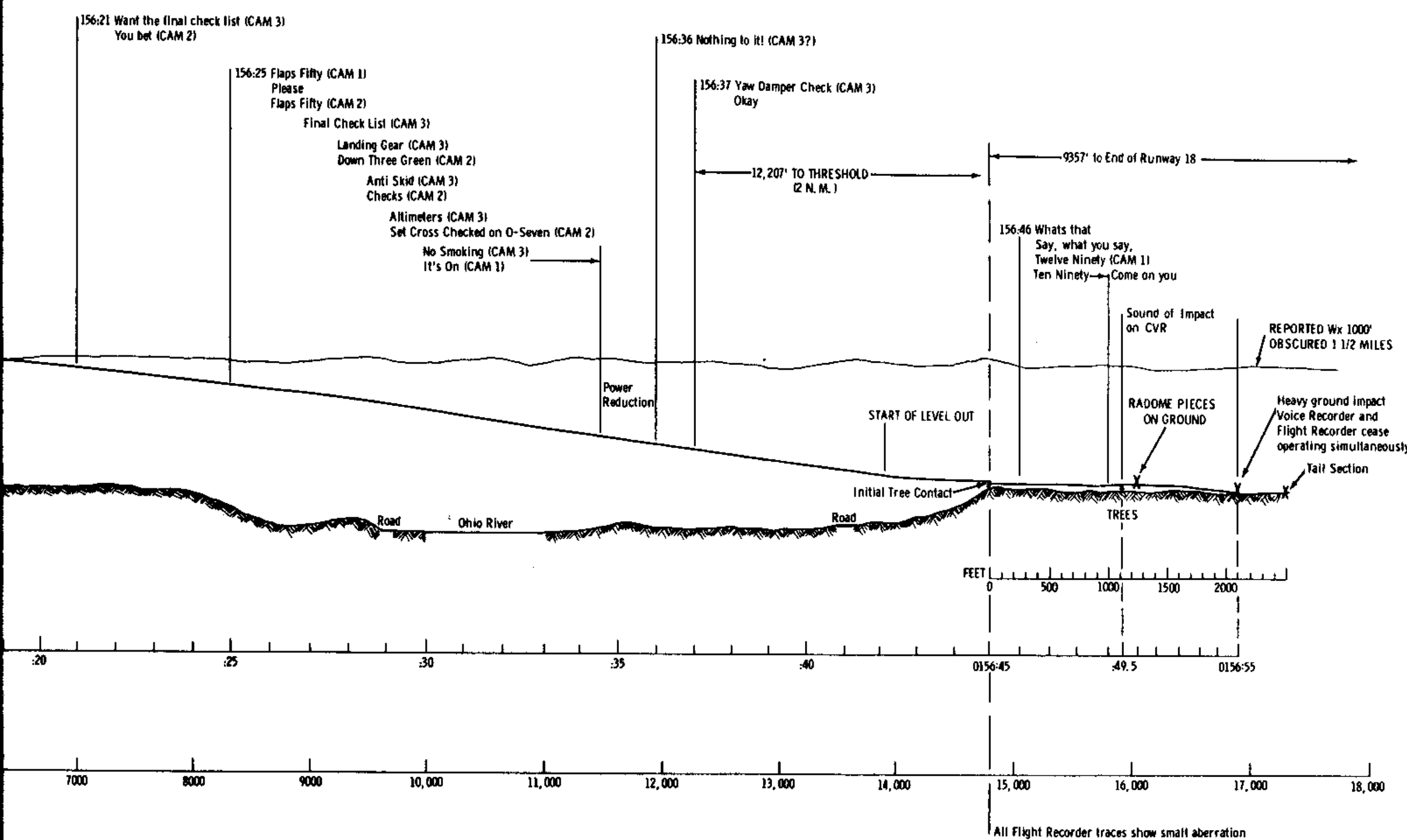
/s/ Joseph J. O'Connell, Jr.

Joseph J. O'Connell, Jr.
Chairman



CENTER OF OUTER MARKER ON CVR
156:08 OK by the marker and no glide slope (CAM 2)
OK we gotta go down to, ah, 400 that
would be, ah, twelve ninety (CAM 1)
156:21 Want the final check list (CAM 3)
You bet (CAM 2)
156:25 Flaps Fifty
Please
Flaps Fifty
Fina
3000
2500
2000
1500
1000
500
Outer Marker
CVR Time
0156:00 Z
2056:00 EST
:05
:10
:15
:20
:25
Feet
1000
2000
3000
4000
5000
6000
7000
8000
9000

"APPENDIX E"



NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
BUREAU OF AVIATION SAFETY
Washington, D.C.

TRANS WORLD AIRLINES C-880, N821TW
CONSTANCE, KENTUCKY
NOVEMBER 20, 1967

INVESTIGATION AND HEARING

1. Investigation

The Board received notification of the accident at approximately 2200 e.s.t. on November 20, 1967, from the Federal Aviation Administration. An investigating team was immediately dispatched to the scene of the accident. Working groups were established for Operations, Air Traffic Control, Witnesses, Weather, Human Factors, Structures, Powerplants, Systems, Flight Data Recorder, Maintenance Records, Cockpit Voice Recorder, and Special Studies. Interested Parties included: the Federal Aviation Administration; Trans World Airlines, Inc.; Convair Division of General Dynamics Aircraft Corporation; General Electric Corporation; Bendix Corporation; Air Line Pilots Association; Flight Engineers International Association; Air Traffic Controllers Association; International Association of Machinists; Kentucky State Police; Boone County Coroner; Federal Bureau of Investigation; Transport Workers Union; U. S. Weather Bureau; and the Armed Forces Institute of Pathology.

The on-scene investigation was completed on November 28, 1967.

2. Hearing

A public hearing was held at Cincinnati, Ohio, on February 27-29, 1968. Parties to the Investigation included: the Federal Aviation Administration; U. S. Weather Bureau; Trans World Airlines, Inc.; Convair Division; General Dynamics Aircraft Corporation; Kollsman Instrument Corporation; Air Line Pilots Association; and Air Traffic Control Association.

3. Preliminary Reports

An Interim Report of Investigation summarizing the facts disclosed by the investigation was published on December 6, 1967. A summary of the testimony which was taken at the public hearing was published by the Board March 15, 1968.

GPO 878-576