SA- 331 CIVIL AERONAUTICS BOARD File No. 1-0031

AIRCRAFT ACCIDENT REPORT

REVISED*

ADOPTED: February 11, 1965 **RELEASED:** February 17, 1965

CAPITAL AIRLINES, INC.,
VISCOUNT, TRI-CITY AIRPORT
FREELAND, MICHIGAN
APRIL 6, 1958

SYNOPSIS

At 2319, April 6, 1958, a Capital Airlines Viscount, N7437, crashed and burned near Tri-City Airport, Freeland, Michigan. All 44 passengers and the 3 crew members were killed.

Capital Airlines Flight 67, a regularly scheduled flight between New York, New York, and Chicago, Illiniois, was making final approach at Freeland by visual reference to the ground when the accident occurred. While making a left turn to final approach the aircraft was flown beyond the extended centerline of the runway and its bank was steepened considerably to effect realignment. The aircraft was observed to return to level flight and pitch steeply to the ground. Weather observations at the time indicated a ceiling of approximately 900 feet, rather severe gusty surface winds, and moisture and temperature conditions conducive to a rapid accumulation of ice on the airframe. The stall warning device of the aircraft is believed to have been inoperative at the time of the accident.

<u>The Board determines that the probable cause of this accident was an undetected accretion of ice on the horizontal stabilizer which, in conjunction with a specific airspeed and aircraft configuration, caused a loss of pitch control</u>.

As a corrective measure the Board brought to the attention of the Civil Aeronautics Administration the necessity of having the stall warning device on Viscount aircraft function properly at all times. Accordingly, corrective action is being taken by the FAA and the carrier to ensure, insofar as is practicable, that this device functions as is required.

Furthermore, the inadequacies in the wind observing equipment were drawn to the attention of the Weather Bureau and more modern equipment has now been installed.

The lack of night-time visibility check points is a problem which is not peculiar to the Tri-City Airport at Freeland. Discussions with the Weather Bureau regarding this problem have revealed that they hope to overcome the problem to a large extent by installing automatic runway visibility measuring equipment at all airport weather stations. This visibility program is part of the Weather Bureau's current five year plan.

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* This report is a revision of the Board's report of April 15, 1959, and reflects new evidence adduced and evaluated since that date. All new factual material in the report is underlined.

INVESTIGATION

The Flight

Flight 67 of April 6 was scheduled between LaGuardia Airport, New York, and Chicago, Illinois, with intermediate stops at Detroit, Flint, Tri-City Airport (serving Saginaw, Bay City, and Midland), Michigan. N7437, the aircraft to be used on this flight, was flown from Cleveland, Ohio, this date and, because of weather and field conditions at LaGuardia, was landed at Newark Airport, Newark, New Jersey. Accordingly, Flight 67 was rescheduled to originate at Newark instead of La Guardia.

The flight departed Newark at 1916, 1 hour and 16 minutes late, with a crew of Captain William J. Hull, First Officer Earle M. Binkley, and Hostesses Ruth M. Denecke and Sue Anne Wessell. Hostess Wessell was among those deplaning at Detroit. The trip to Flint was flown in accordance with an IFR (instrument flight rules) Clearance and was routine; the aircraft landed there at 2237. 1/

Flight 67 departed Flint for Tri-City Airport at 2302 and was to be flown in accordance with an IFR clearance at a cruising altitude of 3,600 feet. At the time of departure the gross takeoff weight of the aircraft was 57,091 pounds, which was well under the allowable gross takeoff weight. According to company records the load was properly distributed. There were 44 passengers on board.

At 2306, four minutes after takeoff, the flight, pursuant to clearance instructions, reported to Flight tower that it was at 3,600 feet and was departing the Flint outer marker. At this time the tower requested the estimated time of arrival at Tri-City and was advised that it was 2315. Flight 67 was then given the following clearance: "ARTC (Air Route Traffic Control) clears Capital 67 to hold north of the Saginaw omni range, one minute pattern, right turn, maintain 3,600 feet. Expect further clearance 2320, change to company frequency for this clearance." This clearance was acknowledged and, as per instructions, the frequency was changed to that of the company at Detroit. At 2310, Capital at Detroit relayed the following clearance to the flight: "ARTC clears Flight 67 for approach at Saginaw (Tri-City) Airport. Report time on the ground to Saginaw radio." These instructions were verified.

The flight then called Saginaw ATCS (Air Traffic Communication Station) and was given the local 2300 weather observation and the runway in use, No. 5. The Tri-City Airport does not have a traffic control tower. The 2300 Saginaw weather was reported as: Measured ceiling 900 feet, overcast; visibility 3 miles; light snow showers; temperature 34; dewpoint 33; wind north-northeast 18, peak gusts to 27 knots; altimeter 29.48; comments--drizzle ended and snow showers began at 2225.

At 2316 Trip 67 advised Saginaw radio that it was over the airport. A short time later, ground witnesses observed the lights of the aircraft when it was on the downwind leg of the traffic pattern. The aircraft was seen to make a left turn onto base leg and at this time the landing lights of the aircraft were observed to come on. During this portion of the approach the aircraft was flying beneath the overcast, estimated to be 900 feet, and appeared to be descending. When turning on final, Trip 67 flew a short distance beyond the extended centerline of the runway

1/ All times herein are central standard based on the 24-hour clock.

and the turn was seen to steepen for realignment with the runway. Soon after this the aircraft was observed to level off and then to descend steeply and strike the ground. A large fire immediately erupted. Available emergency equipment was alerted and brought to the crash site. The operators of this equipment observed that there was some delay in making effective use of such equipment due in part to its inaccessibility at the time of the accident and in part to their unsuccessful attempts to initially get it operating.

The Wreckage

Investigation disclosed that the aircraft struck the ground in an open cornfield muddied from a previous rain. A large tree, approximately 65 feet high, was directly in the line of flight and 148 feet behind the point of impact. There were no marks on this tree made by the airplane during its descent. The wreckage site was 2,322 feet from the approach end of runway 5, almost directly in line with the runway. Line of sight from the main wreckage to the end of runway 5 at its centerline was 45 degrees. The entire wreckage was confined in an area almost equal to the length and span of the aircraft. It was determined that the aircraft struck the ground on its nose and the leading edge of the right wing, with this wing sufficiently forward so that its leading edge was parallel to the ground. The angle of impact was approximately vertical.

The main wreckage, consisting of the major portions of the fuselage, empennage, and wings, was found lying in an inverted position. Most of the aircraft was consumed by the intense fire which followed ground impact. There was evidence that several minor explosions had occurred. These explosions were caused by the ignition of isolated pockets of fuel which were formed after the aircraft struck the ground.

It was apparent that the nose of the aircraft struck the ground with considerable force. The lower half of the nose section, including the nose wheel bay, was compressed by impact forces into a mass one-fourth of its original size and was buried in the ground.

The upper section, which includes the front entrance; the airstair door; baggage racks; the cockpit area, including control columns, instrument panels, radio racks, pilot seats, etc., was severed from the aircraft and continued along the line of flight. Various parts of this section were found at distances ranging from 35 to 60 feet from the initial point of impact. Portions of the upper skin of the aircraft, from the windshield rearward to station 337, were found approximately 85 feet from the point of impact.

The entire wreckage was found not only within the stated small area but aircraft components were approximately in their normal positions relative to the structure of the aircraft. Both wings were severely damaged by fire and a great deal of the wing structure was melted. The bottom spar caps of the wing were completely burned out in places. The entire wing spar webbing was gone except at wing section attach points. The upper skin of the wings, which was lying adjacent to the ground because of the up-side-down position of the aircraft, in some instances, was practically all that was left. The push-pull rods, a part of the control system of the aircraft were not intact because portions of these rods, which are made of aluminum, had melted. The flight controls in the tail section were intact and functioned normally when tested. Examination of all of the damaged controls failed to reveal any evidence of their malfunctioning prior to impact.

It was determined from examination of the flap system that the flaps were selected to the 40-degree "Down" position and also that they were extended to this position.

Most of the instrument gauges were so badly damaged it was impossible to obtain readings, and the gauges which could be read were of little significance.

The fuselage was badly damaged and little could be gained from its examination. All seats from the main cabin area had been torn out and were distributed throughout the entire wreckage area. Seat belts, which were found, indicated that these belts had been fastened at the time of impact. From the rear pressure bulkhead rearward there was little damage except from external fire on the right side caused by burning fuel. The top one-third of the vertical fin and rudder was bent 90 degrees to the left on impact with the ground. This damage was caused when the aircraft turned up-side-down. The left horizontal stabilizer and elevator were essentially undamaged except for some wrinkles. There was considerable fire damage to the aircraft structure back to the rear entrance door. From this point rearward fire damage was confined to the right side.

The nose gear and the main landing gear were determined to be in the "Down" position at the time of impact.

The nose gear Dowmic switch, a part of the stall worning (stick-shaker) circuitry, was found mounted in its normal position on the aft side of the nose strut with its wires still attached. The rubber boot that covers the wires over a distance of approximately four inches from the switch had been partially burned away. However, the rubber boot over the switch plunger was still in position and was undamaged.

Prior to checking the switch electrically, a number of actuations of the plunger were made but no audible operation of the switch was heard nor could contact of the points be felt. Subsequent inspection disclosed that although the operating plunger was in the withdrawn position the rocker or armature subassembly, which supports the movable switch contacts, was in the position it assumes when the operating plunger is depressed. This position permitted the switch contacts associated with the stall warning circuit to be in contact at all times regardless of plunger position. Initial electrical checks disclosed no continuity between these contacts; however, during subsequent checks by the examining group and tests conducted by the National Bureau of Standards continuity did exist between the closed contacts.

The switch contacts in question are normally open in flight and are closed upon landing by movement of the operating plunger, whereupon the stall warning system is rendered inoperative. Upon becoming airborne the plunger is withdrawn permitting the rocker subassembly to be returned by spring force, thereby opening the contacts and arming the stall warning circuit.

It was found that the rocker would return to normal when the lower magnet was removed but would remain in the depressed position when operated with the magnet reinstalled. A similar behavior was noted with the two switch magnets interchanged. Upon restoring the magnets to their original positions, the switch operated properly and continued to do so. It was also determined that the sensing unit of the stall warning system was installed April 28, 1957, and was not calibrated prior to the accident.

In addition to the examination of the nose gear switch, the National Bureau of Standards conducted static and dynamic acceleration tests on four similar switches and the test results indicate the extreme improbability of the nose gear switch malfunction having been the result of crash impact.

All four engines and their respective propellers were forward of the wing spars in a straight line and were in about their normal positions relative to their respective attach points on the aircraft. Nos. 2, 3, and 4 engines were buried in the ground to a depth of about five feet. No. 1 engine had struck a gravel pile and had penetrated into the ground to a lesser depth. All engines lay inverted nose down with their rear portions angled 45 to 70 degrees with respect to the horizontal. The engines separated from the aircraft at their respective mount feet and adjacent structure, and as a result of impact forces were damaged in varying amounts.

The intermediate cases of all engines were broken permitting the separation of the turbine end components. These parts were found lying reasonably close to the remainder of their respective engines. All engines were damaged by ground fire following impact. There was no powerplant fire damage of the nature associated with inflight fire. Engine controls were severed in such a manner their positions prior to impact could not be determined.

All turbine shafts were broken as were three of the second stage impeller shafts. Main rotor shaft bearings as well as other bearings throughout the engines did not show any signs of operational distress. Lubrication had been adequate in each instance. The observed damage was consistent with that caused by axial loading to which these parts were subjected at impact. The high pressure turbine blades and the nozzle guide vanes of all four engines were splattered at random with bits of molten metal.

Engine accessories were functionally tested or, if this was impossible because of damage to them, were disassembled and examined. All appeared to have been capable of normal operation prior to impact. Three fuel trim actuators were recovered and these were found positioned to "full increase trim." Separation of the turbine sections from the remainder of the engines resulted in many combustion chambers coming detached. The ensuing detailed examination of the damaged engines and their accessories did not reveal any condition which indicated maloperation prior to impact.

The four propellers were imbedded in the ground adjacent to the nose sections of their respective engines. The propeller shafts of the four engines were bent generally downward with No. 1 being also bent slightly to the right. Associated with this bending was a buckling of the shaft flanges. Bending of the propeller blades was predominantly rearward. The most severe bending occurred to the blades which were uppermost as related to a normally positioned engine when rotation ceased. The propeller operating piston positions were established as soon as the propellers were removed from their imbedded positions. These positions represented the following blade angles; No. 1 propeller, 28 degrees; No. 2 propeller, 35 degrees; No. 3 propeller, 31.5 degrees; and No. 4 propeller, 25 degrees. These blade angle positions were all in a range above the flight fine pitch stop position established at 24 degrees of blade angle pitch. There was no indication that a failure or malfunction occurred to any of the propellers prior to impact.

The four-bladed Rotol propellers vary in pitch from 0 to about 56 degrees in normal operation. This is accomplished by means of a constant speed unit (governor) which is interconnected with the throttle to provide a single cockpit control lever for each engine. In flight the minimum blade angle is limited to 24 degrees by an inflight fine pitch stop. A ground fine pitch range, 0 to 24 degrees, prevents excessive turbine temperatures at low power and creates a desirable aerodynamic drag to retard the aircraft when on the ground, thereby reducing landing run. Numerous safeguards have been incorporated in the propeller circuitry to prevent the propellers from going into the ground fine pitch range while in flight. Among these are seven switches that must make contact before the propeller blades can go into the ground fine pitch range. These are: A manually operated circuit arming switch; two switches, one each on the right and left main landing gear oleo struts; and four switches, one actuated by each throttle, that are closed when the throttles are below the 14,200 r.p.m. position. In addition, two warning lights are provided to indicate when the aforementioned switches have all made contact. Also, each propeller is fitted with a switch that is actuated when the propeller blades move into the ground fine pitch range thereby illuminating an indicator light for that propeller.

The Witnesses

During the investigation a number of eyewitnesses, located on and around the airport, were interviewed. While they were not in complete agreement as to what they saw, in general it was as follows: None actually saw the contour of the aircraft in the darkness, but some did see its lights and heard the noise of the engines. They said that the aircraft was first seen on the downwind leg of the traffic pattern to runway 5 and that this leg was flown close in at an altitude of 600 feet or higher above the ground. They further stated that as the aircraft turned on base the landing lights came on and the aircraft continued on base beyond an extended centerline of the runway where a steep left turn was made for realignment. A licensed commercial pilot and other witnesses testified that the airplane was banked 50 to 60 degrees during this turn. The witnesses then described a rollout of the turn 2/ followed by a pitchover and a nose-down steep descent to the ground. It was also thought by some that immediately after the rollout of the turn the aircraft nosed up slightly accompanied by a surge of power. The lights, which were seen in varying combinations, were the navigation, landing, and taxiing lights. The wing ice lights or cabin lights were not seen. Some witnesses said that after the aircraft struck the ground, reflection from the fire lighted the scene and the tail of the aircraft could be seen momentarily in a somewhat upright position. The weather at the time of the accident was described by these witnesses as freezing drizzle and strong wind gusts. Some said that pronounced gusts occurred while the aircraft was in the landing pattern. Witnesses were asked to participate in an experiment whereby they were placed at the position from which they observed the airplane the night of the accident in order to watch the flight of a similar Viscount over a flight path believed to be that of N7437. The purpose of the experiment was to determine as near as possible the probable flightpath and altitudes. The altitude of the aircraft immediately prior to the pitchover was estimated to be between 400 and 600 feet.

The Tests

Since this accident occurred when the aircraft was flying in the low-speed range of the flight envelope, the Board decided that the flight characteristics of the aircraft in this speed range and under various operating conditions and

2/ Four of the witnesses stated that the aircraft rolled out of the turn to a level attitude. Estimates of the time the aircraft was level prior to pitchover ranged from four to six seconds.

difficulties should be explored and evaluated. Accordingly, the manufacturer was asked by the Board to conduct certain flight and simulated flight tests. These tests included the determination of exactly when the stall warning (buffet) occurs during an approach to a stall from level attitude and in a turn. These were to be accomplished with the stick shaker both operative and inoperative. Additional tests included those with certain propeller flight locks removed and others showing the effect of wing ice on the stalling speed of the aircraft.

All flight tests were conducted using a standard type Viscount 745D airplane especially instrumented to record the wanted information. The aircraft was loaded to 57,200 pounds and the center of gravity position was 0.236 SMC (standard mean chord). Throughout the tests 12,000 r.p.m. was used and excess "g" force conditions from 0.25 to 1.0 were applied in all straight power-on stalls. These stall tests indicated that a sufficient margin of airspeed existed between the stick shaker warning and the actual "g" break. A rapid change in nose-up pitch was experienced as excss "g" forces were applied resulting in an extreme nose-up attitude and a rapid decline in airspeed. The turning flight stall tests (both power on and power off: were made with the aircraft in a 30-degree bank. Again stick shaker warnings were adequate for safety; excess "g" forces were applied up to 0.5. Stalls occurred in these tests between 70 knots to 93 knots. In all stall tests recovery was positive and prompt with little loss in altitude as a result of the stall.

Flight tests were made with the inflight fine pitch stop removed on the inboard propellers. The basic conditions of overshoots and slow flight with the propellers at or near ground fine pitch were covered in these tests. The tests showed that the propeller blades remained at pitch angles above 22 degrees with power settings as low as 11,000 r.p.m. 60 pounds of torque, and a true airspeed of 90 knots. During the tests of overshoots close to the runway at true airspeeds varying from 97 to 125 knots, the aircraft handled in a normal manner at speeds down to 100 knots. Below this speed the fining of the propellers, when throttles were advanced, prevented a successful go-around without striking the runway.

The slow speed flight tests, with the same locks removed, made at true airspeeds down to 95 knots, initially resulted in a very severe yaw; this was caused by only one propeller reaching 0 degrees pitch. In another test when both propellers reached 0 degrees together there was an extremely heavy nose-down pitching moment which required great care and throttle manipulation to effect recovery; a loss of 500 feet in altitude was experienced.

In order to determine the effect of wing ice on stalling speed, wing tunnel tests were made using a 1/15th scale model. Measurements were made of lift, drag, and pitching moment for a range of incidences up to and through the stall with flaps set at 0, 30, and 40 degrees. These tests showed that the presence of ice caused a loss of lift and an increase in drag, which factors produced an increase in stalling speed and a decrease in time to stall. Any other changes in the flying characteristics were considered negligible.

Because it was believed possible that the nose-over and dive could have resulted from a stall occurring during the turn, and because the stall tests previously made by the manufacturer were all made at lesser angles of bank, the Board later requested the CAA to conduct additional stall tests more closely simulating the conditions described. These tests were made in England and again a representative of the Board was present as an observer. The same model aircraft as that involved in the accident was used and it was properly instrumented to furnish the wanted information.

Fourteen stalls were made. The aircraft weighed 56,800 pounds at the start of the tests and its weight during the final tests was calculated to be 55,700 pounds. The center of gravity was 0.236 SMC. During the tests certain conditions remained constant, the landing gear was extended, elevator trim was 0.6 divisions nose-down, and 11,600 r.p.m. was used. Flap settings varied between 20 and 40 degrees and the stick shaker was off in all but four instances.

Four of these stall tests are described in part so that a clearer understanding may be had:

Weight	56,800 pounds - - - - - - 55,700 pounds			
Flaps:	32 - 40	40	40	20 - 40
Angle of bank:	L 60	0	L 45	L 60
Stick shaker position:	OFF	ON	ON	OFF
Buffet speed (knots):	127	89.5	113	132
"G" break speed (knots):	127	82.5	109.5	132
IAS at stall (knots):	127	75	107	127
Altitude at stall:	11,200	12,000	11,310	10,550
Altitude at recovery:	10,700	11,600	11,300	10,300
Elevator force at "G" break:	84	30	66	96
Elevator force at stall:	84	62	72	73
Maximum "G"	2.2	1	1.5	2.44

In three cases the flaps were changed to a new setting during the stall at the onset of natural buffet; this temporarily destalled the wings. Throughout the tests normal recovery action was initiated after each stall and the aircraft responded in a normal manner.

In addition to the above tests performed by Vickers-Armstrongs, Ltd., the following organizations ably assisted in the investigation of this accident: British Royal Aircraft Establishment; Air Investigation Branch, British Ministry of Transport of Civil Aviation; British Air Registration Board; Eclipse-Pioneer Division, Bendix Aviation Corporation; Borden Corporation; and the National Bureau of Standards.

In the original flight tests made in England for the certification of the Viscount 700 series aircraft it was found that the natural stall warning from buffeting did not, in some configurations and power settings, extend over the speed range required by the British Civil Airworthiness Requirements. Accordingly, a stick shaker was embodied to comply with these stall warning requirements.

When this aircraft was certificated by the CAA, the presence of this stall warning device on the aircraft was accepted and the aircraft was found to comply with all of the applicable provisions of Part 4B and Part 10 of the Civil Air Regulations.

Airport and Facilities

The Tri-City Airport is located at Freeland, Michigan, at an elevation of 667 feet above sea level. It has three paved runways, the longest of which, No. 5-23, is 5,662 feet long. This runway is equipped with high intensity lights having an intensity control of five brightness stages. The other two runways are lighted to a lesser degree of intensity. These lights, together with threshold lights, a rotating beacon, and a lighted tetrahedron comprise the lighting of the landing area. Located on the airport is a low frequency nondirectional radio beacon used for ADF approaches, and terminal omni for omni approaches. The airport does not have an airport traffic control tower or a weather station. Weather and other information is furnished the pilots by a local CAA ATCS. Capital Airlines does not have radio equipment available at Tri-City Airport. All information the company wishes sent to its flights must be transmitted by longline to Detroit and then relayed to the flight or must be given the flight by the ATCS operator at Tri-City. Capital Airlines minimum ceilings and visibilities for Viscount aircraft making instrument approaches to Tri-City Airport are 500 feet and $1\frac{1}{2}$ miles.

The ATCS station at Tri-City was operated by one man at the time of the accident. This man was responsible for taking and transmitting hourly weather observations, maintaining a guard on the air-ground radio frequency, broadcasting weather observations and forecasts for a selected group of stations twice each hour, and operating the airport facilities (VOR, ADF, runway lights, etc.). There are no standard charts at the Tri-City Airport displaying visibility reference points. A table of such reference points is available and this relies upon such factors at night as automobile lights, house lights, lights on barns, etc., in determining visibility distances between 3/16th of a mile and $3\frac{1}{2}$ miles.

Ceilings are determined at night by means of a ceiling light and clinometer. During the day ceiling balloons and pilot reports are used for this purpose.

Wind velocity is determined by means of an instrument using both a light and a buzzer. The number of light flashes seen or buzzes heard during a given period determines wind velocity; wind direction is also noted by a flashing light. In order to arrive at a reasonable determination of wind conditions it is necessary for the operator to observe the instrument for at least a minute. Using this type of equipment it is impossible to accurately measure peak velocity of wind gusts.

<u>The Weather</u>

At the time of the accident a low pressure center was moving across southern Michigan and had just moved eastward between Detroit and Toledo. As Flight 67 approached Tri-City, ceilings were between 900 and 1,100 feet with visibility reported as being three to four miles. There was light snow and a freezing drizzle. Surface winds were reported from the north-northeast 18 to 27 knots. At 1930, the U. S. Weather Bureau issued a "flash advisory" pertinent to the time and place of the accident forecasting low ceilings and visibilities, rain or snow, fog, possible freezing drizzle near the surface with moderate and occasionally heavy icing in the clouds. Company dispatch did not call this advisory to the attention of the crew. Pilots of two other Capital Airlines aircraft, which landed at Tri-City a short time prior to the accident, reported that both moderate turbulence and icing conditions were encountered. The captain of a Capital Constellation, which landed just 13 minutes prior to this accident, testified that his aircraft had approximately one inch or more of ice on its wings on landing. This conditions was not reported to either the company or CAA.

Capital Airlines does all the dispatching of its aircraft from Washington. On the route from New York to Chicago one dispatcher handles the flights as far as Detroit and from that point on the flight is the responsibility of another dispatcher. Capital Airlines' weather office in Washington is associated with dispatch and operates on a strictly advisory basis. One forecaster is employed for each shift. It is his duty to prepare and analyze surface weather charts every six hours covering the company's routes. Each dispatcher is briefed on anticipated weather trends as he comes on duty and the forecaster attempts to point out to the proper dispatcher any significant weather developments which occur over his routes. The company's weather office does not provide any weather information directly to pilots but works exclusively through the dispatcher. All pertinent weather information is available to pilots when the flight's papers are being prepared.

Wing Flap Operation

Wing flaps on Viscount aircraft may be extended over a range of 47 degrees. This is accomplished by four flap lever positions which represent respectively 20, 32, 40, and 47 degrees of extension. The company Flight Training Manual recommends pilots not extend flaps beyond 20 degrees at airspeeds in excess of 142 knots. Full flap extension requires approximately 30 seconds. The manual further recommends that the landing gear and landing lights not be lowered at speeds above 160 knots.

Company-recommended approach speeds are "A - Enter airport pattern 140K and 20° flaps - turn on final. B - Extend gear and 32° flaps - reduce to 120K and 'stabilize approach.' - Extend 40° flaps - reduce to 110K 'over the fence speed.' D - Just prior to touchdown - cut throttles, extend 47° flaps."

Effects of Ice Accretion on the Horizontal Stabilizer

During the investigation of another Viscount accident in 1963[3/] new information became available to the Board regarding the behavior of aircraft with a concave buildup of ice on the horizontal stabilizer. Included was information concerning two Viscount icing incidents.

In one case the Viscount operated in an icing condition an estimated 10 to 12 minutes. Because of the short time the aircraft was in clouds and a surface temperature of 37 degrees, airframe anti-icing was not used. When clear of clouds no ice was visible on the leading edge of the wings. When the landing flaps were lowered to 40 degrees at a reported airspeed of 135-140 knots, the nose dropped and the pilot was unable to arrest this action with the elevator control. Flaps were retracted to 32 degrees, control regained, and the aircraft landed safely. Four minutes after touchdown, an examination of the aircraft revealed that the wings were clear of ice but a concave buildup was observed on the leading edges of the tailplane and the vertical stabilizer. This ice was about 3/4 inch thick at the center and 1½ inches thick at the edges extending 3 inches above the horizontal tail.

A similar incident occurred to another aircraft which had been exposed to icing conditions for an estimated two minutes after the leading edges of the wings were seen to be clear of ice. In this case the aircraft was recovered from severe pitching oscillations when the airspeed decreased to 130-135 knots. The oscillations began when flaps were lowered to 40 degrees on the final approach. Examination of the flight recorder tape showed that the aircraft lost 200 feet during the pitch oscillations with peak acceleration of -.76 g and +2.3 g before control was regained. When

3/ Vickers Viscount 812, N242V, Continental Air Lines, Inc., Municipal Airport, Kansas City, Missouri, January 29, 1963; SA-370.

the aircraft was inspected after landing light rime ice was found on the wings and radome, the propellers were clean and dry, but the horizontal and vertical stabilizers had a concave buildup of rough rime ice. This cup-shaped ice was approximately 1 inch thick with horns extending diagonally upward and downward, approximately 1-1/2 inches into the airstream.

Additionally, there have been three aircraft accidents of which one was a Viscount, which the Board has determined were caused in whole or in part by an accretion of ice on the horizontal stabilizer that disrupted the airflow over and under the horizontal tail surfaces.

As a result of this latter Viscount accident the Board requested the manufacturer to conduct wind tunnel tests to determine the effect on various handling characteristics of the Viscount aircraft.

These tests revealed that horn type ice formations can be developed on the leading edge of an unheated airfoil in an ambient temperature range of -5°C to -10°C. In this range the tests indicated that the time required to produce 1-1/2 inch horn lengths was about 20 minutes with the continuous maximum liquid water concentration required by the British Civil Airworthiness Requirements (BCAR) or 10 minutes with twice this concentration of water content. The BCAR concentration is 0.72 grams per cubic meter with a mean water driplet size of 20 microns.

The manufacturer's wind tunnel tests indicated that horn type ice of the above magnitude on the horizontal stabilizer leading edge had a severe effect on the handling characteristics of the test vehicle under conditions where a large angle of attack was obtained on the horizontal stabilizer.

The aircraft anti-icing system has demonstrated a capability to prevent the formation of horn type ice or to shed the ice, within one minute of the application of heat, if it has been allowed to form before the anti-icing is turned on. 4/

Pilot's Experience

Captain Hull was a veteran pilot who had been with Capital Airlines 17 years. He had approximately 1,700 flying hours on Viscount aircraft and a total of more than 16,000 hours on all aircraft. He was known to be a careful and conservative pilot.

Analysis

From all available evidence the Board believes that the aircraft structure, its control surfaces, and powerplants were in proper operating condition prior to the crash. Although the flight control linkages could not be examined in their entirety,

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4/ With the airframe anti-icing system operating normally, the complete heated areas on upper and lower surfaces can be maintained clear of ice. Small isolated runback ice accretions will occur behind the heated area. With one heat exchanger inoperative enough heat is available to keep the leading edge clear of ice, although a spanwise ridge of ice will form. The amount of runback icing collected during the test produced no significant lift distribution or hinge moment changes.

because of damage caused by the intense fire, those portions examined showed no evidence of a control malfunction.

The Dowmic switch that arms the stall warning system when the aircraft is airborne was found to be malfunctioning after the crash. Examination of the switch and acceleration tests conducted on similar switches indicate strongly that the malfunction existed prior to the accident.

In the course of its investigation the Board was provided test data by Vickers-Armstrongs, Ltd., concerning the effects of heat upon the Dowmic switch, and it was suggested that the malfunction of the subject switch could have been the result of its being heated in the fire that followed inpact. The physical evidence indicates that the switch was subjected to crash fire heating; however, the Board notes that the behavior of switches heated in laboratory tests does not coincide with the behavior of the subject switch. The specimen switches either failed to function at all after heating or at best they functioned intermittently, whereas the subject switch, following removal and reinstallation of its magnets operated repeatedly with normal switching action.

Similar malfunctioning of Dowmic switches has been experienced by Capital Airlines in normal fleet operation without the switches having been subjected to high temperatures. One such malfunctioning switch was intercepted and examined by a CAB investigator as it was returned for overhaul. It had been removed as an "inoperative" unit. This switch repeatedly failed to open its contacts when the plunger was released unless it was given a sharp blow with the hand. Later on, without having tampered with it in any way, the switch was found to operate normally and subsequent examination at the National Bureau of Standards failed to disclose any apparent reason for its earlier malfunction.

The stick shaker is designed to warn the pilot of an impending stall and this is accomplished by means of the ability of the device to sense the angles of attack during an approach to a stall. The device is further designed to furnish the pilot an adequate warning under all flight attitudes normally experienced during transport flight. Under the conditions of flight Captain Hull is believed to have experienced this night, had the stick shaker been operating the warning should have been approximately 15 knots before the "g" break. During the flight tests which were performed subsequent to the public hearings, the tests made at banks of 60 degrees did not have the stick shaker in operation. Therefore, the above figure is an approximation based on calculations made from actual flight test data.

The detector unit of the stall warning system had been replaced sometime prior to this flight. In view of the fact that this unit was not calibrated by flight testing prior to the flight, there is no assurance that an adequate stall warning would have been given, even had the Dowmic switch functioned normally.

During the investigation, it was determined that the aircraft while flying at an altitude between four and nine hundred feet above the ground pitched over and dived nose-down striking the ground in or near a vertical position while on a northeasterly heading. There are a number of facts which point to this conclusion. The open flat terrain presented a clue, an undisturbed tree 67 feet high, 148 feet behind the wreckage and in line with the flightpath of the aircraft. While the fact that this tree was not damaged does not necessarily indicate a steep impact angle of the aircraft it does establish a minimum approach angle of 22 degrees. Other facts which definitely point to a steep impact angle are:

1. There were no trenches, craters, or gouges in the ground except where the wreckage lay.

2. There was no evidence of cartwheeling, bouncing, or of the aircraft striking the ground with any horizontal velocity in any manner which would produce wreckage scatter over a large area; in fact, the wreckage was confined to a small area.

3. The engines were buried inverted about four or five feet in the ground, Nos. 1, 2, and 3 at a 45-degree angle and No. 4 at a 70-degree angle.

4. The right wing leading edge had trenched the ground next to and extending from the No. 4 engine for a distance equal to the partial span from this engine to the wing tip.

5. The nose gear received only minor damage and no impact marks were found on it except on the torque link.

6. The main landing gear was found extended, locked, and undamaged by impact.

7. The forward floor beams, stations 22 to 132, collapsed to form a mass 30 inches deep; each of these beams was displaced only two inches higher than the next rearward beam. This entire mass was buried directly under the No. 132 bulkhead.

The fact that the aircraft was found inverted is explained in this manner: Evidence indicates that it struck the ground in a vertical or near vertical position and that the rotational forces present during the descent caused it to continue over on its back with the engines contacting the ground at some angle beyond the vertical. This is substantiated by the manner in which the propeller blades were bent; the bending downward of all four propeller shafts; the comparably little damage to the nose gear strut; the crushing downward of the outer eight feet of the leading edge of the left wing into two separate folds; the nature of the damage to the windshield, the forward VHF antenna, and the control pedestal and fuselage skin.

Also, by extrapolation of certain data taken from NACA TN4158, "Accelerations in Transport Airplane Crashes," agreement was found to exist between these results and the Board's conclusions with respect to the angle of impact.

In an effort to determine the cause of the sudden pitchover and steep descent, considerable study was given to the propellers and their related systems with particular significance placed on the possible movement of the blades below the flight fine pitch stops during the approach. It has been determined that such a malfunction of one propeller, whereby the inflight fine pitch stop was withdrawn thus permitting the blades to move to a low pitch, would not initiate an abrupt maneuver such as occurred in this instance. Furthermore, the electro-hydraulic stop as well as inherent propeller operating characteristics provide safeguards which practically eliminate the chances of such an occurrence creating a hazardous situation. This conclusion confines the study to those portions of the propeller system that are common to all four propellers.

The circuitry, which permits withdrawal of the inflight fine pitch stops after the aircraft is on the ground, is so arranged that a double fault must exist to accomplish this function in flight. Furthermore, the existence of such a double fault would be indicated by warning lights in the cockpit and precautionary measures to counteract such a development would have been available to the crew. In addition, a test circuitry to detect a single fault in either the positive or negative side of the circuit is provided. Consequently, it is considered that the propeller inflight fine pitch stop control circuitry provides protection against inflight withdrawal of the stops to such a degree that unwanted withdrawal did not occur in this instance.

The inherent propeller-engine operating characteristics are such that a considerable degree of protection against insurmountable drag during approach is provided. This is true in that the propeller is being governed in accordance with engine power and airspeed throughout the approach. High drag is developed only at low airspeeds, 108 knots or less, and with throttles completely retarded. The blade angle would remain above the inflight fine pitch stop with as little as 11,000 r.p.m., with power applied. It is believed, therefore, that the inherent operating characteristics of the propeller would preclude any high drag situation occurring during the final phase of a normal approach. This has been substantiated by both test flights and propeller wind tunnel tests.

There is no question of the crew's competence to fly Viscount aircraft. Both captain and first officer had considerable flying time in Viscounts, and both were properly certificated by the CAA. As stated before, Captain Hull was known by those close to him and by the CAA to be a careful and conservative pilot.

From the witnesses it was learned that the downwind leg of the traffic pattern was flown close in. It was also revealed that the aircraft, when on the base leg, flew beyond the extended centerline of the runway and that a steep left turn in the form of an "S" was made for realignment. Witness observations indicate that the aircraft rolled out of the turn to a level attitude for a few seconds followed by a momentary nose-high attitude and then pitched into a near vertical dive to the ground.

If the turn to the final approach was conducted at or near the normal approach speed, the danger of wing stall would be greatest during the steepest portion of the turn. Once the aircraft rolled level, barring any rapid speed deterioration, the stall speed margin would again increase thereby minimizing the posibility of a stall after that point.

Evaluation of new evidence brought to the attention of the Board during the investigation of recent Viscount accidents and incidents has revealed that horn shaped or concave ice accretions on the leading edge of the horizontal stabilizer, at specific negative angles of attack, can induce an uncontrollable nose-down pitching moment. This type of ice was reproduced in wind tunnel tests conducted by Vickers-Armstrongs. It was indicated that from 10 to 20 minutes was required to establish horn like ice formations of the type which could cause airflow separation over the horizontal stabilizer. Differences in the time required to produce the ice varied with the water droplet size and continuous liquid water concentration.

It is known that a negative angle of attack of the horizontal tail plane increases under the following conditions: A given airspeed with an increase in flap angle; a given angle with an increase in airspeed; a given airspeed and flap angle with a reduction in weight. Aircraft stability tests performed by the manufacturer showed conclusively that horn shaped ice formations on the horizontal stabilizer can result in drastic reductions in the maximum negative lift obtained by the stabilizer and can eventually cause airflow separation on this surface. Because the shape of the ice as it forms on the stabilizer is critical insofar as flow separation and loss of lift is concerned, the results of these tests could only be considered quantitatively. However, it was found that horn type ice could form on the leading edge of the horizontal stabilizer at a given angle of attack without affecting the longitudinal control of the aircraft. Yet, when the negative angle of attack is increased, the same ice formation can disrupt the airflow on the underside of the stabilizer causing airflow separation and a loss of downloading on the tail. For example, an ice formation compatible with a flap setting of 32 degrees at a constant speed, can produce airflow separation and loss of negative lift on the stabilizer when the flap setting is increased to 40 degrees.

In addition, the tests revealed that with reduction of negative lift there is a change in lift distribution such that elevator hinge moments (and therefore control column forces) are increased more than normal as up elevator is applied to counteract the pitchover. Moreover, up elevator control surface deflections could increase the flow separation to the point of reducing the down load on the stabilizer still further, resulting in a steeper nose-down pitching moment.

A review of all weather information pertaining to this flight, in addition to reports by pilots of other aircraft operating in this area, indicates that conditions were conducive to a rapid buildup of airframe ice at altitudes up to 5,000 feet. While no determination could be obtained of water droplet size or liquid water concentration, the temperature ranges in the atmosphere were within the parameters conducive to the formation of stabilizer horn type ice. Actual icing encounters experienced by Viscount pilots reveal that such formations have occurred in as little as two to three minutes.

The testing by the manufacturer indicates that the operation of either one of the two heat exchangers produces sufficient heat at the tailplane to prevent icing even under the extreme conditions tested. It was also found that heat applied following a buildup of horn type ice will remove the ice in one minute or less.

It could not be determined if the anti-icing system had been used during any portion of the flight, particularly the latter stages, as this equipment was found in the "off" position during the investigation. However, this is an approach checklist item and would normally be in the "off" position during a landing approach if an icing situation did not exist or if the crew was unaware of an accretion of airframe ice.

The existence of airframe ice is normally detected through visual observations by the crew of any such information on the aircraft surfaces, particularly the wing leading edge. In order to see ice formations during night operations the use of ice lights, which illuminate the wing leading edge, is required. Ice will also accumulate on the cockpit windshield under most icing conditions and its formation generally serves to alert the crew to an icing situation. However, the Viscount windshield is continually heated inflight and will not normally sustain large ice accumulations. Therefore, the severity of an icing situation may not be accurately measured by examination of any ice collection in this area. In addition, none of the ground witnesses observed any operation of the ice lights prior to or during the approach of N7437.

In view of the above and in conjunction with the weather conditions that existed at the time, it is entirely possible that ice could have formed on the wing and tail surfaces of the aircraft, within a short period of time, undetected by the crew.

In conclusion, the Board believes that horn type ice accumulated on the horizontal stabilizer of the aircraft during the latter stages of this flight. When the turn to the final approach course was completed the flaps were extended to the 40-degree position. The increase in flap angle caused an increase in the nagative angle of attack of the tail plane resulting in airflow separation and a drastic reduction in downloading on this surface. This, together with the pitching moment created by the extension of flaps resulted in an uncontrollable rotation about the lateral axis and a steep dive to the ground.

The only possibility for recovery from this situation would have been the immediate retraction of flaps at the moment the aircraft began to pitch down. However, it is evident that human capabilities of perception, recognition, analysis, and reaction were insufficient in the time and space restrictions of this accident to effect recovery.

Probable Cause

The Board determines that the probable cause of this accident was an undetected accretion of ice on the horizontal stabilizer which, in conjunction with a specific airspeed and aircraft configuration, caused a loss of pitch control.

BY THE CIVIL AERONAUTICS BOARD:

/s/ ALAN S. BOYD
Chairman

/s/ ROBERT T. MURPHY
Vice Chairman

/s/ CHAN GURNEY
Member

/s/ G. JOSEPH MINETTI
Member

/s/ WHITNEY GILLILLAND
Member

S U P P L E M E N T A L D A T A

Investigation and Hearing

The Civil Aeronautics Board was notified of the accident on April 6, 1958, soon after occurrence. An investigation was immediately initiated in accordance with the provisions of Section 702(a)(2) of the Civil Aeronautics Act of 1938, as amended. A public hearing was ordered by the Board which was held in two sections, the first in Saginaw, Michigan, June 3 and 4, and the second in Washington, D. C., July 8 and 9, 1958.

Air Carrier

Capital Airlines, Inc., was a Delaware corporation and maintained its principal offices in Washington, D. C. The corporation held a certificate of public convenience and necessity issued by the Civil Aeronautics Board to engage in the transportation of persons, property, and mail. It also possessed a valid air carrier operating certificate issued by the Civil Aeronautics Administration.

Flight Personnel

Captain William J. Hull, age 43, was employed by Capital Airlines on April 9, 1941. He held a currently effective airman certificate with airline transport and all other appropriate ratings. He had a total flying time of 16,050 hours, of which 1,702 were in Viscount aircraft. He satisfactorily passed his last CAA physical examination March 28, 1958. His last semiannual proficiency check was given by the company's check pilot November 30, 1957.

First Officer Earle M. Binkley, age 27, was employed by the company October 12, 1956. He held a currently effective airman certificate with commercial, airplane single-engine land, and instrument ratings. He had a total of 2,030 flying hours, of which 975 were in Viscount aircraft. His last CAA physical examination was satisfactorily taken July 23, 1957.

Hostess Ruth M. Denecke, age 28, was employed by the company July 30, 1954. Hostess Sue Anne Wessell was employed by the company April 26, 1957.

The Aircraft

Viscount aircraft, model 700 D, N7437, was manufactured August 30, 1956, by Vickers-Armstrongs, Ltd. The aircraft was equipped with four Rolls Royce model R.D.A. 6MK510 engines. The four propellers, model C.R. 130/4-20-4/12E, were manufactured by Rotol, Ltd.