## No. 2

**Braniff Airways Inc., BAC 1-11, N 1553 accident near Falls City, Nebraska, on 6 August 1966. Report, File 1-0008, dated 18 April 1968, released by the National Transportation Safety Board, U.S.A.**

### 1.- Investigation

#### 1.1 History of the flight

Flight 250 was a scheduled domestic passenger/cargo flight from New Orleans, Louisiana, to Minneapolis, Minnesota, with intermediate stops at Shreveport, Louisiana, Fort Smith, Arkansas, Tulsa, Oklahoma, Kansas City, Missouri, and Omaha, Nebraska. The flight departed from New Orleans at 1835 hours CST* and arrived at Kansas City without reported incident.

It departed from Kansas City at 2255 hours on an IFR clearance to Omaha via Jet Route 41 at FL 200. Just prior to take-off, the flight was restricted to 5 000 ft due to conflicting traffic. When the flight was about 12 miles north of Kansas City, control of the aircraft was transferred to the Kansas City Air Route Traffic Control Centre (ARTCC). Radar contact was confirmed and the flight was cleared to climb to and maintain FL 200. After some discussion with ARTCC about the weather the flight crew advised that they would like to maintain 5 000 ft to Omaha. They reported they were at 6 000 ft and ARTCC cleared the flight to maintain that altitude until 5 000 ft was available.

At 2303 hours the Kansas City ARTCC initiated a transfer of control of the flight to the Chicago ARTCC but before the transfer could be accomplished the flight requested and received permission from the Kansas City controller to deviate to the left of course. At 2306 hours the Kansas City controller cleared the flight to descend to and maintain 5 000 ft and contact the Chicago ARTCC. After some discussion of the weather as it was displayed on the Chicago controller's radar, the flight was advised that another Braniff flight, Flight 255, was on the same frequency and was at 10 000 ft climbing to 17 000 ft after departing Omaha. The crews of the two aircraft exchanged weather information and the crew of Flight 255 advised that they had encountered light to moderate turbulence from about 15 miles southeast of the Omaha airport and that it appeared they would be out of it in another 10 miles based on their radar observations. Flight 250 terminated this conversation at approximately 2308:30 hours. This was the last transmission received from the flight.

Ground witnesses stated that they observed the aircraft approach and either fly into or over a shelf of clouds preceding a line of thunderstorms that was approaching from the north and northwest, and that shortly thereafter they saw an explosion in the sky followed by a fireball falling out of the clouds. The aircraft crashed at approximately 2312 hours, 7.6 statute miles on a true bearing of 024.5° from Falls City, Nebraska**, at an elevation of 1 078 ft AMSL. Co-ordinates of the accident site were 40°10'30"N - 95°32'20"W.

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* All times are central standard based on the 24-hour clock.

** 40°10'29.8" North and 95°32'20.3" West.

1.2 Injuries to persons

| Injuries | Crew | Passengers | Others |
|---|---|---|---|
| Fatal | 4 | 38 | |
| Non-fatal | | | |
| None | | | |

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

There was minor damage to growing crops in the area.

1.5 Crew information

The pilot-in-command, aged 47, held an airline transport pilot's certificate with ratings in DC-3, Convair, DC-6/7 and BAC 1-11 aircraft. His last first-class physical examination was taken on 26 July 1966 and was passed without waivers or notations. He had completed BAC 1-11 ground school on 24 April 1965 and received his BAC 1-11 type rating on 1 June 1965. He had completed his initial line check 3 August 1965 and passed an instrument proficiency check on 7 December 1965. On 7 January 1966 his first proficiency check in the BAC 1-11 was graded unsatisfactory. However, following 2.5 hours of additional instruction he passed a re-check given by the same inspector. After this flight the inspector remarked "All work was very good ..." On 28 June 1966 the pilot-in-command satisfactorily completed his semi-annual proficiency check. He was on vacation from 1 July to 31 July 1966 and had flown on 1, 2 and 5 August 1966. Including the date of the accident, he had logged 17.5 hours in the BAC 1-11 since returning from vacation. He had flown a total of 20 767 hours including 549 hours in the BAC 1-11 of which 237 hours was night time and 25 hours was instrument time flown in the last six months. He had flown 5 hours in the preceding 24 hours and had a 17-hour rest period before beginning flying on the date of the accident.

The co-pilot, aged 39, held an airline transport pilot's certificate issued on 10 April 1965 with ratings in the Convair and BAC 1-11. His last first-class physical examination was completed on 20 August 1965 with a waiver for defective colour vision. He was initially qualified in the BAC 1-11 on 20 August 1965 and completed his line check on 8 September 1965. He had flown a total of 9 296 hours as pilot including 685 hours in the BAC 1-11. He had flown 102 hours night time in the last 90 days but had not logged any instrument time during that period.

He had flown 5 hours in the 24-hour period preceding the accident and had a 17-hour rest period prior to his departure from New Orleans.

The two stewardesses were regularly employed by Braniff Airways Inc., and company records indicated that their training was current.

1.6 Aircraft information

The aircraft was properly certificated and airworthy at the time of its departure from Kansas City, Missouri. The aircraft records revealed that the maintenance of the aircraft had been performed in accordance with the airline and Federal Aviation Regulations. On 6 August 1966 another pilot reported "yaw damper jerks pedal". The yaw damper was placarded inoperative and continued flight was approved in view of the fact that there was another yaw damper in the autopilot system and that the primary yaw damper is not a mandatory item for flight.

The computed gross weight for take-off from Kansas City was 65 679 lb and the maximum allowable gross weight for this take-off was 70 900 lb. Computed fuel burn-off was 2 090 lb and the weight of the aircraft at the time of the accident was computed to have been 63 589 lb. The centre of gravity at take-off and at the time of the accident were computed to have been within the established limits.

The aircraft was fueled with 12 000 lb of turbine engine kerosene before take-off and had approximately 9 910 lb of fuel aboard at the time of the accident.

1.7 Meteorological information

The 1845 hours aviation area forecast issued by the Weather Bureau Forecast Centre at Kansas City, Missouri, called for a cold front extending from extreme north-western Iowa southwestward to northeast Colorado moving southeast to northeastern Iowa southwestward to south-central Kansas by 0700 hours. Isolated severe thunderstorms with hail and gusts to 65-70 kt were forecast for the extreme southwestern Kansas and extreme northeastern Nebraska area until 2200-2300 hours. Turbulence was forecast to be moderate in showers and severe near thunderstorms.

This forecast was later amended by In-flight Weather Advisories and Aviation Severe Weather Bulletins. Sigmet Bravo 2, issued at 1920 hours, called for a line of thunderstorms from Mason City, Iowa, across Sioux City, Iowa, to north of Norfolk, Nebraska, with tops at 46 000 ft, moving eastsoutheast at 25 kt. A few of these thunderstorms were expected to become severe and these conditions were expected to continue after midnight. Sigmet Bravo 3, issued at 2215 hours, called for occasional short lines of thunderstorms from Goodland, Kansas, northeastward through Omaha, Nebraska, and Waterloo, Iowa. Tops were forecast to be 35 000 ft and the lines of storms were moving east-southeast at 25 kt with a few severe thunderstorms in eastern Nebraska and Iowa until midnight. These conditions were forecast to continue after 0300 hours.

Aviation Severe Weather Bulletin No. 447, issued at 2002 hours, and pertaining to the area in which Braniff 250 was scheduled to operate, contained a severe thunderstorm forecast which was valid from the time of issuance to midnight. The area covered was along a line from 20 miles west-southwest of Lincoln, Nebraska, to 40 miles south of Waterloo, Iowa, and included the area 60 NM either side of that line. This bulletin forecast a few severe thunderstorms, hail at the surface and aloft to 3/4 in. in diameter, isolated extreme turbulence, surface wind gusts up to 55 kt, and numerous cumulonimbus with maximum tops to 50 000 ft. An active squall line was forecast from extreme southeastern Minnesota to northeastern Nebraska and was expected to move southeastward at about 30 kt.

Pertinent Braniff forecasts were issued at 2000 hours. They contained an 1800 hours map analysis which reflected a stationary front from northwestern Wisconsin to the southwest corner of Colorado and an upper cold front from the northeast corner of

Nebraska to Hill City, Kansas, and on to the southeast corner of Colorado. The significant weather forecast was in part: scattered moderate rain showers and thunderstorms; moderate rain showers in Wisconsin, Minnesota, the Dakotas, and northwestern Nebraska. Most of the system was forecast to be fair to partly cloudy except in thunderstorms, moderate rain showers, or moderate rain shower areas. The twelve hour prognosis called for a stationary front from southeastern Canada westward to northeastern Wisconsin, becoming a cold front to northeastern Iowa, to the southeast corner of Nebraska, central Kansas, and to the northern Texas panhandle. Decreasing moderate rain showers and thunderstorms with moderate rain shower activity were forecast through the night with some moderate rain showers and isolated thunderstorms remaining along the fronts, especially from Kansas, northward to Iowa, Wisconsin, and Minnesota. The Jet Level Forecast issued at 1445 hours and valid from 1500 to 0500 hours called for possible moderate or greater turbulence in the vicinity of cumulonimbus activity. The en-route jet level weather forecast from Kansas City to Minneapolis was for scattered cumulonimbus with tops at 41 000 ft through central and southern Minnesota and central Nebraska, moving southeastward at 15-20 kt with occasional east-northeast-west-southwest lines forming. Moderate to severe turbulence was forecast in the vicinity of the cumulonimbus. This activity was to move to the vicinity of Salina, Kansas, St. Joseph, Missouri, and northeastward to Dubuque, Iowa, by 0500 hours.

The 1716 hours Omaha radiosonde ascent for levels below 10 000 ft AMSL showed absolutely unstable air from the surface to near 6 000 ft, conditionally unstable air from near 6 000 to 10 000 ft and increasing moisture from the surface to near 10 000 ft. The freezing level was near 14 000 ft.

The 2240 hours radar weather observation from Kansas City showed a broken area of echoes containing thunderstorms producing moderate rain showers, increasing in intensity during the previous hour. The area was bounded by points, relative to the antenna in Kansas City, 300° true at 160 NM, 330° 150 NM, 025° 190 NM, 010° 85 NM, and 315° at 90 NM. This area was moving from 350° at 35 kt. The top of detectable moisture was 35 000 ft and a few of the echoes contained thunderstorms producing heavy rain showers. The radar reports from Omaha, Topeka, and Des Moines showed weather echoes in the same general area, which was encompassed by Aviation Severe Weather Bulletin No. 447. The accident site was within the area covered by the Bulletin.

The 0000 hours surface weather chart dated 7 August 1966, prepared by the National Meteorological Centre showed, in part, a low pressure system centred over western Wisconsin and another low pressure system centred over northeastern Kansas with a cold front extending southwestward from western Wisconsin to southeastern Nebraska, then continuing to southcentral Colorado.

Several air carrier aircraft operated in the area of the squall line within one hour of the accident time. Three of these were Braniff aircraft and one was operated by another carrier. The latter aircraft, a Convair 580, departed from Omaha for St. Joseph, Missouri, at 2236 hours under radar control on a heading of 190° and with an assigned cruising altitude of 3 000 ft. The pilot-in-command stated that approximately five miles south of the airport it appeared as though the 190° heading would take him into some heavy shower activity so he requested a deviation to a heading of 145°. Using radar and visual guidance furnished by the lightning, the flight traversed the storm area encountering light to occasional moderate turbulence and rain. During this time the airborne radar presentation showed many large cells and a squall line approximately 30 miles long extending from Shenandoah, Iowa, northeast. More large cells extended 15 to 20 miles to the south and west. The pilot-in-command reported clearly defined cloud bases at 3 500 - 4 000 ft and almost continuous lightning activity. Approximately 12 minutes out of Omaha the cloud base lowered and the flight went on instruments. The turbulence increased to moderate "plus" and heavy rain was encountered. Three minutes later the flight was in the clear and began a climb to 5 000 ft. At this time the turbulence intensified and the pilot-in-command reported encountering severe gusts which threw pillows and blankets from the overhead storage racks. The flight broke into the clear 25 miles northwest of the St. Joseph VORTAC at 2300 hours.

The flight recorder data from this flight indicated that turbulence was encountered on several occasions: the first time, approximately 3 min. and 50 sec. after take-off, it lasted approximately 1 ½ min., with vertical accelerations from +1.5 to 0.0 g; the second time about 10 min. after take-off, it lasted about 5 ½ min. with excursions between +1.9 and 0.0 g. A single large excursion 15 min. and 27 sec. after take-off, ranged from +2.85 to +0.5 g. Immediately after this excursion the "g" trace stabilized for the remainder of the flight. During these "g" excursions the airspeed varied 8 to 10 kt. It was calculated that the last significant in-flight recorded "g" excursion occurred when the flight was approximately 18 miles east of the accident site at 2255 hours.

Braniff Flight 255, a BAC 1-11, departed from Omaha for Kansas City, Missouri, at 2255 hours. The pilot-in-command testified that he observed a squall line just south of Omaha and turned east, climbing to 17 000 ft. The flight proceeded approximately 40 miles east before a spot was found to penetrate the squall line. This penetration was accomplished through use of the airborne weather radar in co-ordination with the assistance of the Chicago ARTCC controller and his radar. After turning south the flight descended to 7 000 ft, encountering light precipitation and moderate turbulence for about 20 to 30 miles. When the flight emerged from the clouds it encountered moderate to heavy turbulence for about one minute. It was calculated that this occurred approximately 29 miles east of the accident site at about 2322 hours. The weather was clear from that point on, and the flight landed at Kansas City at 2341 hours. This crew was in radio contact with Flight 250 until just prior to the accident.

The pilot-in-command of Flight 255 also testified that he delayed his arrival at Omaha by about one hour because of forecast thunderstorm activity in that area. He had consulted with the dispatcher regarding this delay at approximately 2110 hours.

The flight data recorder readout from Flight 255 indicated evidence of turbulence beginning approximately 4 min. after take-off from Omaha and continuing for approximately 16 min. with vertical acceleration ranging from +2.5 to -0.3 g, the most extensive occurring approximately 29 miles east of the accident site at about 7 000 ft.

Another Braniff BAC 1-11, Flight 234, departed St. Louis, Missouri, at 2203 hours, en route to Des Moines at FL 240. The crew observed lightning to the northwest as they began their climb and turned the aircraft weather radar on. The pilot-in-command stated that he observed rather strong radar echoes when he approached within 150 miles of the squall line. As he continued toward the northwest he observed both visually and by radar what appeared to be a severe squall or instability line oriented approximately southwest-northeast. He could find no breaks in the line on his radar except for some small ones at high altitudes. When he approached to within 30-35 miles he reduced the radar range selection to 60 miles and the presentation changed from a solid line to a series of returns which appeared "like popcorn." When he was approximately 60 miles southeast of Des Moines he elected to divert and landed at Kansas City at 2316 hours.

The other Braniff flights in the area reported essentially the same type of weather in the vicinity of the squall line.

Approximately 300 persons on the ground in the area of the accident were interviewed regarding their observations of the aircraft and the weather. Because of their concern about severe weather, residents had been watching the sky and were able to describe in considerable detail the weather phenomena in the local area. All of the witnesses who gave statements reported that the aircraft never reached what they considered to be the main line of storm clouds and that there was no cloud-to-ground lightning near the aircraft at the time of the occurrence. Persons located near the accident site believed that the aircraft entered clouds prior to the observation of the in-flight fire, but persons located a greater distance from the accident scene reported that the aircraft was above the clouds and more or less in the clear at the time they observed the initial fire. Several witnesses described the weather ahead of the squall line as being clear to partly cloudy until a shelf of clouds preceding the thunderstorms caused an overcast condition. Witnesses estimated the base of this overcast to be 1 000 - 2 000 ft. Several witnesses described the leading edge of the shelf as a roll cloud with the cloud rolling forward from the top toward the ground. Most of the witnesses reported a wind shift from a southerly direction to a northerly or northwesterly direction with an increase in velocity from light to as high as 50-60 miles per hour. Some rain was reported after passage of the roll cloud but no heavy rain was reported until approximately 45 min. later. The main line of storm clouds was reported to be "U" shaped and the aircraft was apparently headed toward a light spot in the cloud wall. Lightning in the squall line was described as sheet lightning with occasional vertical or cloud-to-ground flashes. Two funnel clouds were observed one-half mile southeast of the accident site approximately eight minutes after the accident.

The accident occurred at night with a nearly full moon visible before the cloud shelf obscured the moon and stars.

## 1.8 Aids to navigation

The radio navigation equipment aboard the aircraft was selected to the appropriate navigation aids for the intended route of flight. There were no reported discrepancies of the ground navigational aids involved in this flight.

## 1.9 Communications

Communication was maintained between the aircraft and ground stations as well as between Flight 250 and Flight 255 until approximately 2308 hours when Flight 250 terminated its conversation with Flight 255. A review of the cockpit voice recorder tape recovered from the wreckage of Flight 250 revealed that transmissions from Flight 255 and ATC were recorded on the tape after the last transmission from Flight 250.

## 1.10 Aerodrome and ground facilities

Not a factor in this accident.

## 1.11 Flight recorders

The aircraft was equipped with a Lockheed Aircraft Services Model 109-C flight data recorder located in the main landing gear wheel well. Examination after recovery from the wreckage revealed that all the internal components except the cassette had disintegrated. The only portion of the flight record discernible on the recording medium terminated approximately eight minutes after what appears to be the take-off from Kansas City. No reliable data could be established from the recording medium due to heat and mechanical damage.

The flight recorder data from 600 other Braniff BAC 1-11 flights were reviewed in an effort to determine whether there were any abnormalities or peculiarities apparent on the recorder tapes of BAC 1-11 aircraft operating in turbulent air. On 18 August 1966, Flight 233 encountered turbulence between 4 000 and 6 000 ft for about 2 min., beginning approximately 1 min. and 40 sec. after take-off from Kansas City with vertical acceleration excursions of +3.2 to -1.3 g, excursions of the heading trace of 2 to 9° either side of the base heading and excursions of the airspeed trace of more than 20 kt.

A Fairchild Cockpit Voice Recorder (CVR) was removed from the wreckage and a satisfactory record was obtained from it. Each of the four tracks on the tape was found to contain voice transmissions recorded over a time period of approximately 32½ min. The intelligibility of three of the four tracks was good, but the fourth track, which recorded the sounds received by the cockpit area microphone (CAM), was not as readable due to interference from several sources.

A review of the transcription of the tape showed that 8 min. after take-off the crew requested a change in assigned altitude from FL 200 to 5 000 ft. At 2304:44 hours just after a short crew conversation referring to a hole in the line of clouds, the flight requested permission to deviate to the left of course.

At 2306:56 hours in response to a query from the flight, the Chicago Air Route Traffic Control Centre controller replied that the line appeared ". . . pretty solid all the way from west of Pawnee to Des Moines." From 2307:18 until 2310:59 hours there was intermittent cockpit conversation regarding deviation to Pawnee which ended with ". . . we're not that far away from it. Pawnee is a hundred and twelve four* if you want it."

At 2311:42 hours the last intelligible crew voice transmission evident on the tape was "ease power back. . ."

At 2311:42 hours 25.8 sec. before the end of the tape, a noise started which increased to a constant level in 0.16 sec. This sound has been described as a "rushing air" noise. Eight sec. later another unidentified sound was heard. Following this, there was an electronic flutter sound followed by four klaxon horn** sounds, the last of which was terminated by the end of the recording.

The examination of the tape revealed evidence that the recordings on the tape terminated as a result of ground impact.

1.12 <u>Wreckage</u>

The main body of the aircraft impacted in rolling farmland approximately 7.6 miles north-northeast of Falls City, Nebraska. At the time of impact the aircraft was heading approximately 110° magnetic with the right wing low. There was no indication of

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* 112.4 MegaHertz (mHz), the frequency of the Pawnee VORTAC.

** Klaxon Horn - audible warning horns located in the cockpit which are sounded by the stall protection system simultaneously with actuation of the stick pusher.

any horizontal displacement after initial impact. Portions of the right wing and the empennage were not found at the impact site. The right wing had separated near Rib 11 and the outboard section was found 2 503 ft from the main impact site on a true bearing of 147°. The separated portion of the vertical fin with the left tailplane and part of the right tailplane attached was found 131°/2 752 ft from the site, while the piece of the right tailplane outboard of Rib 3 was located 159°/4 375 ft from the site. These and all other major pieces of the aircraft were found within a one square mile area located to the south and east of the site. (See Figure 2-1.)

No evidence of hail damage, lightning strike or static discharge was noted on any of the sections.

Metallurgical studies were performed on the critical fracture surfaces; they did not reveal any evidence of fatigue, corrosion or previous damage. Dimensional checks and chemical analyses showed that the components were of the correct dimensions and of the proper compositions.

Except for the cockpit area, the fuselage was severely fire damaged from the nose wheel well back to the rear pressure bulkhead. There was no evidence of fire in the cockpit.

The left wing was still attached to the fuselage and was extensively fire-damaged. The wing was split spanwise just forward of the centre spar. The right wing broke chordwise at Rib 11 with tensile failures evident in the upper wing planks and compression failures in the lower planks. The lower part of the centre spar exhibited compression failure as did the entire rear spar. The wing also exhibited a partial failure in the area of Rib 2, where upper panels 3 and 4 failed in tension. Sections of the stub end of the right wing were scattered around the impact site. The separated outboard portion of the wing was relatively undamaged. The wing upper surface, the front spar and the leading edge shear diaphragms all exhibited light buckling in the area of Ribs 17-19, with the upper surface buckles progressing forward and inboard. The separated part of the right wing exhibited no evidence of fire damage whereas the inboard end attached to the fuselage exhibited varying degrees of fire damage.

The landing gear were found in the retracted position.

The vertical fin separation occurred near Rib 7 at the front spar and at Ribs 3-4 at the rear spar. The rear spar failure showed evidence of compression on the left side. The part of the fuselage frame to which the front spar attaches was pulled out of the fuselage in bending to the left with indications of counterclockwise rotation looking downward. The upper part of the fin was intact and still attached to the left tailplane and the remainder of the right tailplane. The control surfaces had all separated from the empennage. The upper surface of both tailplanes had some evidence of chordwise buckling and the right tailplane separated just outboard of Rib 3, about 145 in. from the tip. The fracture in the lower surface was a tensile failure, while that of the upper surface exhibited compression buckles.

The upper rudder actuator cylinder had failed in tension, permitting the piston to separate from the cylinder. The rudder feel simulator was extensively damaged by impact and could not be functionally tested. However, the control valve assemblies were recovered and functionally tested in a serviceable unit, with no significant discrepancies noted. The extensions of the Nos. 1 and 2 feel simulator jacks were 2-½ and 1-¾ in.

respectively, positions which are not compatible with a complete hydraulic system failure. The series yaw damper was placarded inoperative in the cockpit and this status was confirmed by an internal inspection of the unit.

The two elevator power control units were recovered in place in the elevator assemblies. The actuator rod of the left unit was bent, limiting functional testing to a pressure test only. The right unit was functionally tested. No indication of operational difficulty was noted in either unit. The elevator feel simulator jack extensions were determined to be 2-9/16 in. and 1-5/8 in. for the No. 1 and No. 2 systems respectively. These are also positions which are not compatible with a complete hydraulic system failure.

The tailplane trim actuator, which is manually or hydraulically operated to trim the variable incidence tailplane, was found with a setting which corresponded to $3/4^{\circ}$ aircraft nose up on another aircraft. This would be the approximate setting for an airspeed of 260-280 kt at 5 000 ft mean sea level.

The left wing control surfaces all remained attached to the wing, except for the outboard flap section which was found lying in the immediate area. The flaps and spoilers were retracted and their respective actuators were in corresponding positions. The aileron and spring tab had received both mechanical and fire damage. The aileron control and trim cables were continuous to the wheel well area.

The right aileron and spring tab and the spoilers remained attached to the separated piece of the wing and were relatively undamaged. The outboard flap section tore off this section of wing, the attachments at each end remaining with their respective carriages.

The empennage control surfaces all separated from their attach structure. Evidence on the rudder hinges showed that the rudder had overtravelled in both directions, with more severe indications to the left. The left side of the rudder had two chordwise buckles, one 3-½ ft and one 5 ft above its base.

The left elevator had separated from the tailplane as a complete unit and was found near the tail section. All hinge shrouds were rolled upward - damage which would be expected if the surface overtravelled upward.

The right elevator failed in upward bending near the tailplane fracture and both elevator pieces separated from the tailplane. This elevator also showed evidence of having overtravelled in an upward direction.

The control cable continuity was established from the cockpit to the empennage. All broken cables exhibited tension failures with reduced cross-section at the breaks.

Examination of all control surfaces revealed no evidence of flutter or any significant preimpact distress or malfunction.

Most of the autopilot units were damaged by impact and detailed examination provided relatively little information. Disassembly of the aileron servo revealed a broken torque limit switch. The switch housing was cracked and the contacts were frozen in the open position.

Both engines remained attached to the airframe and were recovered in an area where extensive ground fire had occurred. Evidence of rotation was exhibited in the compressor and turbine sections of both engines. The condition of blades and vanes in the compressor and turbine sections was consistent with impact damage, sudden stoppage and ground fire damage. The positions of various fuel and air valves from both engines were compatible with their normal positions at a low power setting.

No evidence of any pre-impact failure was observed in the hydraulic and electric systems.

Examination of the radar controls revealed that the weather radar was turned on with full gain selected.

1.13 Fire

A majority of the witnesses interviewed reported seeing an explosion or a brilliant flash in the sky followed either by a ball of fire or a flaming aircraft falling to the ground. No evidence of fire was reported prior to the flash and there was no evidence of any fire fighting activities by the crew. One nearby witness stated that the whole aircraft burst into flames at impact and that several small explosions occurred in the main fire area of the fuselage. The ground fire continued sporadically for several hours after the accident until it was extinguished by local volunteer fire departments and rain which fell after the accident.

1.14 Survival aspects

This accident was non-survivable.

1.15 Tests and research

Because of the relative novelty of the T-tail design configuration and because of the fact that in-flight failure of the structure had occurred, special attention was given to the design, testing, and certification of the aircraft.

The Board noted that neither the British Civil Air Regulation nor the U.S. Federal Aviation Regulation required consideration of the effect of simultaneous application of the horizontal and vertical limit (66 ft/sec.) gusts, or of the application of the limit gust at some angle, in the design of an aircraft. The effect of such gust application varies from one aircraft to another and although an angled gust produced a negligible effect on the loading of another T-tail aircraft, it was found that in the case of the BAC 1-11 an angled gust applied to the empennage at the worst possible direction would give a loading on the tailplane approximately 10 per cent more severe than would be produced by the same load applied vertically.

It was found that the flight load requirements applicable to the BAC 1-11 are basically the same as those that apply to all of the jet aircraft currently in the British and United States civil transport fleets. Specifically, these requirements specify that the aircraft must be designed for certain flight manoeuvre and gust loads. The loads so specified are limit loads, the maximum loads expected in service. However, the aircraft must also be capable of withstanding ultimate loads at least 50 per cent greater than limit load before structural failure will occur. In the clean configuration (gear and flaps up and speed brakes retracted), the positive limit manoeuvre load factor is +2.5 "g" up to the design dive speed ($V_D$) and the negative limit load factor is -1.0 "g" up to the design cruising speed ($V_C$), decreasing linearly to 0 "g" at $V_D$. Below 20 000 ft the aircraft is designed to withstand limit derived gust velocities of 66 ft/sec. at the design speed for maximum gust intensity ($V_B$), 50 ft/sec. at $V_C$, and 25 ft/sec. at $V_D$. The term "derived gust velocity", or "$U_{de}$", does not imply the actual or true velocity of a mass of moving air. This term simply refers to an artificial gust of a specific shape which, when used in the appropriate formula, will give accelerations generally in line with those which have been measured on similar aircraft in similar weather conditions.

It was stated by one spokesman from the UK Air Registration Board and one from the U.S. Federal Aviation Agency that care must be taken to assess properly the rolling moment due to yaw to which the tailplane subjects the fin of a T-tail aircraft. This loading, which is unique to the fin-mounted tailplane, is considered to be the most important difference in terms of loading between the T-tail and the conventionally configured aircraft. For lateral gust cases the tailplane rolling moment is a significant percentage of the total load for which the fin must be designed. However, as was pointed out by the ARB spokesman, the structural problems involved in T-tail design should not be very difficult for an experienced manufacturer.

Trajectory Analyses

From the outset of this investigation the wide dispersion of some major components made it obvious that the aircraft broke up in flight. In an attempt to determine the sequence of the break-up, the Board requested BAC and the Langley Research Centre of NASA to perform trajectory analyses.

Since Flight 250 was being tracked by USAF Air Defence Command radar reasonably accurate information regarding the track, ground speed and height above ground was known. The drag coefficients of the various falling parts and the mean velocity of the wind acting upon these parts were estimated. Reasonable variations in these parameters did not affect the following basic conclusions: (1) the breakup must have occurred within a very short time, perhaps in a time interval in the order of two seconds, and (2) the fin-tailplane combination probably separated before the wing.

BAC and NASA also studied the trajectory of the main portion of the aircraft and arrived at calculated times to impact after initial failure of 25 and 28 sec., respectively. NASA also performed a dynamic model test, launching a 1/40 scale model of the main body of the aircraft from a simulated height of 6 400 ft and observing its time-to-fall and its falling gyrations for the first 4 000 ft of altitude loss. The results of this test generally verified the NASA time-to-fall calculations and indicated that an aircraft in this configuration had a tendency to settle into a slow, flat spin after some initial random tumbling motion.

Cockpit Voice Recorder Studies

A test flight indicated that the ambient noise level on the cockpit area microphone (CAM) tract varied with airspeed, and that the level recorded shortly before the time of breakup could be reproduced by flying the aircraft at an airspeed of approximately 270 kt. It was further determined that the "rushing air" noise on the tape could be reproduced by increasing the airspeed 45-50 kt, especially if the aircraft had a large sideslip angle at the time.

During the experimentation with this record it was observed that the recorder speed was affected by acceleration of the unit. An effort was made to determine the response of the aircraft to the forces which caused the structural failure by interpretation of the recording speed variations displayed on the accident tape. The effects of angular acceleration of the unit (and therefore of the aircraft) can be reasonably predicted but those due to linear accelerations, while quite significant, may vary from unit to unit. However, since any gusts of a magnitude sufficient to initiate these failures would likely include vertical and horizontal accelerations as well as angular acceleration, it was finally concluded that it was not possible to determine, by analysis of the CVR tape, which type of acceleration caused the tape speed variation.

Summary of Aerodynamic and Dynamic Studies

Early analogue computer studies indicated that a possible explanation of the inflight failures was that the aircraft encountered a high intensity gust. It was further observed that the magnitude of the gust required to cause the failures was reduced when short duration gusts were considered. The gusts considered were similar in shape to that specified in the BCAR and FAR requirements, but the wavelength was varied to produce the maximum effect on the aircraft. These gusts were applied to the aircraft from a number of different angles and the combinations of angle and wavelength which permitted the lowest gust to cause the failure or failures in question were noted. The lowest gust required to cause only the fin and tailplane failures was calculated to be a 140 ft/sec. equivalent airspeed (EAS) gust with a half-time of 0.125 sec. applied from the right and angled upward 45°.

Other computer studies were conducted to determine the probable failure sequence if a gust did cause the initial failure. When the computer was programmed to represent loss of the tail unit, the aircraft pitched downward rapidly causing the negative wing failure. However, loss of the wing first did not cause a response which would have failed the tail without further load input.

The gusts derived from these studies should be considered as actual movements of air. They are not, therefore, directly comparable with the derived gusts velocity ($U_{de}$) specified in the design requirements. For example, the 140 ft/sec. EAS gust would be equivalent to a combination of vertical and lateral derived gusts of 81.5 ft/sec.

In performing these calculations, the increase in airspeed which was manifested by the "rushing air" noise in the CVR recording was taken into account. An increase in airspeed was found to produce a nearly linear reduction in the magnitude of the gusts required to cause the failures in question. For example, the 140 ft/sec. gust calculated to fail the fin and tailplane at 300 kt equivalent airspeed (KEAS) would have to be nearly 158 ft/sec. to produce the identical failures if the aircraft were at the turbulence penetration speed ($V_{RA}$). Thus, the effect of a momentary change in airspeed due to an encounter with an abrupt longitudinal gust could have been appreciable in this case.

Other aerodynamic studies indicated that control deflections within the limits of the autopilot authority would have a rather small effect on the gust required to cause the various failures sustained by the aircraft (approximately a 5-10 per cent reduction in the required gust). Even with maximum pilot applied force on the rudder, the effect on the gust required to fail the tail would be small since the force limiter restricts the allowable rudder travel.

Other calculations were conducted to determine the effects on the aircraft of a possible rudder feel system malfunction. If a complete loss of rudder feel is postulated with the aircraft at $V_{RA}$, a rudder deflection of 17.5° applied at the rate of 25°/sec. may be attained. This could result in the fin reaching ultimate load although the loads on the tailplane would be considerably less than ultimate.

An effort was also made to determine if the tailplane failure could have occurred after the fin failed. All calculations performed showed that this was not possible either due to dynamic forces resulting from fin failure, aerodynamic forces generated during the fin failure (when the tailplane attitude is changed by deflection of the fin), or due to aerodynamic forces generated during a tumbling descent of the unit. For example, calculations performed to show the nature of the structural failure which could be caused by rudder deflection showed that the tailplane would reach only about 70 per cent of its ultimate load before the fin rear spar failed completely. Following the fin rear spar failure, the tailplane would pitch nose downward rapidly, causing the aerodynamic forces on it to decrease.

The results of these studies led to the conclusions that: (1) the fin and tailplane failures together were not consistent with a steadily applied load such as that produced by a rudder-induced yawing manoeuvre and (2) the only reasonable explanation remaining for the failure of both the fin and tailplane is that the failures were near-simultaneous.

Weather Studies

A special weather study was carried out by the Weather Bureau. In this study an attempt was made to reconstruct the low-level atmospheric conditions at the time and place of the accident by correlating the positions of pressure jump lines, radar fine lines*, and surface wind gusts. The study indicated that the first gust line produced by the leading edge of the downrush flow of air out of the thunderstorms ahead of the squall line was very nearly coincident with the location of the pressure jump line as it progressed over eastern Nebraska and western Iowa during the evening. Also, the position of the Des Moines WSR-57 radar fine line at 2252 hours closely approximates the position of the pressure jump line in that area at that time. Comparison of the extrapolated position of the pressure jump line at 2300 hours with the reported times of passage of the wind shift line in the area of Falls City, Nebraska, indicated that the two were nearly coincident in the vicinity of the accident.

The report mentioned that, in previous investigation of radar fine lines, pressure jumps and surface wind gusts have been observed to accompany the passage of fine lines and concluded that the above correlations in conjunction with surface wind gusts estimated to have been as high as 70 miles per hour in the area of concern make it apparent that the strong gusty surface winds ". . . were indicative of rather pronounced low-level turbulence associated with the leading edge of the downrush gusts ahead of the thunderstorm activity present in the area."

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* A fine line is a weather phenomenon which may be observed on radar. It is an area of refractive air found in the first few thousand feet above the surface which is produced along the leading edge of cold air which is advancing into a region of warm moist air.

An independent study of the weather conditions at the time and place of the accident was conducted by a specialist in meso-meteorology. He stated that the amount of excess atmospheric pressure, and the outflow wind speed, of a weather system is proportional to the amount of surface rainfall if the height of the convective cloud base remains unchanged. Having used data from the Weather Bureau to determine the precipitation patterns and to locate fine lines, which may be regarded as wind-shift lines near the ground, he stated that at 1800 hours the squall line was accompanied by a well-organized squall line circulation of medium intensity. He also estimated that the pressure-jump line as a whole was in its maturity around 2300 hours. He concluded that the pressure field of the mesohigh pressure system as a whole was medium to strong and that the precipitation amount averaged over a large area of the squall line was light to medium although the variation of the precipitation from one location to another, was unusually large. As the rainfall in an area located about 30 miles northeast of the accident site was observed to be over four times that to the west of the site, he concluded that the rain-induced cold air mass to the east was about four times larger than that to the west of the site. The effect this variation has on the velocity of the wind-shift line and/or the first speed just behind that line is shown in Figure 2-2. It will be noted that between the masses of air of different velocity there is a zone of strong horizontal wind shear and accompanying eddies.

He stated that the horizontal wind shear is strongest at levels between 2 000 and 3 000 ft above the ground. Finally, he concluded that, in an attempt to avoid the area of intense radar echo, the heavy rain area, the flight deviated to the left and crossed above the surface wind-shift line at 2310 hours, at a time, location, and altitude most favourable for the development of roll circulations with horizontal vortex axes parallel to the windshift line and for that of circulations with vertical vortex axes.

In addition to studies of the actual weather existing at the time of the accident, the Board reviewed the results of other weather studies concerning the nature of turbulence and of its effect on aircraft. In particular the airspeed, vertical acceleration and altitude data collected by the NASA during its VHG programme initiated in the early 1930's were reviewed.

The experience accumulated during this programme totals nearly 150 million flight miles, of which 2.5 million were recorded on turbojet transports.

In reference to the BAC 1-11 VGH records, it was noted that the maximum derived gust recorded for that aircraft was between 40 and 44 ft/sec. The overall gust experience of the BAC 1-11 was significantly lower than that for other short-haul type aircraft.

The maximum true gusts recorded during the National Severe Storm Project (NSSP) in 1960 were 208 ft/sec. vertically and 146 ft/sec. laterally, with a maximum derived gust of 50 ft/sec. Based on data from that project, lateral gusts may be expected to be as intense as vertical gusts. These measurements were generally not of independent vertical and lateral gusts, but were the components of given angular gusts.

The maximum true gusts recorded at low altitude over mountainous terrain during a study for the USAF were 110-115 ft/sec. vertically, 175 ft/sec. laterally, with longitudinal components in the order of 80 to 85 ft/sec.

Although the latter were reported as being of low reliability, the longitudinal components appear to be quite comparable to the vertical and lateral components.

1.16 Braniff Meteorological Training and Procedures

A review of the airline's procedures and training of flight crews and flight dispatchers regarding operation in or near areas where turbulence exists or is forecast was made.

The Flight Operations Manual read in part: "No flight shall be planned or dispatched that will knowingly require penetration of thunderstorm cells .... when more than scattered thunderstorms are forecast or known to exist along the route of flight, the flight will be planned and dispatched to avoid the area of thunderstorm activity if practicable to do so .... when a line of solid and intense storms is known or forecast to exist across the route of flight such as may be anticipated in severe squall or frontal activity, and detouring is not practicable, flights will be held on the ground until the line has passed, dissipated or can be circumnavigated."

Since thunderstorm penetration was to be avoided Braniff pilots were not briefed on the optimum altitude at which a thunderstorm penetration should be made and did not receive specific thunderstorm and turbulence penetration instruction in the BAC 1-11 simulator although some turbulence was given the pilots during their training.

The airline's BAC 1-11 Operations Manual stated that if severe turbulence cannot be avoided, the best airspeed, from all aspects of handling and strength, was 270 kt IAS up to 30 400 ft. Attitude flying was stressed and, in all cases, the autopilot should be engaged with the altitude hold switch "OFF". Pilots were also cautioned to remain at least 5 miles away from thunderstorms when operating below the freezing level.

It was also noted that flight dispatchers initial training course included 8 hours of weather instruction.

According to Federal Aviation Regulations (FAR) 121.533:

"(b) The pilot-in-command and the aircraft dispatcher are jointly responsible for the pre-flight planning, delay, and dispatch release of a flight in compliance with this chapter and operations specifications.

(c) The aircraft dispatcher is responsible for -

(1) Monitoring the progress of each flight;

(2) Issuing necessary information for the safety of the flight; and

(3) Cancelling or redispatching a flight if, in his opinion or the opinion of the pilot-in-command, the flight cannot operate or continue to operate safely as planned or released."

The flight dispatchers pointed out that their flight planning takes place 2 to 3 hours before the scheduled take-off time and is based on the weather information available at that time. They also stated that the pilot must make the final decision regarding his course of action since he can evaluate the situation existing at the time but that this in no way relieved them of their responsibility to notify the pilot of any change in the weather they became aware of. The dispatcher handling Flight 250 from Kansas City to Omaha stated that, in his opinion, the flight could proceed because as far as he knew the thunderstorm activity consisted of a "broken line", and the company meteorologist had said that he "expected decreasing rainshower and thundershower activity through the night."

The dispatchers were aware that Flight 255 had delayed its take-off from Sioux City because of the terminal weather at Omaha. Also, Flight 234, en route from St. Louis to Omaha, had diverted to Kansas City after the pilot elected not to penetrate the squall line. These actions were co-ordinated with the dispatchers; however, they did not inform the crew of Flight 250. The dispatcher handling Flight 250 at the time of the accident testified that he did not believe it was necessary to inform Flight 250 of the diversion of Flight 234 because of the considerable distance between their respective flight paths. He further testified that, should he receive a severe weather warning for an area through which company aircraft were operating, it was doubtful that he would forward the information to en-route aircraft because he believed the crews would be in better position to evaluate the weather than he.

## 2.- Analysis and Conclusions

### 2.1 Analysis

#### Design and Type Certification

It was obvious quite early in the investigation that loads in excess of the airframe strength had been imposed on the structure, but the nature and origin of these loads were not apparent. Possible causes of an overload condition which were considered included an encounter with some extreme weather condition, a combination of forces or accelerations produced by weather and pilot response, or by some system-induced manoeuvre. Areas which could have rendered the aircraft understrength included fatigue or other prior damage, defective material used in construction, deficiencies in design structural strength, or inadequate design requirements.

In order to ascertain if the strength was adequate the Board conducted an extensive investigation of the development of the BAC 1-11, including the design, certification and construction stages.

The NASA review of the aerodynamic load and stability predictions indicated that the methods used were satisfactory and were in fact quite similar to those in general use throughout the industry. Similar findings stemmed from the review of the stress and dynamic analyses. In regard to the stress analysis, the Board noted that BAC conducted an extensive static structural test programme, more than was required by either the BCAR or the CAR. No evidence that the strength of N 1553 was less than that predicted by calculation, or less than that specified in the applicable requirements or that fatigue or other prior damage existed before the accident was found.

Whether or not the design requirements themselves were entirely adequate, especially in regard to the gust design cases, is a moot point; however, they have generally withstood the test of time. One aspect of the design requirements which the Board did question is the practice of considering the application of lateral and vertical gusts separately instead of considering a combination of these components acting simultaneously. While the adequacy of the present gust requirements has been proven statistically, and the present requirement for a 66 ft/sec. limit gust separately applied both vertically and laterally gives substantial, although not, in the Board's opinion, full capability for combined gusts, the fact that the relatively new T-tail aircraft configuration may be more critical in terms of combined loading than were former configurations was raised.

In the case of the BAC 1-11, it has been determined since the accident that the maximum increase in severity of gust loading due to application of an angled limit gust is of the order of 10 per cent.

The proximity of the turbulence penetration speed ($V_{RA}$) to the design cruising speed ($V_C$) of most jet transports presents another problem in respect to the effects of combined gusts.

It was determined that the "rushing air" noise heard on the cockpit voice recording was likely caused by a lateral gust with a component head-on to the aircraft, or a longitudinal gust. A longitudinal gust is normally considered to be of little consequence in consideration of airloads or strength limitations since its primary effect is on airspeed rather than angle of attack. The requirements do not at present consider application of longitudinal gusts to the basic airframe. However, the aircraft is designed for a limit vertical or lateral gust of 66 ft/sec. at $V_{RA}$ and 50 ft/sec. at $V_C$. In the case of the BAC 1-11 then, a 50 kt indicated airspeed (KIAS) abrupt longitudinal gust would, in effect, raise the indicated airspeed from $V_{RA}$ (270 KIAS) to $V_C$ (320 KIAS) until the aircraft could respond to the gust. Thus, the limit vertical and lateral gust capability of the aircraft could suddenly drop from 66 to 50 ft/sec., a reduction of nearly 27 per cent.

In a recent draft of proposed changes to the BCAR, the ARB specified the application of a longitudinal gust. This gust, which is a combined loading, would be applied to the aircraft at the worst angle between 30° above or below the flight path. However, the proposed change still makes no reference to other cases of combined gust loading.

The Board believes that the use of the derived gust loading ($U_{de}$) as specified in the requirements is somewhat outmoded in terms of the current state-of-the-art. The derived gust has proven in the past to be a useful tool for analysis of the effects of vertical gusts but it is a highly artificial concept which in no way relates directly with any specific atmospheric condition. Instead, it is just a number which, when used in the appropriate formula, will give accelerations generally in line with those which have been measured on similar aircraft in similar conditions. With the computerized design methods presently in use, a more realistic means of expressing and considering the aircraft's atmospheric environments could be used. Perhaps the power spectral density method*, which is coming into use for fatigue and passenger comfort considerations, could be adapted by the industry for use in determining maximum design loads as well. Another possible improvement might result from abandoning attempts to idealize measured records into specific gust patterns such as isolated gusts and random turbulence, and instead, using these records directly as time histories in calculations for their effects on a specific aircraft.

Conduct of Flight

The intensity of the weather system which crossed the intended route of Flight 250 appeared to have been underrated by airline personnel responsible for forecasting the weather and dispatching the aircraft. Witnesses who spoke to the pilot-in-command before the flight stated that he showed concern about the weather even before his departure from New Orleans; however, he did not obtain a formal weather briefing before leaving Kansas City, although facilities were available for this, but he discussed the weather with another

* A means of mathematically describing atmospheric turbulence which may be used to obtain the probability distributions of the various intensities of turbulence.

pilot-in-command who just arrived from Chicago and who told him ". . . This was a solid line with very intense thunderstorms with continuous lightning and no apparent breaks, as long and mean a one as I'd seen in a long time and I didn't feel the radar reports gave a true picture of the intensity." This information was not relayed to the airline flight dispatcher.

The airline's Flight Operations Manual prohibits the dispatch of an aircraft into such weather conditions; however, the airline forecast indicated only scattered thunderstorms, while Aviation Severe Weather Bulletin No. 447, a copy of which was found in the wreckage, forecast a few severe thunderstorms and "numerous" cumulonimbus with maximum tops to 50 000 ft. The dispatcher involved stated that he would not hesitate to ground an aircraft but that the weather situation did not, in his opinion, warrant such action. It was, therefore, believed that the flight was dispatched in good faith although that faith was founded on an inaccurate analysis of the weather situation. While the dispatcher is by regulation jointly responsible with the pilot for the safe conduct of the flight, it appears that, since the advent of the airborne weather radar, the pilot is often relied upon to observe and evaluate the weather situation and then to make the final decision regarding his course of action. Another example of this policy was observed when Braniff Flight 233 departed Kansas City twelve days later into similar weather conditions and encountered extreme turbulence shortly after take-off (see 1.11).

The air traffic control of Flight 250 was very adequately conducted. Included in the information given the crew was the observation that the line ahead of the flight looked solid from west of Pawnee City to Des Moines. At that time the aircraft had already deviated from its original course toward what appeared to the crew as a hole in the line of clouds. Following this observation the co-pilot suggested deviating to Pawnee City to circumnavigate the squall line. There was no evidence that the pilot-in-command ever intended to deviate, rather, it was believed that he decided to penetrate the squall line in the area of the hole observed on his radar. Had he known of the efforts of other crews to avoid penetrating this weather system, his decision might have been different. The dispatcher, who was aware that other Braniff flights had diverted to alternate airports or remained on the ground until safe flight could be undertaken, should have so informed Flight 250, or better, recommended to the pilot-in-command that the flight be delayed or re-routed to pass around the squall line.

Analysis of CVR Record

The analysis of the background noise on the cockpit voice recorder record indicated that the aircraft was at or near the recommended penetration speed of 270 kt. The unit was found to give reasonably accurate information regarding the airspeed of the aircraft as well as recording the accelerations to which it was subjected. However, whereas a flight data recorder records only accelerations normal to the flight path, the cockpit voice recorder is sensitive to angular accelerations as well as linear accelerations in different directions and it was not possible to separate the effects of the various accelerations and therefore determine the exact response of the aircraft to whatever forces caused its failure.

Analyses of the tape frequency variations revealed no significant aberrations until the onset of the "rushing air" noise, at which point a relatively large, abrupt variation was noted. It was at this point, approximately 29 sec. before the end of the recording, or before impact, that the aircraft was subjected to some abrupt, violent manoeuvre. Although the exact nature of this manoeuvre will never be known, the tape speed variations were such that it could have been caused by a left roll, an upward acceleration, or, very possibly, to some combination of these. The violence of this manoeuvre and the fact that its timing coincided approximately with the time of break-up predicted by the trajectory analyses suggested that the initial failure of the aircraft occurred at this point.

Failure Sequence

Although the trajectory analysis indicated that the tail section failed first, this was not entirely accepted until reinforced by the finding that a tail-first sequence was required in order to explain the failure of both wing and tail.

This finding, in conjunction with the report that the separation of both tail surfaces could be explained only if the failures were near-simultaneous, led the Board to conclude that while flying basically in a straight and level attitude the aircraft was suddenly subjected to forces which caused it to respond violently, accelerating upward and in left roll. At this time the right tailplane and the fin failed and the aircraft pitched nose down until the right wing reached its negative ultimate load. The total time required for this sequence was estimated to be in order of 1 to 2 sec. The loss of these components rendered the aircraft uncontrollable and shortly afterward it probably began a random tumbling motion which stabilized sometime before impact into a flat-spinning attitude, as observed by the ground witnesses.

The rupture of the integral fuel tank in the wing released a large quantity of fuel into the surrounding atmosphere. This fuel ignited creating the ball of fire observed by witnesses.

Cause of Structural Failure

The rapid sequence of structural failure tends to rule out a longitudinal upset and certain system-induced manoeuvres as possible causal areas.

One system-induced malfunction considered was a hard-over control deflection. This is considered a system malfunction because control deflections of a magnitude sufficient to fail the aircraft could not be caused without a complete failure of the independent dual feel units of the hydraulically powered controls. If, for example, the rudder feel system failed completely and the rudder was fully deflected at 270 kt, the resulting forces could fail the fin. However, this "rudder kick" case appears to be incapable of producing a tailplane failure consistent with that sustained by the aircraft. Also, in spite of careful examination of the feel system, no evidence of any such malfunction could be found.

The possibility that a hard-over control deflection occurred was considered even less likely when the findings of the autopilot examination were analysed. The damage done to the microswitch in the torque limit assembly of the aileron servomotor was considered most likely to have been caused by a high load reaction from the control surface side of the servomotor acting through an engaged clutch. Since this clutch is only energized when the autopilot is engaged it was considered that the autopilot was engaged when the structural failure of the wing occurred and therefore that a large control deflection was improbable. Even if the rudder feel were completely lost, the autopilot would not apply any such rudder deflection, and the 120 lb. force required for the crew to overpower the autopilot would, in effect, be a substitute for the lost feel.

Because of the proximity of the squall line to the accident site and the witness reports of a roll cloud in the immediate area, a study of the possible effects of turbulence on the aircraft was conducted. The results of this study indicated that any of the primary failures could have been caused by an encounter with a very large, abrupt gust. The lowest gust which could cause the failure of both the fin and the tailplane was a 140 ft/sec. EAS gust of the shape specified by the requirements applied at a 45° angle upward to the left and perpendicular to the longitudinal axis of the aircraft. The time required for the calculated gust to reach its maximum velocity was 0.125 sec. Preliminary calculations had previously indicated that somewhat lower gusts would be required to fail either the wing or the fin alone, but these were of the same order of magnitude as the gust calculated to fail the fin and tailplane simultaneously.

In performing these calculations the increase in airspeed which was manifested by the "rushing air" noise in the cockpit voice recording was taken into account.

To relate the 140 ft/sec. EAS gust which BAC calculated would fail the aircraft to actual weather phenomena is difficult since gusts of that severity have not been measured. This is not to say that movements of air with greater velocities than 140 ft/sec. have not been recorded; maximum vertical and horizontal velocities of 208 ft/sec. and 175 ft/sec. respectively, have been recorded. However, depending on the rate of change of velocity, or the shear, the disturbance can be considered as a draft, or gust and the peak velocity of that disturbance determines whether it is a large or small gust. An aircraft encountering a large draft will likely have adjusted its attitude and flight path before reaching the peak velocity and the resulting forces and accelerations produced on it will be small. In a gust though, the aircraft will not have had time to adjust its flight path before it encounters the peak velocity and very large forces and accelerations can be produced. These, in turn, result in dynamic effects which raise the stresses in the structure to values which may be considerably higher than those which would result if the loads were applied slowly.

A review of the various data relating to gust velocities showed that the 140 ft/sec. gust calculated by BAC is out of, but not far from, the limits of measured experience and that roll circulation was among the most severe disturbances ever measured by an aircraft. In summary, then, although the precise gust velocities present in this system cannot be computed, the Board considered that extreme turbulence was present and was, in fact, encountered by the aircraft.

Evaluation of Comments of the Parties to the Investigation

In accordance with Board procedural regulations three of the six designated parties to the investigation of this accident submitted recommendations as to the conclusions to be drawn from the evidence gathered during this investigation.

Of these three parties, one party, the British Aircraft Corporation, outlined views which were basically similar to those of the Board. The other two parties, Braniff Airways, Incorporated, and the Air Line Pilots Association concluded that the accident was caused by a complete loss of rudder feel which permitted the pilot inadvertently to apply full left rudder. The latter, in support of their position, cited the following evidence:

(1) A number of directional control incidents involving BAC 1-11 aircraft which occurred approximately a year after the accident were the result of feel system malfunctions caused by sticking feel control valves. A total of 29 cases of sticking valves were reported and re-examination of the feel system of N 1553 disclosed evidence that such malfunction had occurred.

(2) Markings on the rudder leading edge and the shroud of the fin which were observed during an independent mockup of the erpennage of the aircraft indicated that the rudder was deflected 15° to 19° at the time of the initial fin failure.

(3) The tailplane failure could have occurred at some stage during a progressive failure of the fin when the tailplane attained an extreme angle of attack.

(4) Evidence regarding the engagement of the autopilot was inconclusive.

A joint FAA/industry team established to study the sticking valve problem found only one documented case of a sticking valve and no case of an inflight loss of rudder feel. Rather, those cases of directional control problems for which an answer was found were attributed to the series yaw damper. Nevertheless, as a result of these reported feel system problems the evidence observed in the wreckage was again studied by Board specialists. They did not find any indication that total feel failure had occurred. Board specialists who also studied the mockup were unable to agree with the contention that the markings on the rudder and fin indicated the rudder was almost fully deflected at the time the fin failed. There was evidence of a large left rudder displacement; however, it was concluded that the rudder assumed this position after the initial fin failure occurred.

With regard to the breakup sequence of the empennage, the Board concluded that the analyses performed indicated quite conclusively that the tailplane failure could not have occurred after the structural integrity of the fin was destroyed by a failure of the fin rear spar. After that failure the fin no longer had sufficient strength to react to the loads which would be required to fail the tailplane. In fact, the distortion of the front spar following the rear spar failure would have permitted the tailplane to assume a nose-down attitude with an accompanying reduction in the tailplane loading.

Finally, the autopilot aileron servo components were subjected to extensive examination by the Board, and additionally, by the United States designers of the equipment and the United Kingdom manufacturers. All agreed that the evidence indicated that the autopilot was engaged when the right wing failed.

The Board was aware that late in 1967 the Administrator issued two Airworthiness Directives, one dealing with the yaw damper and another dealing with the rudder feel simulator linkage.

The series yaw damper AD was aimed at eliminating small rudder displacements due to unwanted repositioning of the yaw damper control valve. The rudder feel AD was designed to preclude feel force reversal in the event of multiple failures in the feel system. Additionally, FAA modified the prestart hydraulic system check to detect any possible feel system failures. The significance of these FAA actions and their possible relationship to N 1553 was fully considered by the Board during its evaluation of the accident evidence and the Board concluded that a rudder feel malfunction as the cause of this accident cannot logically be supported.

## 2.2 Conclusions

### (a) Findings

The design of the BAC 1-11 was in accordance with the current state-of-the-art and the aircraft met or exceeded all applicable design requirements.

The aircraft was properly certificated and airworthy at the time of take-off from Kansas City.

The crew was properly certificated and qualified for the operation.

The aircraft was confronted with a severe squall line which was oriented across its intended flight route. This system was adequately forecast and reported by the Weather Bureau; however, the company forecast was somewhat inaccurate with respect to the number and intensity of thunderstorms and the intensity of the associated turbulence in the system. The crew was aware of the forecast weather and was aware that the system could have been circumnavigated to the west. This was, in fact, suggested by the co-pilot.

Because the company forecast did not predict a solid line of thunderstorms, the company dispatcher did not take any action to delay or to reroute the flight. However, the dispatcher did not relay to the crew information which might have persuaded the pilot-in-command to avoid the storm system. In fact, when the dispatcher was informed of the efforts of other aircraft to avoid the squall line, he should have recommended avoidance action to Flight 250.

In spite of his apparent concern over the en-route weather and his knowledge that the squall line was quite solid, the pilot-in-command elected to penetrate the line using his airborne weather radar to select a "light" area.

Flight 250 never reached the main squall line. Instead, the aircraft broke up in a roll cloud approximately 5 miles from the nearest radar weather echo. At this time the aircraft was at the proper configuration and airspeed for flight in turbulence and the autopilot was engaged.

Flight 250 encountered extreme turbulence generated by the strong horizontal and vertical wind shears associated with the outflow of cold air from the approaching squall line. This turbulence probably caused a large angled gust of very short duration with components in the lateral, vertical, and longitudinal planes.

The forces and accelerations produced by this encounter caused the fin and right tailplane to reach their ultimate loads, with near-simultaneous failures resulting. The aircraft then pitched downward until the right wing reached its negative ultimate load. The loss of these components rendered the aircraft uncontrollable and shortly afterward it probably began a random tumbling motion which stabilized some time before impact into a flat-spinning attitude.

(b) Cause or
Probable cause(s)

The Board determined that the probable cause of this accident was in-flight structural failure caused by extreme turbulence during operation of the aircraft in an area of avoidable hazardous weather.

3.- Recommendations

During the investigation the Board conveyed to the Administrator its findings regarding gust design requirements and the means of selecting turbulence penetration speeds. In a letter dated 31 October 1966, the FAA was asked to review its design requirements to determine (1) if the existing requirements provided an adequate level of safety for vertical and lateral gust combinations on T-tail configured aircraft, and (2) if the methods used by U.S. manufacturers to select turbulence penetration speeds were adequate and if appropriate conservation had been used in substantiating the airframe under existing regulations.

In a letter dated 20 January 1967, the Administrator replied to the first point that the design for high levels of turbulence in the vertical and lateral directions as separate conditions results in substantial capability to sustain gusts at various angles to the empennage. Regarding the selection of turbulence penetration speeds the Administrator stated: "The current practice of biasing penetration speeds toward high speeds and away from stall buffet boundaries is considered sound. Each configuration must be assessed relative to its individual characteristics to ascertain whether the penetration speed for the altitude is appropriate. In the case of the BAC 1-11 we have no evidence to indicate the need to lower penetration speeds at the lower altitudes."

The Board suggests that the industry review the implementation of air carrier dispatch procedures with the view toward determining if the level of safety being achieved in today's operations is considered to be consistent with the intent of existing regulations.

ICAO Ref: AIG/017/66

ACCIDENT TO BAC 1-11, N 1553, OF BRANIFF AIRWAYS, INC.,
NEAR FALLS CITY, NEBRASKA, ON 6 AUGUST 1966

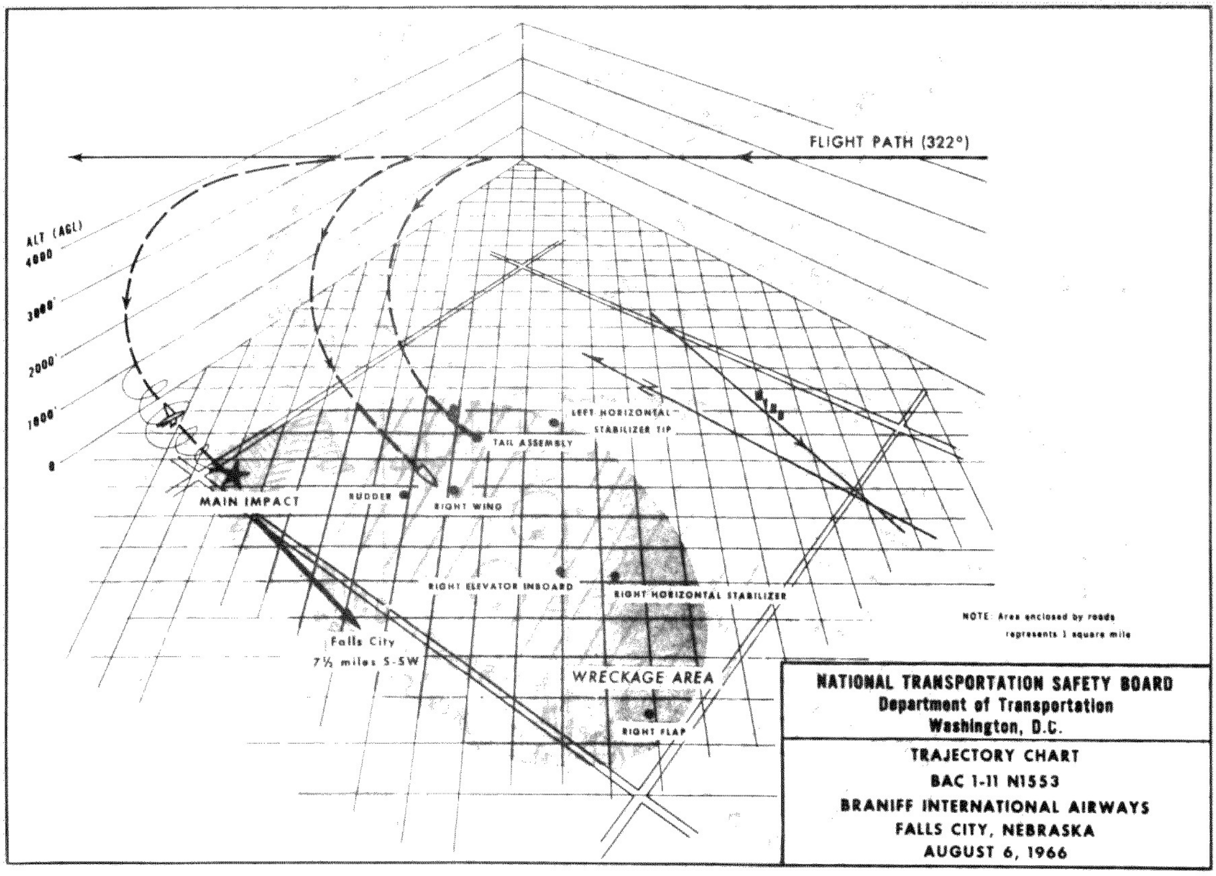


Fig. 2-1

ACCIDENT TO BAC 1-11, N 1553, OF BRANIFF AIRWAYS, INC.,
NEAR FALLS CITY, NEBRASKA, ON 6 AUGUST 1966

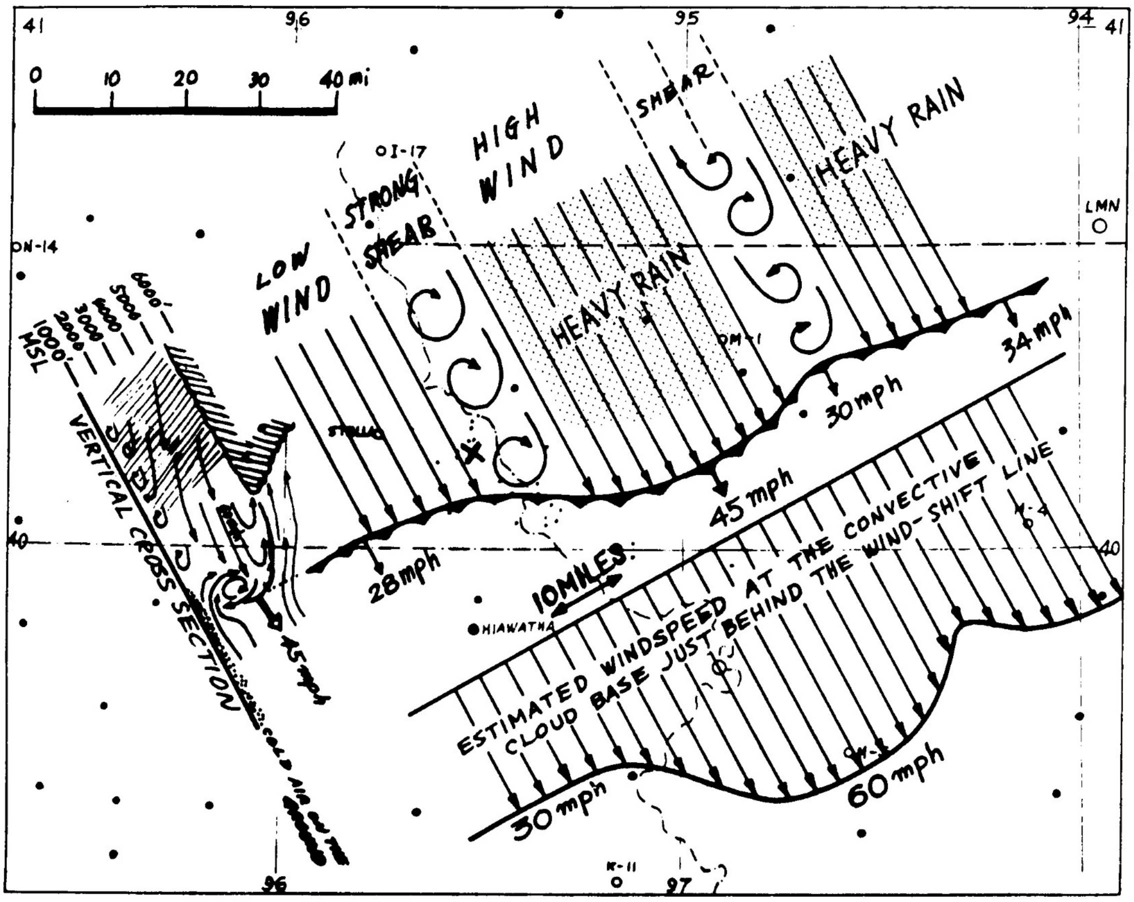


Fig. 2-2 - Schematical diagram showing how clock-wise vortices were produced over the area of the accident.