ISLAND AIG/ M-14188/AIG-13

FLUGMÁLASTJÓRN
OG
FLUGSLYSANEFND

Reykjavíkurflugvelli
Pósthólf 350, Reykjavík

SKÝRSLA UM FLUGSLYS

Sbr. lög um loftferðir, gr. 145

ENDURPRENTUÐ SKÝRSLA
KANADÍSKU FLUGSLYSANEFNDARINNAR
CANADIAN AVIATION SAFETY BOARD (CASB)

GEOTERREX LIMITED
C-GILU, CASA C-212

REYKJAVÍKURFLUGVELLI

2. ÁGÚST 1988

Slys þetta var rannsakað í þeim tilgangi einum, að hindra endurtekningu og til að stuðla að flugöryggi (sbr. lög um loftferðir, 145. gr.)

FORMÁLI

Hinn 2. ágúst 1988 fórst Kanadísk flugvél í Vatnsmýrinni í Reykjavík, þegar hún skyndilega stakkst til jarðar rétt fyrir lendingu á Reykjavíkurflugvelli.

Flugmálastórn Íslands sem kom fram fyrir hönd ríkisins þar sem slysið varð (State of Occurrence), fól rannsókn slyssins hlutaðeigandi Kanadískum yfirvöldum sem komu fram fyrir hönd skráningarríkis flugvélarinnar (State of Registry) og ríkis flugrekanda (State of the Operator), í samræmi við ICAO Skjalauka nr. 13, 5. kafla, gr. 5.1.

Rannsóknin fór því fram á vegum Kanadísku flugslysanefndarinnar, Canadian Aviation Safety Board, en íslenska flugmálastjórnin og íslenska flugslysanefndin tóku þátt í rannsókninni.

Hér á eftir er endurprentuð skýrsla Kanadískra yfirvalda um niðurstöður rannsóknarinnar, en skýrslan var gefin út í Kanada 30. maí 1990.

FLUGMÁLASTJÓRN

FLUGSLYSANEFND

14.06.1990

The Canadian Aviation Safety Board investigated this occurrence for the purpose of advancing aviation safety. It is not the object of the Board to determine or apportion any blame or liability.

AVIATION OCCURRENCE REPORT

GEOTERREX LIMITED
CASA C212 C-GILU
REYKJAVIK, ICELAND
02 AUGUST 1988

REPORT NUMBER 88H0009

SYNOPSIS

The aircraft was on a ILS approach to runway 20 at Reykjavik Airport, Iceland. Approximately one-half mile from the runway threshold, the aircraft was observed to enter a steep turn to the right, and the nose of the aircraft dropped sharply. The aircraft continued to turn right and descended rapidly until it struck the ground and burst into flames. All three crew members were killed on impact.

It was determined that the crew lost control of the aircraft most probably because of large fluctuations in the power output of the right engine caused by the shift of an incorrectly installed speeder spring in the right propeller governor.

NOTE: In accordance with Annex 13 to the Convention on International Civil Aviation, Iceland, as the State of Occurrence, has delegated the conduct of the investigation to Canada, the State of Registry. Iceland has continued to support and facilitate the Canadian Aviation Safety Board's investigation into this occurrence.

Ce rapport est également disponible en français.

17 January 1990

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1.0 FACTUAL INFORMATION

1.1 History of the Flight

The CASA C212 was on a ferry flight from Ottawa, Ontario to Nantes, France. The flight consisted of five legs with two overnight stops. On 31 July 1988, the aircraft departed Ottawa at 1250 Coordinated Universal Time (UTC)* and arrived at Goose Bay, Labrador at 1700 UTC. The aircraft made a 40-hour planned stop at Goose Bay. On 02 August 1988, the aircraft departed Goose Bay at 0905 UTC and arrived at Narsarsuaq, Greenland at 1250 UTC. The aircraft was refuelled and departed one hour later at 1350 UTC for Reykjavik, Iceland, at a planned altitude of 13,000 feet above sea level (asl)** on an instrument flight rules (IFR)*** flight plan.

At Reykjavik, the crew flew an instrument landing system (ILS) approach to runway 20 at Reykjavik Airport. Approximately one-half mile from the runway threshold, the aircraft was observed to enter a steep turn to the right, and the nose of the aircraft was seen to drop sharply. The aircraft continued to turn to the right through 270 degrees and descended rapidly until it struck the ground approximately 900 feet short of the runway threshold. The aircraft burst into flames shortly after impact. All three crew members were fatally injured in the accident.

The accident occurred at an elevation of 15 feet asl at lat 64°08'N, long 21°57'W at 1742 UTC during the hours of daylight.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	3	-	-	3
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	3	-	-	3

* All times are UTC unless otherwise stated.
** Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.
*** See Glossary for all abbreviations and acronyms.

1.3 Damage to Aircraft

The aircraft was destroyed by the impact and post-crash fire.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

	Pilot-In-Command	Co-Pilot
Age	51	63
Pilot Licence	Airline Transport	Commercial
Medical Expiry Date	Valid	Valid
Total Flying Time	13,000 hr	21,300 hr
Total Last 90 Days	250 hr	141 hr
Total on Type Last 90 Days	250 hr	141 hr
Hours on Duty Prior to Occurrence	10 hr	10 hr
Hours off Duty Prior to Work Period	40 hr	40 hr

The pilot-in-command's instrument rating had expired on 01 June 1988. The co-pilot did not possess an instrument rating, and there was no indication in his records that he had ever possessed one. He had commenced his flying career with the Air Force where he would have received training in instrument flying.

1.6 Aircraft Information

Manufacturer	Construcciones Aeronauticas, S.A. (CASA)
Type	C212-CC39
Year of Manufacture	1982
Serial Number	245
Certificate of Airworthiness	Valid
Total Airframe Time	4049.8 hr
Engine Type (2)	Garrett TPE 331-10 R-511C
Propeller Type (2)	Hartzell HC-B4MN-5AL
Maximum Allowable Take-off Weight	16,427 lb
Recommended Fuel Types	JET A-1, JP-4

The airframe of the aircraft had been extensively modified for aerial survey work. These modifications consisted of two probes mounted on the fuselage above the cockpit and extending 10 feet in front of the aircraft nose, a 16-foot tail boom, and two wing tip pylons. The pylons were removable, whereas the nose probes and tail boom were not. The probes, pylons, and tail boom served to support a wire loop antenna which ran around the aircraft.

A considerable amount of electronic equipment required for survey work and other survey associated hardware had been installed in the main cabin and rear fuselage areas. In addition, a ferry fuel tank had been installed in the cabin area.

1.6.1 Weight and Balance

The all-up-weight (AUW) of the aircraft at take-off from Narsarsuaq was estimated to be 19,500 pounds, some 3,000 pounds above the maximum authorized take-off weight. At the time of the accident, the AUW was estimated to be about 16,600 pounds, some 200 pounds above the maximum authorized take-off weight. These weights were calculated using a dry aircraft weight of 12,347 pounds, a crew weight of 540 pounds (as per Canadian Aeronautical Information Publication RAC 3.4), a baggage and spares weight of 500 pounds, and fuel loads of 6,097 and 3,236 pounds respectively at take-off and at the time of the accident. A review of the aircraft journey log showed that many of the previous entries in the Total Weight at Take-off column were in excess of the maximum authorized take-off weight.

The centre of gravity of the aircraft at the time of the accident was 22 per cent of the mean aerodynamic chord (MAC), within the centre of gravity limits of 10 to 30 per cent of MAC.

1.7 Meteorological Information

The weather forecast for Reykjavik valid from 1200 UTC 02 August 1988 until 1200 UTC 03 August 1988 was as follows:

Wind 140°T at 20 gusting to 30 kt, visibility greater than 10 km in rain, 4/8 stratus at 1,000 ft agl, 6/8 stratocumulus at 2,000 ft agl, 8/8 altostratus at 6,000 ft agl, tempo visibility 5 km in rain, 6/8 stratus at 600 ft agl, 8/8 stratocumulus at 2,000 ft agl, gradu 1600 to 1800 wind 240°T at 15 kt, visibility greater than 10 km, 4/8 stratus at 1,000 ft agl, 7/8 cumulus at 1,500 ft agl, tempo 8 km in showers, 6/8 stratus at 600 ft agl, 8/8 cumulus at 1,000 ft agl.

The 1700 UTC observation for Reykjavik was as follows:

Wind 210°T at 13 kt, visibility greater than 10 km in recent rain, 3/8 stratus fractus at 300 ft agl, 4/8 stratus fractus at 1,200 ft agl, 6/8 stratus fractus at 1,500 ft agl, temperature 12°C, barometric pressure 998 mb.

The 1800 UTC observation for Reykjavik was as follows:

Wind 230°T at 15 kt, visibility 9 km in recent drizzle, 4/8 stratus fractus at 400 ft agl, 8/8 stratus fractus at 800 ft agl, temperature 10°C dew point 10°C, barometric pressure 998 mb.

The visibility from the Reykjavik Tower at 1738 UTC was three to four kilometres. At 1741 UTC, just prior to the accident, the tower controller observed a visibility of 1.5 to 2 kilometres, a ceiling of 360 feet asl, and a wind of 240 degrees true at 10 knots.

1.8 Aids to Navigation

The aircraft flew an ILS approach to runway 20 at Reykjavik, and, at that time, all navigation aids at the airport were indicating serviceable. The ILS had been fully flight checked on 21 June 1988 and had been serviceable at that time. A flight inspection of the ILS was carried out approximately two hours after the accident. The flight inspection console was not installed in the flight inspection aircraft at the time; however, the ILS was flown in visual flight rules (VFR) conditions, and comparisons were made with other navigation aids in the area and with the visual approach slope indicator system (VASIS). The operation of the ILS appeared to be normal.

1.9 Communications

The crew contacted Keflavik Approach Control at 1712 UTC and was switched to Reykjavik Approach Control at 1733 UTC. The aircraft was radar vectored to the ILS localizer and was cleared for the ILS approach to runway 20 at 1736 UTC. At 1737 UTC, Reykjavik Approach switched the aircraft to Reykjavik Tower, and the aircraft remained on tower frequency until it crashed. There was no indication from the transmissions from the aircraft that there were any problems with the flight.

1.10 Aerodrome Information

Reykjavik Airport is located just south of the downtown area of the city of Reykjavik. The airport has three intersecting runways. Runway 20 is the main instrument runway and is 1,749 metres long by 45 metres wide. The airfield reference elevation is 27 feet asl.

1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder nor a cockpit voice recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

1.12.1 Accident Site

The accident site was located 900 feet short of the threshold of runway 20 and 185 feet to the right of the extended runway centre line. The aircraft crashed on a gravel airport service road which ran in an east/west direction. Drainage ditches approximately three feet deep were located on either side of the road. The terrain at the site was generally flat and was approximately 10 to 15 feet below the runway elevation.

1.12.2 Aircraft Impact

The aircraft struck the ground in a 45-degree nose-down attitude with a small amount of right bank, in a slip to the right. The heading at impact was 110 degrees magnetic after a 270-degree turn to the right. There was no indication of a ground impact prior to the accident site and no wreckage trail. The wing fuel tanks were ruptured on impact, and an intense fire erupted immediately.

1.12.3 Aircraft Wreckage

Most of the cockpit, main cabin, tail surfaces, and left wing were destroyed by the post-impact fire. The right wing, right side of the fuselage, and rear cargo ramp were intact although heavily damaged by impact forces. Both engines were damaged during the impact, and there was heavy fire damage to the left engine. All eight propeller blades were found in or near the wreckage.

1.13 Medical Information

The autopsy results indicated that all three crew members were fatally injured on impact. There was no evidence that incapacitation, physiological, or psychological factors affected the crew's performance.

The co-pilot occupied the left-hand seat and was most likely the pilot flying at the time of the accident. During the months of February and March 1988, the co-pilot had been operated on for a small malignant growth on his neck and, following the operation, had undergone a series of radiation treatments. In March 1988, the co-pilot underwent his Transport Canada (TC) medical. No mention of the operation or the treatment was made on the TC medical form.

A review of the co-pilot's personal and TC medical records was carried out by a qualified aviation medical officer. The co-pilot's recent clinical history was not recorded on the Transport Canada medical form which the co-pilot and the medical examiner had signed at the time of the co-pilot's latest medical examination. Had the co-pilot's recent surgery and treatment been recorded, his Licence Validation Certificate would probably not been extended. The review also indicated that there was no direct evidence in the medical records or in the autopsy findings which would suggest the tumour had any relation to the accident.

Toxicological testing was carried out where possible. The tests did not reveal the presence of any drugs or toxic substances other than traces of caffeine in all three crew members and traces of carbon monoxide in the flight engineer, a heavy smoker.

1.14 Fire

An intense fire erupted shortly after the aircraft struck the ground. Three crash vehicles from the airport were on the scene within 90 seconds. On arrival, there was an intense fire which engulfed the left wing and the fuselage area. The city fire department arrived approximately three minutes after the airport vehicles. The fire was extinguished within six minutes of the arrival of the first airport vehicles.

1.15 Survival Aspects

The accident was not survivable. The impact forces were not within the level of human tolerance. It appeared that both the pilot and co-pilot were wearing their seat-belts. Damage to these belts and their anchor points precluded any assessment of their effectiveness at impact.

1.16 Tests and Research

1.16.1 Flap Position and Usage

The left flap and associated control tubes were destroyed by the post-crash fire. The right flap was intact and still attached to the wing. Impact marks on the right flap hinges and on adjacent surfaces of this flap and wing indicate that the right flap was at the 25-degree position at impact. On the C212, full or 100 per cent flap is 40 degrees of flap.

The cockpit flap position indicator receives its flap position information from a transmitter which is located in the left centre wing and which is connected to the left flap by a linkage assembly. Laboratory analysis of the flap position indicator determined that, at the time of the accident, the indicator was reading 57 per cent flap. This is equivalent to 22.8 degrees of flap.

The flap actuator was found in the wreckage in the fully extended position. Disassembly of the actuator revealed that there were two witness marks on the piston rod which dimensionally matched the cylinder end cap. These marks indicated that the piston was 2.3 inches from the fully retracted position, which equates to 57 per cent of the total possible piston travel of 4.0 inches. In addition, the cylinder wall and the mating areas of the piston were noticeably scored. There were repeated score marks on the cylinder wall, running the full length of the cylinder. This damage appeared to be of a relatively long-term nature and was not indicative of a failure of any kind.

1.16.2 Engine Teardowns

The left engine was the most severely damaged of the two engines. It was heavily damaged by the impact and then further damaged by the post-crash fire. The engine mounts were broken away, and the rear area of the engine was crushed and distorted. On impact, the location. The right hub assembly was intact and had not been damaged by the post-crash fire. Three blades of the right propeller had broken off at the cuff; the fourth had broken approximately 20 inches outboard. It was noted prior to disassembly of the propellers that one blade of each propeller had shifted in its clamp. Blade L-2 had turned approximately 12 degrees in the direction of fine pitch, and blade R-1 had turned approximately 24 degrees in the same direction.

All four blades of the right propeller were examined for evidence of delamination repairs in the area of the repairs carried out by the propeller repair station. Evidence of delamination repairs was found on blade R-1; however, it should be noted that damage to the tip areas of blades R-2 and R-3 precluded any verification that repairs had not been carried out on these blades.

Both propeller assemblies were examined in an attempt to determine the pitch angles of each blade at the time of impact. On this type of propeller, blade ground strikes will typically result in semicircular imprints around the inner bearing areas of the hub pilot tube and the mating butt face of the blade shank. Blade angle limits measured at the blade reference location (42-inch station) are as follows: feathered-plus 83 degrees, flight idle-plus seven degrees, and full reverse-minus 10 degrees.

Three of the left blades (L-1, L-2, and L-4) had hub/butt imprint marks located in the blade trailing edge quadrant, whereas the imprint mark for blade L-3 was located in the leading edge quadrant. The location of the L-1, L-2, and L-4 marks is consistent with the loading encountered when rotating blade tips strike the ground. The L-3 marks suggest that the propeller had stopped rotating before this blade struck the ground. When the imprint marks on the hubs and blades of the left propeller were aligned, all four blades were found to be at a similar pitch angle of approximately zero to three degrees positive at the blade roots. Because the blade angle decreases toward the blade tip, this root angle is equivalent to a blade pitch angle of minus 18 to minus 15 degrees at the blade reference location. The common pitch angles of the four blades obtained when the hub/butt marks were aligned indicated that the slippage of blade L-2 occurred subsequent to the initial impact.

The interior components of the left piston/cylinder assembly were examined for impact marks. There were marks on both the piston wall and pitch change rod which equated to blade angles (at the reference location) of plus three, minus one, plus four, and plus

28 degrees. As the oil in the propeller system prevents blade movement to coarser angles at impact, the 28-degree mark was likely made by the impact of the first blade and represents the blade angle at impact. This initial and subsequent impacts would have moved all four blades to a finer pitch and accounted for the lower pitch settings obtained from the remaining three witness marks.

The marks on both the butts and the hubs for blades R-2 and R-3 were centred approximately 10 degrees aft of the propeller plane of rotation. The marks for blade R-4 were aft of this plane by 45 degrees. For R-2, R-3, and R-4, the blade chord line at the root was approximately coincident with the propeller plane of rotation. The marks for blade R-1 were aft of the plane of rotation by 32 degrees but 75 degrees from the blade chord line at the root. There was also a significant variation in the length and depth of the imprint marks with the lightest mark at blade R-1 and the heaviest at R-4. Alignment of the butt and hub imprint marks for blades R-2, R-3, and R-4 each resulted in similar blade root angles of approximately zero degrees. The blade root angle for R-1 was approximately minus 45 degrees.

Detailed examination following disassembly showed that blade R-1 had actually slipped approximately 28 degrees rather than the 24 degrees noted in the initial examination. It was apparent from this detailed examination that this blade had shifted back slightly after the initial slip as a result of subsequent impacts or handling during recovery. Although there is a possibility that blade R-1 slipped in its clamp prior to impact, it is more likely that the following occurred: if blade R-1 was the first to make ground contact and this contact was relatively light, this could impart a rotational force sufficient to slip the blade in the clamp and break the blade at approximately mid-station, yet not have sufficient aft bending displacement to mark the hub/butt area. The rotational force would be transmitted through the blade actuating mechanism to turn the other blades toward fine pitch. The subsequent ground impacts of blades R-2 and R-3 would continue the twisting action through and beyond the full reverse position. Blade R-4 showed the heaviest reaction imprint and probably absorbed most of the remaining rotational energy. By the time R-1 struck the ground again, the propeller had either stopped or almost stopped rotating, and therefore the hub/butt marks on R-1 were more the result of the forward motion of the aircraft rather than of the rotational motion of the propeller.

The actuating components of the right propeller were examined for impact marks. There was a mark on the pitch change rod which equated to a blade angle of plus 29 degrees.

1.16.5 Engine and Propeller Controls

The controls and linkages on the right-hand engine were generally intact. Although these appeared to be in correct adjustment, this could not be confirmed since the verification of some adjustments requires functional testing. In addition, there was some impact damage to these controls. The parts on the left-hand engine were much more severely damaged, both by impact and fire; examination was limited to comparing linkage lengths and control travels to those on the other engine. No significant discrepancies were identified. The fuel valves were found in the closed position on both engines, but this condition was assessed as impact related. The propeller pitch controls were partially disassembled and appeared in good condition.

The fuel control/fuel pump assembly from the right engine was undamaged. It was functionally tested at the manufacturer and was found to be functioning normally. The same assembly from the left engine had suffered severe impact and fire damage. Functional testing of this assembly was attempted at the manufacturer; however, the damage to the unit precluded any meaningful evaluation of its performance.

The left propeller governor was functionally tested at the manufacturer and was found to be functioning within manufacturer's specifications. When the right propeller governor was similarly tested, the maximum governing speed attained was 90 per cent of that required by the specifications. Disassembly of the unit revealed that the speeder spring of the governor pilot valve, although in the seated position on the lower spring seat, was not properly positioned on this seat in that the tang of the spring was not in the slot of the pilot valve. Further examination revealed wear marks on both the spring tang and the valve stem which indicated that, during initial assembly, the tang of the spring had not been aligned with the slot in the pilot valve stem, and, therefore, the spring had hung up on the tapered end of the stem. At some later time, during operation of the governor, the speeder spring shifted a distance of 5/64 of an inch and seated on the seat or shoulder of the pilot valve but with the spring tang out of the slot in the valve. The effect of this shift was to reduce the pre-load on the spring which resulted in the low maximum governing speed observed during functional testing.

1.16.6 Right Engine Operation

The engine manufacturer was asked to determine the effect of the right propeller governor speeder spring shifting, as discussed, in flight. The manufacturer's analysis was carried out for the following operating conditions at standard day temperatures and pressures:

1. Take-off power - 100% torque, 100% engine rpm, 650° C exhaust gas temperature (EGT), sea level.

2. Cruise power - 70% torque, 96% engine rpm, 650° C EGT, 12,000 feet asl.

3. Approach power - 30% torque, 96% engine rpm, 650° C EGT, 12,000 feet asl and sea level.

4. Flight idle power - flight idle, 100% engine rpm, low EGT, 12,000 feet asl and sea level.

For the take-off power setting, changing the speeder spring height by 5/64 of an inch will cause the propeller governor set point to reset from 100 per cent to approximately 90 per cent. At the instant the spring resets, the governor will sense that the engine is operating at an overspeed condition and will open fully, dumping the propeller dome oil and causing the propeller blades to go toward a very high pitch angle in order to load the engine and reduce its speed. The underspeed governor (USG) will begin increasing fuel flow to try and hold the engine at its underspeed set point of 96.5 per cent. However, the propeller governor's gain is much higher than that on the USG so that the engine speed will continue to decay toward 90 per cent. The USG attempts to control the engine speed at 96.5 per cent by increasing the fuel flow until it reaches the acceleration schedule in the fuel control unit. As the engine speed continues to decay toward 90 per cent, the acceleration schedule will reduce the fuel flow until it reaches approximately 390 pounds per hour (pph) at 90 per cent rpm.

For the cruise power setting, the engine rpm would decay from 96 per cent to 80 per cent and the fuel flow would be reduced to 206 pph. For both the approach and flight idle settings, the engine rpm would decay to 90 per cent and the fuel flow would reduce to 283 pph at 12,000 feet and 390 pph at sea level.

From this point on, it is difficult to predict how the engine will respond. The manufacturer's analytical models are set up to deal with systems when they are operating and interfacing at their design operating points. In this situation, however, the systems are operating in such a way as to interfere with each other, and therefore it is difficult to determine specifically what the engine operation will be after the engine rpm decays to the aforementioned values. The initial engine response is predictable, however, in that, the sudden propeller pitch change to a very high angle will result in an abrupt and large thrust surge of short duration on the right engine. Despite the difficulty in predicting the longer term engine response, it is believed that, following the initial thrust surge, the engine rpm would begin to oscillate in the following manner. When the spring suddenly re-positioned, the governor flyweights would move fully out, moving the pilot valve full travel to dump oil from the propeller dome into the engine case. This would move the blades toward coarse pitch, slowing the engine speed. Normally, the pilot valve moves only a very small amount to modulate the pressure to the propeller in response to small rpm changes. It is probable that it would not be able to respond quickly enough to the rapid decrease in propeller speed that would occur initially when the spring re-positioned, and the rpm would drop significantly below the new control speed (90 per cent) before the speeder spring moved the pilot valve to block the dump and port high pressure oil back to the propeller. With the flyweights now fully in, the valve would then move full travel in the opposite direction, porting maximum oil flow and pressure to the propeller. This 'overshooting' of the new setting of the governor speeder spring would likely repeat through several cycles. These oscillations will either dampen out, remain at a constant amplitude and period, or become divergent.

1.16.7 Bulb and Instrument Examination

Laboratory examination of the warning/advisory lights was carried out. Of the 30 indicators on the annunciator panel, four were missing and the remaining 26 were determined to be off at impact. Of the other cockpit lights which were available for examination, the right beta light and the VOR 2 indicator were considered to be on at impact. The beta lights are illuminated by a switch which senses oil pressure in the propeller system. The illumination of a beta light indicates that that propeller is operating at a pitch angle below the flight idle setting of seven degrees.

The examination of the engine instruments resulted in the following engine parameters at impact: right engine - torque 20%, rpm 96 to 98%, oil pressure 82 psi; and left engine - torque 19 to 20%, rpm 92%, oil pressure 110 psi. Although these parameters are not in agreement with the blade angles determined at 1.16.4, it is considered likely that there were significant and rapid changes in the operating conditions of both engines following the departure from controlled flight as a result of airspeed and load changes and possible crew inputs, and that these changes combined with the lag in the instrument readings could account for this disagreement.

A review of the propeller control system in relation to the abnormal operation of the engine tends to indicate that the beta light may not have been indicative of propeller pitch position. Since the switch for the beta light senses oil pressure, it is possible that a pressure rise sufficient to operate the switch could occur and that the illumination of the light could be repeated a number of times with the oscillations of the engine.

1.17 Additional Information

1.17.1 Witnesses

Thirty-five witnesses saw and/or heard the aircraft at some point from the time the aircraft descended below the lower cloud layer until it crashed. Twenty-five of these witnesses saw the aircraft depart from controlled flight, and all but one of these 25 reported seeing the aircraft roll to the right at the beginning of the out-of-control sequence. A total of 21 witnesses heard some sort of unusual engine noise either just prior to or during the out-of-control sequence. A total of 15 witnesses both heard a noise and saw the aircraft depart controlled flight.

1.17.2 Radar Monitoring

The ILS approach into Reykjavik Airport was monitored on Keflavik radar. Plots of altitude, airspeed, and rate of descent versus distance from the runway threshold were derived from this radar data. The data from the radar scope were manually plotted and contained only 21 data points in a five-minute period. The resultant plot showed large variations of altitude and airspeed versus distance/time, and, as a result, various computer-generated curve fits were used to smooth the data. Values from this computer curve rather than the source radar data were used for analysis purposes. Because of the lack of accurate and frequent source data, caution must be used in the interpretation and analysis of the computer curves.

The source radar data indicate that the aircraft was established on the ILS localizer from the time of localizer intercept until the second from last data point. The position of the last source data point is to the right of the localizer and approximately 1,000 feet from the runway which coincides with the position of the accident site. Because of this, the last source data point most likely represents the aircraft position during the accident sequence.

The aircraft intercepted the ILS glide path at approximately 10 nautical miles from the runway threshold, at an altitude of 3,600 feet asl and an airspeed of 160 knots. This position corresponds with the published approach procedure which gives a glide path intercept altitude of 3,500 feet asl at the outer marker located 10.1 nautical miles from the runway threshold. From the outer marker until approximately three nautical miles, the airspeed maintained 135 knots and the rate of descent averaged approximately 900 feet per minute. The aircraft then levelled off for approximately three quarters of a nautical mile and, just inside two nautical miles, began descending again at 500 to 800 feet per minute. The airspeed steadily decreased from 130 knots at three nautical miles to an average airspeed of 97 knots between the last two source data points. The computer curve gives an aircraft altitude of 200 feet asl just prior to the accident sequence.

1.17.3 Engine Operation in Flight

Engine speed (rpm) and power are controlled by two control levers, the speed levers and the power levers. In flight, the engine is operated in the propeller governing mode where rpm is maintained by the propeller governor at the speed lever setting, and fuel flow is controlled by the main fuel valve in the fuel control through the power levers. The propeller governor maintains the engine rpm by positioning the propeller blade angles to absorb whatever power is set by the pilot's positioning of the power levers. In flight, the speed levers can be used to set the engine rpm from 96.0 to 100.0 per cent.

Speed lever settings are detailed in the C212 Aircraft Flight Manual check-list as follows: descent check - 96 per cent, approach check - 100 per cent (take-off/land setting), and landing check - 100 per cent. The approach check would normally be carried out prior to intercepting the glide path on an ILS approach, and, in response to this check, the crew would advance the speed levers from 96 to 100 per cent. A speed lever setting of 100 per cent is again called for in the landing check to ensure that this selection has been made prior to landing.

1.17.4 Fuel

The aircraft was capable of carrying 6,097 pounds of fuel, 3,836 pounds in the wing tanks and 2,261 pounds in the cabin installed ferry tank. The aircraft departed Ottawa with a full load of fuel and was refuelled at Goose Bay with 3,737 pounds of JET A-1 fuel. The aircraft was subsequently refuelled at Narsarsuaq with 2,821 pounds of JET A-1 fuel.

Aircraft fuel consumption figures are contained in the CASA C212 Pilot Training Manual. These figures and fuel consumption information obtained from discussions with C212 pilots indicate that typical cruise fuel consumption at 10,000 feet asl is approximately 740 pph. The actual fuel consumptions Ottawa to Goose Bay and Narsarsuaq to Reykjavik were 911 and 752 pph respectively, based on the length of the trip and the fuel added at the end of the trip. At typical cruise fuel consumption, the fuel required for the first leg was 3,034 pounds. The reason for the high fuel consumption on this first leg could not be determined; however, calculations indicate that the aircraft departed Narsarsuaq with a full load of fuel.

1.17.5 Aircraft Type Approval

In 1982, CASA approached Transport Canada (TC) to obtain a Canadian aircraft type approval (ATA) for the CASA C212 aircraft. The requested ATA was for the basic C212 transport aircraft under Federal Aviation Regulation (FAR) 25. That same year, TC test pilots flew the aircraft in Spain and discovered a number of deficiencies with the aircraft which prevented type approval at that time. These certification test flights were conducted on an unmodified aircraft at flap settings greater than 10 degrees.

In 1984, CASA again approached TC with a list of proposed modifications to be made to C212 aircraft serial number 245 (the accident aircraft) in order to comply with the TC requirements for type approval. The requested type approval this time was for a survey aircraft rather than a passenger-carrying aircraft. At that time, the aircraft was flying under a Swiss registry.

In 1986, the survey version of the aircraft was granted a unique restricted ATA for survey work only. The issue of this restricted ATA was based on the following:

1. The basic C212 certification as approved by the Spanish Civil Aviation authorities;
2. A series of modifications proposed by CASA;
3. A supplementary type approval (STA) covering the installation of the survey system and the stability finlets; and
4. A series of flight restrictions.

The main modifications made to the aircraft and the flight restrictions imposed on its operation prior to granting this ATA were as follows:

1. The installation of vertical finlets on the horizontal tail to improve directional stability;
2. The installation of a stall warning system;
3. Aircraft operations except in an emergency were restricted to 10 degrees (25 per cent) flap;
4. Flights into known or predicted icing conditions were prohibited; and
5. Essential flight and survey crew only were permitted.

The aircraft was imported into Canada with the ferry fuel tank installed.

1.17.6 Aircraft Configuration

For the purposes of this ferry trip, the survey loop antenna and the wing tip pylons had been removed and stowed in the main cabin area. The Air Carrier Operating Certificate issued to the company did not specify that this was an authorized configuration, and, therefore, a ferry permit was required to authorize this configuration. A ferry permit was neither applied for nor obtained prior to the flight.

1.17.7 International Requirements for IFR Flight

Annex 1 to the International Civil Aviation Organization (ICAO) Convention, paragraph 2.1.7, covers the circumstances in which an instrument rating is required and reads as follows: "A contracting state having issued a pilot licence shall not permit the holder thereof to act either as a pilot-in-command or a co-pilot of an aircraft under IFR unless such holder has received proper authorization from such contracting state. Proper authorization shall comprise an instrument rating appropriate to the aircraft category." Paragraph 1.2.3 states that "A contracting state shall not permit the holder of a licence to exercise privileges other than those granted by that licence". Further, in Chapter 9 to Annex 6 under qualifications it states that "The pilot-in-command is to determine if the aircrew are properly rated, if the aircrew are currently valid and if they have maintained competency by state of registry."

1.17.8 Oxygen Requirements

Air Navigation Order (ANO), Series II, No. 9, the Oxygen Equipment Order, states that "No person shall fly an aircraft for more than 30 minutes at an altitude between 10,000 and 13,000 feet above mean sea level unless there is readily available to each flight crew member an oxygen mask and a supply of oxygen sufficient for the duration of the flight at cabin pressure altitudes above 10,000 feet." This ANO also states that "No person shall fly an aircraft for more than 30 minutes at a cabin pressure altitude between 10,000 and 13,000 feet above mean sea level unless each flight crew member on duty is continuously wearing and using an oxygen mask supplying oxygen." In addition, Annex 6 to the ICAO Convention indicates that the crew is required to wear oxygen masks throughout the duration of the time between 10,000 and 13,000 feet.

The C212 is an unpressurized aircraft. The oxygen system in the C212, when fully charged to 1,850 psi, will provide 7.99 man-hours of normal oxygen at 13,000 feet. It could not be determined whether the crew used the aircraft oxygen system during the trip.

1.17.9 Aircraft Performance

Because the aircraft was issued a restricted ATA, only a limited series of performance charts were drawn up specifically for the unique configuration of this aircraft. These charts were part of a Flight Manual Supplement pertaining to this aircraft only. The charts contained in the supplement did not include performance data for flap settings above 10 degrees. From the supplement, the recommended final approach speed at an AUW of 16,600 pounds and 10 degrees of flap was 103 knots. The minimum control speed airborne (V_{mca}) was 90 knots, five knots above the V_{mca} for the basic C212.

Discussions with TC certification test pilots regarding the initial evaluation flights conducted in Spain indicated that, as the flap setting was increased on the aircraft, the directional stability of the aircraft was gradually weakened. Directional stability requirements were satisfied at up to and including 10 degrees of flap. The increase in weight of the basic aircraft as a result of the addition of the survey-related hardware increased the aircraft stall speeds by approximately five knots. Apart from an increase in stall speed from the additional weight, however, neither the addition of this survey-related hardware nor the overweight condition of the aircraft at the time of the accident would have aggravated the aircraft stall characteristics.

1.17.10 Air Carrier Operating Certificate

The aircraft was being operated under the operations specifications and conditions of Air Carrier Operating Certificate (ACOC) Number 5037. The ATA and Certificate of Airworthiness, both requirements for issuance of the ACOC, had been previously issued. Section 3.2 of the ACOC lists the duties, responsibilities, and authority of operations personnel. In general terms, the operations manager (in this case the pilot-in-command) and the chief pilot (in this case the co-pilot) were responsible for the overall supervision of the company flying activities and for ensuring that TC and company regulations were adhered to.

The investigation revealed five areas of non-compliance within the flying operations, namely: the operations in excess of the maximum authorized take-off weight; the use of flap settings above those authorized; the unauthorized configuration of the aircraft; the flight under IFR with neither pilot IFR rated; and the extended flight above 10,000 feet asl with insufficient oxygen on board. Under the terms of the ACOC, the conduct of the operations in all five of these areas was the responsibility of the operations manager and the chief pilot. Of these five items, the first, the operations in excess of the maximum authorized take-off weight, would have been apparent from even a cursory review or audit of the operation.

2.0 ANALYSIS

2.1 Introduction

The aircraft departed from controlled flight approximately one-half mile from the runway threshold during an ILS approach. The loss of control appeared to be sudden and resulted in the aircraft turning rapidly to the right through 270 degrees before striking the ground. The analysis will focus on the operation of the aircraft with respect to gross weight and flap settings, the certification of the ferry tank, the possible slippage of a blade of the right propeller, and the incorrect installation of a spring in the right propeller governor.

2.2 Aircraft Weight

The aircraft weight was approximately 3,000 pounds or 19 per cent above the maximum authorized take-off weight on departure from Narsarsuaq. At the time of the accident, the weight was about 200 pounds above the maximum. The journey log entries showed that the aircraft had frequently been flown at weights exceeding that authorized. The effect of the high aircraft weight was to reduce the stall margin of the aircraft at any given speed.

2.3 Flap Usage

The investigation established that the flaps were set at between 20 and 25 degrees at impact. The relative agreement between the flap position determined by examination of the flap indicator (left flap position) and that determined by examination of the right flap and wing indicates that both flaps were in the same position at impact and that a split flap condition did not exist. Although the effect of an increase in flap setting above 10 degrees was to reduce the aircraft directional stability, the precise effect of the use of 20 to 25 degrees of flap could not be determined.

Although the flap actuator was found in the fully extended position indicating a flap setting of 40 degrees, it is likely that the actuator piston was forced to this position during the accident sequence. The witness marks on the piston give a flap position which is consistent with the other evidence. The repeated scoring the full length of the actuator cylinder indicated that the piston had been exercised the full length of the cylinder numerous times and therefore that flap settings up to 40 degrees had been selected on numerous occasions. All or some of this scoring could have occurred during the period that the aircraft was flying under a Swiss registry and no flap restrictions existed.

2.4 Ferry Fuel Tank

It is not uncommon for the maximum zero fuel weight (MZFW) of an aircraft to be such that the addition of a full load of fuel would result in an aircraft AUW in excess of that allowable. This gives operators greater flexibility in operational planning by enabling them to trade off fuel with payload, providing they remain within the constraints imposed by MZFW and AUW.

For the basic CASA C212 aircraft with a basic weight of approximately 9,000 pounds, a ferry fuel tank is a viable option as it does provide the operator with this greater flexibility. However, in the case of the accident aircraft, the basic weight had increased to 12,347 pounds because of the addition of all the survey-related hardware. As these additions were either fixed structural modifications or electronic equipment installations, this additional weight was not readily removable to permit additional fuel to be carried. At any rate, the only type of service permitted by the Air Carrier Operating Certificate was aerial photography and survey, and these additions were required for that survey role. In fact, with the minimum crew complement of three (required for survey operations) and no cargo or baggage, the addition of wing fuel alone increased the aircraft AUW to 16,747 pounds, 210 pounds above the maximum authorized ramp weight. The basic aircraft weight, therefore, had been increased to the point where a ferry fuel tank was no longer a viable operational system.

In short, anytime the ferry tank was used by the operator, the aircraft was operating at a weight in excess of both the maximum authorized ramp weight and the maximum authorized take-off weight. Approval of this system on the aircraft did not appear to take into account the fact that the basic aircraft weight had already been substantially increased with survey-related modifications and that any operational use of the ferry tank system required the operator to exceed the aircraft weight limitations.

2.5 Instrument Qualifications

Neither pilot possessed a valid instrument rating as is required for international IFR flights.

2.6 Oxygen Requirements

A total of 9.75 man-hours of oxygen would have been required for the three crew members for the flight, assuming that the aircraft was below 10,000 feet asl for the first and last 15 minutes of the flight. The 7.99 man-hours of oxygen on board the aircraft was insufficient for the duration of the flight above 10,000 feet asl. It does not appear that the crews' performance was affected by their exposure to cabin altitudes above 10,000 feet asl without oxygen as both the radar and air traffic control tapes indicated that the crew followed the published approach procedures and responded normally to instructions.

2.7 Propeller Blade Slippage

The evidence relating to the left propeller indicated that the slippage of blade L-2 occurred after the initial impact. For the right propeller, the evidence concerning the position of blade R-1 at the time of impact was less conclusive than for L-2. Although the most probable reason for this slippage was ground impact, the possibility exists that this blade rotated in its clamp prior to impact, but after the shift of the speeder spring, as a result of forces generated by the oscillations of the right engine.

2.8 Propeller Blade Angles

Although it was not possible to make a specific determination of the propeller blade angles at initial impact, the evidence indicated that the twist of all blades into the negative pitch area occurred during the impact sequence. The marks on the actuating mechanisms of both propellers indicated that both were within the normal operating range at impact.

2.9 Propeller Governor Spring Shift

The evidence indicated that the improperly installed speeder spring shifted during the final stages of the approach to land and that, as a result of this shift, oscillations in engine power occurred which precipitated the loss of control.

The possibility exists that the speeder spring shifted to the seated position either because of impact forces generated during the crash sequence or because of overtravel of the governor control head arm during the crash sequence. This is thought to be highly unlikely as the governor unit itself was undamaged and the mechanical stops on the governor head which limit control arm travel were intact and undamaged. The shift in spring position, therefore, must have occurred during the accident flight.

On take-off from Narsarsuaq, a shift of the speeder spring would have been readily apparent to the crew from the right engine instrument indications and by the response of the aircraft, and the crew would have aborted the take-off. If the shift had occurred during cruise flight, the crew would have shut the engine down and either returned to Narsarsuaq or continued to Reykjavik. Similarly, had this occurred during descent or during the initial part of the approach, the crew would have shut the engine down and continued for landing. An engine shutdown would have been followed by a transmission to air traffic control, and this was not the case. Also, the engine examinations indicated that both engines were operating at impact. It is concluded, therefore, that the shift in the position of the speeder spring occurred on late final approach and that the effect of this shift was such that the crew had insufficient time to either shut down the engine and/or contact air traffic control. If the crew had delayed advancing the speed levers from the descent setting of 96 per cent rpm to the landing setting of 100 per cent rpm until the aircraft was on late final, then this selection and the subsequent normal reaction of the propeller governor may have provided the impetus for the spring shift.

Analysis of the radar data indicated that the crew flew a relatively stable ILS approach as far as localizer position was concerned. The approach appeared to be less stable as far as rate of descent was concerned, although the rate of descent variations appeared to be well within those which could be encountered during an ILS approach. The airspeed appeared to be well controlled and had been decreased to slightly below the recommended approach speed at the time of the accident.

The immediate response of the crew to a large thrust increase on the right engine would have been to apply right rudder to correct for the left yawing moment of the aircraft. The normal crew response would then be to assess the situation to determine the cause of the asymmetry. This would be confusing in this case because the applied rudder would indicate a left engine failure; however, the left engine instruments would show normal operating conditions. When the thrust on the right engine suddenly decreased, the crew would have had a large rudder input still applied. As well, if this change in thrust resulted in a right engine thrust level below that of the left engine, then an asymmetric power condition would also exist. The yaw resulting from this asymmetric power condition would be in the same direction as the yaw from the applied rudder, The combined effect of the rudder and thrust induced yaws may have been sufficient to cause the crew to lose control of the aircraft. When the additional effects of the weakened directional stability because of the flap setting and the reduced stall margin because of aircraft weight are also considered, loss of aircraft control would seem highly likely.

3.0 CONCLUSIONS

3.1 Findings

1. The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

2. The centre of gravity was calculated to be within the prescribed limits.

3. The weight of the aircraft was calculated to be approximately 3,000 pounds above the maximum authorized take-off weight on take-off from Narsarsuaq.

4. Although the pilot's instrument rating had expired and the co-pilot did not possess one, the crew filed an IFR flight plan from Narsarsuaq to Reykjavik.

5. The approach into Reykjavik was flown with the flaps set at approximately 25 degrees, 15 degrees above the approved maximum of 10 degrees.

6. The speeder spring of the right propeller governor pilot valve was incorrectly installed during assembly of the component.

7. Because of the incorrect installation, the speeder spring probably shifted when the aircraft was on late final approach, and this shift resulted in large thrust fluctuations of the right engine.

8. As a result of the right engine thrust fluctuations, the crew probably lost control of the aircraft.

9. A ferry permit authorizing the aircraft configuration for the flight was not obtained prior to the flight.

10. There was insufficient oxygen carried on the aircraft for the duration of the flight above 10,000 feet asl.

11. Approval of the ferry tank installation did not appear to take into account the significant increase in the basic weight of the aircraft as a result of the survey-related modifications.

12. The aircraft had frequently been flown at weights in excess of the maximum authorized.

13. The co-pilot's latest Transport Canada medical form did not indicate that he had recently undergone surgery and treatment.

14. There were no physical, physiological, or psychological factors which may have affected the crews' actions at the time of the accident.

3.2 Causes

The crew lost control of the aircraft most probably because of large fluctuations in the power output of the right engine caused by the shift of an incorrectly installed speeder spring in the right propeller governor.

4.0 SAFETY ACTION

4.1 Action Taken

4.1.1 Propeller Governor Speeder Spring Installation

The investigation of the aircraft powerplants found that the speeder spring on the right engine's propeller governor was improperly installed. Because many similar mechanisms are in service on this and other type engines, the CASB issued Aviation Safety Advisory 1054 to Transport Canada on 16 May 1989. This advisory suggested that Transport Canada ensure that installation and quality-control procedures are in place to preclude a recurrence of improper installation, and that Transport Canada consider a one-time inspection of propeller governors which were assembled and calibrated at Garrett during the same period. A reply to this advisory has yet to be received from Transport Canada; however, Garrett has stated that a program is underway to improve the design of the spring and to examine propeller governors in service to verify proper assembly.

4.2 Action Required

4.2.1 Surveillance, Audit, and Inspection

This accident once again underlines the CASB's longstanding concerns with respect to the effectiveness of Transport Canada's processes for regulatory control of operations and maintenance. In May 1989, CASB report 87-W70073 cited several examples of substandard performance and deviations from regulatory requirements which went undetected by Transport Canada's surveillance program; hence the CASB recommended that:

> The Department of Transport cause an independent study to be made of Transport Canada's policies and procedures for the audit, inspection and surveillance of the operations and maintenance functions of air carriers engaged in remote operations.
>
> CASB 89-05

In response, Transport Canada has provided for the intent of this recommendation in the contract with a consulting firm currently examining Transport Canada's capability to monitor the safety of the Canadian aviation industry; a report to Transport Canada on the results of this study was expected in December 1989.