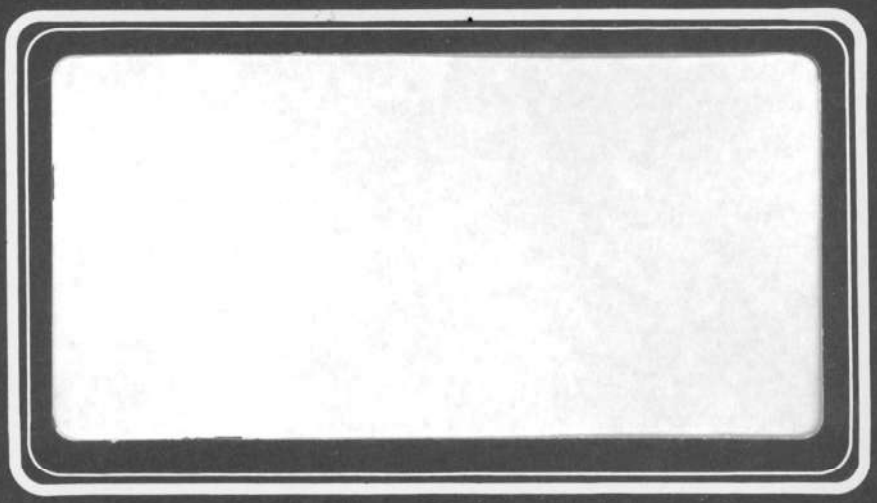
Canadian Aviation Safety Board

Bureau canadien de la sécurité aérienne



Civil Aviation Occurrence Report

Rapport d'un fait aéronautique civil

Canada

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

AIRCRAFT ACCIDENT REPORT

NORTH AMERICAN ROAD LTD.
MITSUBISHI MU-2B-35, C-GLOW
EDMONTON, ALBERTA
6 DECEMBER 1981

REPORT NUMBER 81-W10137

SYNOPSIS

The aircraft was on a night visual approach to runway 30 at Edmonton Municipal Airport. The aircraft departed from controlled flight and struck the roof of a hospital one mile short of the runway. The aircraft experienced a reduction or loss of engine power for undetermined reasons.

1 May 1986

Ce rapport est également disponible en français.

Introductory Note

This accident was originally investigated by the Aviation Safety Bureau of Transport Canada. The Aircraft Accident Review Board (AARB), an independent group of experts from outside the public service who reported to the Minister of Transport, audited the report, and it was released by the Minister in December 1983. It concluded that both engines lost power because of fuel starvation when an inadvertent switch selection was made.

After the release of the public report, a private investigation consulting firm employed by the owners of the aircraft brought forward evidence indicating a possible pre-impact failure of the left engine. In addition, the surviving first officer petitioned the AARB to reconsider the finding that an inadvertent switch selection had been made. As a result of the new evidence and this petition, the AARB recommended and the Aviation Safety Bureau agreed that the accident investigation should be reopened. On 1 October 1984, the Canadian Aviation Safety Board was established by law as the agency with exclusive authority when investigating aircraft accidents to determine the causes and make recommendations to prevent similar accidents; consequently, the reopened investigation was completed by the Canadian Aviation Safety Board. This new report by the Canadian Aviation Safety Board supersedes the previous report released in December 1983.

Because of the complex technical investigation into this accident and the widely differing views of the parties who had a direct interest in the findings, the Board, exercised its discretion in accordance with Section 23(3) of the CASB Act, and allowed the parties to make representations in person. These representations were made at the Board's head office in Hull, Quebec on 23 and 24 April 1986. The participants are listed in Appendix H.

After a complete review of the evidence and after considering the representations made orally and in writing, the Board is of the opinion that there is sufficient evidence to conclude that the aircraft experienced a reduction or loss of engine power to one or both engines and the aircraft departed from controlled flight while on final approach. The reasons for the reduction or loss of engine power remain undetermined. In addition, it is the Board's opinion that, based on the available evidence, the conclusion cannot be supported that an inadvertent switch selection was made shutting off fuel to the engines.

TABLE OF CONTENTS

1.0 FACTUAL INFORMATION

1.1 History of the Flight

On the evening of 6 December 1981, a Mitsubishi MU-2B-35, registration C-GLOW, owned by North American Road Ltd. of Edmonton, departed Fort McMurray at 1706 mountain standard time* (MST)** and climbed to 15,000 feet*** for a one hour flight to Edmonton. The first officer was occupying the left seat and at the controls. The flight was cleared to descend to 5,500 feet for a visual approach to runway 30 at Edmonton Municipal Airport. When below cloud at 8,000 feet, about 40 miles north of the airport, the first officer saw the lights of Fort Saskatchewan ahead and to the left, and the Municipal Airport ahead and to the right. He has no recollection of the subsequent events of the flight.

The aircraft was observed to be on a stable but lower than normal final approach. It then suddenly banked sharply to the left and dropped at a steep angle towards the hospital. The aircraft struck, then penetrated the side of the mechanical penthouse and settled on to the wider roof of the six-storey hospital. The unoccupied penthouse contained heating, ventilating, and electrical equipment.

The accident occurred at 1805 during the hours of darkness. The crash position was at lat 53° 33' 22" N and long 113° 29' 45" W.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	1	-	-	1
Serious	1	-	-	1
Minor/None	-	-	-	-
Totals	2	-	-	2

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces.

1.4 Other Damage

The aircraft penetrated the east concrete block wall of the mechanical penthouse and damaged equipment inside. As there was a danger of fire when aircraft fuel flowed into the hospital, the operating rooms on the sixth floor, as well as the entire hospital ventilating and heating systems were shut down.

* All times are given in MST (Coordinated Universal Time (UCT) minus 7 hours) unless otherwise stated.
** See glossary for all abbreviations and acronyms.
*** Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

1.5 Personnel Information

	Captain	First Officer
Age	64	19 (1)
Pilot Licence	Airline Transport	Commercial
Medical	Valid	Valid
Total Flying Time	25,000 hr	3,250 hr
Total on Type	3,000 hr	1,500 hr
Total Last 90 days	44 hr	42 hr
Total on Type Last 90 Days	44 hr	42 hr
Hours on Duty Prior to Occurrence	3 hr	3 hr
Hours Off Duty Prior to Work Period	36 hr	36 hr

The captain and the first officer were the only pilots employed by the company. They regularly flew the MU-2 together and routinely exchanged seating positions.

1.6 Aircraft Information

Type	Mitsubishi MU-2B-35
Manufacturer	Mitsubishi Heavy Industries Ltd.
Year of Manufacture	1974
Serial Number	624
Certificate of Airworthiness	Valid
Total Airframe Time	3,329 hr
Engine Type (2)	Garrett AiResearch TPE 331-6-251M
Propeller Type (2)	Hartzell model HC-B3TN-5
Maximum Allowable Take-Off Weight	10,800 lb
Recommended Fuel Types	Jet A, Jet B, Jet A-1

The calculated weight of C-GLOW at the time of the accident was 9,000 pounds. The weight and centre of gravity were within limits.

On departure from Fort McMurray, there were approximately 220 gallons * of Jet A-1 fuel on board.

Maintenance records and inspections were complete and in accordance with approved procedures.

There were no known deficiencies prior to the flight. The only known irregularity was an unprogrammed shutdown of the left engine while the aircraft was on the ground at Fort McMurray.**

The aircraft was certified for the flight.

* all figures in US gallons.
** see section 1.17.2

1.7 Meteorological Information

Visual meteorological conditions existed with visibility more than 15 miles, temperature -2 degrees celsius, dewpoint -8 degrees celsius, and the surface wind which was reported to C-GLOW was 200 degrees magnetic at 5 knots. No unusual or significant weather phenomena were observed.

1.8 Aids to Navigation

Following notification of the accident, Transport Canada personnel conducted a special flight check between 2050 and 2150 on 6 December. Particular attention was paid to the accuracy of the visual approach slope indicator system (VASIS) which provided visual descent guidance information to runway 30. They reported it to be within tolerance.

All navigational aids serving the airport were operating and serviceable at the time of the accident.

1.9 Communications

Communication with Air Traffic Services was normal, and there was no transmission from the aircraft indicating any form of in-flight emergency or difficulty.

Transcriptions of Air Traffic Services tapes could not be related to actual time as the device used to record time on the tapes at the Edmonton Municipal tower was unserviceable.

1.10 Aerodrome Information

The Edmonton Municipal Airport, situated within the city limits, was home base for the aircraft and suitable for its operation. The runway in use was 5,868 feet in length at an elevation of 2,200 feet. The runway threshold is displaced 1,187 feet, leaving a landing distance of 4,681 feet. There is no published instrument approach to runway 30, but visual approach guidance is provided by a VASIS with a glide path of 3 degrees.

1.11 Flight Recorders

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

1.12 Wreckage and Impact Information

1.12.1 Site Information

The Royal Alexandra Hospital, which is located 1 mile southeast of the Municipal Airport, is directly in line with runway 30. On a normal visual approach, an aircraft flying the VASIS glide slope would be about 260 feet above the hospital and about 360 feet above ground level (agl).

1.12.2 Aircraft Structure

The cockpit area maintained its structural integrity when the underside of the aircraft struck the hospital. The right main landing gear was displaced upwards into the cabin causing deformation to the aft cabin fuselage, and, as a result, the seat rails were deformed, and some empty passenger seats were released from the rails. The tail section separated from the fuselage at a production break line. The left wing was demolished outboard of the left engine, while the right wing broke off outboard of the right engine and landed on the penthouse roof. The damage indicated that the aircraft had struck the hospital in a left-wing-down, nose-low attitude at a low airspeed and at a high rate of descent.

1.12.3 Cockpit Switches and Controls

Some switches and controls were moved or damaged during the rescue efforts within the cockpit. The roof portion of the cockpit, including the overhead electrical control panel, was cut away by the rescuers.

1.12.4 Propellers

An examination indicated that both propellers were serviceable and capable of normal operation prior to impact. There was minor impact damage to the propellers. One blade on the left propeller was bent rearward, and there was some evidence of rotational scraping on the third blade of the left propeller. Two blades on the right propeller were bent rearward, and the right propeller showed no rotational scraping.

Impact damage to the propeller governing controls was severe. The left propeller governor stops were slightly out of adjustment; impact damage to the right propeller governor made analysis impossible.

1.12.5 Engines

On impact, the right engine hit a concrete pillar in the wall of the penthouse, and the left engine struck the roof of the hospital.

Both engine torsion shafts failed in torsion overload because of sudden stoppage of the propeller. Both main shafts failed in bending overload when the engine structure collapsed during impact. No damage to the impellers or to the turbine wheels was evident. Aluminum shavings were found in the entrance to the combustion chambers, but no splatter on the turbine wheels was present. Impact marks on the gear teeth in the gearbox section were imprinted without scraping.

1.13 Medical Information

1.13.1 Captain

The captain survived the initial impact but died within a few hours from the injuries he had received. Deceleration injuries caused soft tissue tearing and haemorrhaging which resulted in a massive blood loss. There were also serious injuries as a result of impact against the instrument panel. The autopsy report showed no evidence of disease that might have impaired his flying performance. Death was attributed to massive blood loss from deceleration injuries.

1.13.2 First Officer

The first officer survived the accident. 19 (1)

19 (1)

1.14 Fire

There was no evidence of fire either before or after the aircraft struck the hospital.

1.15 Survival Aspects

Both pilots survived the initial impact but the captain died within a few hours from the injuries he had received.

The aircraft was not equipped with shoulder harnesses. The crew seats and lap belts maintained their integrity.

1.16 Tests and Research

1.16.1 Voice Identification

The voice transmissions from the aircraft were positively identified. The first officer operated the radios en-route to Fort McMurray, while the captain operated them on the return flight to Edmonton.

1.16.2 Landing Gear

The main and nose landing gear incorporated screw-jacks which are driven by a common electrically operated motor. The forward and rear landing gear doors were found open indicating that the landing gear was in transit. The screw-jacks were found at some intermediate position, neither fully extended nor fully retracted. Damage to a travelling nut on the landing gear mechanical stop assembly and the surrounding structure showed that the nut was moving toward the landing gear "up" limit switch at impact and therefore was being raised. The position of the nut also indicated that the landing gear had retracted 28 per cent at impact.

1.16.3 Flaps

The flap selector handle was found in the 20-degree position and was bent to the left. The flap screw-jacks were examined and both main actuators were found to be at the same extension. Although the exact position could not be determined, the extension equated to about 20 degrees of flap, which is the normal approach setting.

1.16.4 Flight Controls

The flight control system was inspected for condition and position. No evidence of any pre-impact fault was found. Examination of impact marks indicate that the flight controls were at the following positions at impact:

Left Spoiler	Retracted
Right Spoiler	Retracted
Elevators	Approximately full nose-up position
Rudder	Partial right rudder

Both aileron trim actuators were found in approximately the neutral position and no indication of any mechanical fault was found. The elevator trim tabs were in the full-down position and the rudder trim tab was partially deflected to the left. The position of the rudder and elevator cable-operated trims was caused by impact forces on the cables during aircraft breakup.

1.16.5 Instruments

The instrument panel, except for the lower mounting area, escaped severe damage. Individual instruments received relatively little damage. The fuel gauges showed the following quantities:

Main Tank	134 gal
Left and Right Tip Tanks	0 gal
Fuel Totalizer	177 gal

The design of the fuel gauges is such that they retain the readings that were being displayed at the time of power interruption.

1.16.6 Light Bulbs

The light bulbs were examined for illumination at impact. The 20-degree flap light and the instrument lights showed some indication that they were illuminated at impact. None of the other bulb filaments were broken or stretched in a manner that could determine whether the filaments were illuminated at impact.

1.16.7 Air Cycle Unit

The air cycle unit was found relatively undamaged and was still securely mounted in the fuselage.

The oil in the air cycle unit reservoir, which lubricates the turbine compressor unit bearings, was level with the upper surface of the mounting flange. This is one-half inches higher than the level recommended in the maintenance manual.

The inner surface of the outlet duct was coated with a thin layer of a black soot-like substance. Analysis of this residue determined that it was not toxic.

1.16.8 Electrical

Electrical circuits which could have contributed to an engine power loss were identified, examined, and tested for continuity and resistance. There was no indication of pre-impact failure or overload. No evidence of arcing was found, and a large number of circuit-breakers were found open.

The batteries were undamaged, and when tested, were found to be charged and capable of delivering adequate power.

Static inverters, voltage regulators, reverse-current relays, and generator field over-voltage controls were examined and tested, and exhibited no indication of unserviceability or excessive load.

1.16.9 Engine Fuel Shut-off Valves

The fuel shut-off valves on both engines were found closed. Each valve can be closed electrically by placing the run/crank/stop (RCS) switch to the "stop" position or mechanically by placing the condition lever in the "emerg stop" position (see Appendix A). Both RCS switches were found in the "run" position; the condition levers were not in the "emerg stop" position (see section 1.17.7). The Board's engineering analysis concluded that displacement of the engines at impact, relative to the control linkages, closed the engine fuel shut-off valves.

1.16.10 Analysis of Engine Power

The engines and propellers were examined by the manufacturers and at the Board's engineering facility.

Garrett Turbine Engine Company, the engine manufacturer, examined the engines under the supervision of the investigation team and concluded that the damage to the engines indicated that both were rotating at similar rpm levels at impact, but no determination of engine power or rpm levels could be made. In addition, Garrett found no pre-existing conditions that would have precluded normal operation of either engine. Their conclusion was that any component damage found was caused at impact.

TRW Hartzell Propeller Company, the propeller manufacturer, could make no positive determination of engine power level at impact by assessing the propeller blade damage. However, inspection of the start lock assemblies indicated that both propellers were rotating at a minimum of 900 rpm at impact. Normal in-flight propeller rpm is about 2000 rpm. No positive determination of pitch angle from either propeller could be made.

The Board's engineering analysis determined that very little rotation is required to fail the torsion shafts and concluded that the propeller and engine impact damage was consistent with powerplant sudden stoppage while operating under low power or at low rpm. An examination of the engines did not disclose any reason for the apparent lack of engine power. A metallurgical examination was made of the engine tail pipes. There was some indication that the right engine was hot at impact, but no evaluation of the left engine could be made, because the left engine tail pipe was only slightly deformed, and this test requires a more than slight deformation to determine whether the tail pipe was hot at impact.

1.16.11 Main Fuel Valve Switches

A separate switch (see Appendix A) controls the main fuel shut-off valve for each engine. Each switch is a two position toggle-type switch with a spring-loaded locking mechanism which holds the toggle in the selected position (see Photo 2, Appendix E). To operate this type of switch, a toggle head must be pulled out to lift it over detents on the switch base. The switch actuating levers were broken off in line with their detents (see Photos 1 and 3, Appendix E). As a result of this action, the actuating spring was wedged in the remaining part of the lever, and the toggle heads were broken off. Examination of the remaining part of the actuating levers showed that they had both been broken by one-way bending overload. The direction of the breaking force was downward 10 degrees to 15 degrees from the right.

The damage to both switches was similar in direction and severity, and it was determined that both switches were struck by the same force at impact. The metallic smear marks on both detents show a buildup of material in the direction of the applied force (down and to the left) across the face of the detents. The length of the smear marks across the surfaces of the detents corresponds to the length of the moveable catches at the bottom of the toggle heads. This condition confirms that the smears were made by the actuating lever being in the up (open) position at impact rather than by some subsequent force which may have occurred during the rescue operation. The absence of any damage on the lower corners of the detents confirms that the switch actuating levers were not in the down (closed) position at impact.

Testing of the switches for electrical continuity showed the right switch was still electrically operable. The left switch contacts were displaced during impact, resulting in intermittent continuity. There was no evidence of either switch being unserviceable prior to impact.

1.16.12 Consulting Firm's Scenario

The owners of the aircraft obtained the services of a private accident investigation consulting firm, Waldron and Co. During the consultant's examination of the left torque sensor assembly, it was noted that some internal damage had occurred, but the gears could be turned freely, and there did not appear to be any discontinuity in the drive train. However, there seemed to be some bearing roughness, and the module was disassembled for a closer look at the bearing. When the spur gearshafts were separated, an examination revealed that the key which locks the two gearshafts together had been sheared (Item 80, Appendix D). The sheared key halves showed smear marks obliterating the fracture surfaces. The smear marks resulted from the gearshaft of the driving gear rotating within the hollow shaft of the gear it normally drives (Photo 1, Appendix F). Rotational wear on the faces of the key halves indicated a number of revolutions by the driving gear after the key had sheared.

The consulting firm believed the key failed before impact, resulting in an engine flame-out with a corresponding failure of the negative torque sensor (NTS) system. To support this view, the firm argued that:

- the difference in the damage to the left and right main shaft forward splines was important in that, the right showed torsional distress while the left showed an absence of spline yielding or torsion;

- this conclusion was supported by the CASB analysis of the right engine showing the possibility that the tailpipe was hot at impact;

- the imprints on the left torque sensor housing by the main shaft drive coupling were stationary, whereas imprints on the right torque sensor housing showed some rotation;

- although the bearing on the left assembly was lubricated, the lubricant was rust-coloured; the bearing showed signs of corrosion, and there appeared to be brinelling damage to the thrust side of the left inner bearing race traversed by the rolling elements;

- the failed and smeared left key did not exhibit thermal discolouration, the keyway was deformed from repeated pounding loads, and there were rotation score marks and smearing across the raised area of the left gearshaft keyway;

- the appearance of imprint marks without evidence of rotational smearing on the faces of two gears (Photo 3, Appendix F) suggested to the firm that the gears were stationary; and

- an inadequate interference fit existed as a result of insufficient torque applied to the spur gearshaft retaining nut (see Section 1.17.11).

The firm is of the opinion that the bearing was faulty and therefore applied a load onto the spur gearshaft. It is also the firm's opinion that the interference fit was inadequate, and this led to a failure of the drivekey rather than the gearshaft. The firm feels that the scenario is supported by indications of smearing on the key and a lack of evidence of rotation on the left torque sensor assembly and engine. The firm presented this evidence to the Aviation Safety Bureau (see introductory note). Subsequently, the torque sensor assemblies from the left and right engines were examined in detail by the Bureau. As explained in Section 1.16.13 below, this analysis did not support the scenario as put forward by the firm.

1.16.13 Torque Sensor Assembly Examination

When the assembly is intact it drives the following accessories: the fuel pump, the fuel control unit, and the lubrication pressure pump. To ensure there is no relative movement between the two spur gearshafts (Items 95 and 100, Appendix D), a nut (Item 70, Appendix D) is torqued down to draw the two shafts together on to a designed interference fit and a drivekey is fitted into machined slots on both gearshafts. If the key sheared in flight and the frictional load developed by the interference fit was insufficient to sustain operating loads, the assembly would no longer drive the accessories. The result would be an engine flame-out and an interruption of oil flow between the lubrication pump and the propeller governor.

Garrett, the engine manufacturer, examined 12 accident engines about which the operating condition of each engine at impact was known. Eleven of the engines that were studied were operating at normal rpm and power levels at impact. Four of the torque sensor assemblies in these engines had sheared keys. Two of these keys showed metal smearing and transfer on the halves similar to that noted on the left torque sensor assembly from C-GLOW. The twelfth engine was shut down with the propeller feathered at impact; its key did not shear.

The Board's technical investigators examined the torque sensor assemblies from both engines from C-Glow for impact marks and other signs of distress, which would indicate whether the assemblies was rotating at impact. This was done to determine whether pre-impact failure of the left unit had occurred. Impact damage to both assemblies was very similar. The major difference was the damage to the drivekeys (Item 80, Appendix D). Both keys were sheared, but the one from the left engine had extensive smearing that was caused by the rotation of one gearshaft within the other. The drivekey from the right engine was essentially unmarked by rotation (Photos 1 and 2, Appendix F). The spur gearshaft rotates 8.6 turns for every revolution of the propeller.

There was a slight amount of scoring of the metal in the area of the interference fit on both torque sensor assemblies. More extensive scoring would be expected if there was a pre-impact failure of the drivekey, allowing the rotation of one gearshaft within the other.

On 16 January 1986, an MU-2, C-FOUR, had an in-flight engine failure. It was determined that a bolt had come loose and jammed the spur gear (Item 65, Appendix D), stopping the gear train. The drivekey failed and there was relative rotation between the male and female gearshafts resulting in severe scoring and metal transfer between the two gearshafts in the interference fit area. The examination revealed that the smearing on the key fracture was not as pronounced as observed on the key from the left torque sensor assembly on C-GLOW.

One bearing for the left assembly gearshaft from C-GLOW displayed some damage, apparently due to corrosion. An examination of the left assembly bearing races revealed only superficial wear marks traversing both the corrosion- damaged and undamaged areas.

The wreckage had been stored for 18 months prior to its release. Minor surface corrosion was found in pockets on the race and balls of the bearing. The corrosion in the bearing which was in otherwise good condition was consistent with that which could occur if the bearing were stationary over a lengthy period. The CASB analysis concluded that the scoring across the corrosion likely occurred as a result of hand turning the assembly. The physical analysis of the bearing components supported the conclusion that the bearing did not see service after the corrosion had occurred.

The support brackets for both right and left idler gears (Item 5, Appendix D) on the torque sensor assemblies and the gears themselves (Items 95 and 65, Appendix D) had curved imprints on the forward faces (Photos 3 and 4, Appendix F). The gears could be aligned so that the marks were concentric, and there was no indication of smearing.

The impact forces bent both support brackets (Item 5, Appendix D) against the right and left spur gears (Item 65, Appendix D). Both gears and brackets, show similar imprints. Scoring, found on the underside of both brackets, was caused by contact with the rim of the spur gears which were rotating against the bent bracket (Photos 5 to 8, Appendix F). The lesser amount of scoring on the underside of the

left support bracket was attributed to the difference in the material composition between the two brackets. The left is constructed of stainless steel and the right of aluminum alloy. The severity of the scoring indicated that there would have to have been significant resistance to the rotation to cause the deformation. Thus, it is unlikely that hand turning caused the scoring as the assembly was described to turn freely. The impact marks were similar in nature on both the left and right assemblies. The scoring on the underside of the bent support brackets on both assemblies indicates that both spur gears were rotating at impact. If the left assembly drivekey had failed prior to impact, this scoring should have been evident only on the right torque sensor assembly support bracket.

The CASB's examination also considered the degree of loading on the key during normal operation. The loading between the two gearshafts arises from the torque that is transmitted. The nominal running torque transmitted, as reported by the manufacturer, is less than 30 inch pounds. In order to transmit this torque, there are three factors involved: the interference fit, clamping loads resulting from the torque on the retaining nut, and the strength of the key. Stress analysis calculations based on the actual dimensions and tolerances, indicated that the running load on the drivekey would be neligible and the amount of torque that could be transmitted would not be sufficient to overcome the interference fit.

In summary, there was evidence of both rotation and no rotation on the components of the left torque sensor assembly at impact. However, the evidence of rotation is significant and is further supported by the similar evidence of rotation on the right torque sensor assembly, the case histories presented by the engine manufacturer, and the analysis of the torque sensor assembly from C-FOUR. The CASB analysis suggests that key smearing is not indicative of whether the key failed before or as a result of impact forces. Therefore, the scenario of a pre-impact failure put forward by the consulting firm could not be supported and the CASB analysis determined that it was more likely that both drivekeys sheared as a result of impact forces, that is, when the support bracket was bent against the spur gear, thereby stopping rotation.

1.16.14 Negative Torque Sensor System Operation - Flight Test

The heavy spring within the propeller hub tends to move the blade to a high pitch (low drag) angle (Appendix C). This force is assisted by the centrifugal action of the flyweights attached to the blade. Oil pressure working against these forces is used to set a lower pitch (high drag) angle. Filtered engine oil from the lubrication pump is fed to the propeller governor. In the flight mode of operation, the governor maintains a constant engine rpm by adjusting the propeller blade pitch angle through the increase or decrease of oil pressure working against the spring forces in the propeller hub. The NTS system is designed to open the feather valve and automatically reduce the drag under conditions of negative torque, for example, when the propeller is driving a flamed-out engine.

As previously stated in section 1.16.13, a failure in the drive train to the engine accessories would result in a loss of drive to the engine fuel pump and the engine lubrication pump. Thus, an in-flight failure of the drive train would both flame out the engine and affect the normal oil supply to the NTS system. If the NTS system does not function during a negative torque condition, it seems likely that the propeller blades would remain in a fixed position, producing a high level of drag until the propeller is manually feathered. To determine the effects of a failure in the drive train on the functioning of the NTS system, CASB requested that a flight test be conducted.

On 24 July 1985, the test was performed using a TPE-331-6-251 M engine mounted on the Garrett Turbine Engine Company's B-26 flight test aircraft. The engine configuration was standard except for a modified drive train assembly that allowed gear disengagement on command. This simulated exactly an in-flight drive train failure. Two shutdowns were made under the following flight conditions which closely approximated those of an MU-2 on approach:

Altitude	2,800 feet above sea level
Airspeed	120 KIAS
Engine Power	30% torque

The first shutdown was made by shutting off the fuel to the engine and was used to provide a baseline of normal NTS system performance. The second was performed by using the drive train disconnect system. The test revealed that the propeller governor pump provides sufficient pressure to operate the NTS system for 10 seconds after drive train disconnect. The propeller blades very closely followed the rpm and blade angle changes of a propeller with the NTS system operating normally. After 10 seconds, there was insufficient pressure to operate the NTS system; however, by this time, the propeller was at a high angle, low rpm condition producing low drag. The test showed that the NTS system would still prevent a high drag condition in the event of a drive train failure.

1.16.15 Flight Simulation

An MU-2 simulator in Houston, Texas, was used in an attempt to re-enact the accident flight profile. The simulator fidelity is such that, in the United States, the Federal Aviation Administration (FAA) allows U.S. pilots to conduct their biennial review in the simulator.

The simulation was conducted under the supervision of a Board investigator. Several runs were performed, and the following summarizes the pertinent test results.

a) When the loss of the left engine with the NTS operative was simulated, a small power application was required to maintain the glide path and successfully land off the approach. A single-engine go-around with the NTS operative was also attempted. At 300 feet agl, in the landing configuration, an overshoot was successfully executed with no loss in altitude.

b) With the NTS inoperative, loss of the left engine, 3 miles back on a stabilized approach, resulted in the aircraft being difficult to control unless the inoperative engine's propeller was manually feathered. The aircraft became uncontrollable when an overshoot was attempted with the propeller unfeathered. In both cases directional control was lost, the left wing dropped, and the aircraft descended abruptly.

However, it must be noted that the simulator is for training and only approximates flight conditions. The simulator could not simulate any gradual increase in propeller blade pitch resulting from internal oil leakage in the propeller control system.

1.17 Additional Information

1.17.1 Emergency Locator Transmitter (ELT)

The ELT was a Garrett Rescu 88C. The operating toggle switch was in the "arm" position; however, when the aircraft's tail section separated, the antenna was pulled out of the ELT. No ELT transmission was received at the control tower, but when the unit was tested, it was capable of generating a signal.

1.17.2 Engine Shutdown - Fort McMurray

While the aircraft was on the ground prior to taxiing for the flight from Fort McMurray to Edmonton, a passenger returned to the aircraft to retrieve a forgotten article. The first officer, in the left seat, selected the left propeller into reverse idle pitch to reduce air flow and to accommodate access to the main passenger door. After he reset the propeller to normal idle pitch, he proceeded with his check-list and performed the Torque and ITT Limiting System check, which confirms correct operation through an engine rpm decrease when the test switch is engaged. At this point, he realized that the left engine was spooling down, and he completed the engine shut-down check-list.

After a visual inspection, the left engine was restarted, and a functional check was performed with no further abnormal indication.

1.17.3 Training

The surviving first officer reported that simulated single-engine training was conducted as part of special training flights, which were carried out separately from regular operational flights. The pilots would have demonstrated proficiency in conducting single-engine approaches as a part of the Transport Canada annual instrument rating flight test.

1.17.4 Safety Speeds

When flap is selected to 20 degrees, at a calculated all up weight of 9,000 pounds, the stall speed is 78 knots indicated airspeed (KIAS), and the single-engine minimum control speed (VMCA) is 90 KIAS. Final approach is normally flown at 120 KIAS with landing gear and half flap (20 degrees) extended. The surviving first officer reported that it would have been normal practice to allow the airspeed to decrease to about 100 to 110 KIAS in the vicinity of the hospital, in preparation for the landing. VMCA is predicated on the NTS functioning. The simulator runs indicated VMCA to be about 10 to 15 KIAS higher when the NTS is inoperative. The increase in VMCA is not indicated in the Pilot Operating Manual and no flight test data was available to the CASB to confirm this figure.

1.17.5 Post-Accident Activity

Following the accident, the company aircraft maintenance engineer arrived at the scene. He was advised by fire department personnel that fuel was leaking from the aircraft into the hospital. He offered to close the main fuel valves to prevent further leakage. Without the aid of a flashlight, he manually changed the position of the main fuel shut-off valves located in the top of the centre wing area over the fuselage that had been exposed during aircraft breakup. Although this action was carried out, the fuel tanks were punctured in several locations, and therefore the position of the valve had no effect in preventing fuel leakage.

Subsequently, without knowing that the main fuel shut-off valves had already been moved, an Aviation Safety Bureau aircraft accident investigator, with the use of a flashlight, manually closed the main fuel shut-off valves. He visually confirmed this action by correlating the lever position with the corresponding position identification on the body of the valve. Analysis of photographs taken at the scene support this sequencing. Earlier photos clearly show the valves open, and later ones show them closed.

1.17.6 Fuel System

The engines receive fuel from the centre main tank only. Fuel in the tip tanks and outer wing tanks is transferred to the centre main tank. Fuel management is accomplished by utilizing the top four switches installed on the switch panel directly below the pilot's flight instrument panel (see Appendix A). The upper two switches are the left and right main fuel valve switches, which control the main fuel shut-off valve in the fuel feed line to each engine. These main fuel shut-off valves, which are electrically motorized gate valves, are located at the front outlet of the centre tank (see Item 1, Appendix B). As described in section 1.16.11, the main fuel valve switches are spring-loaded, pull-out-type safety switches.

The centre two switches are three-position toggle switches identified as tip tank/outer tank transfer switches (see Appendix A). In the "up" position, fuel is transferred from the tip tanks to the centre tank. In the "down" position, fuel is transferred from the outer wing tanks to the centre tank. In the centre "off" position, no fuel is transferred to the centre tank.

When usable fuel is exhausted from an outer wing tank, a warning light activated by a pressure switch is illuminated on the lower centre instrument panel. The transfer pump switch should be selected "off" at this time. Failure to do this will not interfere with fuel flow from the centre tank to the engine, but will result in the continuous illumination of the two indicator lights and may lead to overheating of the outer wing transfer pumps. The left outer wing transfer pump low pressure warning switch was a 3.2 pounds per square inch (psi) switch instead of the stipulated 1.7 psi switch.

1.17.7 Powerplant Controls

The power lever has four variable positions: "reverse", "start", "flight idle", and "take-off" (see Appendix A). Power lever travel between "flight idle" and "take-off" position is called the propeller governing range. In this range, the power lever establishes the fuel flow, and the propeller governor operates automatically, to maintain a constant engine speed, by changing the propeller blade angle. The remaining travel, from "flight idle" to "reverse" position, is termed the Beta Range. In this range, the power lever establishes the blade angle, and the underspeed governor of the fuel control unit operates automatically, to maintain a constant engine speed, by changing the

fuel flow. Detents are installed at "start" and "flight idle" positions. The power levers were found set between the "flight idle" and "take-off" positions.

The condition lever is provided for engine rpm control and propeller feathering. The lever is linked to the propeller governor, the underspeed governor of the fuel control unit, the propeller feathering valve, and the engine fuel shutoff valve. The condition levers also have four positions and were found set between the "take-off land", and "min cruise" positions (Appendix A). To reach the "emerg stop" position to manually feather a propeller and shut down an engine, the lever must be passed through two detents at the "taxi" and "min cruise" positions.

1.17.8 MU-2 Recertification

In 1983, a special certification review of this twin-turboprop aircraft was requested by the United States National Transportation Safety Board (NTSB), following the investigation of 22 MU-2 accidents in an eight-year period.

The NTSB found that the 22 accidents since 1975 were related to engine failures in flight, uncontrolled collision with the ground, and controlled ground collisions during instrument landing approaches.

The primary cause of six of the accidents was engine failure or malfunction. Another eight accidents were attributed to uncontrolled collision with the ground. The final eight accidents were listed as controlled collision with the ground in instrument meteorological conditions.

The FAA's audit of the MU-2's certification began in October 1983. The FAA review panel concluded that the MU-2 complied fully with applicable regulations and airworthiness standards.

1.17.9 NTSB Study of Turbine Oil Contamination

The NTSB looked at the possibility that a cracked front mainshaft compressor carbon seal element in the TPE 331 engine might allow oil to enter the turboprop's airflow, pass through the compressor bleed air system, and allow toxic or anesthetic by-products of the oil to enter the aircraft's cabin. It was thought that fumes from the oil might cause crew incapacitation and that the problem could extend to all turbine engines that use synthetic oil and use compressor bleed air for the cabin.

The NTSB's study concluded that there was no significant amount of toxic compounds present in the TPE 331's bleed air during any of the engine tests, and even with induced oil contamination of the bleed-air supply, the oil fumes were not of sufficient concentration to produce toxic effects on the flight crew.

1.17.10 Pilot Operating Manual - Engine Failure Emergency Procedure

The Pilot Operating Manual lists the first action under the emergency procedure for an engine failure in flight as:

Dead Engine Condition Lever - "emerg stop"

1.17.11 Garrett Service Bulletins

As a result of a number of cases where the spur gearshaft had failed, Garrett issued three service bulletins. In July 1982, a Garrett bulletin informed operators of an improved bearing (Item 85, Appendix D) that would provide an increased fatigue life. Compliance was listed as optional and to be accomplished at overhaul or the next exposure of affected parts. In March 1983, Garrett recommended that TPE 331 operators perform the following at the next scheduled inspection, or sooner, if affected parts were exposed during an unscheduled repair:

a) Increase the torque value applied to the spur gearshaft retaining nut, because insufficient torque may cause the spur gearshaft to shear, allowing torque sensor disengagement resulting in engine shutdown (see Appendix D).

b) Replace the torque sensor assembly spur gearshaft drivekey with one of a different shape to preclude improper positioning during installation, which could result in fretting and fatigue failure of the gearshaft (see Appendix D).

It is not known if a bearing failure, insufficient torque on the retaining nut or improper positioning of the key would result in a key failure rather than shearing of the gearshaft. Garrett stated that they had no knowledge of any pre-impact failures of the gearshaft drivekey as the primary failure mode resulting in an engine shutdown.

2.0 ANALYSIS

2.1 Introduction

The investigation was reopened to study evidence brought forward by a private accident investigation consulting firm and in response to the first officer's petition to reconsider the conclusion that an inadvertent switch selection had been made.

2.2 Human Factors

2.2.1 Visual Approach Cues

The VASIS was found to be within tolerance; there is nothing to indicate that the approach would have been adversely influenced by its use. The possibility that the pilots may have been the victims of a visual illusion and may have flown too close to the hospital was considered and rejected. As the airport was the pilots' base of operation, they were very familiar with the airport environment and surrounding built-up area. Considering the visibility at the time of occurrence, the visual cues approaching the hospital are easily discernible and not likely to induce a lower than normal approach.

2.2.2 Crew Incapacitation

The black soot-like substance on the outlet duct of the air cycle unit initially suggested that the crew may have been subjected to toxic fumes. However, a complete analysis of the deposit detected no toxic substances. In addition, the NTSB study concluded that there was little or no possibility of toxic substances of sufficient concentration in the engine bleed air to produce flight crew incapacitation.

The selection of landing gear "up" to reduce drag and the nose-high attitude of the aircraft indicate an apparent attempt to reduce the descent rate or to initiate a go-around. These actions suggest a degree of mental and physical capacity on the part of at least one of the pilots.

2.3 Propeller System

Although the left propeller governor stops were found to be slightly out of tolerance, the propellers should have been operating outside of the range where the propeller governor pitch stops could influence propeller operation. The minor error in propeller governor stop adjustment would not have resulted in engine failure.

2.4 Transfer Pump Pressure Switch

The 3.2 psi rather than the stipulated 1.7 psi transfer pump low pressure switch would have no influence on the operation of the fuel system other than to activate prematurely the left "outer tank empty" light on the instrument panel.

2.5 Fuel Supply

An interruption of fuel supply would result in a loss of engine power. The aircraft contained adequate fuel in the centre wing tank for the remainder of the flight. The tip tanks and outer wing tanks contained no usable fuel.

The main fuel valves were found closed after the wreckage had been removed from the hospital. Manual operation was the only method by which they could be moved once electrical power was disrupted following impact. As discussed in section 1.17.5, the company engineer had manually moved the valves to what he believed was the "closed" position. However, he had been working at night without a flashlight, and he had actually moved the valves to the "open" position. Later, a member of the investigation team found the valves open and then closed them. Because of this double movement of the valves, it was first concluded that the main fuel valves were closed prior to impact. The subsequent analysis of the switches showed they were in the up (valve-open) position prior to impact and were then driven to the down (valve-closed) position when they were struck simultaneously by the same force at impact. The valves require about one second to motor from the "open" to the "closed" position. It is possible that electrical power from the battery was available to the main fuel valves, for a sufficient period after impact, for the valves to motor toward the "closed" position. It is also possible that an inadvertent switch selection had been made, closing the valves. The switches could have then been reselected to the open position immediately prior to impact so that they were not able to move significantly from the closed position before power was interrupted; however, the switches were in the proper position for flight at impact, and based on the available evidence it is not possible to conclude that the valve positioning was a result of an inadvertent switch selection.

2.6 Engine Shutdown - Fort McMurray

While the aircraft was on the ground at Fort McMurray and shortly after the propeller was selected from reverse idle pitch to normal pitch, a flame-out of the left engine occurred. According to Garrett, when the pilot selected the propeller out of reverse and proceeded with checking the Torque and ITT Limiting System, the combined action of the underspeed governor, which was rescheduling fuel as a result of the propeller pitch change, and the effect of the system test likely resulted in inadequate fuel to the engine to maintain operation. Although the cause of the flame-out could not be determined with certainty, the Garrett explanation is reasonable, and it is not likely that this event was related to the occurrence.

2.7 Engine Power Analysis

Although there were minor differences in impact damage to both engines, the similarities far outweigh the differences. As mentioned previously, the two engines experienced different impact forces which could explain the minor dissimilarities. It was determined that the

engines were rotating at similar rpm levels at impact, but no conclusive determination of engine power or rpm level could be made; however, the lack of propeller and engine impact damage indicates that they were not developing high power and that possibly they were at a lower than normal rpm. Because these engines run at a constant speed in flight, a lower than normal rpm condition would imply that the engine was failed.

2.7.1 Left Engine Failure Hypothesis

The simulator runs indicated that an aircraft on approach would be marginally controllable if an engine failed when the NTS was inoperative and the engine's propeller was not immediately feathered manually. It was also found that with the NTS inoperative the aircraft would be uncontrollable if an overshoot was attempted. The loss of control experienced in the simulator was quite similar to the observed sudden wing drop and abrupt descent of C-GLOW. The simulator runs also demonstrated that when the NTS is operative, an engine failure would pose no difficulty to an experienced pilot either in completing the approach or in conducting a single-engine overshoot. Therefore, in order for the crew of C-GLOW to have lost control of the aircraft if the left engine had lost power, the failure in all probability would have had to have been accompanied by an inoperative NTS system.

It has been established that the landing gear was in transit when the aircraft crashed into the hospital. It is likely that the gear was raised in an attempt to reduce the descent rate or to initiate a go-around. Indications that a power loss was experienced on the left engine include the following: the sudden left wing drop, the rudder position at impact, and the lack of extensive impact damage to the left engine. The analysis showed that the right engine was hot and therefore possibly developing some power at impact. Neither condition lever was found in the "emerg stop" (feather) position. Since movement through two detents is required, it is unlikely that either lever was moved out of this position by rescue personnel. In addition, both propellers were rotating at impact which indicates that they had not been feathered. Thus, if the left engine had failed, the propeller was not feathered as required by the emergency procedure. The evidence pointing to a left engine failure is contradicted by the evidence showing little rotational damage to the right engine. It would be normal procedure to select the right engine to a high power setting should the left engine fail; however, if the aircraft was below VMCA or if impact with the hospital was inevitable, it is possible that the right engine was selected to a low power setting before the aircraft hit the hospital.

The Board's analysis did not support the scenario put forward by the consulting firm. As discussed in section 1.16.13, it is concluded that both drivekeys likely failed as a result of impact forces. Further, it is unlikely that an in-flight failure of the drivekey in itself would cause a disruption in the drive train as the interference fit of the gearshafts would likely maintain the drive to the engine

accessories. Also, the flight test demonstrated that even should a drive train failure occur in an aircraft with this engine type, the NTS system would function for a sufficient period to allow the propeller to move to a low drag position.

A detailed analysis of the evidence supplied by the consulting firm and a re-examination of the wreckage failed to establish whether there was a pre-impact failure of the left engine.

2.7.2 Dual Engine Failure Hypothesis

A lack of significant impact damage to both engines and propellers indicates that they were developing similar low power levels and possibly rotating below normal rpm levels. For both engines to fail simultaneously on approach, the most likely cause would be a fuel flow interruption. However, the aircraft contained adequate fuel, and no electrical or mechanical failure was found which would explain a loss of fuel flow. In addition, there was no evidence to indicate that some pilot action stopped both engines.

2.8 Restraint System

The availability and use of shoulder harnesses would have reduced the severity of crew injuries and may have prevented the death of the captain.

3.0 CONCLUSIONS

3.1 Cause-Related Findings:

1. The aircraft experienced a reduction or loss of engine power to one or both engines for undetermined reasons.

2. The aircraft departed from controlled flight on final approach.

3.2 Other Findings:

1. Shoulder harnesses would have reduced the severity of crew injuries.

2. Flight data and/or cockpit voice recorder information would have, in all probability, indicated the cause of the accident and greatly reduced the time and cost of the investigation.

3. The ELT was ineffective because the antenna had separated from the ELT at impact.

4. The flight was certified and qualified crew members were licensed to conduct the flight in accordance with existing regulations.

5. The aircraft was certified, equipped, and maintained in accordance with existing regulations.

6. The weight and centre of gravity were within the prescribed limits.

7. There was no known airframe in-flight failure prior to impact.

4.0 RECOMMENDATIONS

4.1 Actions Taken

4.1.1 Shoulder Harnesses

As a consequence of a previous Canadian Aviation Safety Board (CASB) Civil Aviation Occurrence Report (P40061), an Aviation Safety Advisory (5002-12-2-50046) was forwarded to the Department of Transport on 25 March 1985 concerning the requirement for each pilot seat in an aircraft to be equipped with a shoulder harness in addition to a lap belt.

The CASB notes the actions already taken by the Department of Transport through proposed revisions to Air Navigation Orders (ANO) Series II No. 2 which state in part:

a) that no person shall operate an aircraft engaged on a special purpose operation unless it is equipped with an approved seat and an approved individual safety belt, including shoulder harness, for each person on board the aircraft; and

b) after 1 January 1986, any aircraft which is first entered on the register of aircraft maintained pursuant to section 202 of the Air Regulations shall be equipped with a safety belt, comprised of a lap strap combined with a shoulder harness, at each pilot seat and for each front seat adjacent to a pilot seat.

4.2 Further Actions Required

4.2.1 Shoulder Harnesses

The CASB notes that the absence of a shoulder harness is frequently a contributing factor to the degree of injuries sustained in aviation occurrences in Canada. Consequently, the Board is concerned about the limited application of the proposed revisions to ANO Series II NO. 2 and the delay in their promulgation. It is the Board's view that all pilots should be provided with a restraint system incorporating a shoulder harness, regardless of the date of manufacture of the aircraft. At the same time, the Board recognizes that cockpit space, lack of secure mounting points, seat design and the resultant cost implications may preclude the retroactive installation of shoulder harnesses in some aircraft.

Nevertheless, the CASB intends to review the adequacy of the proposed revisions to ANO Series II No. 2 relative to Canada's experience in shoulder harness fitment. After consideration of the above, the Board may make recommendations for more stringent requirements for retrofitting shoulder harnesses.

4.2.2 Cockpit Voice Recorder/Flight Data Recorder

The CASB remains concerned that primary cause factors in many accidents, such as this accident involving a Mitsubishi MU-2B, go undetermined. There continues to be a lack of sufficient information, such as that which could be derived from a cockpit voice

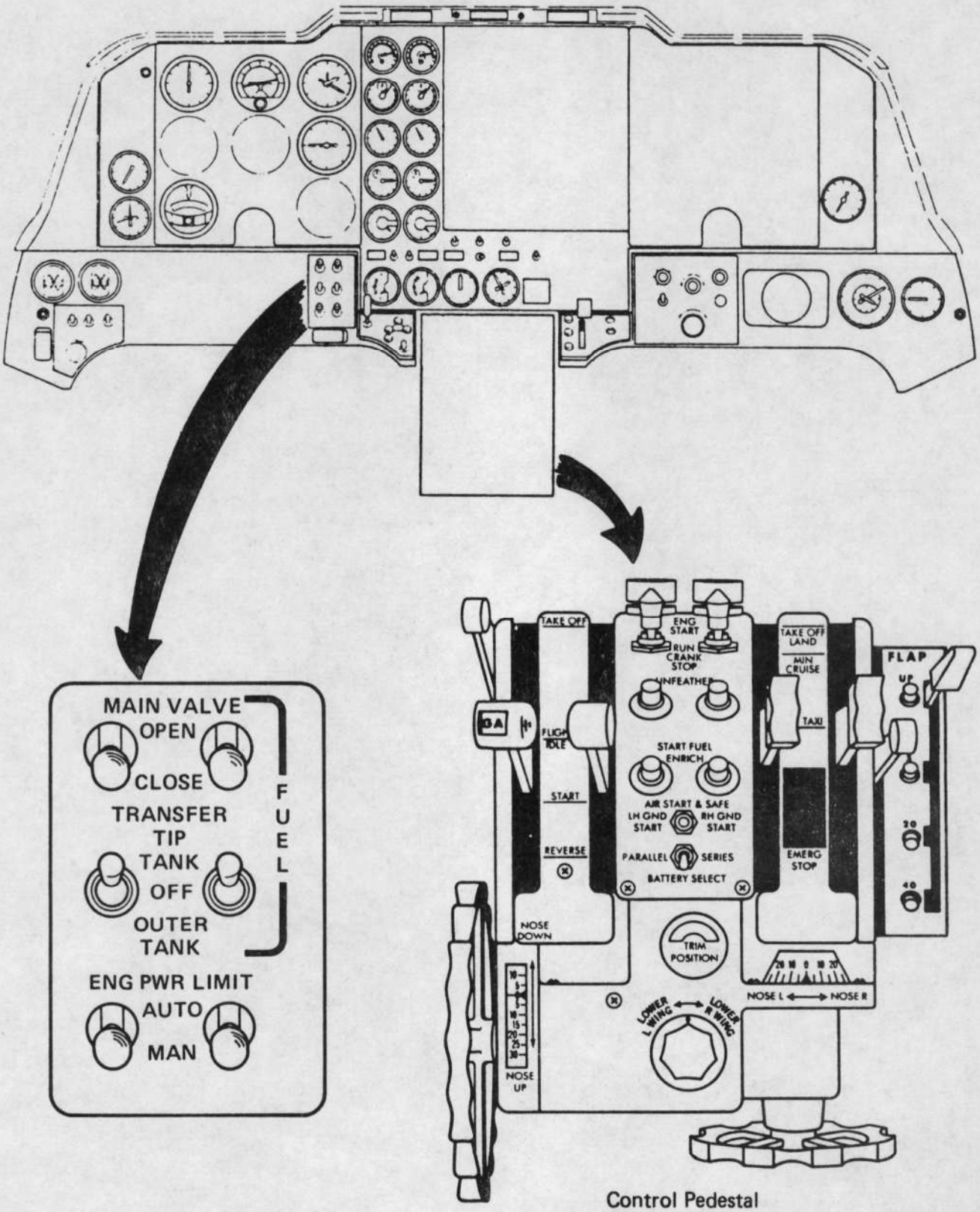
recorder (CVR) or flight data recorder (FDR), to assist the accident investigator. At present, ANO, Series II, No. 13 and 14 prescribe minimum CVR/FDR equipment requirements only for turbine engine powered, pressurized aircraft that:

a) have a maximum certified take-off weight of more than 12,500 pounds;

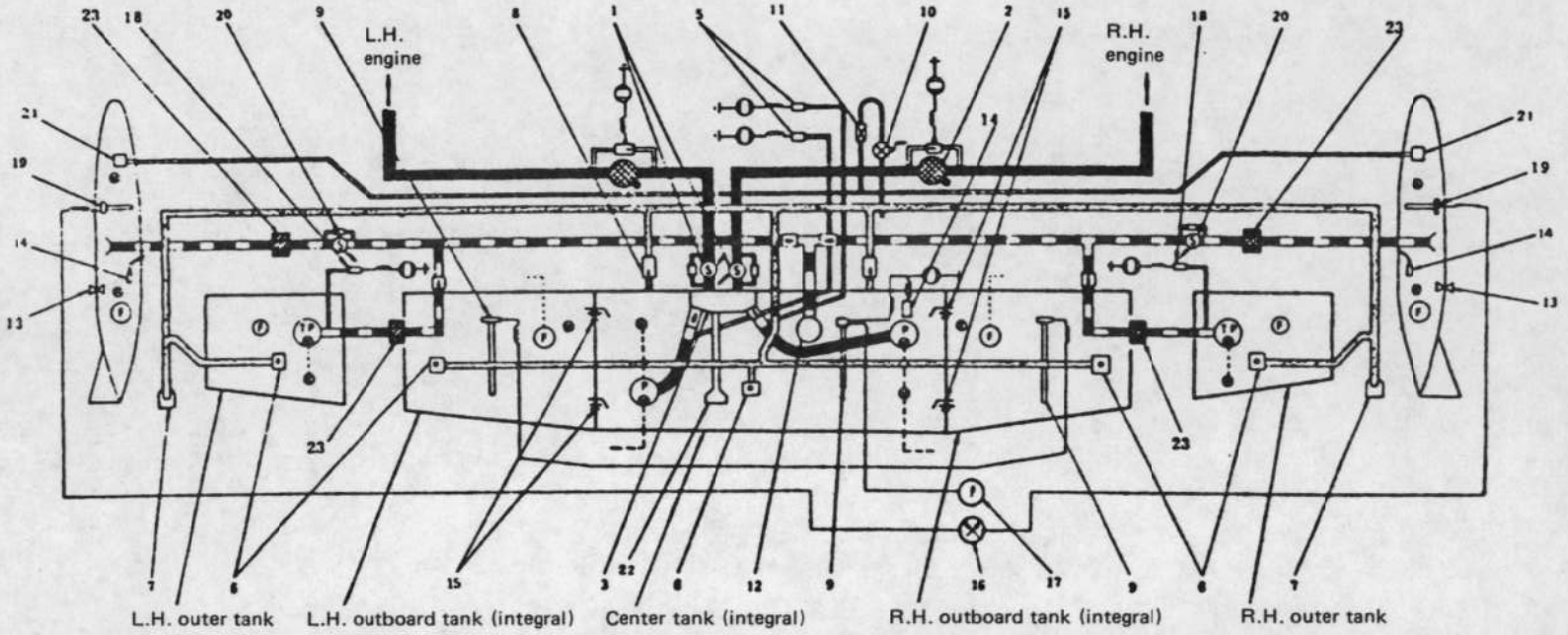
and

b) are registered as commercial aircraft under Part II of the Air Regulations.

As a consequence of a previous CASB Civil Aviation Occurrence Report (Ø40066) involving a Cessna 500 Citation, the CASB decided to prepare a statement of requirements for CVR/FDR equipment for a broader range of aircraft than currently prescribed, including helicopters. It is intended that this statement of requirements will result in a recommendation to amend ANO Series II, No. 13 and 14 in the near future.



Control Pedestal
Pylône de commande



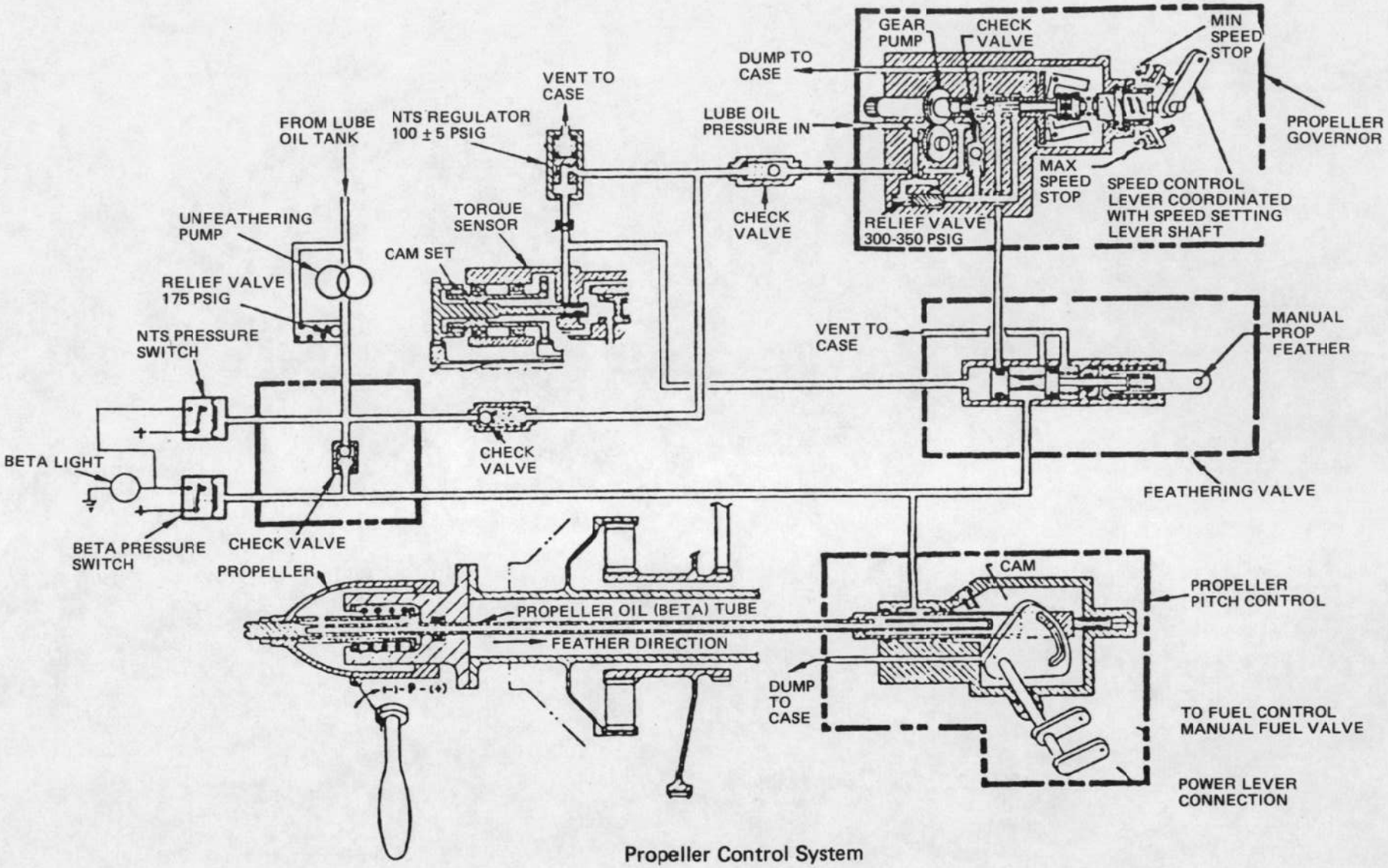
1. Fuel shutoff valve
2. Fuel filter
3. Manifold
4. (Deleted)
5. Boost pump warning switch
6. Vent valve
7. Vent port
8. Pressure relief valve
9. Fuel quantity indicator
10. Air shutoff valve
11. Air regulator
12. Fuel level control valve
13. Sniffle valve
14. Low level switch
15. Interconnector check valve
16. Tip tank fuel quantity indicator
17. Wing tank fuel quantity indicator
18. Fuel low pressure warning switch (Outer tank)
19. Tip tank fuel quantity indicator tank unit
20. Tip tank fuel shutoff valve
21. Vent disc
22. Suction feed valve
23. Strainer

Check valve
Fuel filter
Boost pump
Transfer pump
Fuel quantity indicator (Single)
Fuel quantity indicator (Double)
Drain valve
Warning lamp

Fuel supply line
Fuel transfer line
Pressurized air line
Vent line
Drain line
Electrical wire

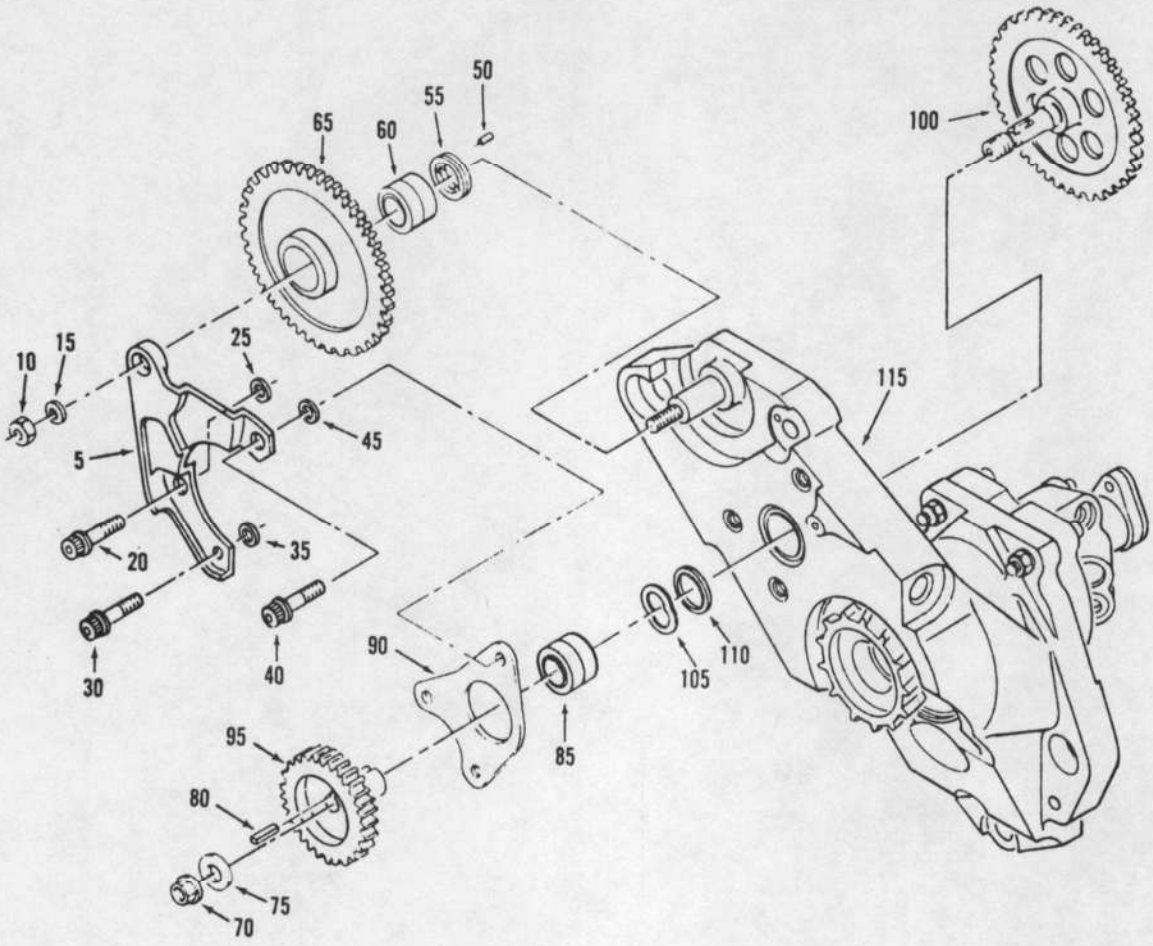
MU-2 FUEL SYSTEM

APPENDIX B



Propeller Control System

APPENDIX C



5. SUPPORT	5. SUPPORT
10. NUT	10. ECROU
15. WASHER	15. RONDELLE
20. BOLT	20. BOULON
25. WASHER	25. RONDELLE
30. BOLT	30. BOULON
35. WASHER	35. RONDELLE
40. BOLT	40. BOULON
45. WASHER	45. RONDELLE
50. PIN	50. GOUPILLE
55. NUT	55. ECROU
60. BEARING	60. ROULEMENT
65. SPUR GEAR	65. PIGNON DROIT
70. NUT	70. ECROU
75. WASHER	75. RONDELLE
80. KEY	80. CLAVETTE
85. BEARING SET	85. ROULEMENT
90. LOCKPLATE	90. PLAQUE DE VERROUILLAGE
95. SPUR GEARSHAFT	95. ARBRE A PIGNON DROIT
100. SPUR GEARSHAFT	100. ARBRE A PIGNON DROIT
105. WASHER	105. RONDELLE
110. WASHER	110. RONDELLE
115. SLEEVE SET AND BODY	115. MANCHON ET CORPS

Torque Sensor Gear Assembly
Engrenage du détecteur de couple

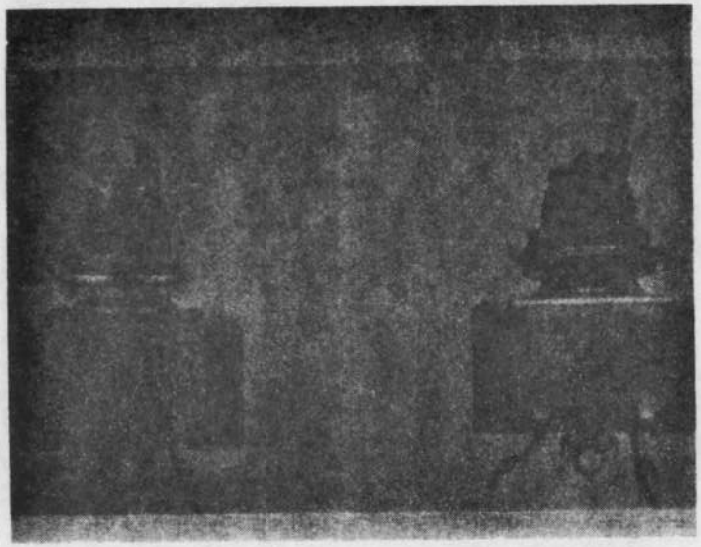


Photo 1 — Side View of Left and Right Main Fuel Valve Switches from C-GLOW
Vue latérale des contacteurs de robinet de carburant principal gauche et droit prélevés sur le C-GLOW

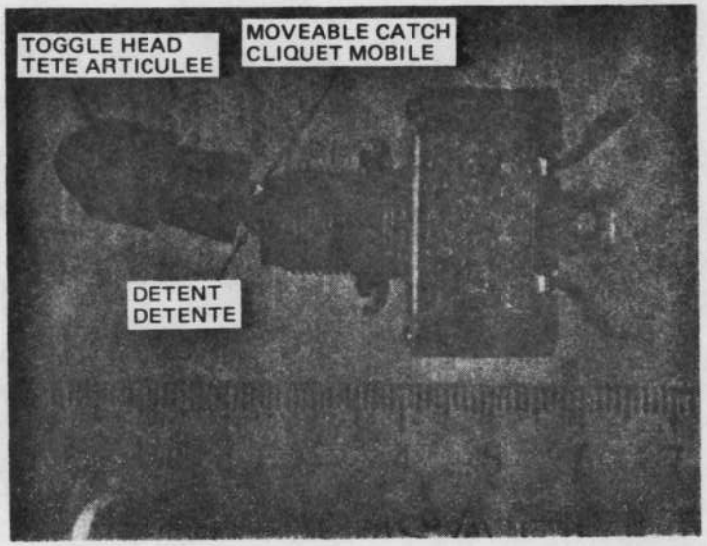


Photo 2 — Identical Type Switch for Comparison Purposes
Contacteur de type identique pour fins de comparaison

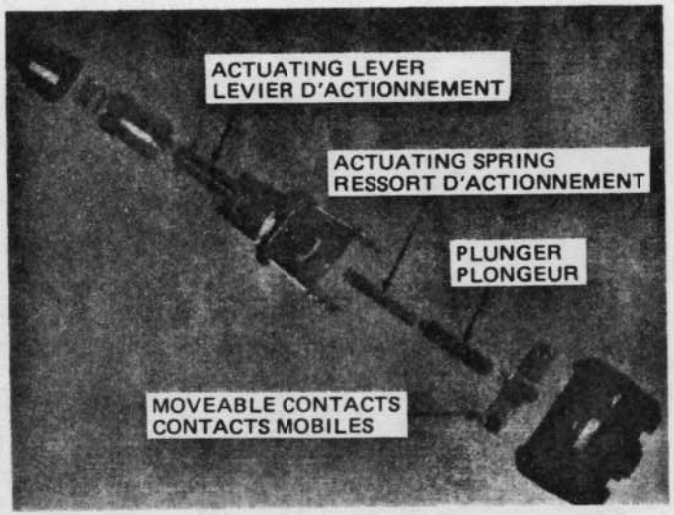


Photo 3 — Exploded View of Identical Type Switch Showing Its Components
Eclaté d'un contacteur de type identique montrant ses composants

APPENDIX E
ANNEXE E

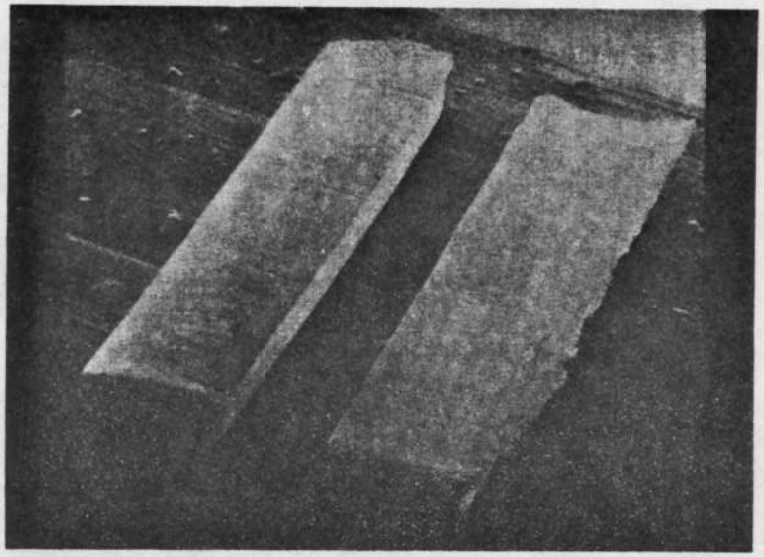


Photo 1 — Key Halves from Left Engine
Moitiés de clavette en provenance du moteur gauche

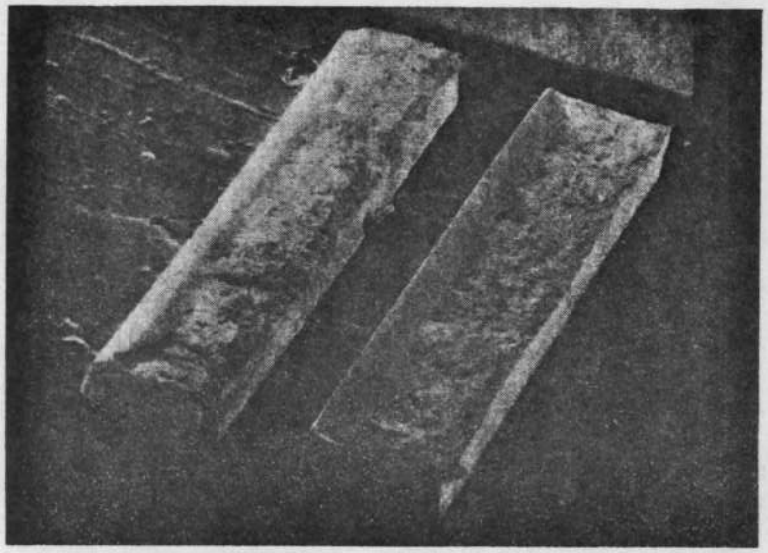


Photo 2 — Key Halves from Right Engine
Moitiés de clavette en provenance du moteur droit

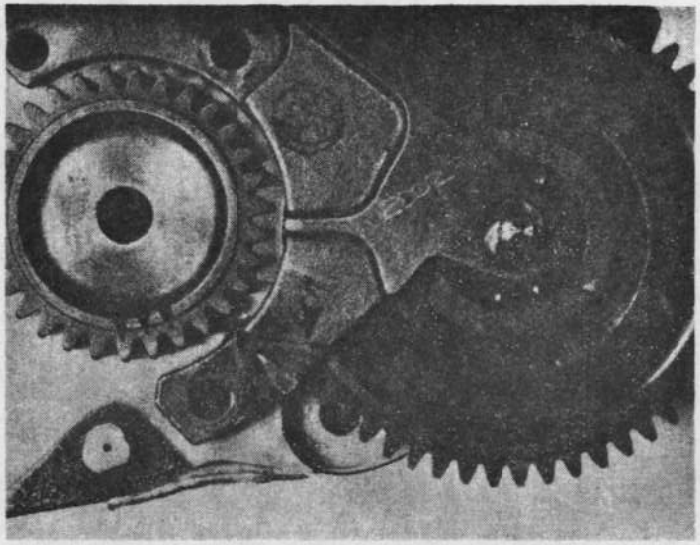


Photo 3 — Imprint Marks on Left Torque Sensor Assembly
Empreintes sur le détecteur de couple gauche

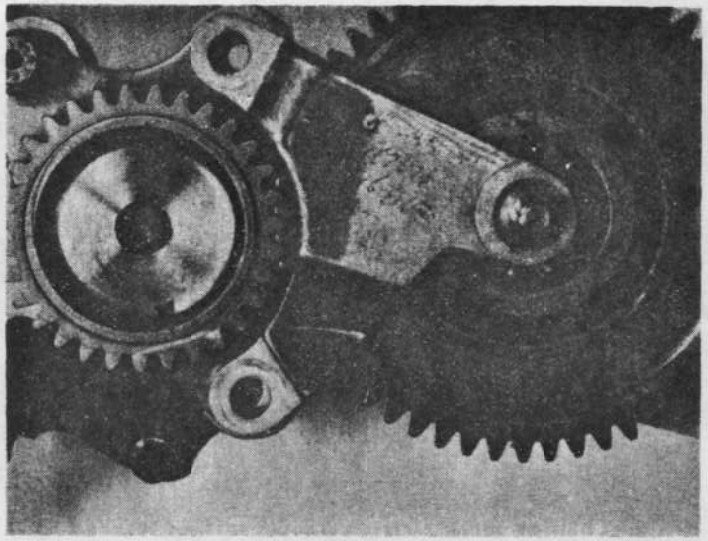


Photo 4 — Imprint Marks on Right Torque Sensor Assembly
Empreintes sur le détecteur de couple droit

APPENDIX F
ANNEXE F

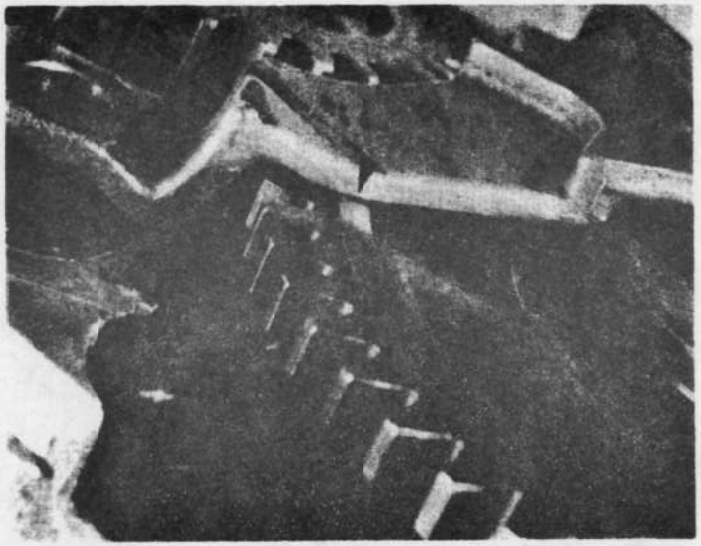


Photo 5 — Bent Support Bracket on Left Assembly
Ferrure de support de l'ensemble gauche déformée

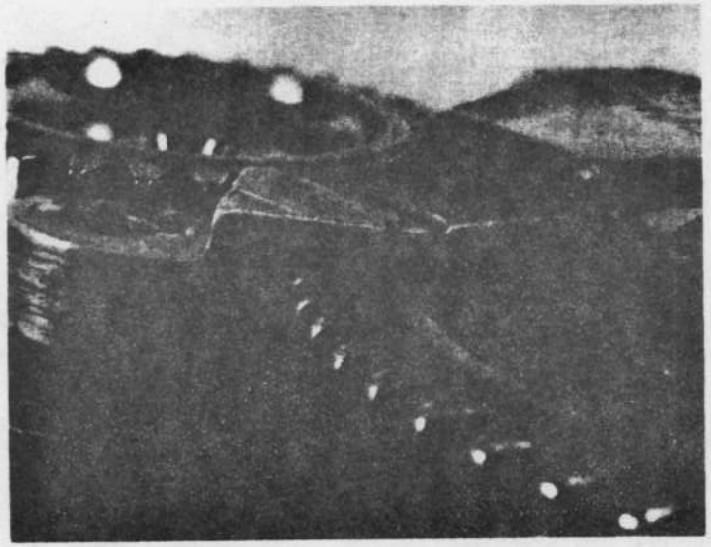


Photo 6 — Bent Support Bracket on Right Assembly
Ferrure de support de l'ensemble droit déformée

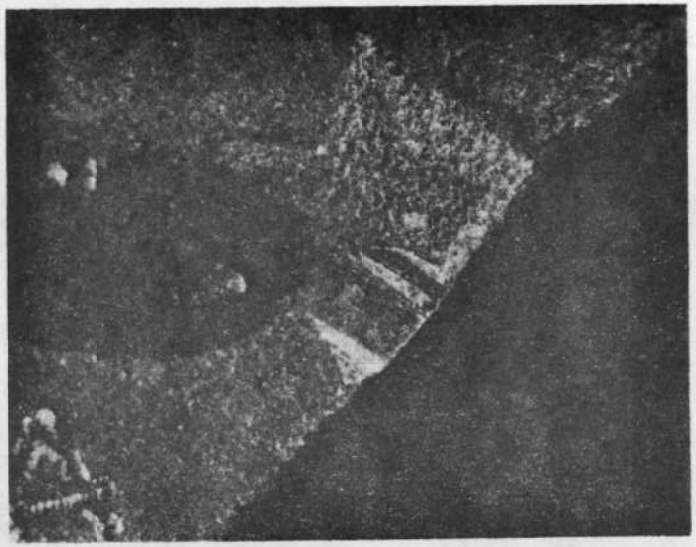


Photo 7 — Scoring on Underside of Left Support Bracket
Rayures sous la ferrure de support gauche

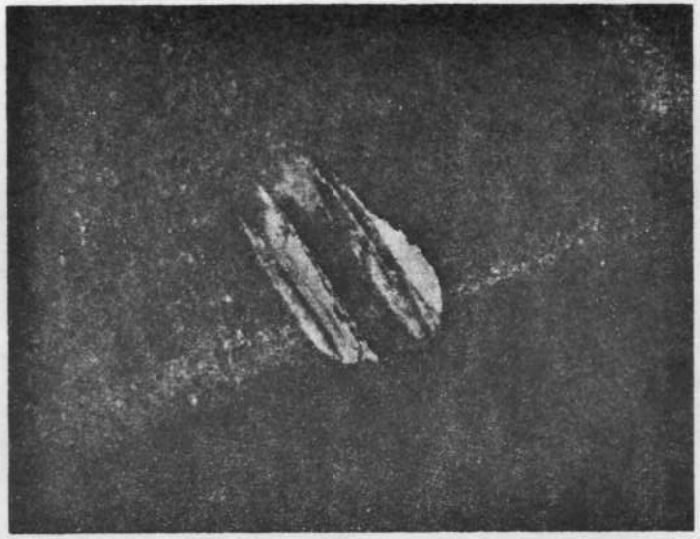


Photo 8 — Scoring on Underside of Right Support Bracket
Rayures sous la ferrure de support droit

APPENDIX F
ANNEXE F

APPENDIX G

LIST OF LABORATORY REPORTS RELATED TO THE INVESTIGATION

Engineering Report Number	Title
LP 449/81	Tail Pipe Impact Temperature
LP 450/81	Oil Filter Analysis
LP 451/81	Air Conditioner Sock Filter Analysis
LP 452/81	Starter/Generator Shaft Failure
LP 467/81	Landing Gear Screw Jack Analysis
LP 7/82	Annunciator Panel Bulbs
LP 10/82	Undercarriage Selector and Indicator
LP 25/82	Outlet Duct Air Cycle
LP 26/82	Engine Torsion Shaft
LP 27/82	Fuel Shut-off Valve 'G'
LP 29/82	Fuel Control Units Examination
LP 46/82	Sprayed Metal Deposit
LP 55/82	Instrument Examination
LP 66/82	Engine Power
LP 359/82	Video Coverage
LP 403/82	Air Cycle Unit
LP 125/84	Review of Independent Report
LP 126/84	Torque Sensing Unit
LP 127/84	Review of Report Rebuttal
LP 165/84	Fuel System Switches
LP 396/84	Analysis of Propeller Loads

These reports are available on request from the Canadian Aviation Safety Board.

APPENDIX H

PARTICIPANTS AT BOARD HEARING

23, 24 April 1986

Canadian Aviation Safety Board

B. M.-Deschênes, Q.C.	Chairman
N. Bobbit	Board Member
R. Lacroix	Board Member
W. MacEachern	Board Member
D. Mussalem	Board Member
A. Portelance	Board Member
B. Pultz	Board Member
R. Stevenson	Board Member
F. Thurston	Board Member
M. Friedl	Advisor to the Board
R. Baker	Advisor to the Board
K. Johnson	Executive Director
T. Hinton	Director, Investigation
R. Hayman	Director, Engineering
F. Reinhardt	Legal Counsel
A. LaFlamme	Investigator-in-Charge
J. Hutchinson	Superintendent, Material Engineering
J. Nelson	Safety Officer
R. Cook	Investigator, Western Region
A. Allinson	Investigator, Western Region

North American Road Ltd.

S. Fleming	Legal Counsel
R. Phillips	Consultant

Mr. Edward Burton

L. Decore	Legal Counsel
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V. Viquesney	Manager, Product Integrity
K. Pfitzer	Manager, Accident Investigation and Engineering Support

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T. Heaslip	Consultant
E. Berry	Manager, Field Service
M. Turner	Legal Counsel
C. Jukes	Legal Counsel

Transport Canada

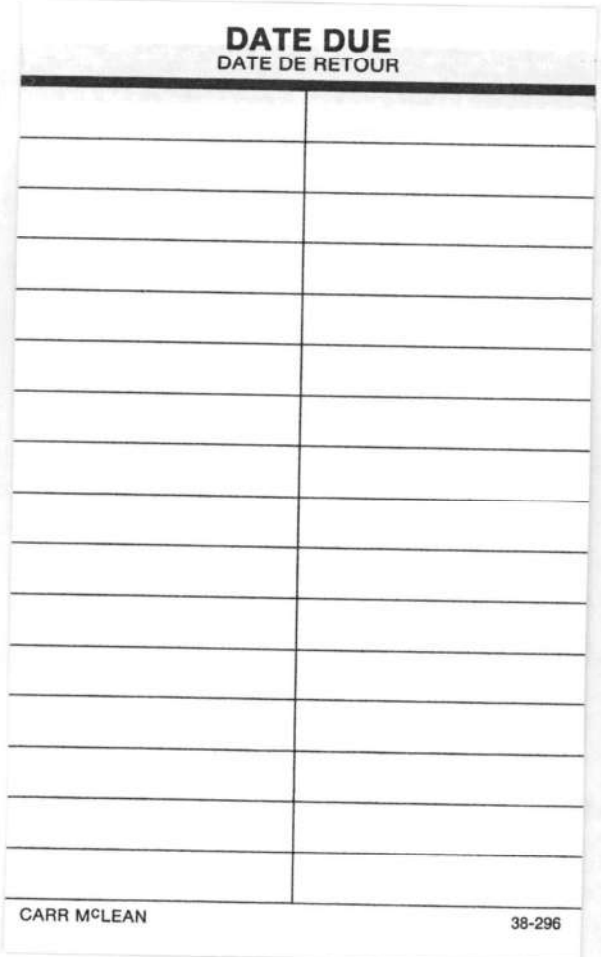
J. Stewart	Minister's Representative

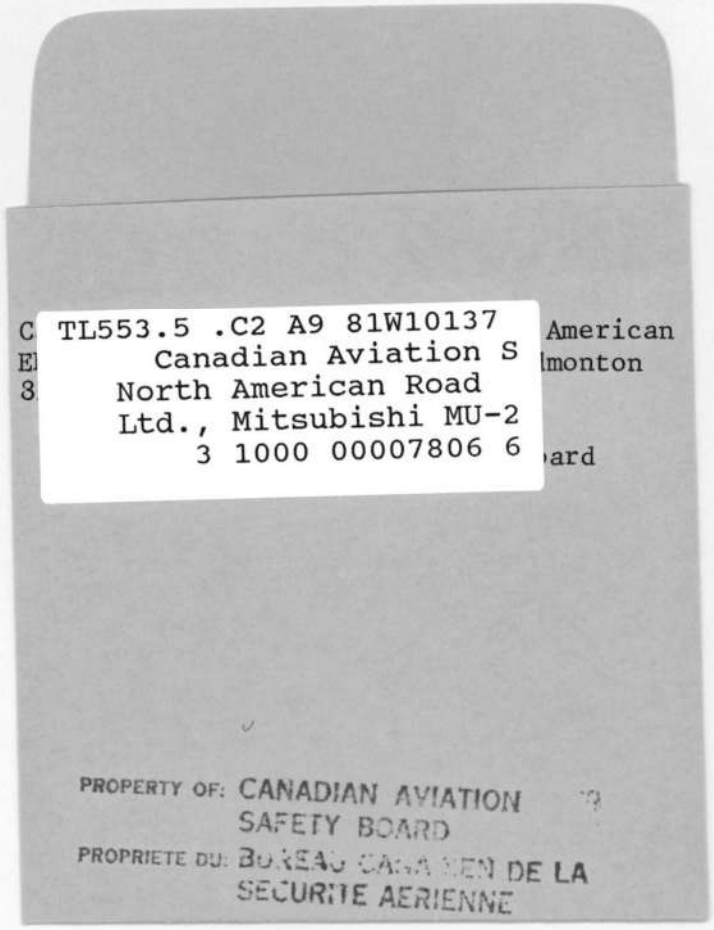
APPENDIX I

GLOSSARY

AARB	Aircraft Accident Review Board
agl	above ground level
ANO	Air Navigation Orders
C	Celsius
CASB	Canadian Aviation Safety Board
CVR	cockpit voice recorder
°	degree(s)
ELT	emergency locator transmitter
FAA	Federal Aviation Administration
FDR	flight data recorder
gal	gallon(s)
hr	hour(s)
KIAS	Knots indicated airspeed
lat	latitude
lb	pound(s)
long	longitude
MST	mountain standard time
N	north
NTSB	National Transportation Safety Board
NTS	negative torque sensor
psi	pounds per square inch
rpm	revolutions per minute
RCS	run/crank/stop

VASIS	visual approach slope indicator system
VMCA	minimum control speed
W	west
°	degree(s)
'	minute(s)
%	per cent
"	second(s)





Canadian Aviation S...

North American Road
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Board.

DATE	ISSUED TO
9 May 94	Denise Groulx

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