CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION REPORT (FSIR)

FINAL REPORT

FILE NUMBER: 1010-188906
DATE OF REPORT: 16 December 2004

AIRCRAFT TYPE: CF188 Hornet
DATE/TIME: 311938Z July 2001
LOCATION: 3 Wing Bagotville, QC
CATEGORY: "C" Category Accident

SYNOPSIS

Shortly after the CF188 Hornet lifted off runway 29 at Bagotville enroute to Toronto on an instrument flight, yellow, acrid smoke began to fill the cockpit. The landing gear and flaps were selected up and, although the gear indicators showed three wheels "up and locked," the light remained on in the gear selection handle indicating the gear doors were not completely closed. The pilot selected the gear down while carrying out the emergency procedures for smoke in the cockpit. While informing Air Traffic Control and Squadron Operations of the situation, several system advisories were noted. During the approach end engagement on runway 36, the arrestor gear failed damaging the aircraft's right side. However, a successful overshoot was conducted. The aircraft was successfully landed on runway 29 (with the cable removed) and was taxied off of the active runway without further incident. There were no injuries however the aircraft sustained "C" category damage.

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1. FACTUAL INFORMATION

General

At the time of accident, Hornet CF188906, a dual seat fighter aircraft, was being flown by a solo pilot on an authorized IFR cross-country mission to Toronto. The entire flight sequence occurred within the 3 Wing Bagotville, Quebec aerodrome area on 31 July 2001.

1.1 History of the Flight

The aircraft was configured with an external fuel tank on each wing (stations 3 and 7) and a luggage pod on the centreline (station 5). Start and taxi were normal. An IFR clearance was passed to the aircraft and it took off on runway 29 at about 1925Z with a total weight of approximately 40,000 pounds.

As the landing gear and flaps were raised after take-off, yellow acrid smoke began to fill the cockpit. The pilot responded to the smoke in the cockpit by carrying out the actions listed in the emergency checklist. Although the landing gear indicators indicated that the landing gear was up and locked, the light in the landing gear selection handle remained on, indicating the landing gear doors were not completely closed. The landing gear was selected down and indicated down and locked. As the smoke in the cabin increased in intensity, the pilot considered jettisoning the canopy; however, because the cockpit instruments were still readable he refrained from doing so.

The aircraft was manoeuvred into a left turn for a downwind leg to runway 29 as several captions illuminated on the caution/warning/advisory panel. These included gun gas, avionics air hot, and voice/DDI/lights for both left and right bleed air (valve) closed advisories. The pilot was talking simultaneously to both the tower and 425 Squadron Operations to co-ordinate the landing and to get advice on the malfunctions. Shortly thereafter, the right Digital Display Indicator (DDI) and the DDI on the centre console with navigation and horizontal situation indicator displays went blank. With the bleed air valves closed, all bleed air functions were lost, including throttle boost which made throttle movement stiff and awkward.

At this point in the flight, the aircraft was in a base leg position for runway 36, which had an approach arrestor cable up and ready. The aircraft was manoeuvred to final for the arrestor gear engagement with a landing gear and tail hook check being carried out. The aircraft was flown on final approach to the runway with reference to the velocity vector and the “E bracket” on the Heads Up Display with the velocity vector slightly low (2-4 knots fast). The 425 Squadron Duty Operations Officer was following developments with the pilot and, when the decision was made to engage the arrestor cable on runway 36 he suggested that the pilot should be ready for an overshoot if the approach or landing did not work out well. The aircraft touched down before the arrestor cable. The arrestor hook then caught the cable with a calculated aircraft speed of 204 knots and an all up weight of about 39,400 pounds. The engagement took place about 2 minutes and 20 seconds after the aircraft had lifted off of runway 29.

The aircraft decelerated slightly (to about 184 knots) and when the pilot did not feel further deceleration, he initiated an overshoot by selecting afterburners. The aircraft became airborne and the pilot immediately consulted 425 Squadron Operations to formulate a recovery plan. During post take-off and aircraft status checks, the pilot selected the flaps to full down and left the landing gear in the down position.

The aircraft had not decelerated after the arrestor cable was engaged because the tape on the left side of the arrestor gear had failed. However, the tape on the right side of the arrestor gear held. After the failure of the left tape, the slingshot effect caused the left portion of the cable to rotate violently around the tail hook in a counter clockwise direction and strike the right side of the aircraft. In addition, the cable and associated heavy (50 pound) metal attachment rig were dragged through the tail hook. Shortly thereafter, the left side tape attachment assembly and a section of about 20 feet of cable were severed from the right side of the arrestor gear and were dropped further down the runway. The pilot, who by then had initiated the overshoot, felt only a slight turn to the left and did not see any cable pieces.

The recovery plan formulated by the pilot and squadron operations officer included a reduction in the aircraft weight by dropping the external fuel tanks. The first drop attempt was successful at dropping only the left external tank as the right tank would not release. Other emergency methods of dropping the right tank were unsuccessful. Observers on the ground told the pilot that the aircraft's arrestor hook was bent right by about 70°. Therefore, the arrestor hook remained down as the pilot conducted an approach to runway 29 with the arrestor cable removed. The aircraft was successfully landed, stopped and taxied off the active runway without further incident.

1.2 Injuries to Personnel

TABLE 1: Injuries to Personnel

	Crew	Passengers	Other
Fatalities	Nil	Nil	Nil
Injuries	Nil	Nil	Nil

1.3 Damage to Aircraft

The aircraft sustained "C" category damage after the arrestor cable failed and its associated fittings struck the aircraft. This also bent the aircraft's arrestor hook to the right by about 70° (Photo 1) and resulted in structural damage to surrounding components, including the structural attachment point for the arrestor hook assembly.

A full damage assessment was completed and several panels on the rear of the aircraft were twisted out of normal alignment. This necessitated an airframe survey to determine the extent of further damage, but no sub-structural damage requiring extensive repairs was detected.

Other damage sustained from the cable strike included scrapes and gouges to components on the nose landing gear (Photo 2) and associated assembly, panels on the right side of the aircraft, the right external fuel tank and associated assemblies, and the upper surface and leading edge of the right stabiliser.

1.4 Collateral Damage

The aircraft jettisoned the left external fuel tank in the Bagotville aerodrome stores jettison area. The drop area was difficult for the pilot to see because the pylons marking its location were not easily identifiable. The fuel tank disintegrated on impact but all components and associated fuel were contained in the designated jettison area. Clean up of these components was carried out by 3 Wing recovery and salvage personnel shortly after the accident.

The cable engagement and associated break of the arrestor gear caused damage to the arrestor equipment on runway 36 and some of the runway edge lighting in Bagotville. Some scars and minor gouges were made to the runway but were not of sufficient size to require substantial repair. The Flight Safety quarantine on the airfield arrestor gear was lifted on 4 Aug 01 and the barrier was quickly repaired and tested before being re-commissioned.

As a result of the damage to the aircraft and the possibility that similar failures might occur, an operational restriction was placed on the arrestor gear; it was to be used for actual emergency arrestor engagements only. Further, the normally required visual inspection of the arrestor gear after each usage was augmented to a requirement for a non-destructive testing (NDT) inspection of the arrestor hook structure. The NDT inspection requirement and technique was documented on a Depot Repair Engineering Disposition, (Ref. 906B0145 03).

1.5 Personnel Information

TABLE 2: Personnel Information

	Pilot
Rank	Capt
Currency/Category valid as of 31 Jul 01	Cat 1
Medical Category valid	Date Extended
Total flying time	768.4
Flying hours on type	274.8
Flying hours last 30 days	16.8
Duty time last 24 hrs	8
Flying hours on day of occurrence	1.4

1.6 Aircraft Information

To suit the mission type, the aircraft was configured with external fuel tanks on stations 3 and 7, a luggage carrier on station 5, a Captive Air Training Missile on station 9, and no ammunition loaded in the gun.

The Maintenance Record System (MRS), a computerized maintenance documentation program, was examined post-accident. Examination showed the accident flight was the first for this aircraft since 11 Jun 01. During this period, several aircraft modifications had been completed and the aircraft had been "robbed" multiple times to supply parts for other squadron aircraft.

The Bleed Air System and Environmental Control System (ECS) were investigated to determine faults that prompted the advisories triggered during the occurrence. Damage was noted on some of the ECS ducting in the form of overheated components and a "blown" duct between two ECS components (Photos 3 and 4). Of note, several small loose components, scrap hardware and other foreign objects (Photo 5) were found as the ECS was disassembled during the investigation. These materials were produced when the ECS duct was blown and as other damage was done to the system via the heating.

1.7 Meteorological Information

The meteorological data showed the weather to be CAVOK with light winds from the west-southwest.

METAR: CYBG 311500Z 25004KT 20SM FEW030TCU 24.1/13.7 A3027 RMK TCU1 TCU TR SLP250 58002

TAF: CYBG 311413Z 311515 VRB03KT P6SM SCT050 RMK NXT FCST BY 18Z

1.8 Aids to Navigation

Nil.

1.9 Communications

The Bagotville Air Traffic Control Tower (ATC) and 425 Squadron Operations communicated with the occurrence aircraft throughout the emergency. Each of these stations transmitted useful information but they used different frequencies and were not monitoring each other. This resulted in the two stations “stepping” on each other at times, thereby adding to the cockpit workload as the pilot sought clarification or repeated communications.

All communications between ATC and the pilot were recorded, however, the communication between the Operations Officer and the pilot on the Squadron Operations frequency could not be taped. It should be noted that military ATC units have the ability to select any frequency to monitor, thereby ensuring that the selected frequency is recorded on the ATC master tape.

It was the 425 Squadron policy to man the Operations Office during squadron flying operations. One function of an Operations Office is to provide airborne crews the opportunity to consult, record and advise of events. This is very effective, particularly for single pilot emergency situations, as the Operations Officer can consult procedure documents and offer other possible solutions to unfolding situations.

1.10 Aerodrome Information

3 Wing Bagotville is a multi-mission airbase, with tactical fighter and combat support units and their associated maintenance and support organizations. The airport has tower, ground, and arrival/departure controllers, a full meteorological reporting capability, and full crash, fire, and rescue response. 3 Wing Bagotville has two runways, 29/11 (10,000x150 concrete) and 36/18 (6000x150 asphalt). The main runway (29/11), is serviced by PAR, TACAN, ILS, NDB and PAPI, whereas 36/18 is only TACAN capable. At the time of the accident all services were operational except for the PAR.

1.11 Flight Recorders

The CF188 is not equipped with cockpit voice or flight data recorder equipment (CVR/FDR). The Maintenance Status Display and Recording System (MSDRS) data was downloaded after the occurrence and supplied many aircraft parameters and advisory information to the Flight Safety Investigation (FSI) Team. Because they were not required for the mission, there were no heads-up display or cockpit cameras loaded. A CVR/FDR system would have simplified the FSI by expeditiously providing aircraft information and recordings of all voice transmissions during the emergency. In addition, it would have allowed for accurate flight path reconstruction.

1.12 Wreckage and Impact Information

A large cable impact scar was noted on the runway asphalt about 123 feet from the left hand arrestor equipment and 20 feet left of the runway centreline. Other small gouges were noted in the concrete of runway 36 at the intersection of runways 29/11, approximately two thirds the distance down runways 36/18; this was likely caused by the arrestor hook contacting the runway.

1.13 Medical

By 1605L (landing plus 22 minutes), the pilot had been transferred to the 3 Wing Hospital and a medical examination commenced. The Wing Surgeon conducted a complete physical examination. Toxicology samples were taken and sent for analysis, results of which were negative.

A review of the pilot's medical file was conducted and it was observed that there had been extensions to the pilots B2 medical completion because certain follow-on examinations had been postponed, cancelled or delayed. Also, some aspects of the immunization protocol were not completed. As well, the pilot's medical category had been extended multiple times from Feb 01 pending the completion of a medical test, which was completed the day after the accident. These deficiencies were non-contributory in nature.

1.14 Fire, Explosives Devices, and Munitions

There was no fire during this occurrence but the smoke in the cockpit was thick, acrid and yellow. The post-occurrence examination of the ECS revealed heat damage in some of the ducting.

The external fuel tank jettison system uses an explosive charge to activate a plunger that pushes the tank off the mounting pylon when the mounting hooks have released the tank. These charges worked on the left tank but were not activated on the right tank due to the damage to the tank caused by the cable strike. The emergency jettison function was employed to drop the external fuel tanks on the first pass in the jettison area but only the left tank dropped. On subsequent passes through the jettison area, the jettison select function and auxiliary jettison function were selected in alternate attempts to drop the right tank. These functions were not armed because the landing gear was left down; these functions are disabled as a safety feature in a landing gear down configuration. The pilot checklist procedure requires the landing gear to remain in the down position after down and locked indications are obtained during the course of a landing gear malfunction.

No other explosive charges were utilized during the flight and the ejection system was not activated. No munitions were carried on this flight.

1.15 Survival Aspects

With smoke in the cockpit, the pilot's response was to select 100% oxygen delivery to his helmet face mask. The mask functioned as designed. There were no Aircrew Life Support Equipment (ALSE) issues related to this accident. Post accident examination revealed all onboard ALSE equipment was properly serviced and maintained.

The 3 Wing crash response consisted of the deployment of fire fighting and emergency vehicles to the landing areas and the initiation of the hospital emergency response plan. When it became evident that the aircraft's arrestor hook had been damaged in the approach engagement, the arrestor gear on runway 29 was lowered so that it would not interfere with the second landing. The pilot was taken from the aircraft to the hospital by ambulance and was examined by the Wing Flight surgeon within 22 minutes of landing.

1.16 Test and Research Activities

The aircraft engagement parameters were utilized to calculate the Total Energy (TE) for the occurrence as 72.6 M ft/lbs. The Original Equipment Manufacturer (OEM) lists the maximum TE absorption for the barrier equipment as 65.0 M ft/lbs. Thus the aircraft exceeded the advertised TE for the equipment by 7.2 M ft/lbs. The failed arrestor gear tapes (both sides) and cable (pendant) were sent to the Quality Engineering Test Establishment (QETE) for analysis.

Several components of the aircraft ECS, including the Valve, Anti-Ice Flow, Temperature Limiting were shipped to QETE for analysis. As well, swabs of soot deposits were taken progressively throughout the ducting of the ECS so that analysis could be performed.

1.17 Organizational and Management Information

During the examination of CF188 pilot training documents and proficiency requirements, it was discovered that the annual training requirement for CF188 pilots to conduct arrested landings had been removed. Examining the pilot's training records also revealed no obvious trace of supervisory review of his file in the preceding four months. Additionally, the pilot's logbook had not been kept up to date or signed by a supervisor during the preceding eight months.

These points and other administrative deficiencies were acknowledged by the 425 Squadron Commanding Officer. It was believed that the root cause of these issues was personnel-oriented; accordingly, additional administrative support for 3 Wing Squadrons was requested.

1.18 Additional Information

Aircraft Documentation.

References:
A. C-05-005-P04/AM-001, Aircraft Maintenance Record Set
B. C-05-005-P09/AM-001, Maintenance Program Implementation – Support Activities
C. C-02-005-009/AM-000, Inspection and Conditioning of Materiel Returned to and Held in the Supply System

1.19 Useful or Effective Investigation Techniques

Nil.

2. ANALYSIS

2.1 General

The mission was properly authorized and planned. The pilot involved in the accident was fit for flying duty.

2.2 The Aircraft

Aircraft CF188906 was declared serviceable prior to flight; however the investigation revealed that there was an unserviceable Valve, Anti-Ice Flow, Temperature Limiting installed in the ECS, which contributed to this accident.

2.3 Aircraft ECS System

2.3.1 Environmental Control System Description

The ECS on the CF188 cools and conditions hot air from the engines bleed air system for use in various aircraft systems. The ECS is a very complex system composed of 13 sub-systems. Of these sub-systems, the air cycle air-conditioning system, cabin cooling and defog system, avionics cooling system, vent suit system and the bleed air system were closely examined as they were suspected of having contributed to the sequence of events that took place during the accident flight.

Bleed air is extracted through ducting from the engine compressor discharge air of either or both engines, as selected by the pilot using the BLEED AIR switch. The LH ADVISORY AND THREAT WARNING INDICATOR PANEL is on the main instrument panel and provides the pilot with a warning light indication of L BLEED and/or R BLEED. When these indications occur, the left and/or right primary regulators and the secondary regulator have shut down and the bleed air system is inoperative. The Bleed air system also features a bleed air leak detection system, which prevents aircraft damage caused by bleed air leaks

The ECS controls the cockpit environment and the environment of avionics equipment on the aircraft. In addition to being complex in the number of subsystems and components, several of these systems are physically and electronically connected to provide continuous airflow and temperature control. It was suspected that the smoke, which filled the cockpit shortly after take-off, came from some component of the ECS. Through analysis of the ECS components, the investigation team was lead to one specific component of the ECS called the Valve, Anti-Ice Flow, Temperature Limiting.

The Valve, Anti-Ice Flow, Temperature Limiting, located downstream of the warm air temperature control valve, is a dual function valve. It is a pneumatically actuated flapper valve and a "muscle pressure" regulator. "Muscle pressure" is the term used to describe the pneumatic system that uses regulated bleed air as a motive force to actuate various systems. The flapper is modulated by muscle pressure, which is controlled by the warm air over-temperature sensor. The valve is normally open during system operation and modulates toward closed only if an over-temperature condition occurs. The muscle pressure regulator on this valve is the source of regulated muscle pressure used by the environmental control systems. It is a dual-diaphragm regulator and uses source air pressure from either the windshield anti-ice and rain removal duct or the air cycle air-conditioning system, whichever pressure is greater.

2.3.2 ECS Failure Analysis

After the aircraft had been taxied from the active runway and the engines were shut down, ground crew personnel noticed that the left engine was very hot compared to the right engine. Since the ECS takes hot air from both engines' bleed air systems, the two engines installed on CF188906 were investigated for anomalies that could have contributed to the smoke in the cockpit. Both engines were inspected with a boroscope and no faults were found. The engines were sent to the test cell and ground run serviceable.

Most of the ECS ducts and components, including the ECS turbine, are located underneath the CF188 in an area referred as the keel of the aircraft (the belly). Panels from the keel area were removed to investigate the ECS. The rubber hose connecting the ECS turbine and the fibreglass duct was found chaffed and disconnected at the turbine attachment point. There was only a small portion of the hose still attached to the ECS turbine and the remains of the rubber hose were found inside the panel removed for access. The other end of the rubber hose was not connected to the fibreglass duct. The end of the fibreglass duct was split and the retaining clamp was found in the keel panel along with other FOD related to the attachment and identification hardware.

After the discovery of the damaged components, the investigation concentrated on finding the component or event that could have resulted in the damaged ECS ducts and could have contributed to the source of the smoke in the cockpit.

The ECS component up-stream of the damaged ducts was carefully removed. Many ECS components were removed from CF188906 and investigated for evidence of heat that could explain the smoke in the cockpit. The FSI Team found ducts and restraining clamps that showed evidence of having been exposed to an unusual amount of heat. These components were located around the Flow Temperature Limiting Anti Ice Modulating Valve.

An initial hypothesis was created in which muscle pressure below the prescribed level was thought to cause an imbalance of the ECS system. This was believed to result in an overheat condition of some component which could then cause smoke in the cockpit. In an effort to verify if the Valve, Anti-Ice Flow, Temperature Limiting was operating normally, support technicians and a Field Service Representative reconstructed a mock up to reproduce the ECS temperature and pressure up stream of the suspected valve. When the valve was installed in the mock up, the muscle pressure regulator portion of the valve was found to be inoperative. The incoming applied air pressure (upstream) had the same value as the out going air pressure (downstream). In other words, the valve did not regulate the system muscle pressure. To confirm this finding, the same test was performed on a valve known to be serviceable and it was found that air pressure was regulated as designed. Initial analysis of the ECS diagram showed that the accident valve (not regularising the pressure) could not correctly control the temperature and thus caused excessive heat egress into the ECS system. The faulty Valve, Anti-Ice Flow, Temperature Limiting, S/N0339, and surrounding ducts and hardware were sent to QETE for further analysis. QETE was tasked to investigate why the valve was not operating as per designed specification and to confirm if the reported heat discoloration marks on the ducts and clamps could be related to the smoke in the cockpit. QETE reported that the valve was not operating as per specifications. The spring used to regulate the pressure had become worn and slipped over the end of the piston that supplies pressure to the diaphragm (Photos 6-8).

In examining the maintenance records for this specific Valve, Anti-Ice Flow, Temperature Limiting, it was found to have been involved in a previous bleed air flight safety incident on CF188751 (425 Sqn) in 1999. In 1999, this valve was removed and returned, through the CF supply system, to the contractor for repair. The CF188 Aerospace Engineering Officer was consulted and advised that the contractor had never received this valve. A collateral supply investigation was initiated to determine how the defective valve was returned to the supply system rather than being sent to the contractor and was ultimately installed “un-repaired” in the accident aircraft.

Although QETE confirmed that this failed item was upstream of heat-damaged ducts, they were not able to determine which part became sufficiently overheated to produce the smoke that flowed from the air conditioning system into the cockpit. The only credible answer technical analysis could arrive at was that the non-functioning valve caused a system overheat which in turn caused the fibre tubing to deteriorate and blow apart, resulting in the smoke. The blown tubing would have ripped due to over limit muscle pressure. This hypothesis was presented to QETE who agreed that it was consistent with the facts available.

When the ECS ducts in the keel area came apart due to the excess pressure and temperature, the Bleed Air Leak Detection System caused the left and right bleed air valves to shut down to prevent the aircraft being damaged by bleed air leaks. The bleed air system then sent a signal (voice/DDI/lights) to the pilot, indicating the L BLEED and R BLEED had been shut down. The other warnings associated with left and right bleed air (valve) closed advisories were a direct result of the ECS being inoperative (gun gas warning, avionics air hot). Shortly thereafter, the right Digital Display Indicator (DDI) and the DDI on the centre console with navigation and horizontal situation indicator displays went blank as a result of the overheat.

2.4 Landing Gear Failure

The nose wheel well Digital Display Indicator was inspected to see if any maintenance codes were stored in the memory. The maintenance code 911 is recorded. The recommended maintenance action for this maintenance code is to verify the main landing gear (MLG) Proximity Switch for the Up and Lock condition. Landing gear retraction was carried out to identify the source of the unsafe landing gear. The retraction revealed that the Left MLG Up Lock Proximity Switch was out of tolerance. The shims used to adjust the Left MLG Proximity Switch were found improperly installed. The aircraft had been subject to MLG UPLOCK Modification, 19 July 2001. The MOD C-12-188-000/ CD 128 (MLG UPLOCK) was successfully completed and the MLG was re-assembled during the week preceding the occurrence. It was found that the MLG reassembly was not performed as per the Canadian Forces Technical Orders in that the shims were installed inverted. Surprisingly, the landing gear retraction carried out in the hangar after the MLG re-assembly did not indicated unsafe MLG. The air load and vibration on the first flight following the modification could explain the unsafe indication on the day of the occurrence.

2.5 Store Jettison System Failure

The FSI examined what could have prevented the right fuel tank from jettisoning properly after the failed attempt to engage the cable. The right fuel tank was removed from CF188906 after the incident. A functional test was carried out on the aircraft to compare the two pylons serviceability. The left pylon successfully passed the functional test while the right pylon failed to eject the store. A separation of approximately 0.5 inches was noticed between the top of the right pylon at the wing attachment point, which is not normal. The right Pylon (SUU-63), Bomb Ejector Rack (BRU33) and the Stores Management System (SMS) were sent to the second line facilities for further testing and investigation.

The SMS tested serviceable. During the first landing attempt, the right Pylon (SUU-63) sustained considerable structural damage when the broken cable struck the aircraft; however, none of this damage contributed to the failure of the stores to jettison. The Bomb Ejector Rack (BRU33), located in the right pylon assembly, and harness assembly also sustained structural damage. This damage prevented the electric signal from the SMS from enabling the lock override and fire signals to the BRU-33. Thus the damage to the ejector rack harness assembly caused by the arrester cable prevented the R/H tank from being jettisoned.

2.6 Supply System investigation

2.6.1 Background

During the course of the FSI it was reported that the same Valve, Anti-Ice Flow, Temperature Limiting (Serial 0339) was also involved in a similar incident on airframe 751 in 1999 (refer to FSIS 96249 10-08-1999 and FSIS 96361 11-08-1999). The maintenance documentation indicated that this valve was removed in Aug 1999 and returned, through the CF supply system, to third line for repair and was never re-installed in another aircraft until installed on the accident aircraft. The CF188 Aircraft Engineering Officer was asked to investigate if the valve was sent to the contractor for Repair and Overhaul (R&O) between Aug 1999 and 31 July 2001. The contractor reported that the occurrence valve had not come to their R&O facilities since 1989. Suspecting the supply process could have contributed to the valve being identified as "Serviceable" after the Aug 1999 incident and put back on shelf at the unit, a Supply System investigation was conducted in Bagotville. This investigation was to concentrate on the supply processes in place at the unit, 3 Wing Bagotville and possibly the CF Supply system. The supply investigation team was composed of the Life Cycle Maintenance Manager (LCMM) for the ECS components, a CF supply supervisor and a DFS Technical Investigator.

2.6.2 Sequence of the Supply Transactions

The supply investigation revealed that in Aug 99, the Valve, Anti-Ice Flow, Temperature Limiting S/N0339 (P/N 979452-3-1, NSN 4820-01-116-8502) was removed from aircraft CF188751 and returned to the unit Supply Section. Unfortunately the valve was misidentified on the paperwork when returned to the CF Supply System with NATO Stock Number (NSN) 4820-01-259-0997 which refers to Valve, Anti-Ice P/N 979452-7-1. The names as well as the part numbers (-3-1 and -7-1) of these valves are similar, increasing the likelihood that a novice technician or a supply technician might confuse them. The supply system received the misidentified part and the supply computer issued an instruction (XBQ-9250-Z004) for the item (still misidentified) to be sent to the appropriate contractor (XBQ) Honeywell Aerospatiale Inc, for R&O. Although the wrong stock number was used, the supply system performed exactly the way it was supposed to. Honeywell Aerospatiale Inc had an R&O line in place for the valve, anti-ice P/N 979452-7-1, and the supply computer automatically directed the misidentified part to that contractor.

Accordingly, Honeywell received a part for which they did not have an R&O line in place and did not have the authority to repair. In late December 99, they re-identified the part with the proper NSN and sent the valve back to the depot in Montreal under Stock Holding Code 70 (awaiting classification). Having no expertise in aircraft components and not normally dealing with this component's LCMM, the Montreal Depot in turn issued the part to Repair and Disposal (R&D)

in Bagotville, expecting that R&D in Bagotville would take the appropriate action (change the Stock Holding Code and assign the right classification) with the item now properly identified. Unfortunately at Bagotville R&D, the part was perceived as being returned serviceable from third line and was placed on the shelf awaiting normal use.

In early Feb 01, the same part, correctly identified, was drawn from the CF188 Supply in Bagotville by a technician to fix an ECS snag for an aircraft on periodic inspection. Six days later, the Anti Ice Flow, Temperature valve, serial 0339, was returned to supply. This kind of supply transaction does happen occasionally. To fix a problem, a technician may try replacing a number of parts and determine in the process that some of the replaced parts are serviceable, and so return the unused replacement parts to supply. In late July 01 the same (unserviceable) part was issued and placed in aircraft 188906.

2.6.3 Limitation of the Supply System

The FSI was not able to determine what happened at R&D Bagotville when the part was received back from the Montreal Depot. The personnel in place at the time when the part was returned to be "classified" were not able to recall the event, and examination of supply system records could not help make that determination.

The sequence of the supply transactions of the valve was mainly determined using the supply system documentation (supply voucher) and the basic aircraft unserviceability record form (CF349). The supply technician should not have put the part back in stock unless it had a CF942 tag (Condition Tag or "rainbow tag") stating the item was serviceable. CF942 tags are not kept for records. With limited information available from the supply system documentation (CF942 and supply vouchers), the FSI Team looked at the maintenance documentation requirements for parts being removed from aircraft and sent to Repair for overhaul through the CF Supply System.

2.7 Maintenance Record Set

2.7.1 Maintenance Documentation

The data recording system for aeronautical products consists of a series of standardized forms that provides a database on the daily technical status of each aircraft in the CF and of its installed equipment. The Maintenance Record Set (MRS) and its administrative procedures have been structured to meet maintenance data and certification requirements pertaining to airworthiness, flight safety and aircraft operations.

Maintenance data must be recorded and retained for all aircraft and specified aircraft equipment. Because each item can be replaced independently of others, and because history records should be kept, the record keeping system is broken down into elements (i.e., airframe, engine, etc.). For convenience and simplicity, forms comprising the aircraft Log Set have been designed to record historical data about specific aircraft items and its installed equipment. Aircraft subassemblies, components and accessories, which are identified in the Equipment Code and Inspection Requirements as having an Overhaul/ Retirement life, or which are selected non-life items, need to be traced using specific forms. The forms of interest to the FSI were as follow:

a. CF349 – Aircraft Unserviceability Record: is a multi-purpose document to record any condition and the maintenance action(s) taken to rectify that condition, including the support work;

b. CF352 – Aircraft Item Replacement Record: lifed items and selected non-lifed items being removed from the aircraft need to be recorded on a CF352. The CF352 shall record the data contained in the Equipment Code and Inspection Requirements in addition to the data transcribed and updated from the CF358, CF349 and CF543. In essence, it records the history of the component on a single document;

c. CF358 - Aircraft Item History Record: is required for the life cycle of specified components, accessories or parts to maintain a recorded history relating to manufacture, overhaul and Special Inspection status. The CF358 also provides a record of certification for the completion of certain maintenance actions in addition to a record of installation time; and,

d. CF543 – Off-Aircraft Unserviceability Record: is to be used on removed aircraft equipment to record defects, malfunctions, suspected faults, preventative inspection requirements and modification action. The CF543 is used to record and provide a record of certification for all maintenance actions carried out on non-installed aircraft equipment.

2.7.2 Maintenance Documentation Requirements

The Valve, Anti-Ice Flow, Temperature Limiting is found under the Work Unit Code DAJF. In accordance with the Equipment Code and Inspection Requirements, the Work Unit Code DAJF is not a lifed item but specifically requires a CF352, a CF358 and CF543 in addition of the CF349 already required for any removal and installation of components. The extensive review of the maintenance documentation by the LCMM revealed no CF352 or CF358 forms associated with the removal and subsequent installation of this part.

2.7.3 Maintenance Documentation Process

With the appropriate maintenance documents apparently never completed, it is difficult to trace the history of the Valve, Anti-Ice Flow, Temperature Limiting S/N 0339. When it was returned to Bagotville, either the CF358 or CF543 could have indicated the defect of the component or the lack of maintenance action that should have been performed at the R&O contractor. The Valve was sent from the contractor under Stock Holding Code 70 (awaiting classification). Given the lack of other documentation on the part, this could be interpreted either as the part had not been repaired at the contractor or as the part needed to be assigned with the Stock Holding Code showing it had been repaired and was now serviceable. Since the contractor normally only sends repaired parts back to the depot, it is reasonable to assume that the latter interpretation was made, and the part, correctly identified by now, was put back in stock. If the first interpretation was assumed, the supply technician should have raised a Repair Material Request form.

2.8 Maintenance and Supply Process

Had the proper maintenance documents been generated at the unit when the valve was removed from CF188751 in 1999, the part condition would have been identified on the maintenance Replacement Record (CF352), History Record (CF358) or the Unserviceability Record (CF543). The CF543 alone would have been tied to the valve and would have indicated to the technicians (supply and aviation) the condition of the valve as still needing repair. A misidentification of this part would still have caused confusion, however, the condition of the valve S/N0339 would have been known. The description of the following sequence represents what could have happened at different steps of the maintenance and supply process.

Had the part been correctly identified at the squadron in 1999, the supply computer would not have found an R&O line to have the Valve, Anti Ice Flow, Temperature (P/N 979452-3-1, NSN 4820-01-116-8502) repaired. The supply technician would have been required to raise a Repair Materiel Request form that would have been sent to the item manager (the LCMM). With the right NSN the item manager then would have been contacted to find repair facilities to get it fixed.

Had the valve been identified as unserviceable, the unit should have raised a CF543 (Off Aircraft Unserviceability Record). The CF543 provides a means of recording very useful information as directed in the C-05-005-P04/AM-001. A clear and accurate description of the unserviceability, the defect, malfunctions, suspected faults, should have been recorded along with, as a minimum, the name and MOC of the technician making the entry and the aircraft type & registration. Furthermore, when an item is not locally repaired, as for the valve S/N0339, the Third Line contractor would have completed certification signatures in the “Work Checked By” block of the CF543. The CF543 would indicate whether the item was considered serviceable or not. All items removed and forwarded to Second or Third Line maintenance repair facilities shall have a CF543 completed.

The contractor receiving the misidentified valve should not have returned the part to the depot without repair simply because it was misidentified. When a part is sent to the contractor, misidentified or not, it is expected to get fixed, not to be sent back without repair. The R&O facility should have sought advice from the National Defence Quality Assurance Region (NDQAR) or the LCMM. In this scenario a phone call could have solved the problem.

When the Valve was issued to R&D in Bagotville from the Montreal depot, under Stock Holding Code 70 (awaiting classification), it should not have been put in serviceable stock unless it had a CF942 (Condition Tag “rainbow tag”) stating the item was serviceable. In the absence of a CF942, or if in doubt, the supply section should have raised a Repair Materiel Request form that would have been sent to the LCMM for disposition. As mentioned, the supply investigation team was not able to verify if a condition tag was tied to the part since the CF942 is normally destroyed after the part is installed in the aircraft. The unit removing the item from the aircraft and returning it to the CF supply for repair must complete a CF942. Again, a CF543 – Off Aircraft Unserviceability Record, could have confirmed the condition of the item. Unfortunately, the supply investigation team was not able to verify if a condition tag was tied to the part since the CF942 is normally destroyed after the part is installed in the aircraft.

When the squadron received the Valve, serial 0339, from the supply system it should have been ensured that all the paperwork was accounted for and accurate. The FSI revealed that there was no CF543 - Off Aircraft Unserviceability Record - with the part, but as a minimum, the part should have been tagged with a CF942 – condition tag. If in doubt, the part should have been sent back to R&O with the appropriate explanation on the proper forms.

2.9 Maintenance Program Support Activities

In conjunction with servicing requirements and corrective and preventative maintenance programs, there are several miscellaneous activities and programs that directly affect the implementation of an efficient weapon system maintenance program. Maintenance and support programs for each aircraft type must address several complex requirements. These complex requirements for Maintenance Program Implementation are referred as Support Activities. These support activities include programs like Tool Control, Management Information System and the Inspection and Conditioning of Material.

The “Inspection and Conditioning of Material” functions described in reference B are carried out by the Technical Inspection Organization. These functions are an integral part of the support activities and shall be established at all units performing maintenance on CF aircraft and aircraft equipment. Installation of any new or used items authorized for use on an aircraft requires a prior assessment of the item's serviceability status. It is essential that material identity and status be properly recorded when being returned to CF units or contractors, through the CF Supply System. This will guarantee the correct destination and the right maintenance actions are carried out. The same process would ensure items being installed on CF aircraft are serviceable or have been serviced properly. The current policy and procedures governing these activities are described as a basic Support Activity in Ref B and are described in Ref C.

No sign of the Inspection and Conditioning of Material program was apparent during the FSI's review of the supply and maintenance documentation. None of the documents reviewed had any "Technical Inspector" stamps, as would be expected. The investigation team inquired about the condition of the Squadron and Technical Inspectors program and was told that there were no qualified Technical Inspectors on either the squadron or at 3 Wing.

The Technical Inspection Organization is an extension of the CF Supply System, which is extensively used as part of the Aircraft Maintenance Programs to provide a level of quality control for aircraft components used on CF aircraft when these components are transported, received, stored, distributed and returned to repair lines.

Based on the examination of the supply system, the associated supporting document requirements and the ideal support structure advocated for Technical Inspection support to the supply system, the investigation team concluded that there is no inherent supply system organizational problem associated with this accident. The reason that an unserviceable part was re-installed on the accident aircraft was that several personnel at multiple levels failed to complete the required paperwork. In addition, several personnel accepted materials without the proper paperwork attached. Finally, there is no Technical Inspection Organization at either the unit or 3 Wing.

2.10 Arrestor Gear

2.10.1 Arrestor Gear Description

All of the arrestor gear systems at 3 Wing are AAE 44B-3H bi-directional water twister type arrestor gears. There is one arrestor system at each end of runways 29/11 which is rigged at the 1500-foot mark, and one arrestor system on runway 36 rigged at the 1600-foot mark. These arrestor systems consist of a cable, which is suspended off the runway surface by a series of rubber pucks. Each end of the cable is connected to 1075 feet of tape, which is wrapped around an above ground drum on either side of the runway. Normal arrestment is accomplished by the drum mechanism supplying a braking force to the tape as it is dispensed off the reel on each side of the runway. A turbine twisting through a water/glycol mixture in the drum assembly generates the braking force. The arrestor gear can be engaged from either direction.

2.10.2 Arrestor Gear Failure

The initial failure point on the arrestor gear tape was about two feet from the left hand attachment rig that connects the cable to the tape. The tape failed after about 120 feet of tape had come off of the reel. In addition, the arrestor cable itself failed at about 20 feet from the left attachment point as the cable, running through the arrestor hook on the aircraft, unravelled. This created “bird nests” on the cable and eventually weakened it to the point where it sheared. The piece of the arrestor gear consisting of two feet of tape, the attachment ring and twenty feet of cable, was deposited about 1075 feet from the arrestor equipment, to the left of the runway. The remainder of the left arrestor tape was found strung out along the left side of the runway but towards the approach end of runway 36 for about 120 feet. The right arrestor tape and about 130 feet of cable was found strung out along the right side of runway 36 for about 325 feet but towards the departure end of the runway. Record examination showed the tape had been properly installed but this occurrence was the first arrestment for the tape. The cable and tape assembly broke several runway sidelights, located down range from the arrestor gear equipment shed, on the right side of runway 36.

Because the tape had not been used on other arrestments, any observed damage was the result of this arrestment or was caused by installation or de-installation of the tape. Initial failure testing of the tape was conducted and yielded failures at 75000 and 81000 pounds. QETE tests used relatively small grips, which tended to cut the webbing during the initial tests; this means that the actual strength of the tape probably is considerably higher. The nominal advertised failure strength for the tape is listed at 108,200 pounds.

QETE noted the tape failed at the edge of the loop sewing. The failure has the appearance of an overload failure with no indication of prior cutting, abrasion or damage. QETE’s initial examination of the tape revealed a wear pattern at about 70 feet which increases in severity up to a point about 148 feet along the tape where it then fades away. At the most severe wear area, the tape is stiffened and has a wavy shape, as though there was stretching and heating occurring. The wear is on the outside of the reel (as shipped to QETE). The other side of the tape also shows a wear pattern that is less severe and more uniform (no stripes). In addition, QETE noted there is a mild "crease" at the 118-foot point on the tape. The wear pattern, described above, (on the outside) continues through this crease without interruption. The wear pattern on the inside has a minor interruption near the crease, but not on the crease. There is some light abrasion on the outside edge of the crease.

The gross energy calculation for the accident aircraft engagement is greater (72.6 M foot lbs) than the stated maximum energy absorption capability of the arrestor gear (65 M foot lbs). It is concluded that the arrester gear failure was due to excessive aircraft energy applied to the arrester gear during engagement on initial approach.

2.11 Pilot Technique

2.11.1 Approach Speed

During the final approach to the first landing and arrestor gear failure, the pilot did not select the flaps down. He flew the final portion with reference to the velocity vector and the E bracket, and was thus unaware of his high airspeed. Standard procedures do not require an airspeed cross check once established on final approach because the aircraft calculates the appropriate speed by referring to programmed parameters and sensors and passes the info to the pilot via the E bracket. An actual IAS crosscheck would have alerted the pilot to the configuration problem (flaps not selected) because of the higher than normal final approach speed of 212 KIAS.

2.11.2 Incomplete Pre-landing Check

The accident pilot was responding to multiple simultaneous aircraft system failures thereby creating a sense of urgency. Additionally he was attempting to concurrently communicate with two separate agencies and manage all this within a very short time frame. The result was a rushed approach without the proper aircraft configuration. The incomplete pre-landing check was the final active failure that led to the aircraft being damaged.

3. CONCLUSIONS

3.1 Findings

3.1.1 The pilot's physical and mental condition before the flight did not affect the outcome of the occurrence.

3.1.2 The aircraft experienced multiple failures after take-off because the Valve, Anti-Ice Flow, Temperature Limiting did not function correctly; this caused the ECS system to overheat which in turn caused the duct damage and the smoke in the cockpit. An unserviceable valve (found U/S during previous maintenance on another aircraft) had been re-installed during maintenance.

3.1.3. The pilot spoke to both ATC and Squadron Operations to co-ordinate the landing and to get advice on malfunctions. Both ATC and Squadron Operations "stepped on" each other's radio transmissions causing the pilot to have to repeat transmissions or request repeats of others' transmissions.

3.1.4 The pilot did not configure the aircraft correctly for landing.

3.1.5 The tape on the left side of the arrestor gear failed when the aircraft engaged the gear with an indicated airspeed of 204 knots and an all up weight of about 39,400 pounds. The total energy for this arrestment attempt exceeded the maximum rated capacity for the arrestor system causing the failure.

3.1.6 The aircraft sustained "C" category damage as a result of the cable and associated fittings striking the aircraft after the arrestor gear failed.

3.1.7 The right fuel tank would not jettison due to damage incurred during the failed arrestor gear engagement.

3.1.8 The jettison area was difficult for the pilot to see because the pylons marking its location were not easily identified.

3.1.9 Maintenance documentation for the Valve, Anti-Ice Flow, Temperature Limiting S/N0339 was not created when removed from CF188751 in 1999. None of the Maintenance Replacement Record (CF352), History Record (CF358) or the Unserviceability Record (CF543), were generated and personnel accepted the unserviceable part at multiple levels in the supply system without the proper documentation.

3.1.10 The Inspection and Conditioning of Material Program was not properly implemented as there were no Squadron Technical Inspectors qualified at the unit.

3.1.11 The technicians performing the MLG reassembly did not follow the CFTO properly and installed the MLG shims inverted.

3.1.12 At the time of this accident there was no written requirement for CF188 pilots to regularly conduct an arrested landing.

3.2 Cause

3.2.1 The pilot did not properly configure the aircraft for landing, which resulted in an airspeed on landing that exceeded the arrestor gear's rated capability.

3.2.2 An unserviceable Valve, Anti-Ice Flow, Temperature Limiting was installed in the accident aircraft. This valve eventually caused a bleed air leak resulting in a multiple emergency situation just after takeoff.

3.3 Contributing Factors

3.3.1 Maintenance documentation for the Valve, Anti-Ice Flow, Temperature Limiting S/N0339 was not created when removed from CF188751 in 1999. Personnel at multiple levels in the supply and repair system accepted improper documentation as the unserviceable part was routed through the system.

3.3.2 The pilot was distracted by multiple emergencies and stepped on radio transmissions. As a result he forgot to lower his landing flap and consequently flew an approach at speeds that exceeded the arrester cable limits.

4. SAFETY MEASURES

4.1 Safety Measures Taken

4.1.1 An arrester system capable of handling the energy loads generated by CF188906 does not exist. A risk analysis and study of the different types of arrester systems currently used across the CF was completed and deficiencies were noted. The Senior Review Board has approved funds to improve and/or replace these systems to bring them up to NATO standard BAK-12. This project is forecast to commence in 2003 and finish by 2005.4.1.2 The accident squadron was briefed on the importance of properly identifying parts returned in the CF Supply system for repair and disposition. The requirement to complete or create all applicable paper work was emphasized.

4.1.3 The accident was briefed as part of the DFS annual presentation to all Wings. Personnel awareness of proper maintenance procedures was highlighted to all maintenance personnel at 3 Wing.

4.2 Further Safety Measures Required

4.2.1 It is recommended that for all arrestor gear engagements conducted as a result of an emergency, the MSDRS data be automatically downloaded and passed to arrestor gear maintenance personnel, along with pilot observations. This will ensure that the most accurate data is considered in the arrestor gear maintenance. Should this avenue of information be impractical, an accurate method or procedure to report engagement velocities needs to be produced.

4.2.2 It is recommended that 3 Wing consider improved means to identify the stores jettison area for easier visual acquisition.

4.2.3 It is recommended that procedures be considered to avoid Air Traffic Services and Operations personnel from interfering with each other during an emergency response. Further, Air Traffic Services should explore the possibility of including operations frequencies in their monitoring equipment so that radio communications on these frequencies are recorded and available for further study.

4.2.4 It is recommended that the importance of conducting an annual approach end arrestor gear engagement be re-emphasized to all CF188 pilots.

4.2.5 It is recommended that the CF188 operational community consider inserting a cross reference check of actual aircraft speed once established on final and flying the E bracket, as a means of confirming that the aircraft configuration is correct.

4.2.6 It is recommended that findings on the missing paperwork be presented to the maintenance community focusing on the importance of proper aircraft documentation.

4.2.7 It is recommended that a process be developed that will prevent the contractor from receiving misidentified parts and from returning the parts back to the supply system without a clear identification that the part is unserviceable. The process should ensure that the R&O facility seeks advice from the NDQAR or the LCMM.

4.2.8 It is recommended that Squadron Technical Inspectors carry out paperwork verification and "Inspection and Conditioning of Material" functions as described in current manuals. The Technical Inspection Organization is an integral part of this process and should be established at all units performing maintenance on CF aircraft and aircraft equipment.

4.3 Other Safety Concerns

4.3.1 There were anomalies in the occurrence pilot's medical file that were not implicated in this occurrence but appear as deficient. More attention should be paid to these pre-flight medical requirements.

4.4 DFS Remarks

This occurrence is a clear example of how seemingly small errors, such as incorrect or incomplete paperwork, can have dire consequences. In this case, a series of these errors, combined with omissions and assumptions culminated in the installation of an unserviceable part in an aircraft. This in turn, lead to a very serious in-flight aircraft emergency during a critical phase of flight.

The investigation concluded that the CF aircraft maintenance system and the supply system have sound processes in place and, as a result, there were numerous opportunities for several people to break the chain of events that ultimately lead to this accident. It was therefore discouraging to learn that this system did not work as intended. All that was required was for one person to realize that the paperwork was not complete and/or correct and, more importantly, to then take the appropriate action. Flight Safety staffs at all levels will continue to encourage all personnel to be proactive and to ask questions if an error is detected. This FSIR will provide a good example of what can happen if the assumption is made that someone else will recognize the mistake and do something about it.

There is no doubt that this pilot was faced with a series of very serious in-flight emergencies which lead to a high cockpit workload. While Squadron Operations and ATC were trying to provide assistance, the poor configuration of the communications system meant that this assistance only further distracted the pilot. This may have contributed to the missed landing check and the resultant major damage to the aircraft in the attempted cable engagement. Once again, flight safety staffs will emphasize that aircrew, when faced with multiple emergencies, must carefully manage time and prioritize their actions. Aircrew will be reminded that the old priority list: aviate, navigate, and communicate is still applicable and is still an effective aid in establishing these priorities. The first priority must always be to fly the airplane and complete critical checklists.

//original signed by//
A.D. Hunter
Colonel
Director of Flight Safety

ANNEX A: PHOTOGRAPHS

Photo 1: Damage to tail hook and nozzle area.

Photo 2: Damage to nose gear.

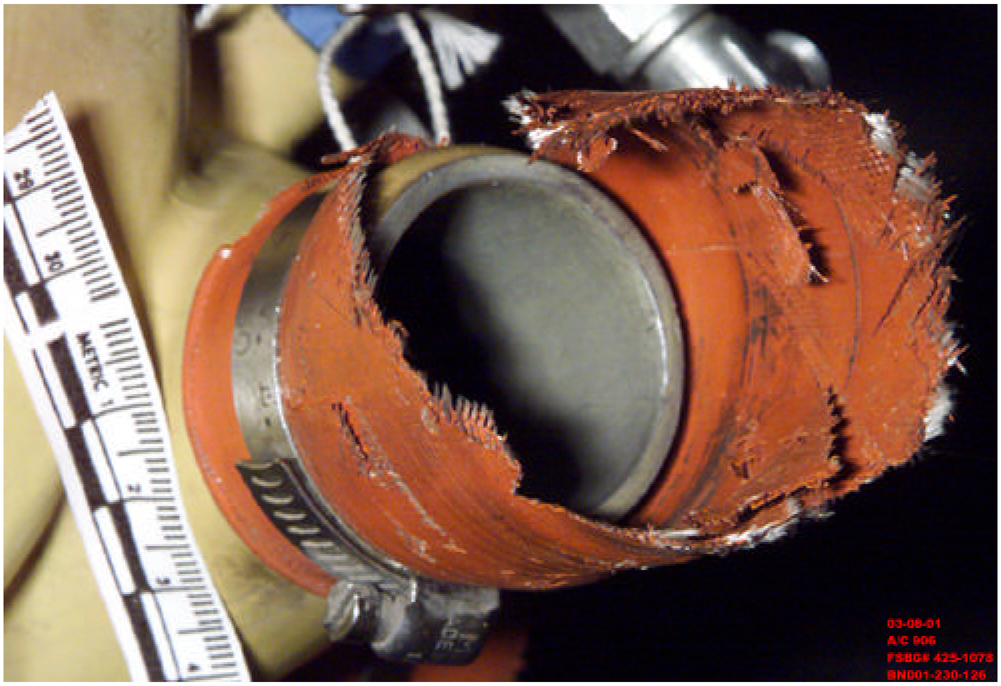

Photo 3: ECS rubber hose located between the ECS turbine and the Anti-ice add heat valve.

Photo 4: Fibreglass duct, found disconnected and chaffed at the turbine attachment point.

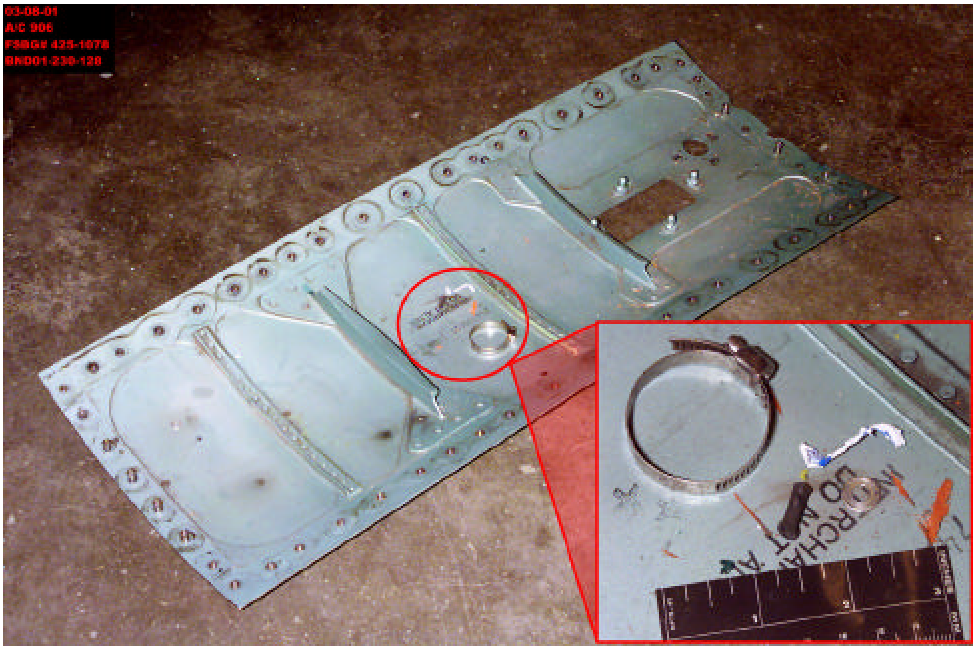

Photo 5: FOD found when the centre line ventral panel was removed to access the ECS.

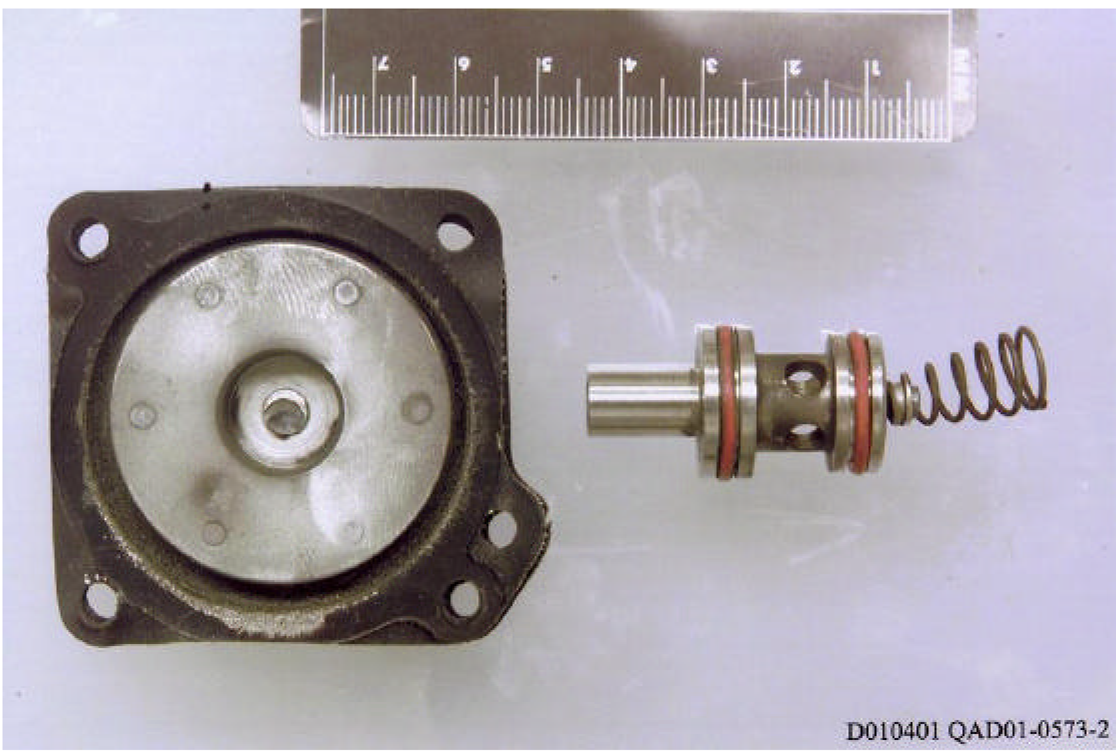

Photo 6: Disassembled anti ice valve. The spring (right) has become worn and slipped over the end of the piston that supplies pressure to the diaphragm (left).

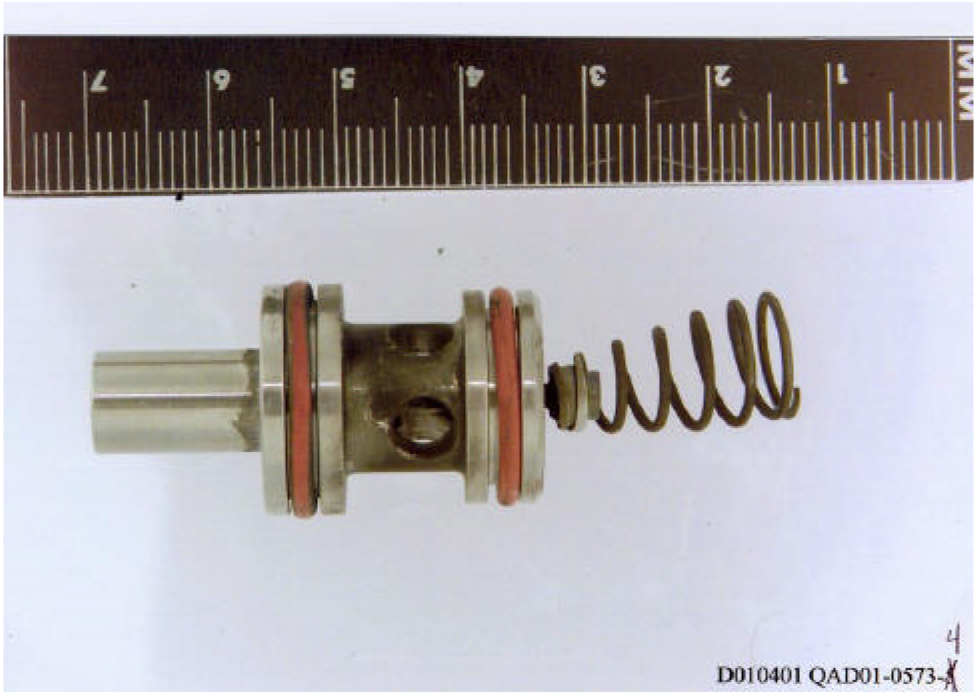

Photo 7: Anti ice valve spring and piston.

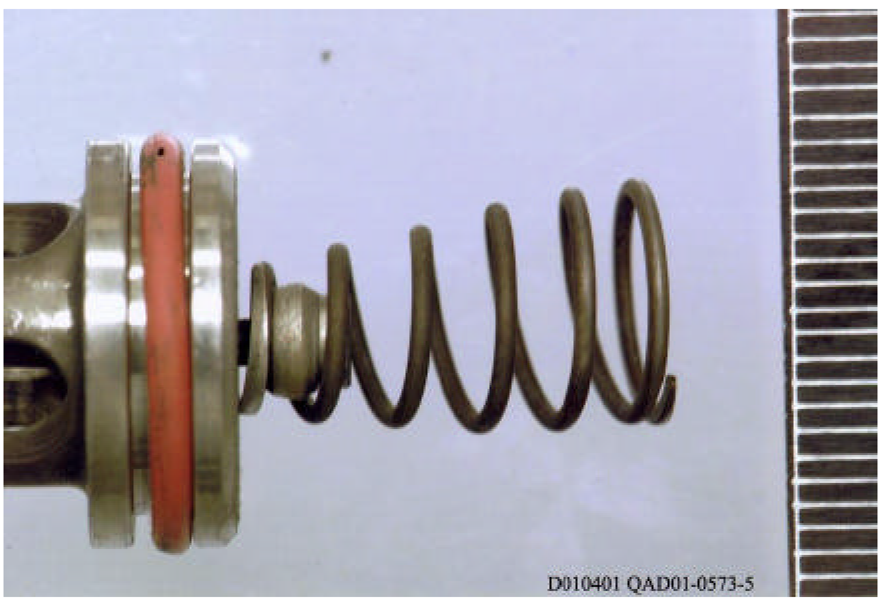

Photo 8: Close-up of anti ice spring and piston.

ANNEX B: ABBREVIATIONS

ATC	Air Traffic Control
CF	Canadian Forces
CVR	Cockpit Voice Recorder
DDI	Digital Display Indicator
DFS	Director(ate) of Flight Safety
ECS	Engine Control System
IFR	Instrument Flight Rules
IAS	Indicated Airspeed
FDR	Flight Data Recorder
FSI	Flight Safety Investigation
FSIS	Flight Safety Information System
KIAS	Knots Indicated Airspeed
LCMM	Life Cycle Maintenance Manager
METAR	Meteorological Aviation Report
MLG	Main Landing Gear
MRS	Maintenance Recording System
MSDRS	Maintenance Status Display Recording System
NDQAR	National Defence Quality Assurance Region
NDT	Non-destructive Testing
NSN	NATO Stock Number
P/N	Part Number
QETE	Quality Engineering Test Establishment
R&D	Receiving and Disposal
R&O	Repair and Overhaul
SMS	Stores Management System
S/N	Serial Number
TAF	Terminal Area Forecast
TE	Total Energy