AVIATION INVESTIGATION REPORT
A99W0061

IN-FLIGHT FIRE

AEROSPATIALE AS 355 F1 TWINSTAR (HELICOPTER)
C-GTUI
FAIRVIEW, ALBERTA 10 NM E
28 APRIL 1999

Transportation Safety Board
of Canada

Bureau de la scurit des transports
du Canada

Aviation Investigation Report

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Summary

The Aerospatiale AS 355 F1 Twinstar helicopter had completed a routine gas pipeline patrol and was returning to Fairview, Alberta, with the pilot and one passenger on board. During a shallow cruise descent into Fairview, at about 800 feet above ground, the red battery temperature light illuminated on the warning caution advisory panel. The pilot observed that the voltmeter and ammeter indications were normal and turned off the battery. About three minutes later, at approximately 500 feet above ground and as the pilot was contemplating a precautionary landing, the helicopter lost all electrical power and the cabin and cockpit began to fill with smoke and fumes. The pilot and passenger opened the side windows to ventilate the cabin, and the pilot accomplished an emergency landing at once on an available farm field. After landing, the pilot shut down the engines and both occupants evacuated the helicopter without further incident or injury. Flames were observed to be emanating from the vicinity of the right baggage compartment, and the helicopter was subsequently destroyed by an intense ground fire.

Ce rapport est galement disponible en franais.

Other Factual Information

Organizational and Management Information

The helicopter was one of four twin-engine Aerospatiale AS 355 Twinstar helicopters owned and operated as private aircraft by an Alberta-based natural gas transmission company. The company had merged with another large natural gas pipeline company in July 1998. The helicopter division of the merging company operated several Bell 206 Jet Ranger helicopters under the authority of an Air Operator Certificate. A Manager of Helicopter Services had been appointed to supervise the merged helicopter operations in November 1998. He had immediately contracted an aviation consultant to conduct an independent operational safety review of the Edmonton helicopter division. The operational safety review report praised several aspects of the helicopter operation, including the utilization of highly qualified maintenance and flight personnel, excellent maintenance standards, and high dispatch reliability. The report also identified numerous safety concerns, including inefficiencies in maintenance communications, unapproved modifications on helicopters, and outdated company manuals. A number of key safety and regulatory issues were addressed by the Manager of Helicopter Services in an Operational Directive to maintenance and flight operations personnel on 25 January 1999. Action on several other safety issues was postponed until the organizational restructuring that accompanied the merger was complete. On 23 April 1999, a meeting was convened with the Edmonton helicopter division employees to discuss the impact of the safety review and various other concerns regarding the merger. Many of the 14 helicopter staff members in Edmonton were critical of the safety review findings, and the meeting was reportedly charged with emotion.

Regulatory Information

Regulation 604.02 of the *Canadian Aviation Regulations* (CARs) requires an operator who transports passengers in a turbine-powered, pressurized airplane or a large airplane to comply with the conditions and specifications set out in a Private Operator Certificate issued pursuant to regulation 604.05 of the CARs, or an Air Operator Certificate issued pursuant to Part VII of the CARs. As a condition of the operating certificate (OC), the operator is required to maintain the airplane in accordance with an approved maintenance control system. Operators transporting passengers in helicopters are not required to operate the helicopters under the authority of an OC nor to maintain the helicopter under an approved maintenance control system. There is no CARs provision for an operator to voluntarily apply for or obtain an OC.

The Edmonton helicopter division did not hold an OC, and the maintenance department was not an approved maintenance organization (AMO).

Personnel Information

The pilot was certified and qualified for the flight in accordance with existing regulations. He had accumulated 15 000 hours of flight experience, including a total of 8500 hours on rotary wing aircraft and 3500 hours on AS 355 Twinstar helicopters. The pilot completed the landing without a loss of engine power or flight control authority. He estimated that he landed about six minutes after the battery temperature light illuminated. The pilot and passenger quickly moved away from the helicopter after the landing and did not attempt to combat the fire due to the intensity of the flames. The pilot had experienced an in-flight battery temperature warning in the past and had landed without incident. The aircraft flight manual (AFM) states that the pilot is to turn off the battery master switch and land as soon as possible if the battery temperature warning light illuminates. The AFM interprets "Land as soon as possible" as "land at the nearest site at which a safe landing can be made".

The maintenance department was staffed by four highly-experienced helicopter aircraft maintenance engineers (AME). Each individual had at least 20 years of aviation maintenance experience and had been employed with the company for between 8 and 17 years. All were trained and endorsed for the AS 355 helicopter. The maintenance department had operated in the past with five personnel, including a designated Director of Maintenance. The Director of Maintenance had left the company before the merger in 1998, and the company then adopted a three-role maintenance department structure that was based on the company philosophy of shared leadership and shared accountabilities. The policy called for each AME to rotate, for an indefinite term, through the supervisory, parts and materials procurement, and line maintenance responsibilities. The maintenance organizational structure would not have met Transport Canada (TC) standards for a maintenance control system.

Procedural Standards

In 1988, a company aircraft maintenance manual had been developed for the use and guidance of the Edmonton maintenance personnel in the performance of their duties. The manual had not been amended since 1991 and did not reflect the present fleet's make-up or the current maintenance organizational structure. The manual was developed in accordance with the requirements of revoked *Air Navigation Orders VII* and made no reference to the CARs.

At the time of the occurrence, the maintenance department was in the initial stage of establishing common organizational and procedural standards with the merging company. Endeavours to rectify several of the maintenance department organizational and procedural discrepancies that had been identified in the November 1998 operational safety review had been delayed due to the anticipation of further changes that were expected to result from the merger. The Director of Maintenance of the Winnipeg-based helicopter division was appointed as Director of Maintenance of the Edmonton-based division on 23 April 1999. His

appointment occurred three business days before the accident, and there was insufficient time for him to have initiated any supervisory or other actions in the maintenance department before the accident.

Aircraft Information

The helicopter, serial number 5084, had been purchased new and was operated by the company since 1981. The twin-engine helicopter was being maintained as a private aircraft in accordance with the manufacturer's AS 355 F1 hourly maintenance schedule.

The company operated two AS 355 F1 and two AS 355 F2 Twinstar helicopters, all of which were fitted with a dual-battery, cold-weather start kit. The accident helicopter was fitted with an optional, dual-battery, cold-weather start kit, MOD 350AOP0699, which was featured in *Service Bulletin 24.01*, in accordance with Pre Mod 07-1123. The installation includes two Saft 1606-1, 16-ampere (A) hour, 24-volt, nicad batteries that were mounted one above the other in the battery compartment in the right side of the fuselage, aft of the cabin. The battery compartment is accessed through a removable side panel. The batteries are connected to the electrical system by direct current cables that are attached individually to the positive and negative battery posts. In the AS 355 F1 dual-battery installation, the positive post of the top or auxiliary battery is connected in parallel to the positive post of the lower or main battery by a cable, through a parallelling relay. A 400-A fuse is installed in the negative lead of each battery to protect the cables and wires in the circuit and the master electrical boxes. The batteries are fitted with sensors that activate the battery temperature warning light when the battery temperature exceeds 71 degrees Celsius. The warning system is designed to alert the pilot to a battery thermal run-away.

The AS 355 F1 models incorporated two cables on the positive post of the main battery and utilized one battery master switch to control the circuit. The AS 355 F2 models incorporated only one cable on the positive post of the main battery and utilized a separate master switch for each battery. The dual battery system can also be installed as an option in the single-engine AS 350 model helicopters. At least one Canadian helicopter operator removed all of the dual-battery, cold-weather start installations in a fleet of Aerospatiale AS 350 helicopters approximately 10 years ago and installed one high-capacity nicad battery, with a single-socket, quick-disconnect connector, to reduce complexity, maintenance, and weight.

The right baggage compartment is located immediately forward of the battery compartment on AS 355 helicopters (see Appendix A). The compartments are separated by a 0.050-inch-thick aluminum bulkhead. The company used the right baggage compartment in each of the four company helicopters for storage of the required survival and emergency equipment. The survival and emergency equipment included a five-person survival shelter and a survival kit that contained emergency flares. The bags that housed the survival shelter and the emergency kit were made of flammable nylon, and the survival shelter was also packaged in a waxed cardboard box. The bags were not required by regulation to be flame-resistant, and during testing, the packaging materials ignited quickly, melted, dripped and were totally destroyed by fire. The burning characteristics did not meet the requirements of any existing flame-resistant textile specifications. The survival kits contained two hand-held, marine-type, parachute flares and four day/night smoke flares. The emergency

flares in two of the three survival bags in the company sister ships were packaged in newspaper to prevent abrasion and the flares in the third survival bag were rolled in cardboard. The flares are packaged and transported as dangerous goods when shipped from the manufacturer; however, current *Transportation of Dangerous Goods Regulations* do not apply to products identified as dangerous goods if the dangerous goods are necessary for the safety of the persons on board the means of transport.

Aircraft Maintenance Information

Maintenance records and interviews identified that both nicad batteries had been changed in accordance with battery maintenance scheduling on 21 March 1999 at 13 217.0 hours (airframe time). The winter heater blankets had been removed from the batteries on 24 April 1999 at 13 313.3 hours. The AME who removed the heater blankets observed that the wing-nut connector on the positive terminal of the main battery was loose and heat-damaged, and replaced the connector. The AME who changed the batteries believed that he attached both cables to the main battery; however, the AME who replaced the wing-nut connector believed that only one cable was attached to the battery at that time. The replacement of the battery terminal wing-nut connector was not recorded in the aircraft records. The accident occurred at 13 333.1 hours, 116.1 hours after the batteries were changed and 19.8 hours after the battery blankets were removed. Both maintenance tasks were accomplished at mid-day in a hangar area that was quiet and well-lit, and there was no evidence that the AME was either fatigued or interrupted while performing the task. The investigation did not identify a specific circumstance
that would explain why the cable was not properly attached, and it was not determined whether the cable was left unattached initially during the battery change or later when the damaged connector was replaced.

The *Maintenance Manual* and the *AS 355 F1 Flight Manual* (AFM) state that Daily Operating Checks are to be performed on the helicopter every day before the first flight (BFF) and after the last flight (ALF). The purpose of the daily checks is to ensure the serviceability of the aircraft. The checks may be carried out by any person qualified for maintenance or by a suitably trained pilot. The BFF inspection requires that the battery connection be checked; while the ALF inspection requires that the battery security be checked. Each inspection requires removal and reinstallation of the battery compartment side access panel. The pilot and AMEs were not aware of the requirement for the battery compartment BFF and ALF Daily Operating Checks, and the checks were not being performed.

The pilot reported that the requirement to perform the battery compartment Daily Operating Checks was not identified during the initial and recurrent flight training at the manufacturer's flight training facility in Grande Prairie, Texas. Consultation with representatives at the training facility identified that the battery compartment checks were performed daily on the training helicopters by maintenance staff prior to the helicopters being released for training flights.

The pilot also reported that he had removed the battery compartment side access panel on 25 April 1999 to visually examine the batteries and had not noticed any discrepancies within the battery compartment.

Meteorological Information

Good visual weather conditions existed at the time of the occurrence, and weather was not considered to be a factor in the occurrence. The helicopter was flying over cleared, level farm land at the time of the occurrence.

Wreckage Information

Examination of the severely fire-damaged nicad batteries determined that the parallelling cable had been attached to the positive post of the auxiliary battery; however, it had not been attached to the positive post of the main battery. A short length of unattached battery cable was found near the batteries in the fire-damaged wreckage. Visual and laboratory examination of the cable identified that the copper end terminal was arc-damaged. Surface analysis and examination of micro sections of the end connector revealed areas where the copper had alloyed with aluminum. This indicated contact at sufficiently high temperature and of ample duration for the aluminum to have diffused into the copper tab. No additional pre-occurrence battery or electrical system discrepancies were identified. Examination of the 400-A fuse in the negative lead of the auxiliary battery determined that the fuse link had failed because of mechanical overload when the battery tray collapsed during the ground fire.

Tests and Research

A battery compartment/baggage compartment mock-up was constructed to determine if the unattached battery cable could have contributed to or caused the in-flight fire. The test session was attended by representatives from the helicopter manufacturer, the battery manufacturer, the operator, and the TSB. The battery compartments in all of the company Twinstars had been painted with Endura paint. Testing determined that the paint functioned as an insulator and that the end terminal of an unattached battery cable would not arc when it contacted a painted area of the forward battery compartment bulkhead. If the cable end terminal contacted an area in the compartment where the paint was missing, it would arc quickly through the bulkhead and ignite the survival shelter bag and waxed cardboard box. The 400-A fuse did not melt during testing despite intermittent, short-duration current flows as high as 1361 A. A simple heat transfer analysis was performed on the fuse, part number 135000A. The analysis determined that the fuse was a 400-A slow blow unit and that momentary surges in current draw, such as might occur on contact with the ground, would not cause the fuse to melt unless the current draw was approximately five times the rating for the fuse and it lasted for more than one second.

Analysis

General

The AS 355 F1 helicopter sustained an in-flight fire that occurred as a result of the auxiliary-battery-to-main-battery parallelling cable not being attached to the positive post of the main battery. The maintenance error was not detected before the flight. Based on witness information, the battery compartment mock-up testing, and the TSB Engineering Laboratory examination of the recovered section of the arc-damaged battery cable, it was concluded that the unattached cable contacted an unpainted area of the battery compartment forward bulkhead, arced through the bulkhead, and ignited the survival gear in the adjacent baggage compartment.

Several system defences that may have prevented this accident were missing or inadequate. The auxiliary-battery-to-main-battery parallelling system provided no cockpit indication that the auxiliary battery was unattached, the company maintenance system guidelines were outdated, the Daily Operating Checks were not being performed in accordance with the manufacturer's recommendations, and the AME who had most recently performed the battery compartment maintenance did not note that the auxiliary battery parallelling cable was unattached. The analysis will therefore address the latent system failures that may have contributed to the maintenance error that occurred and the conditions that resulted in it remaining undetected. The analysis will also address the pilot's actions and the propagation of the fire due to the flammability of the survival gear in the baggage compartment.

Maintenance System, Practices, and Procedures

Maintenance systems and practices have evolved to reduce the likelihood of a maintenance error occurring and to reduce the consequences of any error that does occur. There was no regulatory requirement for the company to operate under the authority of a Private Operator Certificate or Air Operator Certificate, and the maintenance department was therefore exempt from the more stringent TC standards that apply to an AMO. This eliminated several checks and balances that normally exist in an approved aircraft maintenance system. The maintenance department was staffed by four highly experienced AMEs, but they lacked the organizational and procedural guidelines and the assigned leadership to operate in accordance with long-established aviation maintenance standards. The guidelines that did exist in the form of the company aircraft maintenance manual were inadequate and outdated by seven years. The policy of rotating supervisory, procurement, and line-maintenance responsibilities that had existed in the maintenance department for approximately one year was ineffectual, lacking in continuity, and unsuitable for an aviation maintenance department. Since there was no requirement for TC to perform audits on the company, and due to the changes and remedial

actions that were expected to occur within the helicopter division as the merger proceeded, the deficiencies that had existed in the maintenance department for some time remained uncorrected.

The Daily Operating Checks that may have identified that the maintenance error had occurred were not being conducted, and the maintenance was, therefore, not being performed in accordance with the manufacturer's recommendations. Since there was no cockpit indication to identify that the auxiliary battery parallelling cable was unattached, the helicopter was flown for some time with a serious maintenance discrepancy. In fact, the engineer who performed the work became the single line of defence in the system.

The circumstance of having one battery cable normally attached to the positive post of the main battery on two of the company helicopters, and of having two battery cables normally attached to the positive post of the main battery on the other company helicopters would have increased the potential for an auxiliary battery cable to be left unconnected.

The red battery temperature warning light is designed to alert the pilot to a battery thermal run-away condition, and is not intended to function primarily as a fire warning light. Therefore, the pilot initially believed that he had a battery over-temperature problem rather than an in-flight fire. He reacted to the warning light by turning off the battery in accordance with the recommended emergency procedures, continuing a slow descent towards a convenient precautionary landing site, and contemplating a precautionary landing. By landing immediately, he reacted to the loss of electrical power and the appearance of smoke in the cockpit which were the second and more urgent indications of the in-flight emergency.

The nylon and cardboard packaging material and the survival shelter and emergency flares were not flame-resistant. The proximity of this equipment to the electrical wiring in the battery compartment contributed to the initiation of the fire. Propagation of the fire was rapid because of the burning qualities of the packaging material and equipment.

Organizational Structure and Management

The company merger had raised significant concerns among the Edmonton helicopter group regarding their future employment and economic security. Stress is the body's reaction to any stimulus that disturbs its equilibrium and taxes its ability to cope. Stress can have a positive or a negative effect on thinking and performance, depending on the circumstances and the individual. One consequence of emotional stress and anxiety is that an individual may concentrate on the difficulties that are creating the stress rather than on the practical aspects of

the present situation. Hazards that may result include the distraction of attention and the failure to recognize errors. Emotional stresses, such as those resulting from the anticipation of future difficulties, are among the most disturbing distracters of attention.[1]

The maintenance department's three managerial policy changes in the year preceding the accident and the recent company merger had increased employee stress levels significantly. The degree to which the impact of the uncertainty of the merger may have contributed to the occurrence could not be determined. However, it appears that stress and preoccupation with concerns about the future of the company may have affected the performance of one or both of the maintenance engineers who had most recently worked in the battery compartment, creating a situation of inattention to the work being accomplished.

[1] Nicholas A. Bond, *Aviation Psychology* (Los Angeles, CA: University of Southern California, 1985); and *CASB Staff Guide to the Investigation of Analysis of Human Performance Factors*, Draft III, July 1989. Section III, Medical Factors, Chapter 8 - Stress, pp. III-8-1 to III-8-7.

Findings as to Causes and Contributing Factors

1. The auxiliary battery parallelling cable was not attached to the positive post of the main battery during routine maintenance.

2. The in-flight fire occurred when the unattached battery cable arced through the battery compartment forward bulkhead in flight and ignited the flammable nylon survival gear bags in the adjacent baggage compartment.

3. The proximity of the highly flammable nylon survival gear bags to the battery compartment electrical wiring represented a hazard and contributed to the initiation and propagation of the in-flight fire.

4. The battery compartment Daily Operating Checks, which may have identified the error, were not being conducted by either pilots or AMEs.

Other Findings

1. Because the helicopter was being operated as a private aircraft, helicopter maintenance was not required to be performed by an AMO.

2. The recently evolved rotating organizational structure in the helicopter maintenance department was inappropriate and would not have met TC requirements for a maintenance control system.

3. The risk that AMEs would make errors in their work was elevated by the stress and anxiety related to employment and financial security concerns associated with the merger.

Safety Action

Action Taken

The operator took the following actions since this occurrence:

- all aviation staff members were briefed, emphasizing the importance of conducting all Daily Operating Checks, as specified in the AFM;
- all pyrotechnics carried in survival kits on board the operator's Twinstar fleet were removed and replaced with an updated product;
- all pyrotechnics in company survival kits are stored in a suitable container; and,
- all pyrotechnics on the merging operator's Bell 206 fleet were checked to ensure that they were not outdated and that they were stored in accordance with the operational specification.

Transport Canada published, in *Aviation Safety Maintainer* (Issue 4/99), *Floating Battery Cable Fire Hazard*, an article in which risks and hazards associated with this occurrence were identified.

Action Required

Packaging Standards

The survival and emergency equipment carried on board the helicopter included a five-person survival shelter and an emergency survival kit that contained emergency flares. The bags that housed the survival and emergency equipment were made of flammable nylon; the bags were not required to be flame-resistant. During testing, the bag materials ignited quickly, melted, dripped, and were totally destroyed by fire. The highly combustible nature of this packaging material contributed to the severity of this occurrence by providing a ready source of fuel in the face of the arcing event. In addition, survival equipment transported in flammable packaging reduces the likelihood that this equipment will be available for its intended purpose.

The survival kits in each of the four company helicopters contained two hand-held, marine-type, parachute flares and four day/night smoke flares. All flares on board the accident helicopter had ignited and discharged during the fire. The flares are classified as 1.2G and 1.4G explosives. Materials classified as 1.2G explosives are forbidden to be shipped on cargo and passenger aircraft under International Air Transport Association (IATA) dangerous goods regulations. Goods classified as 1.4G explosives can be shipped on cargo aircraft, provided that they are packaged in accordance with the appropriate packaging instructions. The emergency flares in two of the three survival bags in the company sister ships were packaged in crumpled newspaper to prevent abrasion. IATA Dangerous Goods Packing Instruction 905 requires signal devices transported as dangerous goods to be packaged in plastic or fibreboard inner containers. Current dangerous goods regulations do not apply to products that are necessary for the safety of the persons on board the means of transport. Any

condition that unnecessarily increases the potential for the initiation or propagation of a fire on board an aircraft is hazardous, putting passengers and crew at risk. Therefore the Board recommends that:

> The Department of Transport ensure that air operators store aircraft survival gear on aircraft in flame-resistant material and package emergency pyrotechnics and other highly flammable survival equipment at least to the standards required by International Air Transport Association (IATA) *Dangerous Goods Regulations*.
>
> A00-13

Maintenance Control System

Canadian air regulations require that a private operator that transports passengers in a turbine-powered, pressurized airplane or a large airplane comply with the conditions and specifications in either a private OC or an air OC. Under these provisions, the operator is required, as a condition of the OC, to maintain the airplane in accordance with an approved maintenance control system. However, no regulations require private helicopter operators, carrying passengers as above, to operate under the authority of an OC or to maintain the helicopters in accordance with an approved maintenance control system. Moreover, there is no provision for an operator to voluntarily apply for or obtain an OC.

The company was operating four complex, high-performance, twin-engine helicopters to transport company employees throughout Alberta. The company maintenance organization structure, policies, and guidelines would not have met TC standards for a maintenance control system. Such a system is designed to minimize the probability of maintenance errors. The Board is concerned that passengers are regularly being carried in helicopters that are not subject to the more stringent maintenance standards required for fixed-wing aircraft that carry passengers, and it recommends that:

> The Department of Transport ensure that helicopters used by private operators to transport passengers receive a standard of maintenance equivalent to that for fixed-wing aircraft for the same type of operation.
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> A00-14

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 01 June 2000.

Appendix A - Battery and Baggage Compartment Configuration

Appendix B – List of Supporting Reports

The following TSB Engineering Laboratory report was completed:

LP 049/99 - *Battery Cable*

The following University of Alberta Textile Analysis Service report was completed:

Flame Resistance Testing of Nylon Survival Bags

The following University of Alberta Engineering Analysis was completed:

Heat Transfer Analysis of a 400-A Fuse Used on the Aerospatiale AS 355 F1 Twinstar Helicopter

These reports are available upon request from the Transportation Safety Board of Canada.

Appendix C – Glossary

AFM	aircraft flight manual
ALF	after the last flight
AME	aircraft maintenance engineer
AMO	approved maintenance organization
A	ampere
BFF	before the first flight
CAR(s)	*Canadian Aviation Regulations*
E	east
IATA	International Air Transport Association
nm	nautical mile
OC	operating certificate
TC	Transport Canada
TSB	Transportation Safety Board of Canada