Transport Canada Transports Canada

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HUMAN PERFORMANCE FACTORS FOR ELEMENTARY WORK AND SERVICING

Canada

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Introduction

The following document is intended to raise awareness of human performance and human factors issues for individuals tasked with doing “Elementary Work” as per Canadian Aviation Regulation (CARs) 625, Appendix A(3).

Appendix A(3) is specifically for “Operators” and states in part:

> “For aircraft operated pursuant to CAR 406, CAR 604 and CAR Part VII, the following tasks are elementary work, provided they are individually listed in the operator's maintenance control manual and or operational manual as applicable, along with a reference to the training to be undertaken by persons authorized to perform them:…”

This document is designed to meet the initial Human Factors training requirements for personnel tasked with Elementary Work and Servicing duties, in conjunction with other training programs such as crew resource management. It is not intended to replace, but rather to supplement the training referenced above.

The terms “elementary work”, and “servicing” tend to diminish the importance of the tasks being accomplished. It is essential that everyone working on an aircraft understand that no matter how simple the task, if it is not done properly, the results can be serious.

Factors Affecting Human Performance

A list of everyday items, which can influence human performance, was developed for the Transport Canada, Human Performance in Aviation Maintenance workshop. They are:

1) Lack of Communication
2) Complacency
3) Lack of Knowledge
4) Distraction
5) Lack of Teamwork
6) Fatigue
7) Lack of Resources
8) Pressure
9) Lack of Assertiveness
10) Stress
11) Lack of Awareness
12) Norms

The above are all factors that can affect an individual's performance, and will be discussed in greater detail in the body of this document.

Lack of Communication:

It is important to be aware that in general only 30% of verbal communication is received and understood by either side in a conversation. People normally remember what was said first and last in an exchange; consequently it is important to put the most important part of your message first and then repeat it at the end. Depending on the complexity of the message it might be more effective to provide some form of written instruction such as a checklist.

Complacency:

Defined as: "Self-satisfaction accompanied by a loss of awareness of the danger." If an activity has become routine and your feeling "fat dumb and happy", you may be missing important signals. There is a tendency to see what you expect to see.

Lack of Knowledge:

Air operators have a regulatory responsibility to ensure that their personnel have the required training.

Distraction:

This is anything that draws your attention away from the task at hand. Psychologists say distraction is the number one cause of forgetting things. We are always thinking ahead. Thus, we have a natural tendency, when we are distracted before returning to a job, to think we are further ahead than we actually are.

Lack of Teamwork:

An effective team will:

1) Maintain a clear mission
2) Maintain team expectations
3) Communicate to *all* team members
4) Maintain trust
5) Pitch in

Fatigue:

Studies have shown that, similar to being under the influence of alcohol, we tend to underestimate the problem and overestimate our ability to cope with it. These studies have proven that after 17 hours of wakefulness, you are functioning as if you had an equivalent blood alcohol level of 0.05%. After 24 hours the level increases to 0.1%; a very sobering thought. The more fatigued you are, the lower your IQ. It is also noteworthy that the more fatigued you are, the more easily you are distracted.

Lack of Resources:

A lack of resources can interfere with one's ability to complete a task because there is a lack of supply and support. Low quality products also affect one's ability to complete a task.

Pressure:

Urgent demands, which influence our performance, include:

1) Company
2) Client
3) Peer
4) Self-Induced

Interestingly, people put the most pressure on themselves. Self-induced pressures are those occasions where one takes ownership of a situation, which was not of their doing. The "monkey on your back" is yours because you accepted it. Being assertive and not accepting the "monkey" will help.

Lack of Assertiveness:

Assertiveness is the ability to express your feelings, opinions, beliefs and needs in a positive, productive manner. It is not the same as being *aggressive.*
The following are examples of how a lack of assertiveness can be offset:

1) Get the persons attention and state the problem:
   John, I have a concern with…
2) Give consequences:
   If we continue… this will be the result…
3) Give solutions:
   We could… you may want to try… I'd like to…
4) Solicit feedback:
   What do you think?

Remember to deal with one issue at a time (not multiples), do not embellish or exaggerate, stick to the facts, and stay calm.

Stress:

There are two types of stress: acute and chronic. Acute stress relates to the demands placed on the body because of current issues; for example, time constraints for converting the aircraft from passenger to cargo configuration. Chronic stress results from long term demands placed on the body by both negative and positive major life events, such as divorce, or winning the lottery. Chronic stress can exaggerate the effects of acute stress. To handle acute stress, try to take a five-minute break and relax by deep breathing. Dealing with chronic stress is more difficult and usually involves a lifestyle change.

Lack of Awareness:

Defined as, "a failure to recognize all the consequences of an action, or lack of foresight". To combat this, try asking yourself, "What if…, Do I see the complete picture? What have we forgotten?".

Norms:

Norms are unwritten rules or behaviours, dictated and followed by the majority of a group. Norms can be positive and negative. A positive norm would be scanning the area inside the aircraft you have been working on prior to closing up. A negative norm would be pushing an aircraft into the hangar by yourself.

Case Studies

The following are condensed Transportation Safety Board (TSB) reports of incidents and accidents that occurred due to someone failing to complete a task correctly. The intent is to demonstrate the importance of elementary work and servicing and to give some examples of what can go wrong if they are performed incorrectly. In these scenarios, it must be acknowledged that some of the individuals involved were licensed engineers. However, the point is the task accomplished is eligible as an "Elementary Work" item, as per CAR 625, Appendix A(3), and could have been done by unlicensed personnel.

Case Study #1 - Power Loss and Forced Landing

Transportation Safety Board Report Number A94A0180

Bell Helicopter Textron 206L
Long Ranger
Porcupine Point, Labrador
15 September 1994

Synopsis

About 12 minutes into the flight, the engine chip light illuminated. The pilot made a precautionary landing and shut down the engine to inspect the chip detector. Finding only a small quantity of metal paste (fuzz) on the forward facing chip detector, the pilot cleaned and reinstalled the chip detector before departing to continue the flight. Two minutes after take-off, a complete engine stoppage occurred. The pilot entered the helicopter into an autorotation. During the forced landing on a coastal flat, the front of the skid landing gear dug into the soft surface, and the main rotor struck and cut the tailboom. There were no injuries to any of the six occupants.

The Transportation Safety Board determined that the pilot incorrectly assessed the engine as airworthy and took off to continue the flight. The engine stopped two minutes after take-off when the No. 1 bearing failed as a result of separator and/or roller wear. The reason for the failure of the No. 1 bearing could not be determined. Contributing to this occurrence was the lack of adequate training for pilots on checking chip detectors, and the absence of any guidance on inspecting and assessing chip detectors in the flight operations manual.

Damage to Aircraft

The helicopter sustained substantial damage as a result of the main rotor striking and severing the tailboom. Also, prior to being recovered from the coastal flat, the helicopter was partially submerged in salt water when the tide came in.

Wreckage and Impact Information

The helicopter touched down with about 5 to 10 knots forward speed. At touchdown, the front of the bearpaw-equipped, low-skids landing gear dug into the soft surface, bringing the helicopter to a quick stop in a slight nose-low attitude. This caused the main rotor blades to rock fore and aft with sufficient deflection to contact and completely sever the tailboom.

An examination of the engine at the accident site revealed a mechanical lockup of the N1 shafting system. The engine was removed and transported to the operator's facilities in Goose Bay, Labrador, where it was stripped down to three major sub-assemblies: compressor, gearbox, and turbine. The compressor front support was then removed and it was discovered that the No. 1 compressor bearing (part No. 23009609, serial No. MP00948) had failed.

Engine Gearbox Examination

The No. 1 bearing, the compressor front support, and the engine gearbox were shipped to the engine manufacturer's facilities for examination and testing. All work was carried out in the presence of a TSB investigator. The gearbox was fitted for a functional scavenge flow check by applying regulated oil pressure at the oil inlet port and observing flow at the oil outlet port while motoring the oil pump with the use of a 400 rpm speed gun at the oil pump drive gear. After approximately 35- 40 seconds of motoring, the oil pump gained prime and oil began to flow at a steady rate from the oil outlet port. The gearbox cover was then separated from the housing and both the N1 and N2 geartrains were visually inspected and rotated. All gear teeth and splines exhibited a normal wear pattern and rotation was noted to be free. The oil pump was then removed from the gearbox and subjected to a production unit bench test. The bench test was conducted in accordance with Assembly Inspection No. 073 and the oil pump exceeded all minimum test criteria. Only a visual examination and photographic documentation of the No. 1 bearing and the compressor front support were carried out at the manufacturer's facilities. These components were then shipped to the TSB Engineering Branch Laboratory for detailed examination.

Required Maintenance Following a Chip Light

The Allison 250-C20R *Operations and Maintenance* (O & M) *Manual* (ref. para 9.F, "Magnetic Plug Inspection," page 338) contains the following warning: “If a magnetic plug warning light comes on during flight, land and inspect the magnetic plugs as soon as possible. This light is an indication of conditions which could cause engine failure”. The O & M manual, para 9.F.(2), pages 339-340, includes the following information on magnetic particles:

1. Magnetic particles and debris, chips, flakes and slivers are possible indications of bearing or gear failure and/or abnormal wear within the engine.

2. Chips or flakes exceeding 1/32 inch diameter or more than 4 slivers per event are not acceptable. In this case the engine is to be removed from service and sent to an approved Allison repair facility.

3. Chips or flakes less than 1/32 inch diameter or less than four slivers per event are acceptable.

Fuzz falls under this last category and, as further described in the O & M manual, para 9.I, would require the following maintenance action to be performed after reinstallation of the magnetic plug:

1. Carry out a 30 minute ground run at power and observe engine operation and chip light prior to releasing the aircraft for flight. If the chip light illuminates during 30 minute ground run, remove engine from service.

2. If warning light does not illuminate during 30 minute ground run, inspect magnetic plugs for further accumulation of magnetic particles, debris, chips, flakes, and slivers. Clean and reinstall magnetic plugs.

3. If a warning light illuminates within the next eight operating hours following a 30 minute ground run and the cause is determined to be an accumulation of magnetic particles and debris (chips, flakes, or slivers) remove the engine from service.

Pilot Authority to Check Chip Plugs

In accordance with the *Airworthiness Manual* (AWM), chapter 575, appendix B *(Note: This is 1994, pre CARs reference),* pilots of commercial aircraft can be authorized to perform certain elementary maintenance tasks without a maintenance release certification. Prior to being authorized to perform any of the tasks, such persons must have performed the tasks under the direct supervision of an aircraft maintenance engineer (AME). Included in these tasks is the "checking and continuity checking of self sealing chip detectors." Accordingly, the operator's maintenance control manual (MCM) states that, coincident with the pilot's annual training, pilots will receive instruction from a company AME on the performance of these tasks.

Pilots employed by the company had a good understanding as to what are and what are not considered acceptable amounts of magnetic particles found on chip detectors. However, this knowledge appears to have been acquired through informal discussions with maintenance personnel. The pilot of the occurrence helicopter had not been briefed on the significance of recurring chip lights or of the requirement for 30-minute ground runs following inspection of chip detectors. The company flight operations manual (FOM), issued to all employees involved in aircraft operations, including flight crews, does not contain any guidance on checking chip detectors, nor is it required to by regulation. A search of the TSB occurrence database identified four other helicopter accidents where the incorrect assessment of airworthiness, after recurring engine chip lights, resulted in engine failure.

Flight Manual

The 206L flight manual (FM) indicates a lesser degree of urgency for response to engine chip lights than do the manuals for other models of the Bell 206 series helicopter. The 206L FM indicates that a pilot should "land as soon as practical" if an engine chip light illuminates in flight. The manual describes "land as soon as practical" to mean: "The landing site and duration of flight are at the discretion of the pilot. Extended flight beyond the nearest approved landing area is not recommended." All other models of the 206 series helicopter assign a more urgent level of response, i.e., "land as soon as possible," which the manual interprets as: "Land without delay at the nearest suitable area (i.e., open field) at which a safe approach and landing is reasonably assured."

Flight Manual - Chip Light Emergencies

There is a discrepancy between the flight manual for the 206L and the flight manuals for other Bell 206 series helicopters in that a lower level of urgency for response to chip light indications is assigned for the 206L. Since the 206L shares similar components with other Bell 206 series helicopters, and the consequences of an in-flight failure are the same, the less urgent response of landing "as soon as practical" seems inappropriate for 206L chip light indications.

Conclusions

It was found that:

1. An in-flight engine stoppage occurred as a result of the failure of the compressor No. 1 bearing.

2. The No. 1 bearing failed as a result of separator and/or roller wear. However, no metallurgical cause for the failure could be established because of the extensive mechanical damage.

3. The pilot incorrectly assessed the engine as airworthy following a second engine chip light in less than eight operating hours, and took off to continue his flight.

4. The pilot had not been briefed on the significance of recurring chip light indications or of the requirement to perform a 30-minute ground run following inspection of a chip detector.

5. The company flight operations manual did not contain any guidance for pilots on checking chip detectors and making an assessment as to the engine's airworthiness.

6. The pilot had not received any formal training on the checking of chip detectors as per the requirement in the company's maintenance control manual.

7. The 206L flight manual indicates a lesser degree of urgency for response to chip light indications than do the manuals for other models of the Bell 206 series helicopter.

Causes

The pilot incorrectly assessed the engine as airworthy and took off to continue the flight. The engine stopped two minutes after take-off when the No. 1 bearing failed as a result of separator and/or roller wear. The reason for the failure of the No. 1 bearing could not be determined. Contributing to this occurrence was the lack of adequate training for pilots on checking chip detectors and the absence of any guidance on inspecting and assessing chip detectors in the flight operations manual.

Operator Safety Action Taken

Subsequent to the occurrence, the operator expanded its ground-training syllabus to include more detailed instructions on the checking of chip detectors. The operator has also indicated that the company flight operations manual will be amended to provide guidance and a field reference for pilots on the checking of chip detectors.

Manufacturer Safety Action Taken

The manufacturer is in the process of revising the 206L flight manual. The manual's procedural action for chip light emergencies will be amended from "land as soon as practical" to "land as soon as possible." This revision is expected to be completed and distributed to 206L operators in the summer of 1995.

Regulatory Safety Action Taken

In response to a TSB Advisory letter, Transport Canada indicated that regional inspectors have been advised to evaluate the training procedures in operators' maintenance control manuals and, during audits, to ensure that procedures are being followed. Transport Canada has also indicated that *Airworthiness Manual* Chapter 575 will be amended to the effect that personnel will be trained to check chip detectors and, where applicable, assess the airworthiness of the aircraft upon completion of the task.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 04 April 1996.

Contributing Human Factors

The main factors contributing to this occurrence were as follows:

- Lack of Knowledge: The pilot incorrectly assessed the engine as airworthy. There was a lack of adequate training.
- Lack of Resources: Lack of adequate training for pilots on checking chip detectors, and the absence of any guidance on inspecting and assessing chip detectors in the flight operations manual.
- Lack of Communication: The pilot had not been briefed on the significance of recurring chip light indications, or of the requirement to perform a 30-minute ground run following inspection of a chip detector.

Case Study #2 - Separation of Cowling in Flight

Transportation Safety Board Report Number A95W0180

Beech King Air 100
Edmonton, Alberta 50 NM N
26 September 1995

Synopsis

The Beech King Air 100 was on a night instrument flight rules (IFR) medevac flight from Fort McMurray to the Edmonton Municipal Airport, Alberta. On descent through 18,000 feet, at approximately 200 knots indicated air speed (IAS), the aircraft yawed and began to vibrate excessively. The flight crew observed that the upper aft section of the left engine cowling was detached and lodged against the leading edge of the left wing, outboard of the engine. They declared an emergency, continued the descent at 150 knots IAS, and landed without further incident or injury. The detached cowl fell to the runway during the landing roll. Subsequent visual examination of the empennage determined that the outboard 22 inches of the left elevator had also departed from the aircraft before landing.

Other Factual Information

Clear skies, smooth flight conditions, and light surface winds existed at the time of the occurrence. The aircraft was dedicated to medevac flights, and was normally fuelled and hangared to be available for a prompt departure. Both crew members were licensed in accordance with existing regulations. The captain had approximately 2,500 hours of flight experience on King Air aircraft. The first officer had approximately 80 hours on type.

The captain and first officer were telephoned at their residences at approximately 0230 mountain daylight time (MDT) and assigned to the flight. They arrived at the airport at 0300, towed the aircraft from the hangar and conducted the pre-flight inspection on a partially lit area of the ramp. The captain opened the cowling on the right engine, checked the security of the oil cap, and resecured the cowling. The first officer did a similar check on the left engine. The captain assisted with the examination of the left engine with his flashlight when the first officer's flashlight began to dim. The first officer subsequently closed the left cowling and secured it in what he believed to be the normal fashion. The preflight inspection was completed approximately one-half hour before the arrival of the medevac passengers, and there was no evidence that it was done in a hurried manner.

The flight departed Fort McMurray at 0355 with the two crew members and three passengers on board. The aircraft climbed to flight level 200 (FL200) and proceeded en route without incident for approximately 45 minutes. During the initial descent into Edmonton, the cowling opened and separated from the nacelle.

The upper aft cowling on the King Air 100 is a hoop-shaped panel that is approximately 30 inches long. It is secured by two hinges on the left side and two latches on the right side. The cowling hinges upward and outward from the inboard side of the left nacelle to expose the plenum and accessory sections of the Pratt and Whitney PT6 turboprop engine.

The aircraft was fitted with Part No. H296K854 cowling latches, which were manufactured by Hartwell Corporation and shipped to Beech for production from 1967 to 1970. These latches were replaced by Part No. H296K1135 latches in 1970 and the Part No. H296K854 latches were supplied only as spares when requested. The current production Part No. H296K1135 latches have stronger trigger springs and steel hooks for improved service life. Beechcraft Service Instruction (SI) No. 0597-242 recommends that the aft cowl door latches on King Air 100 and other models be inspected at each scheduled inspection for conditions that could allow the cowling to come open in flight. The SI indicates that the latch may be subjected to internal pressure while in flight, and recommends replacing the earlier latches with the improved version if excessive wear, distortion, or other deterioration of the latch is noted.

The intact condition of the latch assemblies indicated they were unlatched at the time the cowling separated from the aircraft. The forward latch was twisted slightly; however, it operated smoothly. The rear latch was difficult to operate due to misalignment. Wear patterns indicated this condition had existed for some time; however, there were no reports that the rear latch had been difficult to operate before the occurrence.

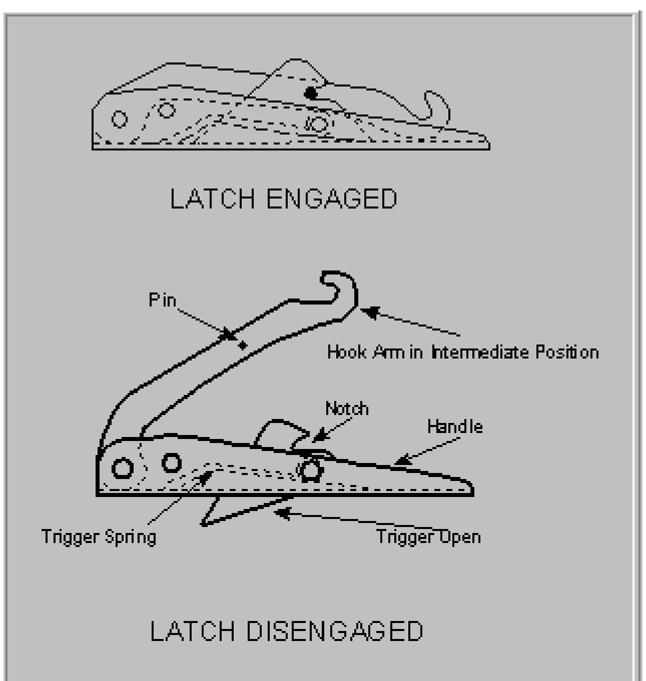

Figure 1 Engine Cowl Latch Assembly (P/N) H296K854)

Both the H296K854 latches and the H296K1135 latches are an overcentre toggle-type latch. The primary locking action is due to tensile loading and the toggle effect between the handle and the hook arm. The edges of the trigger are notched pawls that engage pins on the hook arm to act as a secondary locking device. The top of the trigger must be pushed to release the latch. The trigger is retained in the closed position by a spring. The trigger hinge is set toward the top of the trigger. A pressure differential between the inside and outside of the cowling will tend to open the trigger if the pressure is great enough to overcome the spring and friction resistance. Light tensile loading on the hook will permit the handle to open if the trigger releases.

The aircraft manufacturer reported that the plenum area of the cowling may reach a differential pressure of up to 1.1 psi at 200 knots IAS, due to the combination of ram air effect in the inlet and airflow over the nacelle. Post accident testing determined that the trigger on the forward latch would disengage with an internal air pressure of about one pound per square inch. Calculation determined that with the trigger disengaged, at least 300 pounds of hook tension would be required for the toggle mechanism to keep the handle shut. The rigging of the cowling and the tensile loading on the latches before the occurrence could not be determined.

The left cowling forward latch trigger reportedly protruded into the airstream during flight, and the latch had disengaged on at least one previous flight. Maintenance personnel had visually examined and function-checked the forward latch approximately five weeks before the accident, following the report of the in-flight opening. The latch closed securely, there was no evidence of wear, and no maintenance was accomplished.

Examination determined that the elevator had failed slightly inboard of the outboard hinge, and that the outboard 22 inches had departed with the balance weight. The balance weight was recovered in a field approximately 20 miles north of the Edmonton Municipal Airport. The remainder of the missing elevator structure was not recovered. Examination indicated the failure was a result of a severe up/down bending vibration. The concentrated nature of the damage indicated that there may have been pre-existing damage in the vicinity of the failure; however, no such damage was identified on the recovered components. Control of the aircraft could have been lost had the elevator sustained more damage.

A review of the aircraft logs identified that the left elevator had been inspected in accordance with Airworthiness Directive (AD) 76-22-03 on 11 September 1994; 368.8 hours before the occurrence. A crack was found in a tip rib. Beechcraft repair kit Part No. 100-4005-1S was installed to reinforce the area, and the aircraft was returned to service. The failure occurred inboard of the reinforced area, at the next weakest point.

Analysis

It could not be determined if the left upper aft cowling latches were secured properly before the aircraft departed. It is considered probable, however, that the cowling would have opened sooner if the latches had not been engaged before take-off, as there is normally a pressure differential across the cowling that tends to force it open. The rear latch was misaligned following the accident and wear patterns indicated that the condition had existed for some time. This discrepancy would have made it more difficult to operate the rear latch, and would have increased the likelihood of the rear latch being improperly secured when the cowling was closed. Testing demonstrated that differential air pressure could disengage the trigger on the forward latch because of the weak trigger spring. If the front latch disengaged in flight, as had occurred on at least one previous occasion, the front of the cowling may have lifted as the airspeed increased during the descent. The rear latch could have subsequently disengaged because of the effect of ram airflow in the accessory compartment or because it was not secured properly to begin with.

The detached cowling lodged on the leading edge of the left wing immediately forward of the outboard end of the left elevator. The buffeting generated by the displaced cowling was sufficient to excite a destructive vibration in the elevator. There may have been pre-existing discrepancies in the vicinity of the failure; however, no such condition was identified on the components available for examination.

The following Engineering Branch reports were completed:
LP 138/95 - Performance Analysis
LP 173/95 - Engine Cowl Latch Assembly

Conclusions

It was found that:

1. No physical evidence was found to indicate whether the latches were engaged before flight.
2. The aircraft was fitted with early production Part No. H296K854 cowling latches that have weaker trigger springs than the current version Part No. H296K1135 latches.
3. The design of the latches is such that a pressure differential across the latches results in a force on the latches in the direction in which they open.
4. The forward latch had reportedly unlatched in-flight previously.
5. Testing determined that the forward latch could be triggered open by a differential pressure equal to that present across the cowling in flight.
6. Wear patterns indicated the rear latch may have been misaligned for some time, which would have made it more difficult to operate.
7. The left elevator tip failed as the result of a severe up/down bending vibration that was induced by buffeting from the displaced cowling.

Causes and Contributing Factors

It is probable that the left cowling opened in flight because of the combination of weak latch trigger springs and pre-existing damage on the rear latch. The left elevator failed because of buffeting induced by the displaced cowling.

Safety Action Taken

As a result of this occurrence, the operator has made the following change to the Company Standard Operating Procedures: When possible all night flight walk-arounds are to be completed inside the hangar, with all necessary hangar lighting on. This assists the crew to prepare the aircraft for flight and eliminates the need to use a flashlight for the walk-around.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 04 April 1996.

Contributing Human Factors

The main factors contributing to this occurrence were as follows:

- Complacency: There was pre-existing damage to the rear latch, which had not been repaired, however, the latch was still in use.
- Norms: Replacement of the worn and misaligned rear latch may have been delayed because of attitudes, such as, “It has always been like that”, or “It worked fine last time I flew with it so it must be okay”.
- Lack of awareness: The flight crew may have been unaware of the consequences of a cowling latch failure during flight

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Case Study #3 - Control Difficulty In Flight

Although not an example from Appendix A(3) this report indicates how quickly even the simplest task can go wrong.

Transportation Safety Board Report Number A00O0210

Cessna 150G
Kingston, Ontario
13 September 2000

Summary

The student pilot and the flight instructor took off from the Kingston, Ontario, airport to practice stalls in the Cessna 150 aircraft. The instructor first demonstrated the stall and recovery, then had the student attempt the same procedure. On his first stall recovery attempt, the student was slow to apply back pressure on the control column to bring the nose of the aircraft up. The instructor took control with the aircraft in a nose-low attitude. When the instructor applied back pressure, he found that the elevator control was restricted from full movement. Although he exerted considerable force on the control column, he could not get the elevator control back beyond neutral.

The aircraft reached a speed of approximately 190 miles per hour before the instructor was able to slowly pull out of the dive. The instructor was able to maintain altitude and fly back to the Kingston airport for an emergency landing by using a combination of back pressure on the elevators, full nose-up trim, and an engine power setting of 2500 revolutions per minute. During final approach to the runway, as the instructor applied flap to slow the aircraft, the elevator controls became free, and he was able to carry out a normal landing. The aircraft sustained substantial damage to the wings, flaps, and ailerons as a result of the overspeed situation.

Other Factual Information

The flight instructor was a recent graduate of the aviation program at Seneca College and had approximately 300 hours of flight time, of which 60 hours were instructional. He held a valid Class 4 instructor rating. The student pilot started flight training approximately nine days before the occurrence. He had accumulated a total of 7.1 flight hours.

An aerodynamic stall is performed by slowing the aircraft, while maintaining altitude, by increasing the back pressure on the elevator control. This will result in an increasing angle of attack and increasingly nose-high attitude until the wings stall. When the aircraft stalls, the recovery is accomplished by easing the control column forward while simultaneously increasing engine power. Once the aircraft is no longer stalled, and as it accelerates, back pressure is reapplied to the control column to minimize altitude loss and to regain level flight.

In this occurrence, when the aircraft stalled, the student pushed the control column forward aggressively, and the aircraft entered a dive. The instructor took control when he judged that the student was not initiating an effective recovery. When he pulled back on the control column, he noted considerable resistance and was unable to pull the control column past the neutral position. As the aircraft speed increased, the aircraft slowly came out of the dive while the instructor held the control column as far back as possible. The instructor was able to maintain altitude with continuous back pressure on the control column, combined with a relatively high engine power setting. As he brought the aircraft back to Kingston Airport, the instructor radioed to the flight service station that he had a stuck elevator and would require the emergency response vehicles to stand by for the landing. During a long final approach, the instructor lowered the flaps in an attempt to slow the aircraft to a lower touchdown speed. As he checked forward on the control column to compensate for the pitch change associated with the flap selection, he noted that he now had full elevator control authority. The landing was normal and uneventful.

An examination of the flight control system did not reveal any anomalies that could have restricted or jammed the elevator controls. During the examination of the aircraft, it was noted that the cabin air control knob (ancillary control), which is located on the right side of the instrument panel, was pulled fully out. The aircraft had been modified to facilitate the use of headsets and boom microphones. This included the installation of a radio panel in the centre of the dash, with receptacles for the push-to-talk connections. A push-to-talk button was attached to each control column by a velcro strap. A spring-coiled electrical cord led from the push-to-talk button to the receptacle on the radio panel. The spring-coiled cord on the left side was new and approximately two feet long when contracted. The cord on the right side, which was old and had lost most of its recoil, was approximately four feet long when relaxed. It was common practice for the instructor in the right seat to take up the slack in the electrical cord by wrapping it around the right control column eight or ten times.

Analysis

When the aircraft landed, the elevator control system was functioning normally. There was no binding or indication of any previous binding in the elevator system, nor was there an indication of any damage to any part of the elevator system. The cause of the restriction in the elevator control system had to be something subtle and transitory. The investigation revealed that if the push-to-talk cord was wrapped loosely around the control column, a single loop could snag on the cabin air control knob, and the electrical cord would then restrict the aft movement of the control column. This likely happened as the student was attempting to recover from the stall. The action of pushing the control column forward likely allowed a loosely wrapped electrical cord hanging from the right control column to swing forward and snag the cabin air control knob. The fact that the aircraft was in a nose-down attitude would also tend to allow the loop to swing forward. When the control column was pulled back, the cord would remain snagged and tighten on the knob. This was most likely the condition the aircraft was in when the instructor took control from the student. During the landing approach, when the control column was moved forward to compensate for the flap selection, the tension on the cord would have relaxed, allowing the cord to swing free of the air control knob, freeing the control column through its full travel.

Causes and Contributing Factors

1. The push-to-talk cord on the right side of the aircraft was stretched to twice its normal length and wrapped loosely around the control column. The cord could therefore become entangled on the aircraft ancillary controls.

2. It is likely that the push-to-talk cord became snagged on the cabin air control knob, restricting the movement of the elevator control.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 26 April 2001.

Contributing Human Factors

The main factors contributing to this occurrence were as follows:

- Complacency: The push-to-talk cord was old and too long, yet nobody replaced it before the incident. There might have been the opinion that the cost of replacing the cord was too great to bother spending.
- Lack of Awareness: The occupants of the aircraft were clearly unaware of the hazard associated with the long cord during flight.
- Norms: That might not have been the only stretched out cord on the airfield. If many other aircraft are equipped with the same condition of equipment, then it may give the impression that it is an acceptable practice.

Case Study #4: In-Flight Fire, Landing Gear Well

Transportation Safety Board Report Number A98Q0087

Swearingen SA226-TC
Mirabel/Montreal International Airport, Quebec
18 June 1998

Synopsis

The aircraft, a Fairchild-Swearingen Metro II (SA226-TC), from Dorval / Montréal International Airport, Quebec, around 0701 eastern daylight time bound for Peterborough Airport, Ontario. On board were nine passengers and two pilots. About 12 minutes after take-off, at an altitude of 12 500 feet above sea level (asl), the crew advised air traffic control (ATC) that they had a hydraulic problem and requested clearance to return to Dorval. ATC granted this request. Around 0719, at 8600 feet asl, the crew advised ATC that the left engine had been shut down because it was on fire. Around 0720, the crew decided to proceed to Mirabel / Montréal International Airport, Quebec. At 0723, the crew advised ATC that the engine fire was out. On final for Runway 24, the crew advised ATC that the left engine was again on fire. The landing gear was extended on short final, and when the aircraft was over the runway, the left wing broke upwards. The fuselage pivoted more than 90° to the left around the longitudinal axis of the aircraft and struck the ground. All 11 occupants were fatally injured.

Other Factual Information

During the ground acceleration phase, the aircraft was pulling to the left of the runway centreline, and the right rudder was required to maintain take-off alignment. Two minutes later, the aircraft was cleared to climb to 16 000 feet above sea level.

At 0713, the crew advised the controller of a decrease in hydraulic pressure and requested to return to the departure airport. The controller immediately gave clearance for a 180° turn and descent to 8000 feet asl. During this time, the crew indicated that, for the moment, there was no on-board emergency. The aircraft initiated its turn 70 seconds after receiving clearance.

At 0713:36, something was wrong with the controls. Shortly afterward came the first perceived indication that engine trouble was developing, and the left wing overheat light illuminated about 40 seconds later. Within 30 seconds, without any apparent checklist activity, the light went out.

At 0718:12, the left engine appeared to be on fire, and it was shut down. Less than one minute later, the captain took the controls. The flight controls were not responding normally: abnormal right aileron pressure was required to keep the aircraft on heading.

At 0719:19, the crew advised air traffic control (ATC) that the left engine was shut down, and, in response to a second suggestion from ATC, the crew agreed to proceed to Mirabel instead of Dorval. Less than a minute and a half later, the crew informed ATC that flames were coming out of the "engine nozzle". Preparations were made for an emergency landing, and the emergency procedure for manually extending the landing gear was reviewed.

At 0723:10, the crew informed ATC that the left engine was no longer on fire, but three and a half minutes later, they advised ATC that the fire had started again. During this time, the aircraft was getting harder to control in roll, and the aileron trim was set at the maximum. Around 0727, when the aircraft was on short final for Runway 24L, the landing gear lever was selected, but only two gear down indicator lights came on. Near the runway threshold, the left wing failed upwards. The aircraft then rotated more than 90º to the left around its longitudinal axis and crashed, inverted, on the runway. The aircraft immediately caught fire, slid 2500 feet, and came to rest on the left side the runway. When the aircraft crashed, firefighters were near the runway threshold and responded promptly. The fire was quickly brought under control, but all occupants were fatally injured.

Aircraft Hydraulic System

The aircraft hydraulic system--which does not include the brake system--supplies pressure to operate the flaps and the landing gear in normal operation and to lower the landing gear in an emergency. The approved hydraulic fluid for the aircraft hydraulic system is MIL-H-83282. The approved fluid for the landing gear struts (shock-absorbing systems) is MIL-H-5606.

At 0712, there were indications of a main hydraulic system failure. The L HYD PRESS and R HYD PRESS lights came on, and the hydraulic pressure was decreasing. It was decided to turn back to Dorval and, when required, use the prescribed manual procedure to lower the landing gear. During the turn to Dorval, the flight controls did not feel normal, the IGNITION MODE - AUTO FUNCTION light for the left engine illuminated, and there was a left-wing overheat indication.

Hydraulic Fluid Analyses

The hydraulic fluids collected from the aircraft were analyzed. Samples of hydraulic fluid were also taken from other aircraft in the company fleet, a hydraulic generator cart, and other aircraft not owned by this carrier. The analyses were done by the Department of National Defence Quality Engineering Test Establishment in Ottawa, Ontario. The results of the chemical analyses were as follows:

- The MIL-H-83282 brake fluid from the aircraft contained 34% MIL-H-5606.

- The MIL-H-83282 hydraulic fluid from the aircraft contained 14% MIL-H-5606.
- The MIL-H-5606 fluid from the left landing gear strut of the aircraft contained 5% MIL-H-83282.
- The MIL-H-5606 fluid from the nose gear strut of the aircraft contained 14% MIL-H-83282.
- The wheeled hydraulic generator contained MIL-H-83282 hydraulic fluid with 17% MIL-H-5606. This unit is used to replenish fluids in the aircraft.
- On another aircraft operated by the air carrier, the brakes contained 29% MIL-H-5606, and the aircraft hydraulic system contained 18% MIL-H-5606.
- An aircraft operated by another air carrier contained MIL-H-83282 fluid with 13% MIL-H-5606.

In general, the mixed hydraulic fluids had the qualities of MIL-H-83282 fluid: smell, look, feel, viscosity, etc. However, the MIL-H-5606 contamination in a hydraulic system containing MIL-H-83282 fluid lowers the flashpoint of the fluid.

Wing Overheat Indication

The crew noted a hydraulic failure indication, control problems, and problems with the left engine, and the wing overheat light came on continuously, all within two minutes. Within 30 seconds of the overheat light illuminating, the light went out without any apparent checklist activity. There is no indication that the wing overheat checklist was initiated: both bleed air switches were found in the ON position, and the landing gear was not lowered until the aircraft was on final approach.

Analysis

The investigation determined that overheating of the left landing gear brakes during taxi and take-off caused a fire in the nacelle after gear retraction. The fire spread within the wing structure, leading to wing failure on final approach to land.

Causes and Contributing Factors

It was found that:

1. The crew did not realize that the pull to the left and the extended take-off run were due to the left brakes' dragging, which led to overheating of the brake components.

2. Dragging of the left brakes was most probably caused by an unidentified pressure locking factor upstream of the brakes on take-off. The dragging caused overheating and leakage, probably at one of the piston seals that retain the brake hydraulic fluid.

3. When hydraulic fluid leaked onto the hot brake components, the fluid caught fire and initiated an intense fire in the left nacelle, leading to failure of the main hydraulic system.

4. When the L WING OVHT light went out, the overheating problem appeared corrected; however, the fire continued to burn.

5. The crew never realized that all of the problems were associated with a fire in the wheel well, and they did not realize how serious the situation was.

6. The left wing was weakened by the wing/engine fire and failed, rendering the aircraft uncontrollable.

Findings as to Risk

1. Numerous previous instances of brake overheating or fire on SA226 and SA227 aircraft had the potential for equally tragic consequences. Not all crews flying this type of aircraft are aware of its history of numerous brake overheating or fire problems.

2. The aircraft flight manual and the emergency procedures checklist provide no information on the possibility of brake overheating, precautions to prevent brake overheating, the symptoms that could indicate brake problems, or actions to take if overheated brakes are suspected.

3. More stringent fire-blocking requirements would have retarded combustion of the seats, reducing the fire risk to the aircraft occupants.

4. A mixture of the two types of hydraulic fluid lowered the temperature at which the fluid would ignite, that is, below the flashpoint of pure MIL-H-83282 fluid.

5. The aircraft maintenance manual indicated that the two hydraulic fluids were compatible but did not mention that mixing them would reduce the fire resistance of the fluid.

Other Findings

1. The master cylinders were not all of the same part number, resulting in complex linkage and master cylinder adjustments, complicated overall brake system functioning, and difficult troubleshooting of the braking

system. However, there was no indication that this circumstance caused residual brake pressure.

2. The latest recommended master cylinders are required to be used only with specific brake assembly part numbers, thereby simplifying adjustments, functioning, and troubleshooting.

3. Although the emergency checklist for overheating in the wing required extending the landing gear, the crew did not do this because the wing overheat light went out before the crew initiated the checklist.

4. The effect of the fire in the wheel well made it difficult to move the ailerons, but the exact cause of the difficulty was not determined.

Mixing of Hydraulic Fluids

Analysis of fluid from the accident aircraft's main and brake hydraulic systems revealed a mixture of MIL-H-83282 and MIL-H-5606 hydraulic fluids. These hydraulic fluids are nearly identical in colour and consistency. The mixture had a flashpoint of approximately 114ºC (239ºF).

The SA226 and SA227 specification originally called for MIL-H-5606, with a minimum flashpoint of 82ºC, to be used in the aircraft's main and brake hydraulic systems. However, after two Swearingen SA226-TC Metroliner II cockpit fire accidents in which the MIL-H-5606 hydraulic fluid was involved, the FAA issued Airworthiness Directive (AD) 83-19-02, applicable to certain Swearingen SA226 airplanes, including the Mirabel accident airplane. The AD required that operators drain and purge the main hydraulic and brake system reservoirs, refill them with MIL-H-83282 hydraulic fluid with a minimum flashpoint of 205ºC, and change the placards on both reservoirs to specify the MIL-H-83282 fluid. The accident aircraft was placarded in accordance with AD 83-19-02.

Current maintenance instructions state that MIL-H-83282 is to be used in the main and brake hydraulic systems of the aircraft. However, there is no reference to indicate that MIL-H-83282 is used because of the higher temperature at which its vapours will ignite or that a mixture of MIL-H-83282 and MIL-H-5606 can have a significantly lower flashpoint than the 205ºC flashpoint for pure MIL-H-83282. Given that MIL-H-5606 was the original specified fluid for SA226 and SA227 aircraft, that MIL-H-5606 and MIL-H-83282 are similar in appearance and most properties, and that there are no cautions about the consequences of using a mixture of the two fluids, the Board believes that MIL-H-5606 is being mistakenly used by some air operators and aircraft maintenance engineers as an alternative hydraulic fluid in systems requiring MIL-H-83282. Therefore, in view of the increased risk of fire occurring on Fairchild/Swearingen SA226 and SA227 aircraft resulting from the incorrect use of MIL-H-5606 hydraulic fluid, the Board recommended that:

Transport Canada, as a matter of urgency, notify all Canadian operators of Fairchild/Swearingen SA226 and SA227 aircraft of the importance of, and requirement for, using only MIL-H-83282 hydraulic fluid in the main and brake hydraulic systems of these aircraft; and

Transport Canada, in consultation with the Federal Aviation Administration and the aircraft manufacturer, review the adequacy of existing aircraft standards, procedures, manuals and maintenance practices for the Fairchild/Swearingen SA226 and SA227 aircraft with an aim to ensuring that only MIL-H-83282 hydraulic fluid is used in the main and brake hydraulic systems of these aircraft.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized release of this report on 02 April 2002

Contributing Human Factors

The main factors contributing to this occurrence were as follows:

- Lack of Awareness: The flight crew were unaware of the possible cause of the extended take-off, or that all the subsequent problems were associated with a fire in the wheel well. They did not realize how serious their situation was.

- Lack of Resources: The aircraft flight manual and the emergency procedures checklist provide no information on the possibility of brake overheating, the symptoms that could indicate brake problems, or actions to take if overheated brakes are suspected. Also, the aircraft maintenance manual indicated that the two hydraulic fluids were compatible, but did not indicate that mixing them would reduce the fire resistance of the fluid.

- Lack of Knowledge: Not all crews flying this type of aircraft are aware of it's history of numerous brake overheating or fire problems.

Case Study #5: Inappropriate Repair – Gun Tape

Transportation Safety Board Report Number A89O0453

Cessna A185E Skywagon
Jumping Cariboo Lake, Ontario
15 September 1989

Synopsis

Shortly after the aircraft took off from Jumping Cariboo Lake, Ontario, the engine lost power. The pilot commenced a turn in an attempt to return to the lake for a forced landing, but the aircraft descended steeply into a heavily wooded area beside the lake. There was an explosion seconds after impact, and only the pilot was able to escape the aircraft before it was consumed by fire. The two passengers were killed.

The Transportation Safety Board of Canada determined that the engine stopped because of fuel starvation when the fuel selector valve was inadvertently selected to the OFF position, and the aircraft stalled with insufficient altitude to recover.

Other Factual Information

A large portion of the wreckage was consumed by fire. The aircraft systems were consumed to the greatest degree possible, and no evidence of malfunction was found. The pilot reported that the engine was running properly prior to losing power, with no indications of unservicabilities during the run-up, and that the aircraft flight controls were functioning correctly. The aircraft was properly maintained and serviced in accordance with existing regulations, and no pre-impact unservicabilities were discovered during a teardown of the engine. Calculations made using witness statements and estimates showed that the aircraft was loaded with the take-off weight below maximum allowable and the centre of gravity within the specified limits. The aircraft's emergency locator transmitter (ELT) was destroyed by fire. The aircraft was not equipped with shoulder harnesses.

The fuel system on this model of aircraft is equipped with a fuel shut-off valve and a separate rotary-type fuel tank selector valve. The selector valve has four positions: OFF, LEFT TANK, RIGHT TANK, and BOTH tanks. The OFF selection is an abnormal position for the selector. The selector valve is normally restricted from the OFF position by a ridge of plastic on a D-shaped plastic fuel tank selector cover. If this cover is damaged at the back, there is nothing to prevent the fuel selector valve from being selected to the OFF position. The location of the fuel selector makes in susceptible to being moved out of the selected position by being kicked inadvertently by a passenger or by shifting cargo.

The pilot stated that the fuel tank selector valve cover had been damaged to the extent that the retaining screws no longer held the cover in place. It was held in place using "high speed" tape. He also stated that the fuel tank selector remained on BOTH virtually at all times. The fuel selector valve from the aircraft was recovered from the wreckage and examined. The valve had been damaged by heat, but it showed no other signs of damage or being otherwise marked. When the selector valve was dismantled, it was found to be in the OFF position. The fuel shut-off valve was not found, thus, it's selected position could not be determined.

The pilot reported that, immediately before the engine lost power, the back of his seat had been kicked by the passenger who was occupying the rear seat, and that both passengers were moving around in their seats.

Analysis

It is probable that the fuel selector valve was inadvertently moved to the OFF position by a passenger at some point during the take-off or the initial stage of climb. The location of the fuel selector makes it susceptible to inadvertent movement by a passenger's feet or by shifting cargo. It is possible that the passenger in the rear seat kicked the selector, noticed what had happened, and in an effort to correct the change, made the faulty selection to OFF. The engine may have restarted when the fuel pump scavenged enough fuel from the header tank and fuel lines to start the engine momentarily before impact.

A seldom, if ever, used fuel selector was found in a position to which it should not have been capable of being moved. In the BOTH position, a small pointer handle faces forward, and the selector would not be susceptible to a 180 degree movement at the time of impact, particularly without being damaged in the process.

After the engine stopped, the pilot began a relatively steep turn in an attempt to return to the lake for a forced landing. During the turn, the pilot's attention was drawn from flying the aircraft to his efforts to find the reason for the loss of power, and to restart the engine. While he was working on these problems, the airspeed decreased to the point where the aircraft stalled. The pilot attempted to effect recovery from the stall, but had insufficient altitude to complete the manoeuvre, and the aircraft descended into trees.

Conclusions

It was found that:

1. The engine lost power shortly after take-off, and the pilot attempted to return to the lake.
2. The aircraft stalled at an altitude too low to allow recovery.
3. There was an explosion shortly after impact, and an intense fire broke out.

4. The aircraft fuel selector valve was found in the OFF position even though it cannot normally be selected OFF.

5. It could not be determined what position the fuel shut off valve was in.

6. The aircraft was not equipped with shoulder harnesses

Causes

The engine lost power because of fuel starvation when the fuel selector valve was inadvertently moved to the OFF position, and the aircraft stalled with insufficient altitude to recover.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board has authorized release of this report.

Contributing Human Factors

The main factors contributing to this occurrence were as follows:

- Lack of Communication: Passengers were not given a clear pre-flight safety briefing on accidental manipulation of the fuel selector, or how to avoid such an event.

- Lack of Awareness: Operator was unaware of the possible consequences of not properly repairing the fuel selector.

- Distraction: During the pilot's initial turn back towards the lake, following the engine stopping, his attention was drawn from flying the aircraft to his efforts to find the reason for the loss of power and to restart the engine.

- Norms: If the incorrect repair had existed for an extended period of time, it may have been perceived as an acceptable method.