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Swiss Transportation Safety Investigation Board STSB
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Swiss Transportation Safety Investigation Board STSB

Final Report No. 2319 by the Swiss Transportation Safety Investigation Board STSB

concerning the serious incident involving the Robinson R22 Beta II helicopter HB-ZGO

on 6th April 2016

1 km south-east of Worb, canton of Bern

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General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances around and causes of the serious incident under investigation.

In accordance with article 3.1 of the 10th edition of annex 13, effective from 18th November 2010, on the Convention on International Civil Aviation of 7th December 1944 and article 24 of the Federal Aviation Act, the sole purpose of an investigation into an aircraft accident or serious incident is to prevent further accidents or serious incidents from occurring. Legal assessment of the circumstances and causes of aircraft accidents and serious incidents is expressly excluded from the aircraft accident investigation. It is therefore not the purpose of this report to establish blame or to determine liability.

Should this report be used for purposes other than those of accident prevention, this statement should be given due consideration.

The German version of this report constitutes the original and is therefore definitive.

Unless otherwise indicated, all information relates to the time of the serious incident.

Unless otherwise indicated, all times mentioned in this report are given in local time (LT). For the region of Switzerland, Central European Summer Time (CEST) was the local time at the time of the serious incident. The relationship between LT, CEST and coordinated universal time (UTC) is:
LT = CEST = UTC + 2 h

Final Report

Aircraft type	Robinson R22 Beta II			HB-ZGO	
Operator	Mountain Flyers 80 Ltd., Airport / Hangar 7, 3123 Belp				
Owner	Mountain Flyers 80 Ltd., Airport / Hangar 7, 3123 Belp				
Flight instructor	Swiss citizen, born 1969				
Licence	European Aviation Safety Agency (EASA) commercial pilot licence helicopter (CPL(H)), issued by the Federal Office of Civil Aviation (FOCA)				
Flying hours	**Total**	7,510:28 h	**During the last 90 days**	119:15 h	
	On the incident type	2,203:34 h	**During the last 90 days**	25:16 h	
Trainee flight instructor	Swiss citizen, born 1989				
Licence	EASA commercial pilot licence helicopter (CPL(H)), issued by FOCA				
Flying hours	**Total**	886:43 h	**During the last 90 days**	26:06 h	
	On the incident type	679:37 h	**During the last 90 days**	12:03 h	
Location	1 km south-east of Worb, canton of Bern				
Coordinates	611 500 / 197 300, at an altitude of approximately 3,100 ft AMSL[1]				
Date and time	6th April 2016, 14:30				
Type of operation	Visual flight rules (VFR), training				
Flight phase	Cruise flight				
Type of serious incident	Fire in the engine bay				

Injuries to persons

Injuries	Crew members	Passengers	Total no. of occupants	Third parties
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	2	0	2	n/a
Total	2	0	2	0

Damage to aircraft	Minor
Third-party damage	None

[1] AMSL: above mean sea level

1 Factual information

1.1 Background and history of the flight

1.1.1 General

The following description of the background and history of the flight is based on the statements made by the flight crew, consisting of the flight instructor and the trainee flight instructor, as well as recordings of the radio communication between the flight crew and the aerodrome control tower (TWR). The flight path has been retrieved from the navigation software on the tablet computer that was carried on board.

The flight was carried out under visual flight rules and was a training flight.

1.1.2 Background

As part of a flight instructor course, the flight instructor and his trainee flight instructor planned a training flight from Bern Belp Airport (LSZB) for the afternoon of 6th April 2016. That morning, a maintenance company had carried out a 50-hour inspection of the Robinson R22 Beta II helicopter, registered as HB-ZGO, used for this flight. This inspection included a ground run (see section 0).

The two pilots took charge of the helicopter approximately two hours after the maintenance work was completed, and carried out the pre-flight checks. As is customary for a flight instructor training flight, the flight instructor seated himself in the pilot seat on the right-hand side and the trainee flight instructor took his seat on the left.

1.1.3 History of the flight

At 14:26, the flight crew took off from Bern Belp Airport in HB-ZGO. The flight path led via reporting point Hotel Echo (HE) towards the east (see illustration 1).

After a few minutes in the air, both pilots heard noises through their headphones that were similar to the crackling noise of a defective headphone jack connection. A little later, they saw that the needle of the ammeter, which measures the charge current to or discharge current from the battery, fully deflected up to its stops. The pilots decided to disconnect the alternator from the electrical system using the toggle switch in the cockpit and additionally to actuate its circuit breaker (CB). At the same time, they noticed an electrical burning smell which faded shortly afterwards.

At this time, the helicopter was still within the Bern Belp control zone (CTR), just south-east of Worb, approximately 8 km from the airport. Due to radio communication being disrupted, the flight instructor was at first unable to contact the air traffic controller (ATC) at Bern Belp TWR and the flight crew therefore considered a precautionary landing at their current location. However, when the trainee flight instructor was able to establish contact with the ATC and was given immediate clearance to return to the airport, they decided to return to Bern Belp without delay.

During the short return flight, the pilots switched on the alternator for a short time, which produced the same result as before: a fluctuating ammeter and re-occurrence of the electrical burning smell. They switched off the alternator and left it switched off until the end of the flight.

At 14:35, i.e. after 9 minutes of flying time, the helicopter landed on the apron of Bern Belp Airport. Immediately before landing, the ATC notified the two pilots via radio that smoke was visible around the engine bay. The trainee flight instructor therefore disembarked the helicopter immediately after the landing and saw an open engine fire in the area of the alternator. He fetched a fire extinguisher and was able to extinguish the fire himself.

Coincidentally, the Bern Belp Airport fire service was carrying out a drill at the time of the serious incident and reached the helicopter a few moments after it had landed. By this time, the fire had already been extinguished by the trainee flight instructor.

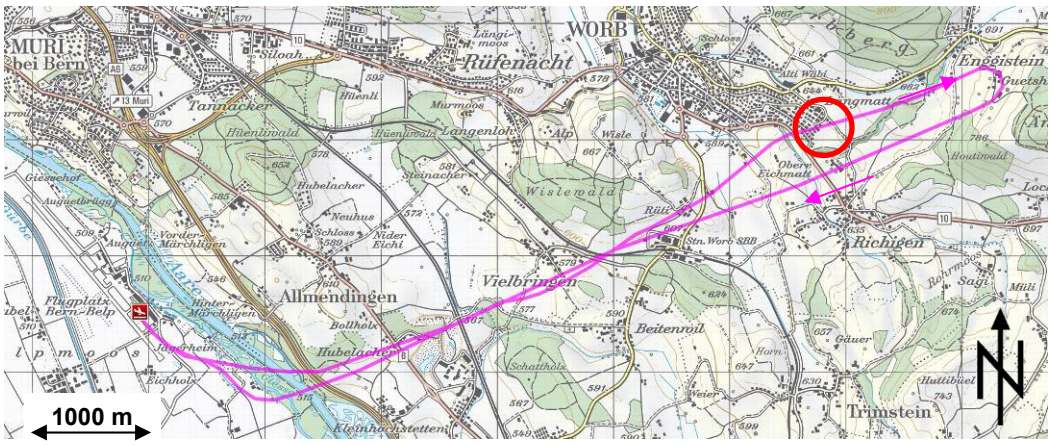

Illustration 1: The flight path according to the navigation software recordings; the red circle indicates the approximate position at which the flight crew noticed the problem with the electrical system; source of base map: Federal Office of Topography.

1.2 Meteorological information

1.2.1 General weather conditions

Behind a cold front, a narrow ridge of high pressure extended from the Bay of Biscay to the northern side of the Alps.

1.2.2 Weather at the time and location of the serious incident

Wind	From 150° at 6 kt, wind direction variable between 110° and 190°
Meteorological visibility	10 km or more
Clouds	1/8-2/8 at 3,800 ft above airport elevation (LSZB) 3/8-4/8 at 6,000 ft above airport elevation (LSZB)
Temperature	14°C
Dew point	8°C
Atmospheric pressure (QNH)	1,015 hPa, pressure reduced to sea level, calculated using values of the ICAO[2] standard atmosphere
Outlook	No significant change

[2] ICAO – International Civil Aviation Organisation

1.3 Information on the aircraft

1.3.1 General information

Registration	HB-ZGO	
Aircraft type	Robinson R22 Beta II	
Characteristics	Single-engine, two-seater light helicopter with piston engine and skid landing gear, with semi-rigid main rotor system and conventional two-blade tail rotor for torque balance	
Manufacturer	Robinson Helicopter Company, 2901 Airport Drive, Torrance, CA 90505, USA	
Owner/operator	Mountain Flyers 80 Ltd., Airport / Hangar 7, 3123 Belp	
Engine	Manufacturer: Type: Serial number:	Lycoming O-360-J2A L-39053-36A
Alternator	Manufacturer: Type: Serial number:	Hartzell ALX-8521LS 0042001
Alternator filter	Manufacturer: Type:	Lone Star Aviation LS03-01004
Operating hours	Airframe: Engine:	3,383:15 h TSN[3] / 1,201:01 h TSO[4] 5,601:01 h TSN / 1,201:01 h TSO
Max. permissible mass	622 kg	
Mass and centre of gravity	The helicopter's mass at take-off was approximately 614 kg Both mass and centre of gravity were within the permissible limits as per the pilot's operating handbook (POH)	
Certificate of registration	Issued by FOCA on 4th August 2011	
Certificate of airworthiness	Issued by FOCA on 10th May 2007	
Airworthiness review certificate	Date of issue: 8th May 2015 Date of expiry: 19th May 2016	
Approved operation	Private, VFR by day and night	
Technical restrictions	None recorded	

[3] TSN: time since new

[4] TSO: time since overhauled

1.3.2 Maintenance work on the helicopter

According to the technical documentation of the helicopter HB-ZGO, a 50-hour inspection of the airframe and engine was carried out and certified at 3,383:15 operating hours on the morning of the 6th April 2016, the day of the serious incident. No special maintenance work relating to the serious incident was undertaken during the inspection.

1.3.3 Electrical system

HB-ZGO's direct current system has an operating voltage of 14 V and is supplied by a maintenance-free battery as well as an alternator (see illustration 2).

The alternator control unit regulates the output current at the alternator's A+ terminal and is connected via an alternator switch and a CB to the bus bar and the battery respectively. Turning off the alternator switch or actuating the CB turns off the alternator's exciter field which means the alternator's A+ terminal ceases to be live.

The instrument panel is fitted with an ammeter which displays the charge current to or discharge current from the battery. There is also a low voltage light, which indicates a failure of or malfunction in the alternator.

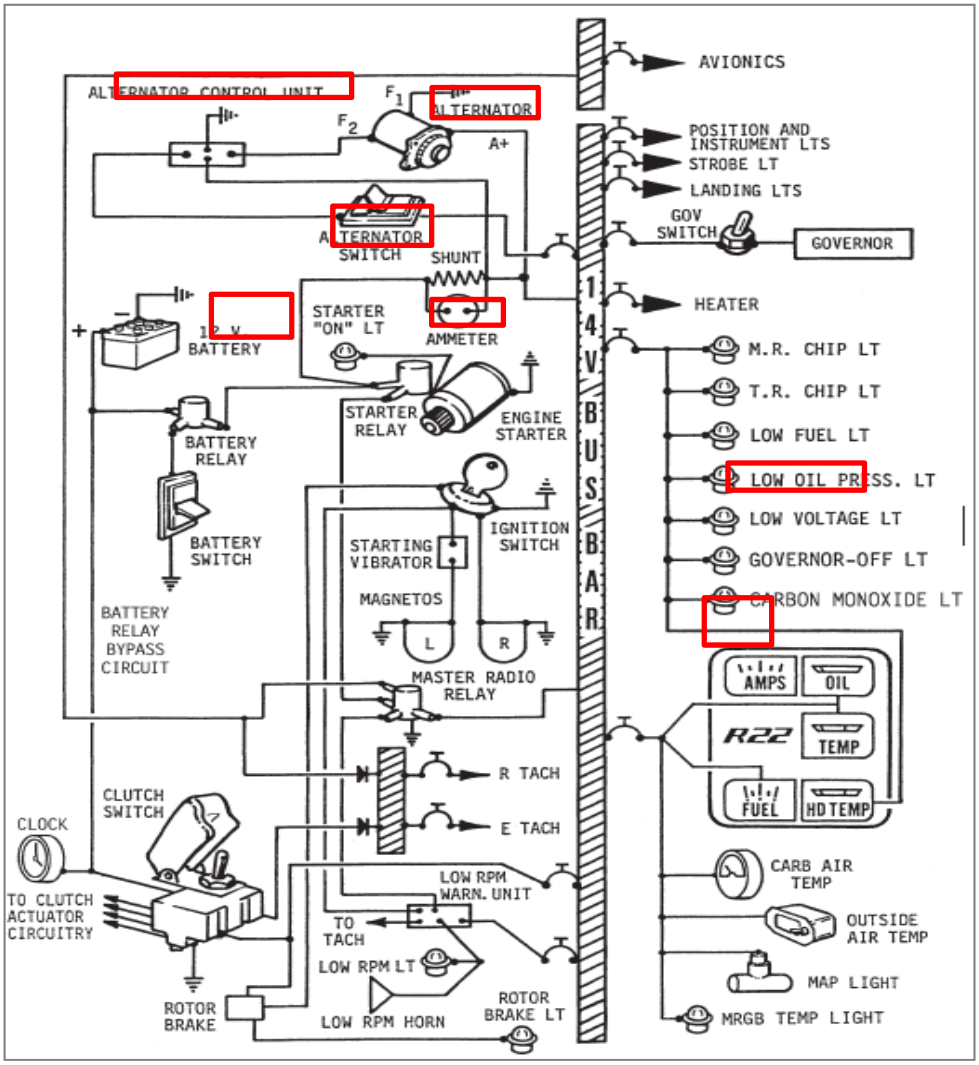

Illustration 2: A schematic diagram of HB-ZGO's electrical system as per the POH. The components relevant to the serious incident under investigation have been highlighted with a red rectangle by the STSB for better visibility.

1.3.4 Replacement of the alternator

On 18th July 2015, the maintenance company replaced HB-ZGO's alternator with an ALX-8521LS alternator which had previously been fitted to another helicopter. For this alternator, the maintenance company had filled in an EASA Form 1[5] on 3rd February 2014, where they entered "*Inspected/Tested*" under section 11 Status/Work. However, the serial number had not been recorded. In addition, there were no work documents for the alternator replacement.

ALX-8521LS alternators have been approved for installation in R22 Beta II helicopters by the helicopter manufacturer.

1.3.5 Installation of an alternator filter

In HB-ZGO's electrical system, a Lone Star Aviation Corp. LS03-01004 alternator filter was installed between the alternator's A+ terminal and the aircraft earth. The installation was not recorded in the technical documents and there were no other relevant documents. According to the statement made by the mechanic, who had undertaken the maintenance work on HB-ZGO, the previous maintenance company had installed this alternator filter before 2010 and he had been working as a mechanic at this company at the time. He said the reason for the installation had been noise interference in the intercom caused by the transponder. This noise interference manifested itself as short clicking sounds. However, these had not been eliminated through the installation of the alternator filter.

HB-ZGO was the only helicopter known to the maintenance company which had been fitted with this kind of alternator filter. However, according to the mechanic other aircraft had also been fitted with this kind of alternator filter.

According to a PMA[6] granted by the FAA, the installation of an alternator filter is approved for various light aircraft (e.g. Cessna C172), but not for Robinson Helicopter Company helicopters. General installation instructions provided by the manufacturer of the alternator filter (see illustration 3) explain how the alternator filter's earth clamp is to be mounted to the alternator using a single bolt and the alternator filter cable is to be connected to the alternator's A+ terminal.

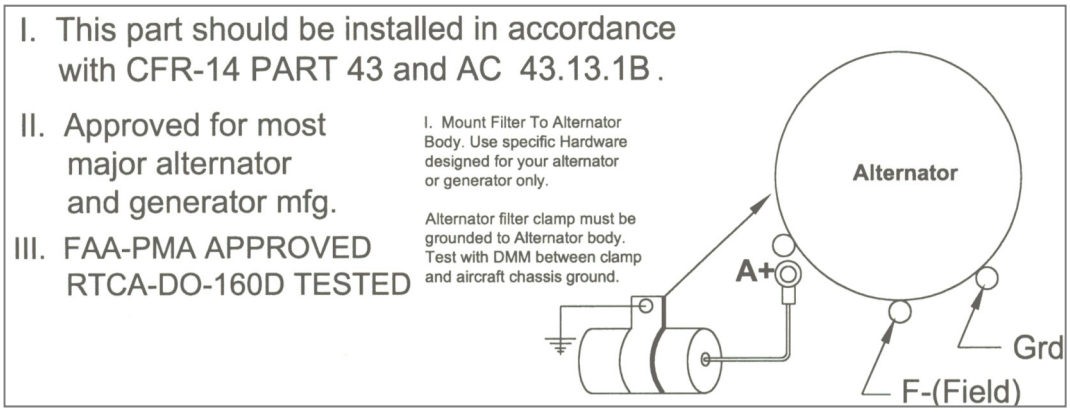

Illustration 3: Installation instruction for the alternator filter from its manufacturer

[5] The EASA Form 1 is an airworthiness certificate for aircraft components, which is issued by manufacturers and/or maintenance companies.

[6] PMA (part manufacturer approval) is an approval granted by the FAA (the US Federal Aviation Administration) for the manufacturing of spare parts or modified parts for aircraft. It enables a manufacturer to sell components for installation in certified aircraft.

The helicopter manufacturer Robinson Helicopter Company (RHC) confirmed that the installation of the alternator filter did not correspond to a factory installation and that RHC does not install such alternator filters in R22 Beta II helicopters. The engine manufacturer Lycoming was also unfamiliar with the use of such alternator filters.

1.4 Damage to the aircraft

The engine bay was inspected after landing. Burn marks were found in the lower left part of the engine bay around the alternator and significant traces of soot were found on all components nearby (see illustration 4).

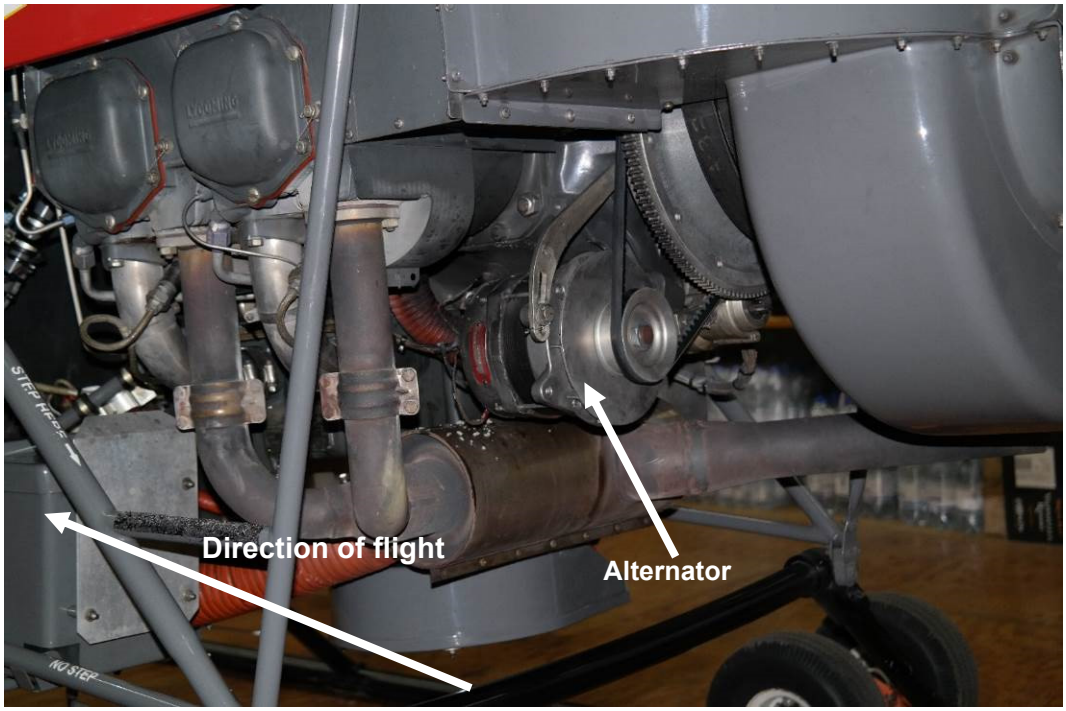

Illustration 4: The lower left part of the engine bay; burn marks and traces of soot around the alternator

The most severe burn marks occurred around the alternator's electrical connections closest to the alternator filter (see illustration 5).

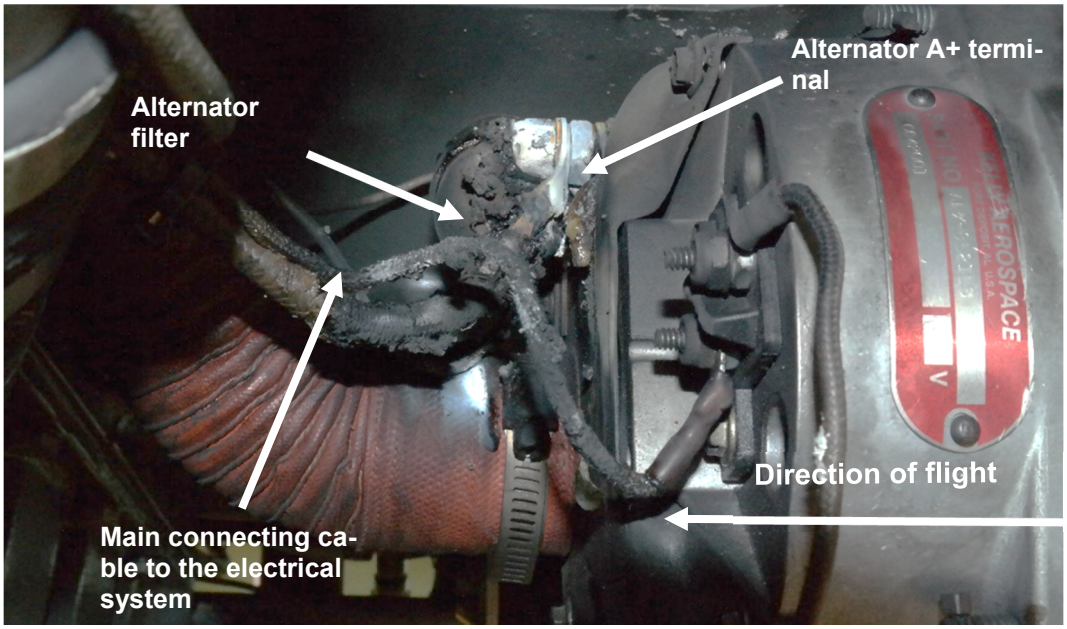

Illustration 5: The alternator with the alternator A+ terminal, the main connecting cable to the electrical system and the alternator filter

Subsequently, the alternator was removed from the helicopter for further investigation and examined.

As can be seen in illustration 6, the greatest amount of heat had developed around the alternator's A+ terminal. Both the alternator's plastic cover and the rubber terminal cover (rubber fitting), which had covered the A+ terminal before the fire, were melted and singed. It is remarkable that the gap between the upper locking nut on the alternator's A+ terminal and the alternator filter housing only measures a few millimetres.

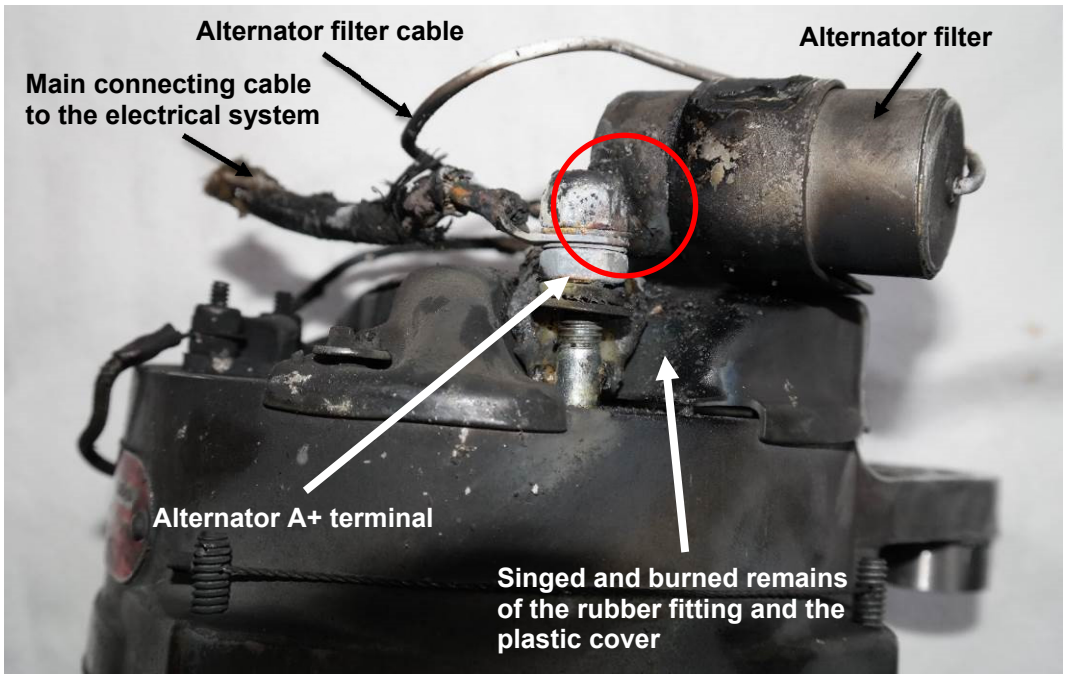

Illustration 6: The alternator after removal, with A+ terminal, main connecting cable to the electrical system, cable to the alternator filter, alternator filter and the singed and melted remains of the rubber fitting and plastic cover respectively. The small distance between the alternator's A+ terminal and the alternator filter housing can be seen in the red circle.

1.5 Relevant procedure

The pilot's operating handbook provided by the manufacturer describes the guidelines for an electrical fire in flight as follows:

"1. Battery and alternator switches – OFF.
2. Open cabin vents.
3. Land immediately.
4. Fuel mixture OFF and fuel valve OFF.
5. If time permits, apply rotor brake to stop rotors.
6. Exit helicopter."

According to the procedure specified above, the first measures to be taken are to switch off the battery switch and the alternator switch. This disconnects the battery from the electrical system and switches off the alternator output (see section 1.3.3).

2 Analysis

2.1 Technical aspects

The alternator filter was mounted on the alternator in such a way that the distance between the earthed alternator filter housing and the alternator's A+ terminal only measured a few millimetres. The rubber terminal cover (rubber fitting) for the A+ terminal, which isolated against a short-circuit in the alternator and/or the battery, was therefore jammed between the A+ terminal and the alternator filter and it is highly likely that, over time, engine vibrations caused mechanical wear of the cover. Because of that, electrical isolation was no longer ensured and electrical sparks were produced between the earthed alternator filter housing and the alternator terminal.

In the process, the rubber fitting, the surrounding electrical cables' plastic insulation and the alternator's plastic cover caught fire and melted, causing the electrical burning smell that was noticed by the pilots and the visible development of smoke which is typical of plastic and rubber fires.

When the flight crew operated the alternator switch, the alternator control unit was electrically disconnected from the electrical system and the alternator's A+ terminal therefore ceased to be live (see section 1.3.3). The battery, however, remained connected to the electrical system, which meant that the alternator's A+ terminal was still supplied with power from the battery via the alternator connecting cable and, as a result, the short circuit and the ensuing sparks still occurred.

The alternator filter's mounting bracket had only one hole and was therefore fixed to the alternator with just a single bolt (see illustration 7). The alternator filter's position in relation to this mounting axis was therefore not clearly defined. It is likely that, over time, the alternator filter rotated around its mounting axis due to vibrations and that the distance between the alternator's A+ terminal and the alternator filter housing decreased even further.

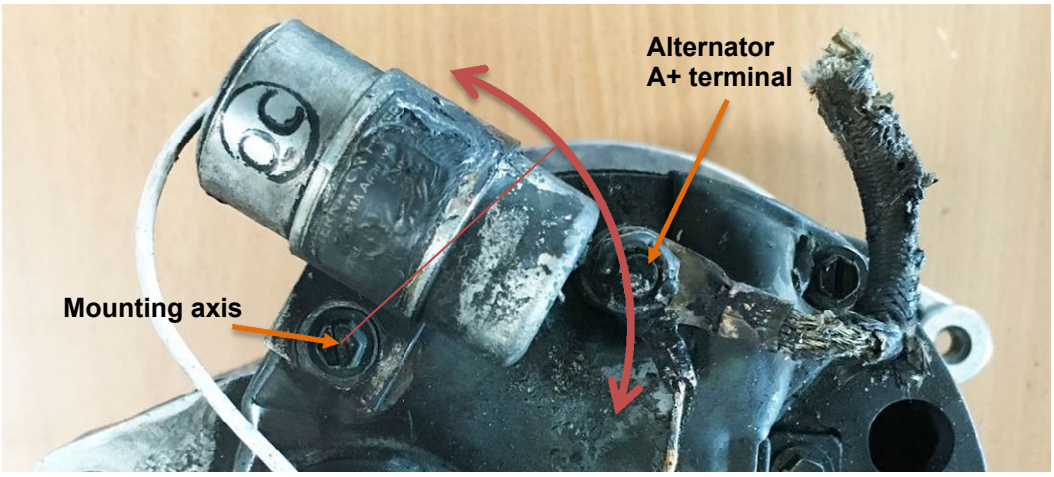

Illustration 7: Mounting of the alternator filter to the alternator housing using one bolt; the position of the alternator filter when rotated around the mounting axis is indicated by the circular arrow in dark red.

As the alternator filter is not approved for installation in a Robinson R22 helicopter, there were no relevant type-specific installation instructions. The documentation from the manufacturer of the alternator filter only provides a schematic installation note, which was followed when the alternator filter was installed in HB-ZGO (see section 1.3.5). Based on a PMA granted by the FAA, it is however permissible to fit this kind of alternator filter to various small aircraft (e.g. Cessna C172). Because installation using only one mounting bolt is not explicitly defined, the installation of

such an alternator filter generally constitutes a risk of a short circuit as in the serious incident under investigation.

During regular maintenance work and airworthiness reviews, there were no objections to the alternator filter which had been fitted. The short circuit with subsequent sparks allows the conclusion to be drawn that the distance between the alternator filter housing and the alternator's A+ terminal was insufficient and that the rubber fitting no longer fulfilled its protective function. This rubber fitting must have worn away over an extended period of time. The insufficient distance and the pre-existing damage to the rubber fitting were neither detected during the checks by the maintenance company immediately before the flight, nor during the pre-flight checks.

2.2 Human and operational aspects

The first signs of a technical defect became apparent to the flight crew in the form of noise interference through their headphones, followed by strong needle deflections in the ammeter and a slight smell of electrical burning. The flight crew's analysis of the situation led to the decision to switch off the alternator immediately and to abort the planned flight.

Because the burning smell faded once the alternator had been switched off and the air traffic controller gave clearance via radio for the direct return flight, the flight crew decided to return to Bern Belp Airport, which was 8 km away. The decision not to immediately perform a precautionary landing despite the burning smell is therefore understandable. At this moment, the flight crew did not have any indication that a short circuit would occur despite the alternator being switched off and that a localised fire was developing in the engine bay.

The manufacturer stipulates in the case of a fire in flight not only to switch off the alternator but also to disconnect the battery from the electrical system (see section 1.5). In the present case, this would have resulted in the alternator's A+ terminal no longer being supplied with power from the battery, and the short circuit would have been interrupted and the resulting sparks halted.

The serious incident under investigation shows how difficult it is for a flight crew to analyse the situation comprehensively and correctly when a burning smell develops. Despite the suspicious electrical circuit being switched off and the subsequent fading of the burning smell as in the present case, a short circuit can still occur and develop into a fire within a short period of time. This can spread to other aircraft systems despite the use of fire-resistant materials. An immediate precautionary landing is therefore to be considered as a basic principle whenever a burning smell occurs.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The fire started because of a short circuit between the alternator and a retrofitted alternator filter.
- Although the flight crew switched off the alternator, the short circuit still occurred.
- The alternator filter type was not approved for this helicopter type. In addition, the installation was not recorded in the technical documentation.
- During regular maintenance work and airworthiness reviews, there were no objections to the alternator filter which had been fitted.
- The installation of the alternator filter had been inappropriate, resulting in mechanical damage to the insulating rubber fitting on the alternator terminal. Because of this, a short circuit with the earthed alternator filter housing was able to form.
- The insufficient distance and the pre-existing damage to the rubber fitting were neither detected during the checks by the maintenance company immediately before the flight, nor during the pre-flight checks.

3.1.2 Flight crew

- The flight instructor and the trainee flight instructor held the appropriate licences for the flight.
- There is no evidence of the flight crew experiencing any health problems.

3.1.3 History of the flight

- At 14:26, HB-ZGO took off from Bern Belp Airport for a training flight.
- Shortly after take-off, the flight crew heard crackling noises through their headphones and saw a wildly varying ammeter display. At the same time, they noticed a slight electrical burning smell.
- Because of the fluctuating ammeter, the flight crew switched off the alternator and returned to the airport, which was 8 km away.
- As the short circuit at the alternator persisted, a localised fire spread in the engine bay. This was not visible to the flight crew.
- After the landing in Bern Belp at 14:35, the air traffic controller notified the pilots about the smoke that was visible around the engine bay of HB-ZGO.
- The trainee flight instructor fetched a fire extinguisher and extinguished the fire in the lower left part of the engine bay.

3.1.4 General conditions

- The weather had no influence on the development of the serious incident.

3.2 Causes

The serious incident can be attributed to a short circuit between the alternator terminal and the housing of a retrofitted alternator filter. The short circuit caused sparks which led to a fire in the engine bay.

The following factors were identified as causal:

- The way in which the alternator filter must be mounted on the alternator was not described in the installation instructions.
- The inappropriate installation mounting of the alternator filter and the poor condition of the rubber fitting were not detected.

Although the fact that there was no type-specific approval for the installation of the alternator filter did not contribute to the development of the serious incident, it was nevertheless identified as a factor to risk within the context of the investigation.

4 Safety recommendations, safety advice and measures taken since the serious incident

4.1 Safety recommendations

None

4.2 Safety advice

The STSB may publish safety advice in response to any safety deficit identified during the investigation. Safety advice shall be formulated if a safety recommendation in accordance with (EU) regulation no. 996/2010 does not appear to be appropriate, is not formally possible, or if the less prescriptive form of safety advice is likely to have a greater effect. The legal basis for STSB safety advice can be found in article 56 of the OSITI:

"Art. 56 Information on accident prevention

The STSB may publish general relevant information on accident prevention."

4.2.1 Installation of an alternator filter

4.2.1.1 Safety deficit

An open fire in the engine compartment of a Robinson R22 Beta II helicopter occurred in cruise flight, which had been caused by a short circuit between a retrofitted alternator filter and the alternator terminal.

According to a PMA[7] granted by the FAA, the installation of a Lone Star Aviation Corp. LS03-01004 alternator filter is approved for various light aircraft (e.g. Cessna C172). However, the installation instructions do not describe how the alternator filter must be mounted to the alternator. As a result, the alternator filter can be mounted in such a way that a short circuit may occur between the earthed alternator filter housing and the alternator's A+ terminal.

In general, PMA-approved components as granted by the FAA with approval for installation in certain aircraft types do not always come with detailed installation instructions. The STSB considers it to be a fundamental risk that installations are performed which may carry a hidden or long-term hazard potential.

4.2.1.2 Safety advice no. 18

Topic: Installation of an alternator filter subject to a PMA granted by the FAA

Target group: Aircraft owners, operators and maintenance companies

In all aircraft that have been retrofitted with an alternator filter mounted on the alternator subject to a PMA granted by the FAA, it should be ensured that no short circuit can occur between the earthed alternator filter housing and the electrical system.

[7] PMA (part manufacturer approval) is an approval granted by the FAA (the US Federal Aviation Administration) for the manufacturing of spare parts or modified parts for aircraft. It enables a manufacturer to sell components for installation in certified aircraft.

4.3 Measures taken since the serious incident

The measures known to the STSB are listed below without comment.

Since the serious incident, the instruction on the subject of an electrical fire on board of a helicopter and a subsequent precautionary landing has been emphasized.

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014.

Bern, 12 December 2017 Swiss Transportation Safety Investigation Board