Published March 2021

REPORT Aviation 2021/03

REPORT ON AIR ACCIDENT ON NORDNESTJØNN, EAST OF ARENDAL AIRPORT GULLKNAPP ON 14 AUGUST 2019 INVOLVING PIPISTREL ALPHA ELECTRO, LN-ELA

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the NSIA's task to apportion blame or liability. Use of this report for any other purpose than for flight safety shall be avoided.

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

INDEX

AIR ACCIDENT REPORT

Type of aircraft:	Pipistrel Alpha Electro
Nationality and registration:	Norwegian, LN-ELA
Owner:	Norwegian Air Sports Federation (NLF)
Operator:	Same as owner
Crew:	1 (uninjured)
Passengers:	1 (uninjured)
Accident site:	Nordnestjønn, 2 NM east of Arendal Airport Gullknapp (ENGK)
Accident time:	Wednesday 14 August 2019 at 1440 hours

All times given in this report are local time (UTC + 2 hours), if not otherwise stated.

NOTIFICATION

The Norwegian Safety Investigation Authority (NSIA) was notified of the accident at 1456 hours, by a representative of the Norwegian Air Sports Federation (NLF). NSIA decided to not deploy investigators to the accident site, but requested help from the police to document the accident site and the aircraft, primarily by taking photographs. Furthermore, NSIA agreed with the NLF that the aircraft should be disassembled and transported to the NSIA's premises in Lillestrøm. LN-ELA arrived at the NSIA premises the following day.

Notification of the accident was sent to the Slovenian Ministry of Infrastructure – Air, Maritime and Railway Accident and Incident Investigation Unit and to the European Union Aviation Safety Agency (EASA).

An accredited representative from the Slovenian accident investigation unit assisted in the investigation[1]. The manufacturers Pipistrel (aircraft), EMRAX (motor) and EMSISO (motor control unit) contributed with technical advisors.

In addition, NSIA has engaged in dialogue with the investigation authorities in the Netherlands and Switzerland, who simultaneously conducted investigations of accidents involving Pipistrel Alpha Electro aircraft in their countries.

SUMMARY

LN-ELA was used to demonstrate electric aircraft for politicians and other interested parties in connection with Arendalsuka 2019 (a Norwegian political festival). On approach to land at Arendal Airport Gullknapp, the aircraft suddenly lost motor power during the final part of the demonstration flight. The commander was unable to restart the motor, and completed an emergency landing on

[1] According to international agreements, under the provisions of the Norwegian Aviation Act, investigation authorities in the aircraft's country of origin may appoint an accredited representative who will have the right to participate in the investigation. The accredited representative may be assisted by technical advisors. Typically, advisors are manufacturer representatives. The contributions from the accredited representative and advisors have been useful to the accident investigation of LN-ELA.

Nordnestjønn Lake, 2 NM east of the airport. Neither of the two people on board was injured in the emergency landing. The aircraft received relatively minor damage during the landing itself. However, subsequent water penetration caused major damage.

NSIA finds it most likely that the LN-ELA motor failure was caused by the power controller interrupting power to the motor. This is likely to have been caused by overheating due to low fluid level and air in the cooling system.

The investigation indicate that an insufficient quantity of coolant was added in connection with a motor replacement that was conducted by the aircraft's maintenance organization in Norway. A contributing factor was inadequate descriptions in the manufacturer's maintenance manual regarding the procedure for replenishing coolant.

Based on this investigation, NSIA has issued four safety recommendations

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 LN-ELA was stationed at Arendal Airport Gullknapp, where it was being used to demonstrate electric aircraft for politicians and other interested parties in connection with Arendalsuka 2019. The flights lasted 10–15 minutes. A typical flight would head toward Arendal town after take-off, then circle the town before heading back to Gullknapp Airport.

1.1.2 The first flight was at 0900 hours in the morning. At the time, the aircraft batteries were fully charged, and they were recharged between flights. Before the accident flight, the commander had completed five uneventful flights. At 1429, LN-ELA took off from Gullknapp Airport. Also this flight was a brief sightseeing trip to Arendal town.

1.1.3 According to the commander, he had begun descent and approach towards Gullknapp when the motor suddenly lost power. He estimated that they were about 800 ft above the ground the when power was lost. The commander has explained that one of the three temperature bars on the main instrument for propulsion system operational parameters (EPSI 570), lit up red at the same time as the motor failure occurred. As far as he could recall after the accident, it was the power controller temperature bar that lit up. At the time of the accident, the aircraft was in level flight, and the power output was 20–30 kW. The commander has stated that there were no warning signs before the loss of motor power.

1.1.4 Immediately after loss of motor power, the commander attempted to restart the motor by pulling the throttle back to idle, and then pushing it gently forward. This resulted in the motor regaining some power, but then failing again. After several failed attempts, the commander decided to stop trying to regain power, and instead focus on conducting an emergency landing. He alerted the air traffic services about this.

1.1.5 When the aircraft lost motor power, it was flying over a forested area with few landing options. However, the commander remembered having previously passed some open areas. He saw a field diagonally behind the aircraft, which he thought would be suitable, and initiated an approach. He informed the passenger about what was about to happen, and how she should act.

1.1.6 At a low altitude, during the final part of the approach toward the field, the commander noticed that it was sloping too much, and decided that it was unsuitable for landing. There were some trees at the other end of the field. Behind the trees there was a small lake.

1.1.7 As LN-ELA was approaching the field, it had gained some surplus altitude. Consequently, the commander flew much of the base leg and final approach with sideslip[2]. When the aircraft reached the field and the commander saw that it was unsuitable, he neutralized the flight control deflections which caused sideslip, and used the reduced sink rate he achieved to continue past the field and over the trees, before landing on the lake (see Figure 1).

1.1.8 The aircraft overturned during the landing, and came to a stop floating upside down. Neither the passenger nor the commander was injured. They both evacuated the aircraft through the side doors on their respective sides, and stepped dry-shod onto one wing each.

1.1.9 LN-ELA remained afloat, and gradually drifted toward the shore of the lake. The commander then stepped into the water and pulled the aircraft to the shore, enabling the passenger to step directly from the wing onto the shore. He then hauled the aircraft further onto the shore as far as he could (see Figure 2), and completed the SHUTDOWN checklist. He also switched off the emergency locator transmitter, which had activated during the landing. He then called his contacts at Gullknapp, and sent a photo from his mobile phone showing his GPS position.

[2] Slideslip, or forward slip, means flying with opposite rudder and aileron deflections. This is done to increase the sink rate.

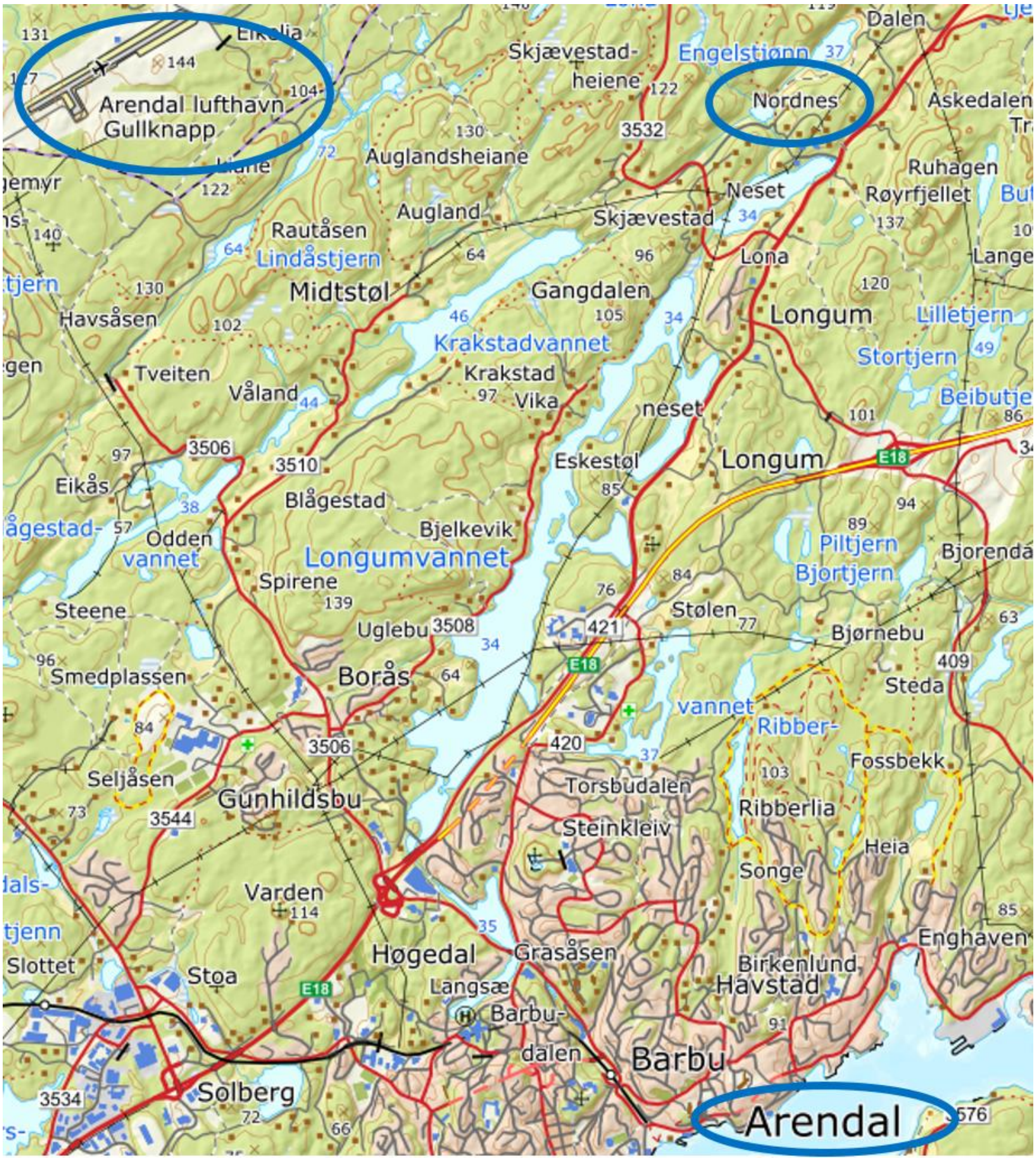


Figure 1: Map section showing the location of Nordnestjønn Lake in relation to Arendal town and Arendal Airport Gullknapp (all indicated by blue circles). Figure 14 in Chapter 1.12 shows a more detailed section of the accident site. Map: © The Norwegian Mapping Authority. Markings: NSIA

Figure 2: LN-ELA after the aircraft had been hauled partly onto the shore. Photo: Agder Police District

1.1.10 The air traffic unit at Gullknapp Airport notified the emergency services when they received the distress call from LN-ELA. Shortly after the accident, a Norsk Luftambulanse helicopter arrived at the lake and picked up the two people from LN-ELA.

1.1.11 LN-ELA was equipped with a Ballistic Parachute Rescue System (see chapter 1.6.5). When asked by NSIA about using it, he answered that he generally would not consider deploying the rescue parachute unless the aircraft had become uncontrollable, or there were other circumstances that made it impossible to perform a normal gliding landing. He did not want to deploy the rescue parachute unless he really had to, because he would then have lost all control of the aircraft and the landing.

1.1.12 When LN-ELA lost motor power, he had not considered deploying the parachute since the aeroplane was still intact and maneuverable. He added that the aircraft documentation did not contain information about the minimum altitude for safe deployment of the rescue parachute. Nor were there any placards in the aircraft or information in the airplane flight manual about this.

1.1.13 The commander told that he routinely briefed his passengers about the rescue parachute deployment handle, instructing them to use it should the pilot become incapacitated.

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	1	1	

1.3 Damage to aircraft

The aircraft was significantly damaged. For more details see section 1.12.2. There was also significant water damage to the instruments.

Figure 3: Photo of the fuselage, taken during the initial investigations in NSIA's hangar. Photo: NSIA

1.4 Other damage

Not registered

1.5 Personnel information

1.5.1 <u>Commander</u>

1.5.1.1 The commander was 65 years old. He had been flying since he was 19 years old, and had experience as a fighter pilot in the Norwegian Air Force and a commercial pilot in the civil aviation sector. At the time of the accident, he held a valid Private Pilot’s License and a type rating for operating the Pipistrel Alpha Electro. He held a valid medical certificate without limitations. The commander has stated that he felt fit and adequately rested when he turned up for the flights of the day.

Table 2: Flying experience commander

Flying experience	All types	On type
Last 24 hours	1	1
Last 3 days		
Last 30 days		
Last 90 days	3	3
Total	12,000+	10

1.5.2 Maintenance manager

1.5.2.1 A licensed aircraft technician associated with the NLF continuing airworthiness organization, CAMO, had been approved by CAA Norway as maintenance manager for LN-ELA. The technician had completed a technical course at Pipistrel in Slovenia. He also held a pilot's license with a type rating for operating the Pipistrel Alpha Electro.

1.6 Aircraft information

1.6.1 Generally about Pipistrel Alpha Electro

1.6.1.1 The aircraft manufacturer Pipistrel d.o.o. is headquartered in Ajdovščina, Slovenia. The manufacturer was established in the late 1980s, producing mainly microlight aircraft, gliders and light sport aeroplanes.

1.6.1.2 Pipistrel Alpha Electro derives from the Alpha Trainer, which is a more conventional piston engine powered aircraft, primarily intended for flight training. In Norway, Pipistrel Alpha Trainer is registered in NLF's microlight aircraft register, whereas aircraft of the Alpha Electro type have been registered in the Norwegian Civil Aircraft Register.

1.6.1.3 Alpha Electro is a two-seat light electric aircraft with fixed landing gear. The two seats are placed side-by-side. There is one door on either side of the cabin. The aircraft is a T-tail high-wing aircraft. The wingspan is 10.5 m. The structure is made almost entirely of composite materials, based on glass, carbon and kevlar fibers. The maximum allowed take-off mass (MTOM) is 550 kg according to the flight manual. Specified stall speed in the landing configuration is 38 kt[3].

1.6.1.4 The aircraft is equipped with a 60 kW (80 hp) electric motor with a three blade, fixed pitch composite propeller. The aircraft has two battery boxes containing Lithium-ion cells located in separate compartments in the fuselage forward and aft of the cabin. The useful battery capacity with fully charged batteries is 20.0 kWh, which equates at best 80 minutes of flying time without reserve power. Take-off with a charge status below 40 % is not permitted.

1.6.1.5 The best glide ratio in the event of motor failure is 15:1. The glide ratio can be achieved by maintaining best glide speed, which is 64 kt.

1.6.1.6 Pipistrel Alpha Electro has been differently categorized and operated in accordance with different airworthiness certificates / permit-to-fly in different countries. For instance in Canada, the aircraft type has been categorized as "Advanced ultra-light aeroplane", while it in Australia and New Zealand has been categorized as Light Sport Aircraft (LSA). In France and Switzerland Permit-to-fly with reference to EASA Flight Conditions were issued. In Norway as well the type was categorized as aircraft without type certificates

[3] In order to meet the EASA microlight definition, similar equipped aeroplanes must have a maximum take-off mass below 472.5 kg and a stall speed in the landing configuration of less than 35 knots.

and with reference to Annex II to EU Regulation (EC) 216/2008[4], see section 1.6.7 for further details.

1.6.1.7 The EASA certification specification for type approval of light sport aircraft is found in CS-LSA. Pipistrel has informed the NSIA that they have not applied for EASA type approval of the Alpha Electro.

1.6.2 Description of the aircraft's electrical propulsion system

1.6.2.1 300–400 V direct current from the main batteries travels into a junction box attached to the motor compartment firewall. The junction box contains the aircraft’s main relays and a transformer. The transformer supplies 12 V direct current to units such as the motor's main instrument (EPSI 570), water pump, avionics, and throttle lever. In addition, a 12 V backup battery is installed under the instrument panel.

1.6.2.2 The power controller is next to the junction box. It is an EMSISO Power Controller receiving direct current from the main batteries via the junction box. The unit has an inverter which supplies 400 V, 3-phase alternating current to the aeroplane’s motor. The power controller is also connected to the motor's main instrument (EPSI 570) and the throttle lever.

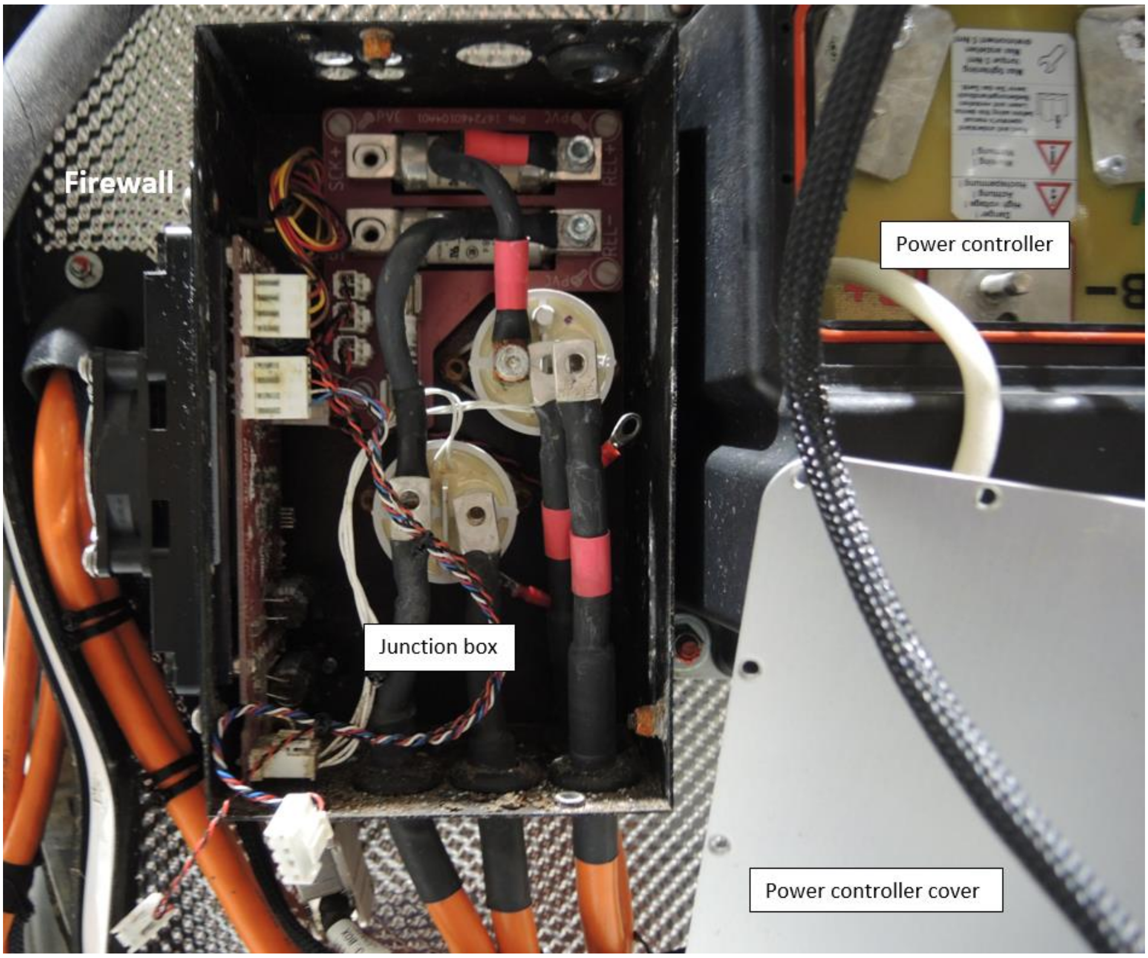


Figure 4: The fire wall, junction box and power controller. The photo shows the junction box and power controller without their covers. Photo: NSIA

[4] EU has replaced regulation (EC) 216/2008 by Basic Regulation (EU) 2018/1139. In the new regulation, non-type certified aircraft are listed in Annex I.

1.6.2.3 The electric motor is a liquid-cooled, 3-phase permanent-magnet alternating-current motor (synchronous motor). Maximum allowed take-off power is 60 kW. Maximum allowed continuous power is 50 kW. Recommended cruising speed power is 20–30 kW.

1.6.2.4 In Chapter 3 *Limitations* of the operating handbook, the following warning concerning the engine is given in the section *Powerplant limitations*:

> *WARNING! The motor is not certified for aviation use, therefore, there is no assurance it cannot fail in its operation at any given moment, without prior notice.*

1.6.2.5 The propeller is attached directly onto the motor without gearing. Normal speed range is 0–2400 rpm. Maximum allowed speed is 2500 rpm.

1.6.2.6 The cockpit electrical system panel is located on the center console below the instrument panel. It contains electric switches and fuses (see Figure 5). The panel incorporates four switches:

- MASTER – main power switch
- AVIONICS – switch for electrical power supply to the instruments
- BATT EN[5] – switch for activation of the battery boxes
- PWR EN – switch for activation of the motor

[5] EN means ENABLE.

Figure 5: Cockpit electrical system panel. Photo: NSIA

1.6.2.7 The pilot regulates the motor power by means of a single throttle lever situated between the seats on the floor of the cabin, below the cockpit electrical system panel.

1.6.3 <u>Cooling system</u>

1.6.3.1 On Alpha Electro, motor and power controller are liquid-cooled. The coolant is circulated by an electric water pump in a closed cooling system. A cooler (radiator) is located in the lower, forward part of the aircraft's nose. It has an opening to the airstream below the propeller (see Figure 6). The system has an expansion tank with a removable lid and a plastic overflow bottle, also with a removable lid. The expansion tank lid has spring-loaded ventilation, which both releases overpressure and lets air back in again in the event of underpressure in the system. The lid is connected to the overflow bottle by a transparent plastic hose for collection of any coolant from the expansion tank (see

Figure 6). According to the maintenance manual[6], the system can hold 1 liter of fluid. The fluid consist of a 50/50 mixture of antifreeze and water[7].

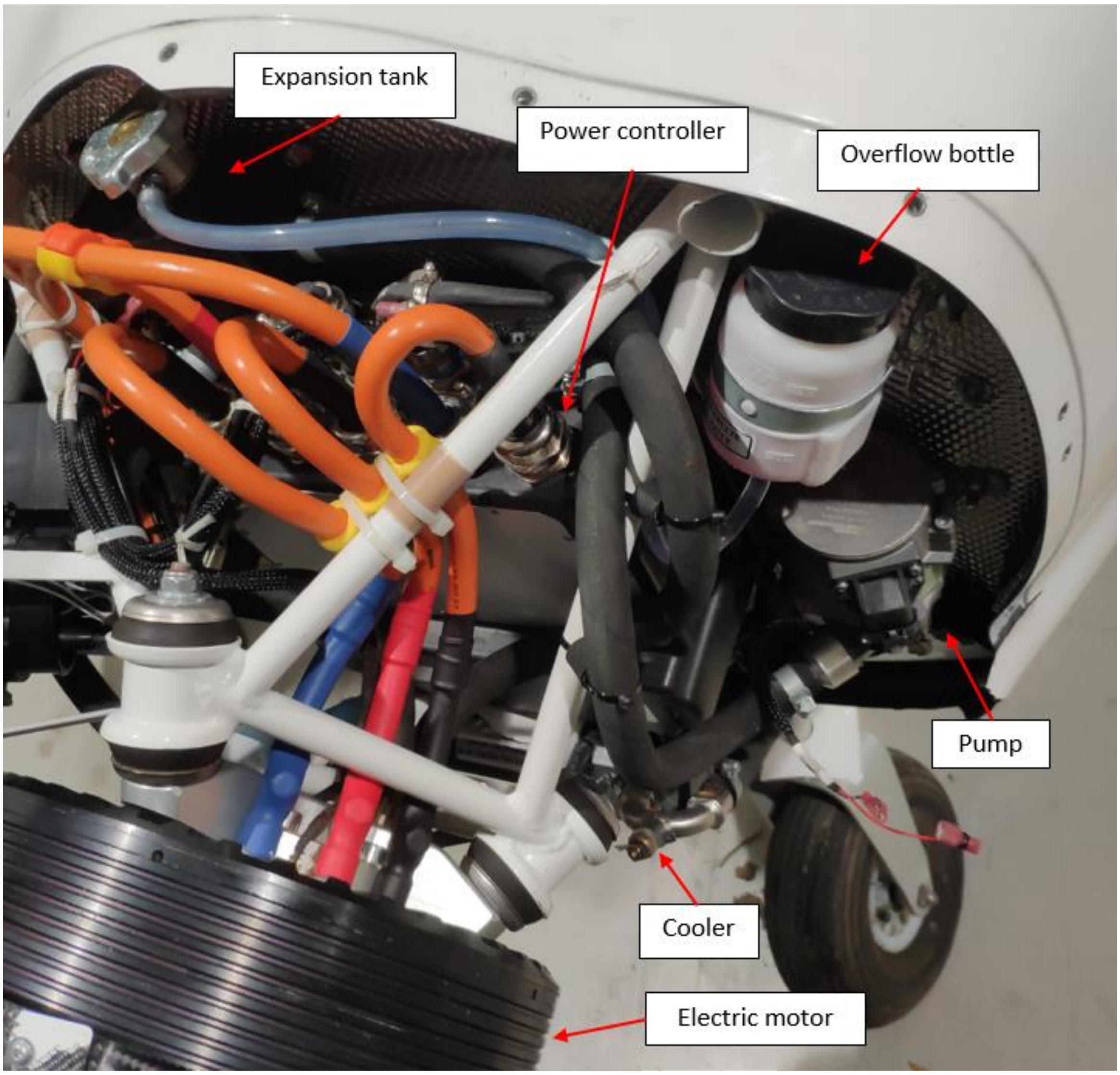


Figure 6: LN-ELA motor installation showing the main components of the cooling system. Photo: Pipistrel

1.6.3.2 The cooling system has a number of temperature sensors. Figure 7 shows a principle drawing of the cooling system, also indicating the location of the temperature transmitters.

[6] Alpha Electro Aircraft Maintenance Manual 12-10 *Replenishing*, 1. *Description*, *Table* 12-001 (AMM-167-00-60-001, Rev B00, January 26, 2018).
[7]According to information from Pipistrel to NSIA, the required fluid volume is 0.9 liters.

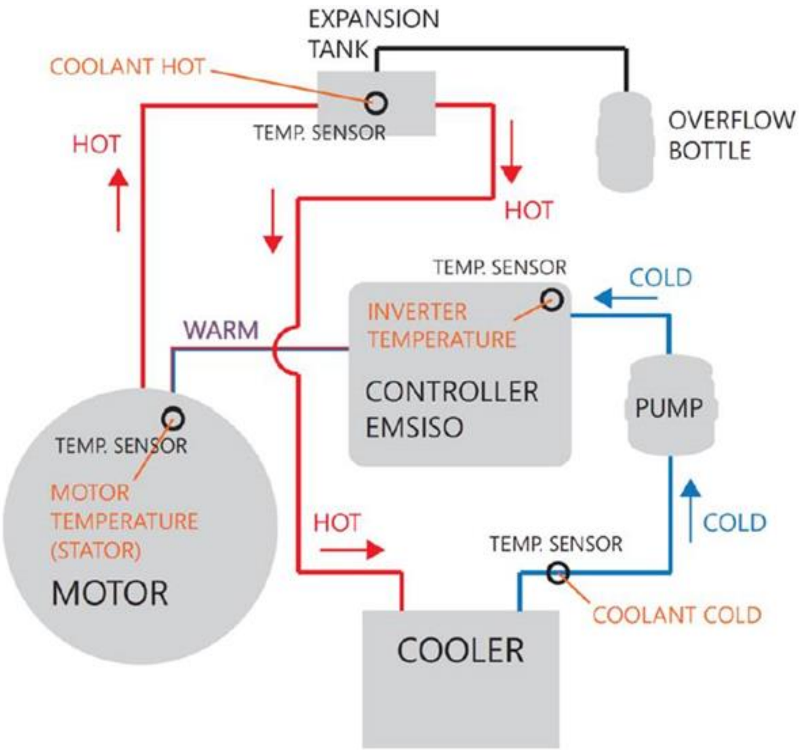


Figure 7: Principle drawing of the cooling system. This drawing shows one temperature sensor on the power controller (EMSISO). This unit has in fact a total of four sensors. Illustration: Pipistrel

1.6.3.3 The power controller has a total of four sensors, three of which are adjacent to their respective Insulated Gate Bipolar Transistor (IGBT) in each of the three electronics chambers. The fourth temperature sensor is located at the warmest point on the outside of the power controller's capacitor housing. Figures 8 and 9 show the principle for cooling of the power controller electronic chambers, and the location of the three IGBTs with one temperature sensor each.

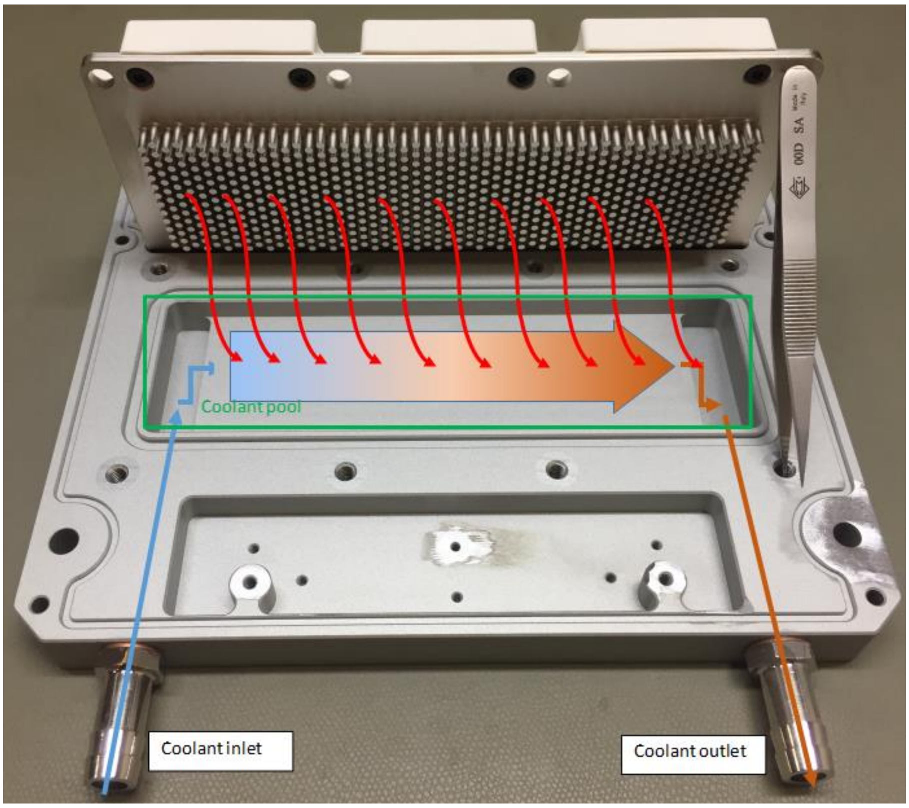


Figure 8: The principle for liquid-cooling of the power controller's electronics chambers. There are three electronics chambers on top of "the lid" and cooling ribs underneath. The chambers are displayed in Figure 9. Illustration: EMSISO

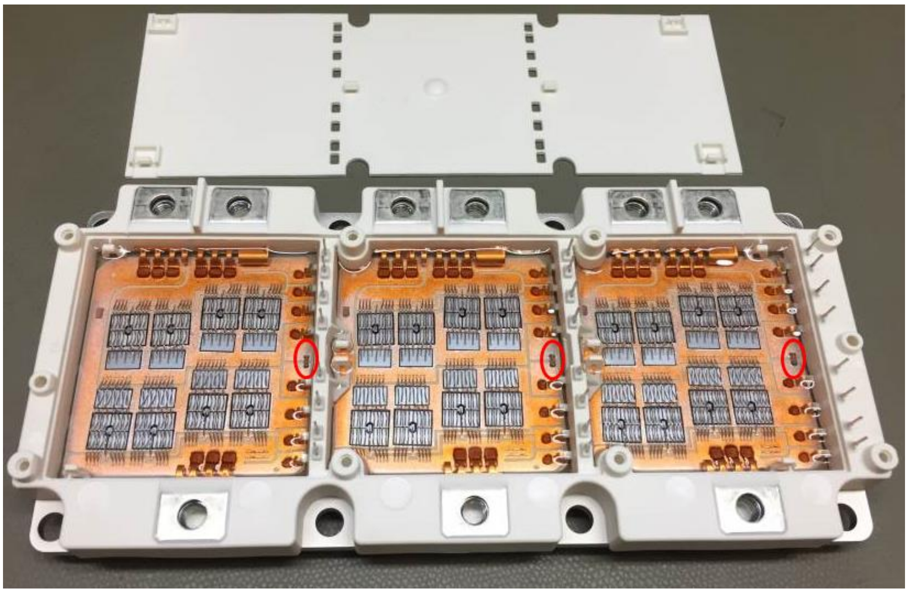


Figure 9: The three electronics chambers in the power controller. Three IGBTs with their associated temperature sensors indicated by a red circle. Illustration: EMSISO

1.6.3.4 The manufacturer (EMSISO) has stated that if the power controller overheats, it may go into failure mode and reduce or cut the motor power. In such an event, it must be reset before it can supply power to the motor again. According to EMSISO, the unit may also go into failure mode if too large temperature difference is registered between individual temperature transmitters. The manufacturer has advised that this type of failure mode may occur. See section 1.6.3.7 and the warning in section 1.6.6.4 *Drive temperature sensor failure*.

1.6.3.5 According to Chapter 2 *Limitations* of the flight manual, the following temperature limitations apply:

Motor

Maximum operating temperature: 95°C

Maximum ambient temperature: 40°C

Power controller

Maximum operating temperature: 65°C

Maximum ambient temperature: 40°C

Batteries

Maximum operating temperature: 55°C

Maximum battery temperature for take-off: 40°C

1.6.3.6 Pipistrel has stated to the NSIA that it is essential that the cooling system is sufficiently topped up, and that there are no air pockets in the system. To NSIA filling of coolant was described as an elaborate and time-consuming process, where the system has to be circulated, ventilated and refilled a number of times to ensure that there is no air left in the system. However, this was not described in the maintenance manual.

1.6.3.7 According to EMSISO, if an air pocket forms in the power controller cooling chamber, it could cause local overheating of one temperature sensor, which again would result in deviating sensor temperature readings, causing the unit to enter failure mode and thus cutting power to the motor.

1.6.4 EPSI 570

1.6.4.1 EPSI 570 is an electronic instrument for monitoring parameters for the electric motor, battery and cooling systems. In flight mode, the instrument is used to monitor the:

- Motor speed
- Cooling system temperature
- Charge status of the batteries
- Battery temperature
- Battery state of health

The instrument also provides warnings and error messages in the event of problems with the electrical motor system.

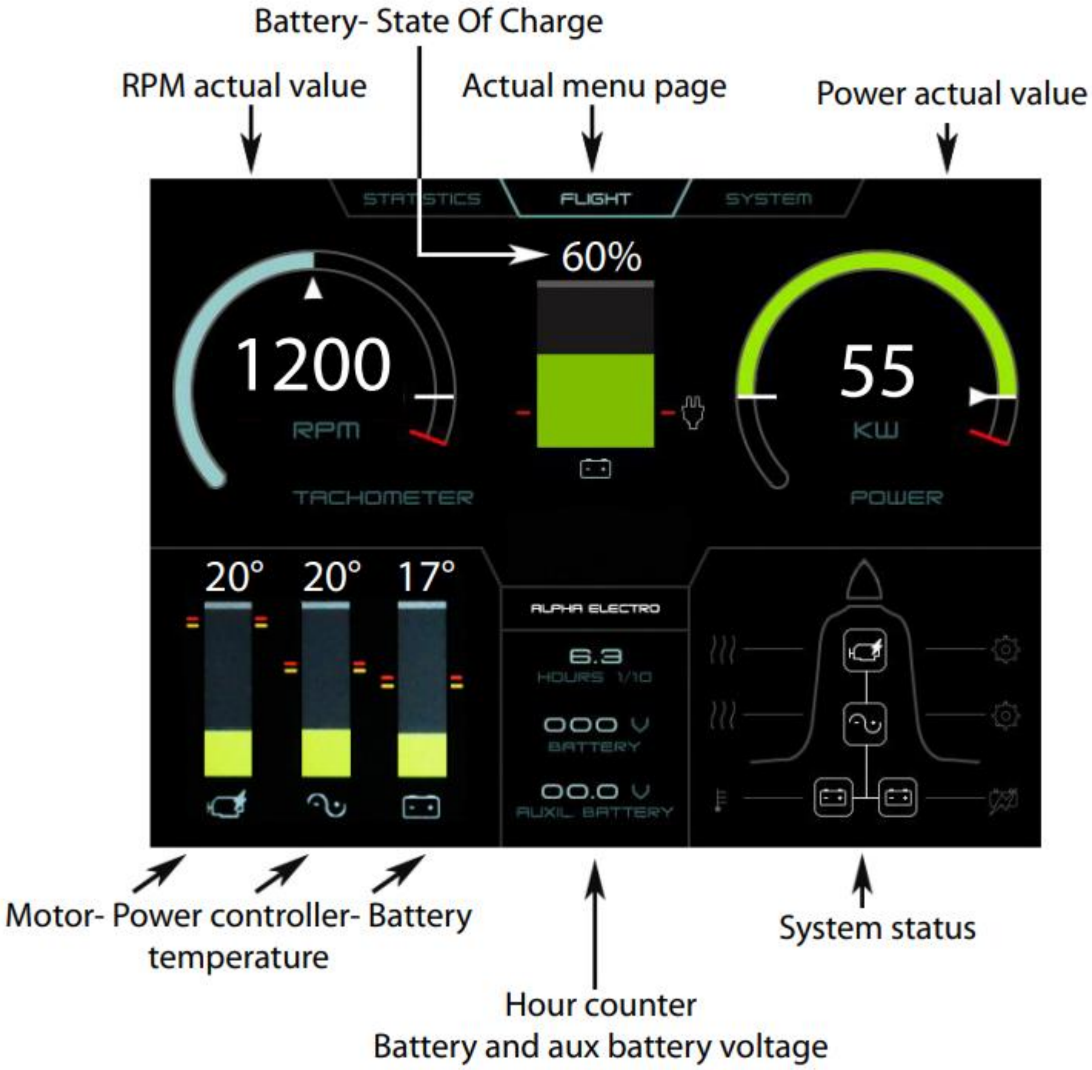


Figure 10: Flight manual illustration showing how EPSI 570 typically looks in flight mode. According to the commander on LN-ELA, it was the middle of the three temperature bars in the lower left-hand corner of the screen (power controller temperature) that increased and turned red. Illustration: Pipistrel.

1.6.4.2 In addition, EPSI 570 has functions/pages for statistics and diagnosis, which are used e.g. in connection with maintenance.

1.6.5 Ballistic Parachute Rescue System – BPRS

1.6.5.1 The aircraft model is equipped with an emergency rescue parachute of the Galaxy GRS Ballistic Parachute Rescue System (BPRS) type. The parachute is located in a canister behind the cockpit. It is deployed from the cockpit by a handle placed above the seat backs (see Figure 11). A pyrotechnical charge will eject the parachute from the aircraft. The whole aircraft will then descend to the ground in the rescue parachute.

1.6.5.2 Pipistrel has not indicated a minimum altitude for safe deployment of the rescue parachute. According to the Alpha Electro flight manual, it will take 3.2 seconds from when the rescue parachute is deployed until it is fully open. Pipistrel has pointed out to the NSIA that "PRS Galaxy Rescue Systems Manual for Assembly and Use" indicates that the minimum safe altitude for aeroplanes in this category is between 180 ft and 250 ft. The Pipistrel flight manual refers to the above manual, but do not contain the information about the minimum altitude or other limitations.

1.6.5.3 The flight manual lists a number of examples of situations when deployment of the rescue parachute may be an alternative:

- structural failure
- mid-air collision
- loss of aircraft control
- motor failure over hostile terrain
- pilot incapacitation

Figure 11: The emergency rescue parachute activation handle. Photo: NSIA

1.6.5.4 There is also a warning stating that once the parachute has been deployed, the pilot will have no control of the landing:

> *As a pilot you should know that the phase following parachute deployment is unpredictable. If in such a situation for the first time, understand that determining where to land and doing so properly is out of your control.*

1.6.5.5 The pyrotechnical charge of a non-deployed rescue parachute represent a hazard to rescue personnel arriving at an accident site. This issue will be subject to further discussion in the NSIA report after the accident with LN-YZU on 10 July 2020.

1.6.6 <u>Relevant checklists</u>

1.6.6.1 *Normal procedures – Daily inspection / Pre-flight inspection*

The checklist for *daily inspection* and the checklist for *pre-flight inspection* are identical.

Both checklists include the following items:

> *Motor, motor cover*
>
> *Coolant level: expansion tank full, overflow bottle between min and max*

Radiators and hoses: no mechanical damage and/or leakage

Fastener and motor cover screws: tightened, motor cover undamaged

The introduction to this checklist emphasizes the importance of the commander performing the check-up in the *"utmost thorough and precise manner"*.

There was a laminated copy of the *Daily inspection / Pre-flight inspection* checklist on board the aircraft.

It is not possible to perform the checklist items without unscrewing the cowling, which is held in place by 12 screws. When asked by NSIA, the maintenance manager for LN-ELA stated that it was complicated and time-consuming to unscrew and then fasten the cowling to perform the checklist items. NSIA's investigation indicates that it was not common practice to unscrew the cowling[8]. Furthermore, the investigation has revealed that when the fluid level was checked, the focus seems to have been on the fluid level in the overflow bottle rather than in the expansion tank.

On 23 January 2019, Pipistrel released a service bulletin, SB-167-002, in which a four-step control was prescribed to verify correct function of the cooling pump before take-off. Pipistrel described the reason for the function check of the cooling pump as follows:

> *To avoid rapid unnoticed temperature rise of the inverter in critical stages of flight (i.e. during take-off and climb-out) we are recommending an additional pre-departure check-list item to be performed.*

The manufacturer recommended that this check should be performed at each pre-flight inspection until the new software update had been installed. The maintenance manager has explained that after having received the service bulletin, he emailed a copy of it to everyone flying LN-ELA. He also put an extra copy in the aircraft, and referred to the service bulletin in NLF's maintenance documentation. The new software update had not arrived at the time of the accident.

1.6.6.2 *Emergency procedures – Motor failure*

The flight manual contains two checklists with the heading *Motor Failure*. One for motor failure during take-off or initial climb, and one for motor failure during climb. Both checklists describe how to perform an emergency landing, but not how to restart the motor. In other words, there is no separate emergency checklist which also contains a description of how to restart the motor.

1.6.6.3 *Emergency procedures – EPSI 570 Failure*

> ***Without power to the motor****: Look for a spot to carry out a safe outlanding. If practical check the circuit breakers, disengage the system's four main switches, power lever to cut-off, and attempt a restart.*

[8]The LN-ELA commander has confirmed that the cowling was not opened prior to the accident flight.

1.6.6.4 *Emergency procedures – EPSI 570 user action guide*

The following are relevant excerpts from the “EPSI 570 user action guide”:

Warning	**User action**
Drive overtemperature	This error appears when the maximum power controller or motor temperature is exceeded: - **Reduce power** - **Monitor temperature** - **If temperature doesn’t drop abort mission**
Drive temperature sensor failure	**WARNING!!! The power controller may reduce power to 0 if and when sensor failure happens.** - **Reduce power** - **Abort mission**
Coolant sensor failure	- **Reduce power** - **Abort mission**

1.6.6.5 Emergency procedures – Emergency landing

1. Master switch OFF

2. Fasten your seat harness tightly

3. Approach and land with extreme caution with +10 km/h (+5 kts) airspeed reserve if the chosen landing terrain length permits.

4. Leave the aircraft immediately after landing.

1.6.6.6 *Checklist for starting the motor*

To restart the motor, the pilot will have to use the ordinary checklist for motor start. This checklist is available in Chapter 2 of the flight manual *Aircraft and Systems*, pages 2-5:

Motor start-up

PWR CTR BREAKER – PUSH

MASTER SWITCH – ON

AVIONICS SWITCH – ON

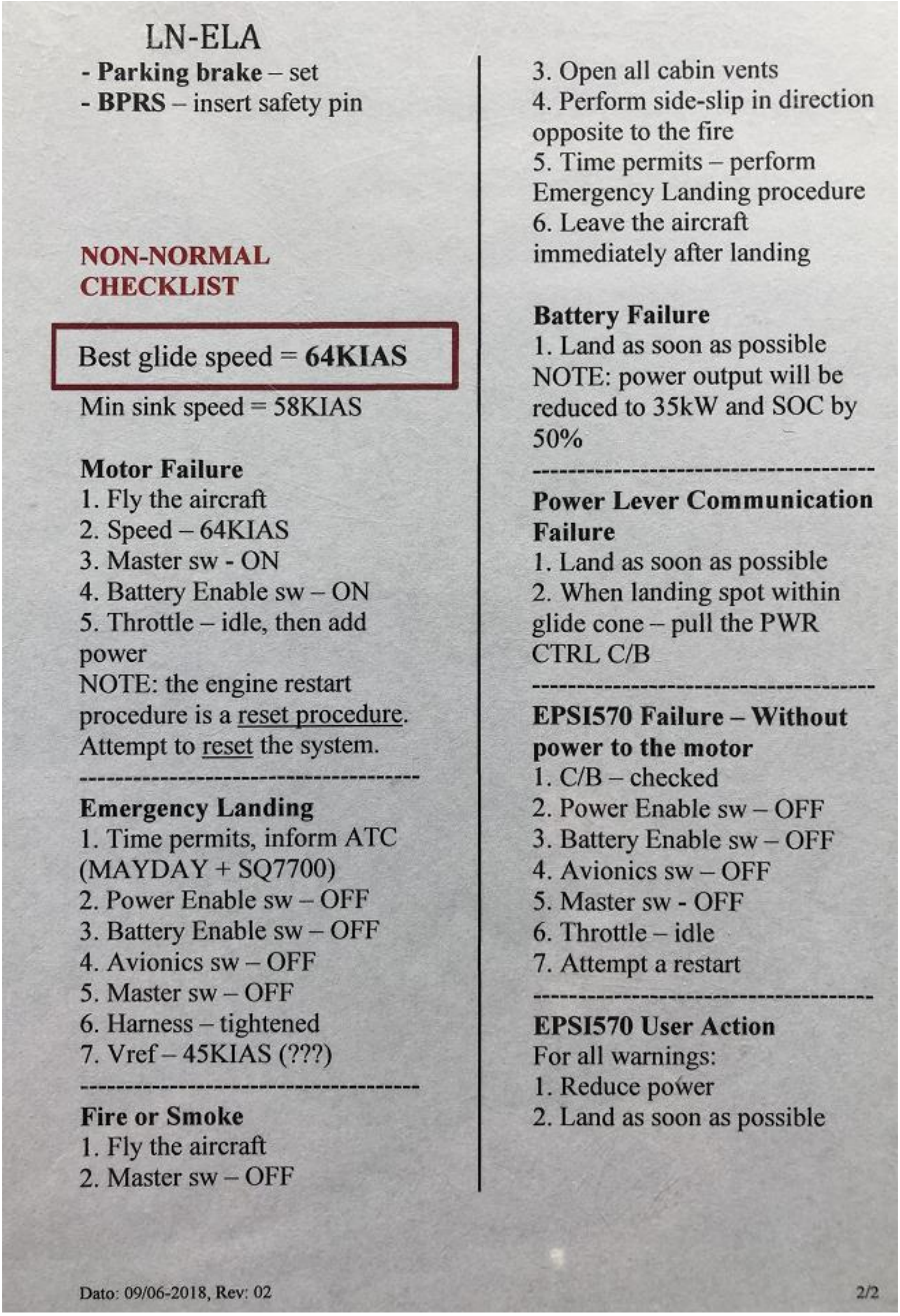
POWER ENABLE SWITCH – ON

Other switches – ON as desired

Chapter 7 *Normal Procedures* contains a section with the headline *Motor start-up* referencing the above-mentioned checklist, where it is stated that the motor will not start unless the throttle lever is retarded to the idle position.

1.6.6.7 *Norwegian Air Sports Federation - Non-normal checklist – LN-ELA*

NLF had prepared its own checklists for LN-ELA. Figure 12 shows the checklist for emergency situations:



LN-ELA

- **Parking brake** – set
- **BPRS** – insert safety pin

NON-NORMAL CHECKLIST

Best glide speed = **64KIAS**

Min sink speed = 58KIAS

Motor Failure

1. Fly the aircraft
2. Speed – 64KIAS
3. Master sw - ON
4. Battery Enable sw – ON
5. Throttle – idle, then add power

NOTE: the engine restart procedure is a reset procedure. Attempt to reset the system.

Emergency Landing

1. Time permits, inform ATC (MAYDAY + SQ7700)
2. Power Enable sw – OFF
3. Battery Enable sw – OFF
4. Avionics sw – OFF
5. Master sw – OFF
6. Harness – tightened
7. Vref – 45KIAS (???)

Fire or Smoke

1. Fly the aircraft
2. Master sw – OFF
3. Open all cabin vents
4. Perform side-slip in direction opposite to the fire
5. Time permits – perform Emergency Landing procedure
6. Leave the aircraft immediately after landing

Battery Failure

1. Land as soon as possible

NOTE: power output will be reduced to 35kW and SOC by 50%

Power Lever Communication Failure

1. Land as soon as possible
2. When landing spot within glide cone – pull the PWR CTRL C/B

EPSI570 Failure – Without power to the motor

1. C/B – checked
2. Power Enable sw – OFF
3. Battery Enable sw – OFF
4. Avionics sw – OFF
5. Master sw - OFF
6. Throttle – idle
7. Attempt a restart

EPSI570 User Action

For all warnings:

1. Reduce power
2. Land as soon as possible

Dato: 09/06-2018, Rev: 02 2/2

Figure 12: NLF non-normal checklist for emergency situations. The NLF checklists were on board LN-ELA at the time of the accident. Photo: NSIA

1.6.7 LN-ELA

LN-ELA was manufactured in 2018 and imported to Norway new. The aircraft was registered in the Norwegian Civil Aircraft Register. A Special Certificate of Airworthiness for aircraft without type certificates and with reference to Annex II to EU Regulation (EC) 216/2008 was issued. The airworthiness certificate did not contain information concerning which of the ten aircraft categories belonged to (se Appendix B).

In the airworthiness certificate CAA Norway further classified LN-ELA in the airworthiness category "*Experimental"*.

LN-ELA was operated in accordance with "Pilot's Operating Handbook – applies to ALPHA Electro 167 aircraft operated outside the scope of EASA PfT".

LN-ELA was mainly used to promote electric aircraft in Norway. At the time of the accident, the aircraft had a total flight time of around 58 hours.

Figure 13: LN-ELA. Photo: Richard Toft

1.6.7.1 *Mass and balance*

LN-ELA was approved for a maximum take-off weight (MTOM) of 560 kg. This 10 kg MTOM increase had been approved by CAA Norway based on an understanding with the manufacturer. The forward and aft center of gravity limitation is 195 mm and 368 mm respectively, behind the leading edge of the wing root. The commander has stated that LN-ELA had a take-off mass of 520 kg at take-off from Gullknapp, and that the aircraft was loaded within the applicable center of gravity limitations.

1.6.7.2 *Motor replacement*

In connection with an inspection in the winter of 2019, the maintenance manager noticed that the motor was "dragging" when turned. He believed the "drag" could indicate narrow tolerances at low temperatures. He contacted the manufacturer who offered to take back the motor and send a new one.

The motor was replaced in January 2019 by the maintenance manager, with the help of an assistant. The assistant had also completed the Pipistrel technical course.

NSIA interviewed the two technicians and presented a description of findings from the technical investigations of LN-ELA (see Chapter 1.16.1). Their comments were as follows:

Reusing coolant hoses: Considering that the aircraft had only been in operation for about six months after manufacturing, and the hoses seemed to be in good condition, the technicians decided to not discard them. Consequently, the hoses were reused. The maintenance manager has also remarked that a new set of hoses was not provided with the new motor.

Replenishing coolant: Coolant was one of the last items on the list, after the motor had been installed and the hoses were in place. They topped up until the expansion chamber was full, and assumed that to be sufficient. They did not know that it was necessary to ventilate the system and replenish several times, to ensure that no air was trapped in the system. The maintenance manual gave instructions to replenish, but did not contain a detailed description of how to do it. Also, the relevant chapter[9] contained no reference to the table[10] which shows coolant quantities.

The accident flight with LN-ELA was the 45th flight after the motor was replaced. The insufficient coolant quantity had not been noted and no coolant had been added.

1.6.7.3 *Motor failure three weeks prior to the accident*

Three weeks prior to the accident, another pilot experienced motor failure on take-off with LN-ELA from Kjeller Airport (ENKJ). The departure was aborted before the aircraft became airborne. The outdoor temperature at the time was around 30°C. The motor stopped suddenly, followed by an overheat warning.

The commander contacted the maintenance manager, who told him to check the coolant level after the system had cooled down. Due to a misunderstanding, it was the liquid level in the overflow bottle that was checked. The expansion tank lid was not removed. Consequently, the fluid level in the cooling system itself was not checked.

Before returning LN-ELA to service, NLF contacted Pipistrel and described the incident. They also sent a picture showing a mixture of coolant and air in the transparent plastic tube running from the expansion tank to the overflow bottle (see Figure 6). Pipistrel then prescribed a test that should be performed to check that the power controller would deactivate at the right temperature. If this test was successful, the aircraft could be put back in operation. The test was performed successfully, and LN-ELA was returned to operation.

1.7 Meteorological information

1.7.1 The following routine weather observations applied to Arendal Airport Gullknapp at the time of the accident:

METAR ENGK 141250Z 250009KT 9999 SCT049 19/06 Q1008=

[9] Aircraft Maintenance Manual 75-20 *Liquid Cooling*
[10] Aircraft Maintenance Manual Table 12-001 in Chapter 12-10 *Replenishing*

1.7.2 The observation shows that the weather conditions and visibility were good, with scattered clouds at 4900 ft, and a light westerly breeze. The temperature was 19°C and the barometric pressure 1008 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Communications

In connection with start-up before departure, LN-ELA established communication with the AFIS unit at Arendal Airport Gullknapp. Radio contact was maintained throughout the entire flight. At 1438 hours Gullknapp Information received a distress call (MAYDAY) from LN-ELA. The commander informed that the aircraft motor had failed, and that they would not be able to reach the airport. He stated their position, and said that he had spotted a clearing where they would attempt an emergency landing. Gullknapp confirmed that they had received the distress call, adding that the emergency services would be alerted.

1.10 Aerodrome information

1.10.1 Arendal Airport Gullknapp (ENGK) is located in Froland municipality in the county of Agder. The airport is privately owned and operated.

1.10.2 Gullknapp is situated about 10 km north-northwest of Arendal town center. The airport has a staffed aerodrome flight information service unit (AFIS) during daytime.

1.10.3 The airport runway is 1199 m long with directions 05 and 23. The altitude above sea level is 415 ft.

1.11 Flight recorders

1.11.1 LN-ELA was not equipped with an ordinary flight data recorder or cockpit voice recorder. It is not a regulatory requirement for the aircraft to carry such equipment. The aircraft had the following data storage equipment:

- GPS – navigation system
- FLARM – collision avoidance system
- EPSI 570 – motor and battery system monitoring

1.11.2 The first two systems can register information about the flight itself, such as course, altitude, and ground speed, whereas the EPSI 570 system can register technical data about the motor, batteries and remaining operating system. During the initial phase of this investigation, NSIA obtained the memory cards from the GPS and EPSI 570. FLARM had not been used, and whereas there were some stored data on the GPS stick, the EPSI 570 memory card was empty.

1.11.3 Pipistrel has explained that registration on the internal EPSI 570 memory card had not been activated, as the intention was to store technical data in a separate data logger instead. NLF had ordered such a data logger, but did not receive it before after the accident had occurred. Consequently, the NSIA investigation is not supported by electronic data from EPSI 570 about the motor, batteries, or any other system monitoring data.

1.12 Wreckage and impact information

1.12.1 The accident site

1.12.1.1 The emergency landing on Nordnestjønn took place in a north-easterly direction. LN-ELA first passed over a narrow field near the small lake. The field is less than 200 meters long. There were some trees between the field and the lake. From the lakeshore nearest the field, the distance to the spot where the aircraft was pulled up, is about 125 meters.

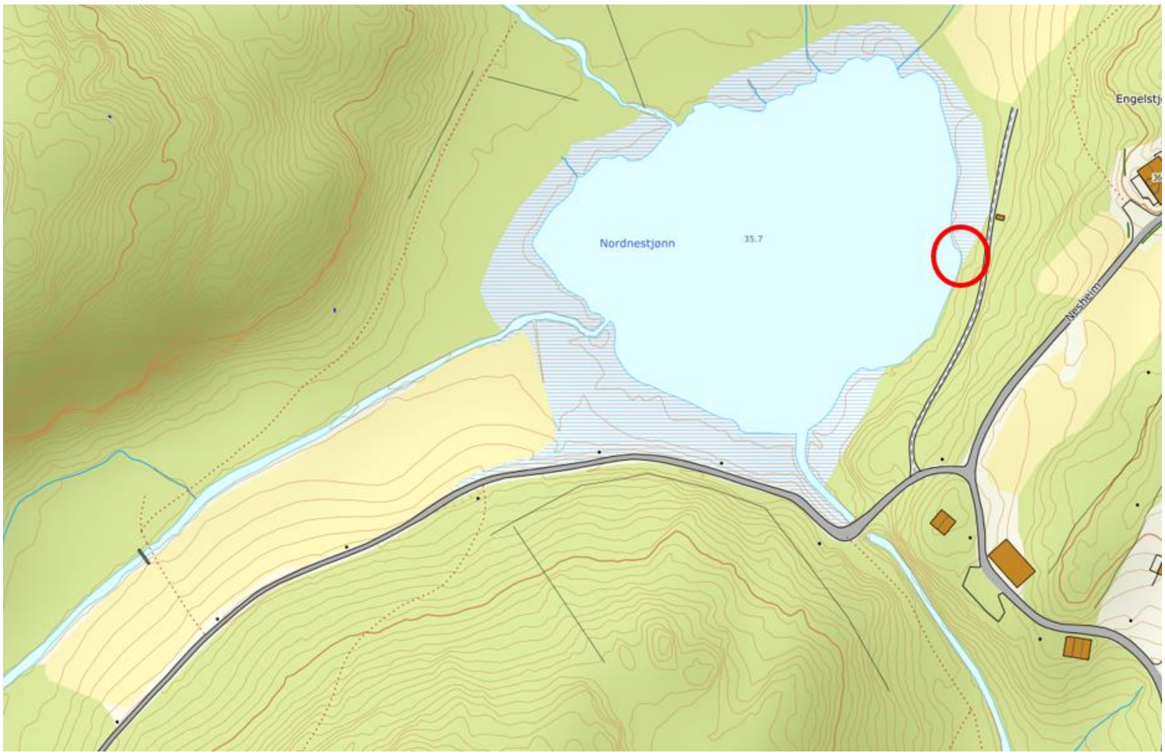


Figure 14: Map section showing Nordnestjønn and the field LN-ELA flew over before landing on the lake. The red circle indicates the area where the aircraft reached the shore. Map: © The Norwegian Mapping Authority

1.12.1.2 Figure 2 in section 1.1.9 shows how the aircraft was left by the lakeshore. It was possible to drive a tow truck all the way to the shore. The wings were removed before the fuselage was lifted out of the water. The aircraft was then placed on its own trailer and transported to the NSIA premises.

1.12.2 Wreckage

1.12.2.1 Except for substantial water damage, LN-ELA received relatively minor visible impact damage during the landing on the lake. The propeller and spinner were broken and there was damage to the top and lower part of the cowling. The nosewheel leg was bent, and all three wheel fairings had been torn off. There was also some minor damage to the wings, including a tear under the left wing flaperon[11]. The motor room, forward battery box and instruments received major water damage (see Figure 3).

[11]Flaperons are control surfaces on the wings. They have a combined function as both aileron and flaps.

1.12.2.2 A more detailed description of NSIA's technical investigations is available in section 1.16.1.

1.13 Medical and pathological information

The police who arrived on the accident site took a routine breathalyser test of the commander. The result was negative.

1.14 Fire

No fire occurred in connection with the accident. See section 1.18.1 regarding a potential fire hazard associated with the aircraft battery boxes.

1.15 Survival aspects

1.15.1 The emergency landing itself did not cause much visible damage to the aircraft. This indicates relatively modest deceleration forces. Both occupants wore safety belts[12]. The cabin was not deformed and the survival space was thus intact.

1.15.2 One functioning door on either side and an intact cabin facilitated the evacuation. A complicating factor was that the occupants ended up upside down in their safety belts after the landing. However, the cabin did not fill up with water. It was therefore not time-critical to loosen the safety belts and evacuate. As the aircraft was floating and drifting toward the shore, it was not necessary to swim.

1.15.3 The aircraft Emergency Locator Transmitter was activated when the aircraft landed on the lake. The signals were received by the Cospas-Sarsat satellite-based search and rescue system, and transmitted to the Joint Rescue Coordination Center South Norway.

1.16 Tests and research

1.16.1 <u>Technical examinations of the aircraft – relevant findings</u>

1.16.1.1 When LN-ELA arrived at NSIA's premises in Kjeller, the data from two main batteries were recorded before they were removed and stored in accordance with recommendations received from the manufacturer. The readings indicated that both battery boxes had sufficient state of charge and that the battery state of health was very good. The forward battery room had been submerged, and the battery box showed signs of having been under water. The aft battery box did not seem to have been exposed to water.

[12] H type safety belts with three mounting points (hip harness and a harness across each shoulder).

Figure 15: The charge status of the forward battery box was 78%, and the battery state of health was 97%. These readings were taken after the battery box had been submerged in water. Photo: NSIA

Figure 16: The charge status of the aft battery box was 83%, and the battery state of health was 93%. Photo: NSIA

1.16.1.2 NSIA went on to conduct an initial investigation of the aircraft and a preliminary registration of the extent of damage.

1.16.1.3 After consulting with the aircraft manufacturer, the main instruments were removed from the aircraft, opened, and air-dried. The memory cards from EPSI 570 and the GPS were removed and secured. Afterward, parts of the interior were removed, and the aircraft was left to dry in NSIA's hangar.

1.16.1.4 LN-ELA remained in the NSIA hangar for several weeks while drying. The aircraft was then put on its trailer, which was sealed and transported to Pipistrel in Slovenia. There, the trailer was kept unopened until representatives from NSIA and the Slovenian accident investigation unit arrived and started further investigations.

1.16.1.5 Before the electrical propulsion system was dismantled, the damaged propeller was removed. Thereafter external power was connected, and a test run was performed. It was established that the motor was running and that the cooling pump was functioning. At the same time, all hoses, connections, and other cooling system components were examined, while the motor was running. No signs of leakage were detected.

1.16.1.6 Afterward, the propulsion system was dismantled. All coolant was collected and measured. The total quantity was less than 6 dl; 5.7 dl in the cooling system itself, 0.1 dl in the overflow bottle and an insignificant quantity which could not be collected.

Figure 17: Coolant collected from LN-ELA. Photo: NSIA

1.16.1.7 The coolant appeared to be discolored and seemed possibly to contain some sediments/particles. Consequently, NSIA asked the Norwegian Armed Forces' chemistry and material technology laboratory service at Kjeller to perform an analysis. The report from this laboratory service concluded as follows:

> *Both[13] coolants satisfy ASTM D3306, and should therefore be compatible. The concentration found in the sample from the aircraft shows a concentration of 78 vol%. This is somewhat high. The manufacturer does not recommend higher concentrations than 70 vol%.*
>
> *The coolant contains organic particles with Na-, Al-, Si- and Ca elements. A potential source could be plastic.*

1.16.1.8 Indications that the cooling system hoses had been previously removed and reused were found. The Aircraft Maintenance Manual states that hoses should not be reused. Chapter 75_20:2.2.1. *Removal* contains the following caution:

[13]NSIA also requested a comparison between the LN-ELA coolant and the coolant that the manufacturer had specified for use in Pipistrel Alpha Electro.

CAUTION: Hoses disconnected from fittings must be replaced by new ones.

1.16.1.9 After the function of the electrically operated water pump had been tested, it was disassembled and examined. No pump defects were discovered.

1.16.1.10 The motor was transported to the manufacturer (EMRAX) for further investigation and tests, with an accredited representative of the Slovenian accident investigation unit present. The investigation showed that there was corrosion damage on one of the bearings. This was probably due to water penetration and internal moisture having formed after the accident happened and until the motor was removed. There were thus some abnormal sounds when a test run was performed at 2000 rpm. No other faults or irregularities were discovered in the motor. When the motor was tested the first time no abnormal sounds was registered, but RPM was then substantially lower.

1.16.1.11 The power controller also showed signs of having been submerged in water. There were e.g. several corroded metal parts. The unit was examined and tested by EMSISO, who found the electronics to be intact and functioning according to the specifications.

1.17 Organizational and management information

1.17.1 <u>Flight operations and maintenance</u>

1.17.1.1 LN-ELA was owned and operated by the Norwegian Air Sports Federation (NLF), but was also sponsored by various aviation organizations, such as Avinor – the Norwegian airport operator and ATM/ANS provider. Flights were conducted in accordance with the provisions for non-commercial air operations. The pilots had a special type rating for electric aircraft.

1.17.1.2 LN-ELA was classified as maintenance category III in accordance with the provisions in “Regulations relating to maintenance of aircraft materials for non-commercial air transport (the Maintenance Regulations – Private), (BSL B 2-3)”. A NLF maintenance program had been prepared for the aircraft. This program was based on the Pipistrel Aircraft Maintenance Manual, AMM-167-00-60-001 Rev. B00.

1.17.1.3 A licensed aircraft technician associated with NLF CAMO had been approved by CAA Norway as maintenance manager. The maintenance manager completed a technical course at Pipistrel in Slovenia, together with another person who was to take part in the maintenance of LN-ELA.

1.17.2 <u>Flights with passengers</u>

1.17.2.1 LN-ELA had capacity to carry one person in addition to the pilot. There were no stipulations in the aviation regulations against operating LN-ELA with passengers on board, and such flights did, in fact, take place frequently.

1.17.2.2 Since the aircraft had a Special Airworthiness Certificate in the Experimental class, regulations required that both aircraft doors were externally marked with the word “Experimental”. In addition, the aircraft had a mandatory warning placard in front of the right seat.

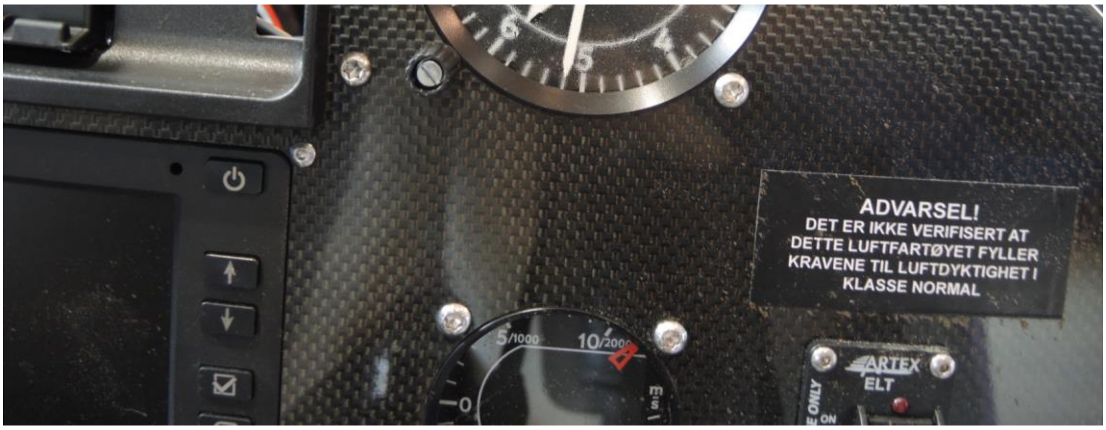


Figure 18: Passenger information placard on board LN-ELA. The text translates: "WARNING! It has not been verified that this aircraft complies with the normal class airworthiness requirements". Photo: NSIA

1.17.2.3 At the 2019 Norwegian Aviation Conference, NSIA addressed passengers' opportunity to make informed choices, before accepting the risk associated with taking a flight with aircraft that did not satisfy ordinary airworthiness requirements. NSIA questioned whether the above-mentioned markings and placards were sufficient.

1.17.2.4 Based on several accident investigations, NSIA has determined that this is an important topic to inform about. In the investigation report on the accident with LN-YSZ on 28 August 2018, a recommendation was issued about this (see NSIA Report SL 2020/06)[14]

1.17.2.5 In its report "Norske flysikkerhetsresultater 2019" (*2019 Annual Safety Review*) the Civil Aviation Authority Norway has published accident statistics for various types of non-commercial flights, including accident rates which make it possible to compare accident frequency rates for the aircraft categories that are included in the statistics.

1.17.2.6 The Civil Aviation Authority Norway has also defined "Passasjersikkerhet i ikke-kommersiell luftfart" (*Passenger safety in non-commercial aviation*) as a special safety issue:

> *The Civil Aviation Authority has addressed this safety issue with the purpose of ensuring that passengers in non-commercial aviation are sufficiently aware of the risk …*
>
> …
>
> *The Civil Aviation Authority has decided to incorporate requirements in the national legislation (rules for aircraft not comprised by EASA regulation) stating that passengers must be informed about the risk they are taking. We will also prepare guidelines for such information to the passengers, and we believe EASA should incorporate requirements for such information in their regulations. At year-end 2019, the Civil Aviation Authority established a work group. The group will propose solutions that will enable the authority to ensure that passengers can make informed choices when deciding whether to be a passenger on non-commercial flights. The work group will also look into what possibilities are embedded in regulations, safety communications and opportunities vis-a-vis EASA, also beyond what is described here.*

[14] NSIA Report SL 2020/06 is in Norwegian only.

1.17.2.7 On 23 September 2020, the Civil Aviation Authority submitted a proposal for new regulations relating to aviation operations involving aircraft used for private flights or air sports. The proposed regulations state e.g. that:

> *The commander must inform passengers about the main differences between the planned flight and commercial flights, including that the aircraft does not meet international requirements relating to technical standards. The information must sufficiently ensure that the passengers have a sound basis for considering whether they want to take the flight.*

1.18 Additional information

1.18.1 <u>Battery handling after accidents</u>

1.18.1.1 Lithium battery packs that have been exposed to external stress, represent a certain risk of fire. This does not necessarily happen instantly, but can might as well occur in connection with later handling. If they catch fire, they will burn with high intensity and discharge toxic gasses, and in addition be hard to extinguish. In the event of contact with water, hydrogen may sometimes be formed, representing an explosion hazard. Consequently, it is essential to handle batteries correctly.

1.18.1.2 Immediately after the LN-ELA accident, Pipistrel contacted NSIA about the batteries, providing handling and storage advice. As the battery boxes had been exposed to water penetration and possible impact damage, there was a perceived heightened risk of fire or explosion. The battery boxes were consequently stored safely outdoors. Before the battery boxes were removed from the aircraft, their internal temperature was measured by using an infrared sensor instrument to determine if the temperature was starting to rise.

1.18.1.3 No evidence of fire, or other serious condition, was detected on the battery boxes.

1.19 Useful or effective investigation techniques

No methods warranting special mention have been used in this investigation.

2. ANALYSIS

2.1 Introduction

2.1.1 This analysis is divided into four parts. In the first part, the motor failure, and how it could occur, will be discussed. After that, some aspects of the motor replacement will be discussed. Then, the commander's handling of the motor failure and how the emergency landing was performed will be reviewed. Finally, passenger flights, and the preparations that were made for demo flights in connection with Arendalsuka, will be discussed.

2.1.2 This investigation has been conducted in accordance with the NSIA Method, Framework and Analysis Process for Systematic Safety Investigations (the "NSIA method").

2.2 The motor failure

2.2.1 Summary of the investigation results

2.2.1.1 The probable cause of the LN-ELA motor failure was the power controller interrupting power to the motor. This is most likely to have been caused by overheating due to low fluid level and air in the cooling system.

2.2.1.2 As the investigation has not had access to electronic data, other reasons for the motor failure cannot be ruled out. A power controller sensor failure unrelated to local overheating, would for instance likely result in similar symptoms. However, there were no indications of sensor failure during the engine test run after the accident, or subsequent examinations of the power controller.

2.2.2 Power controller interrupting power

2.2.2.1 NSIA is of the opinion that the following indications support the theory of power controller interrupting power:

- The commander's statement that the power failure was total, and that it occurred without prior warning. The motor power was lost, and the EPSI 750 power controller temperature column changed color to red, displaying too high value.
- The commander's statement that the motor did not respond normally when he moved the throttle lever after the motor failure had occurred.
- Thorough examinations and testing, including a test run of the motor before it was removed, revealed no technical faults that could otherwise explain why the motor failed.
- Both Pipistrel and EMSISO have stated to NSIA that they considered power controller interrupting power to the motor to be the most likely cause of the loss of motor power.

2.2.2.2 Viewed from an aviation perspective, the power controller appears to be vulnerable considering its relatively low operating temperature limitation of 65°C, combined with the unit's tendency to suddenly cut off the power supply if entering failure mode. It seems as if protecting the electronics in the power controller takes priority over safe operation of the propulsion system. This does not appear to be in line with common aviation design philosophy.

On the other hand, as Pipistrel has pointed out to NSIA, overheat without power reduction could also result in an unsafe situation.

2.2.2.3 Admittedly, it may be that design criteria for reliability and redundancy are less stringent for aircraft like this. However, NSIA believes that there is nevertheless reason to question whether the reliability of the propulsion system in Pipistrel Alpha Electro is acceptable. Taking into account that LN-ELA was categorized as a EU Regulation (EC) 216/2008 Annex II aircraft, it is considered to be beyond the scope of this investigation to analyze this question further.

2.2.3 Local overheating

2.2.3.1 Despite the fact that more than a third of the coolant was missing, NSIA finds it most likely that this was a case of local overheating and not a total overheating of all the coolant. The LN-ELA motor power output was relatively low when the motor failure occurred, according to the commander. The aircraft was not climbing, and the ambient air temperature was not particularly high. If the circulation had been normal and the coolant had started to overheat, one would expect a more gradual temperature increase, which could have been read on the EPSI 570 before the motor stopped. Moreover, overheating is more likely to have taken place in connection with take-off or climb, when the power output was significantly higher.

2.2.3.2 NSIA has identified two scenarios which may explain the power controller overheating. Both are based on the fact that the lack of coolant caused significant amounts of air in the closed cooling system.

1. The cooling pump draws coolant up from a vertical supply hose. If sufficient air quantities form in front of the cooling pump inlet, there is a risk that the entire coolant circulation stops. If this happened, the stagnant coolant in the power controller's cooling chamber would quickly heat up and exceed the temperature limitation.

2. The cooling chamber in the power controller is vertical. If an air pocket had remained in a part of this chamber, one might imagine that the temperature could have become too high in one or more of the unit's four temperature sensors.

Without coming to a decision as to which of the two above scenarios might have occurred, or whether it was a combination of the two, NSIA finds that this is the most likely explanation why the power controller entered failure mode.

2.2.3.3 However, NSIA believes that the motor failure should be seen in relation to the motor failure that occurred three weeks earlier. In connection with the latter, coolant was discovered in the overflow bottle and its hose. This could be a result of overpressure in the cooling system, which often is associated with overheating. This in turn could give rise to suspicion about a possible lack of coolant. NSIA considers the fact that the fluid level in the expansion tank was not checked to be a lost opportunity to discover that more than a third of the coolant was missing.

2.2.4 Failure to perform pre-flight check of coolant

2.2.4.1 An impractical design made it cumbersome and time consuming to check the coolant level before each flight as required by the checklist. NSIA believes that this resulted in the development of an unfortunate practice where the coolant level was not checked regularly before each flight. NSIA believes it should be easier to check the coolant level, and makes a recommendation to Pipistrel in this regard (Safety recommendation Aviation no. 2021/01T).

2.2.4.2 At the same time, it should warrant serious consideration for all parties involved that the failure to perform such a check could have contributed to the low coolant level remaining undiscovered. In NSIA's opinion, this was a contributing factor to the aircraft motor failure.

2.2.4.3 Furthermore, when checks were performed, the focus seems to have been on the fluid level in the overflow bottle, not the expansion tank. This further reduced the opportunity to discover that the fluid level was too low. This also reveals insufficient detailed knowledge about the aircraft systems.

2.2.5 Cooling pump function

2.2.5.1 If the cooling pump did not work, it would also have stopped the coolant circulation, as described in item 1, section 2.2.3.2. The prescribed function check of Pipistrel SB-167-002 was to verify that the cooling pump was working before take-off. In connection with the investigation of LN-ELA, the cooling pump was function-tested without any defects being discovered. Afterward, it was dismantled and examined in detail, without any signs of malfunction. Consequently, NSIA does not find it likely that technical malfunction or failure of the cooling pump was a factor in this accident.

2.2.6 Motor restart

2.2.6.1 Given that the motor failure was a result of the power controller interrupting power to the motor, and there was not a case of massive overheating of the coolant, it might, in theory, have been possible to restart the motor. This can be done by first resetting the power controller, so that it starts supplying power to the motor again, and then restart the motor. The first step is to deenergize the system. The procedure is described in a section called *EPSI 570 Failure - Without power to the motor*. The above-mentioned procedure is described on page 6-4 *EPSI 570 Failure,* in Chapter 6 of the flight manual, *Emergency procedures.* The second step is to restart the motor. The checklist for this is available in Chapter 2 *Aircraft & Systems* on page 2-5 and in Chapter 7 *Normal Procedures* on page 7-6.

2.2.6.2 There is no single, complete, emergency procedure for resetting the power controller and restarting the motor in the section *Emergency Procedures,* which describes motor failure (6-2 *Motor failure*). NSIA believes that this is unfortunate, and that the flight manual is not very user-friendly when it comes to motor failure. Consequently, NSIA issues a safety recommendation to Pipistrel to update their flight manual and checklists in this regard (Safety recommendation Aviation no. 2021/02T).

2.2.6.3 Compared with the flight manual, the NLF checklist for motor restart is, in NSIA's opinion, more comprehensive and user-friendly. It contains step-by-step instructions on how to proceed to restart the motor after the power controller has been reset. As in the flight manual, the checklist for restart of the power controller is also called *EPSI 570 Failure - Without power to the motor.*

2.2.6.4 NLF has a note in the *Motor failure* checklist stating that the procedure for motor restart is the same as for resetting the system. NSIA believes, however, that it is not optimal with such an indirect reference to the checklist *EPSI 570 Failure - Without power to the motor*. Bearing in mind that a sudden motor failure is a stressful experience for most people, it would be better to have an unambiguous and literal name for the checklist in question. Then, a pilot in such a situation would not have to remember that there is a separate checklist for resetting the system, and would not have to try to figure out the name of that checklist.

2.3 The motor replacement

2.3.1 Reuse of the cooling system hoses may explain the presence of particles in the coolant. The hose nipples are aluminum, with external grooves to keep the hose better in place. The grooves have sharp edges, making it difficult to remove the hose without scraping off particles, which means they could end up on the inside of the hose. Particles may then also enter the cooling system if the hose is replaced without first cleaning the inside. There was a relatively small quantity of particles, and the NSIA has not found any evidence suggesting that the particles had negative impact on the coolant's qualities, nor on the coolant circulation.

2.3.2 Considering that it is a closed circuit cooling system, that no evidence of leakage was found, together with the explanations of the personnel replacing the motor, NSIA finds reason to conclude that an insufficient quantity of coolant was replenished in connection with the motor replacement, and that, consequently, there was a significant amount of air trapped in the system. They replenished the expansion tank until it was full, acting in good faith when they interpreted this as an indication that the system had been sufficiently replenished. NSIA finds that their unawareness of the necessity to run and ventilate the system repeatedly, can largely be ascribed to incomplete descriptions in the maintenance manual. It would also have been an advantage if the description of how to replenish the coolant had referred to the table of fluid quantities (see last part of section 1.6.7.2).

2.3.3 This investigation has revealed a need to improve the work descriptions in the maintenance manual, and NSIA has issued a safety recommendation to Pipistrel in this regard (Safety recommendation Aviation no. 2021/03T).

2.4 The emergency landing

2.4.1 When the motor failed, the commander of LN-ELA realized that they were flying at an altitude and a distance from the airport which meant that they would be unable to reach the runway. Nor were there any suitable spots for an emergency landing between the aircraft and the runway. Had they continued on course the aircraft would most likely have ended up in the trees.

2.4.2 The decision to turn back toward an area with several open spots in the vegetation, was a sound one, in NSIA's view. It shows that the pilot was composed and quickly adapted to the sudden emergency. It was also an advantage that the commander already had spotted some potential emergency landing sites en route.

2.4.3 Given that LN-ELA was 800 ft above the ground when the motor failed, there was not much time for troubleshooting and attempts to restart the motor. NSIA finds it unlikely that continuing the applied restarting procedure would have been successful.

2.4.4 In NSIA's opinion, it was also important not to spend too much time on trying to restart the motor, and instead focus on preparing an approach to the field that the commander had spotted earlier. This is also in line with the Pipistrel checklist in case of loss of motor power: *"Look for a spot to carry out a safe outlanding"*. Although it turned out later that the field was unsuitable, which is not always easy to see from the air when a decision has to be made, the commander nevertheless managed to perform a successful emergency landing.

2.4.5 NSIA finds that Gullknapp Information handled the emergency correctly, and no doubt contributed, by raising the alarm, to the speedy arrival of the emergency services on the scene. In terms of speedy notification, it was also an advantage that LN-ELA already had radio contact with the local air traffic control service when the emergency occurred. The ELT was automatically activated in the landing and its signal received, but it was of no significance for the rescue in this particular case.

2.4.6 The Ballistic Parachute Rescue System (BPRS) was another alternative that could have worked out well in the situation LN-ELA was in. NSIA has noticed that the flight manual does not contain information about minimum altitude for safe deployment of the rescue parachute, or other limitations. Such information can be important when a pilot in an emergency situation has to decide whether to deploy the rescue parachute. NSIA has issued a safety recommendation to Pipistrel about this (Safety recommendation Aviation no. 2021/04T).

2.5 Flights with passengers

2.5.1 Single-engine type-certified aircraft that satisfy the normal airworthiness requirements, are often colloquially referred to as light aircraft. However, so are microlight aircraft and homebuilt aircraft. Both latter category aircraft are subject to less stringent regulations and presumably have lower safety levels than type-certified aircraft, and probably different safety levels in between them. Occasional passengers cannot be expected to know about these differences, and thus they have very little basis for determining the risk they expose themselves to by flying.

2.5.2 It is NSIAs view that it should be up to anyone who wish to participate in different forms of non-commercial aviation to decide whether the risk is acceptable. However, it is important that this choice is based on sufficient knowledge about the risks involved. NSIA therefore approves of the Norwegian Civil Aviation Authority's initiative to contribute to passengers making more informed choices.

2.5.3 Even so, one question would be how thorough and reliable information it in reality is possible to provide. LN-ELA did not belong to any of the three aircraft categories mentioned in section 2.5.1. The aircraft type was not built in large enough numbers to provide sufficient basis to draw reliable conclusions about the safety level.

2.5.4 In addition, the technology was relatively new and unproven in aviation. The NSIA is of the opinion that there was not a very good basis for knowing how small or large the risk was, especially not for the passengers.

2.5.5 In view of this, the NSIA also question the adequacy of NLF’s support for determining the risk when they decided to offer passenger flights with LN-ELA. Not the least when taking into account the manufacturer’s distinct reservations considering the reliability of the propulsion system. See section 1.6.2.4 about the possibility of the motor stopping without prior notice, and section 1.6.6.4 about how it could be expected that the power controller would sooner or later cut power supply to the engine.

2.6 Flight preparations made to demonstrate the aircraft in connection with Arendalsuka

2.6.1 Considering the difficult terrain, and the fact that there were few places suitable for an emergency landing between the town and the airport, NSIA is of the opinion that it would be advantageous for the pilots, who conducted flights from Arendal Airport Gullknapp during the Arendalsuka with LN-ELA, to have pre-defined suitable emergency landing sites.

2.6.2 NSIA understands the desire to give the passengers as good a view as possible and the opportunity to spot details on the ground. These details are best spotted if the flying altitude was not too high. At the same time, a higher altitude would give pilots more time to consider what to do in an emergency, and a wider range to reach suitable emergency landing sites.

2.6.3 The NSIA commends the commander’s routine of briefing the passengers about the rescue parachute and its use.

3. CONCLUSIONS

3.1 Main findings

3.1.1 The likely cause of the LN-ELA motor failure was the power controller interrupting power to the motor. The reason for this was most likely overheating due to low fluid level and air pockets in the cooling system.

3.1.2 NSIA's investigation have revealed that the technicians most probably did not replenish enough coolant in connection with motor replacement in Norway. Insufficient descriptions in the procedure for topping up coolant in the manufacturer's maintenance manual contributed to this.

3.2 Investigation results

3.2.1 <u>The aircraft</u>

a) LN-ELA had valid registration- and airworthiness documents.

b) LN-ELA had a Norwegian Special Certificate of Airworthiness and had the airworthiness classification *“Experimental”*.

c) The doors on both sides were marked “Experimental”, and in front of the right seat there was a warning placard stating that it was not verified that the aircraft complied with airworthiness requirements in the normal class.

d) According to the manufacturer's flight manual, the coolant level should be checked prior to each flight. However, this was complicated and time-consuming because the cowling had to be unscrewed.

e) An unfortunate practice had developed where the coolant level was not checked regularly before each flight.

f) When checks were performed, the focus seems to have been on the fluid level in the overflow bottle, rather than in the expansion tank.

g) A motor failure three weeks prior the accident flight was a lost opportunity to discover that more than a third of the coolant was missing.

h) The accident flight with LN-ELA was flight number 45 after the motor replacement, where the lack of coolant had remained undiscovered.

i) The ballistic parachute may present an important safety barrier in an emergency, such as motor failure. The flight manual did not contain any information about minimum altitude for safe deployment, or other limitations.

3.2.2 Flight operations factors

a) The relatively low altitude above the terrain at the time of the motor failure, gave the pilot little time for troubleshooting, and for trying to restart the motor.

b) The manufacturer's flight manual lacked a complete and easily identifiable checklist for restoring motor power in situations like these.

c) The NLF emergency checklist contained a procedure for restarting the motor in the event of motor failure, but the initial steps of the procedure were missing.

d) The commander chose a field and started his approach toward it, but when the aircraft reached a lower altitude, the field turned out to be unsuitable.

e) A successful emergency landing was performed on a small lake at one end of the field.

3.2.3 Flights with passengers

a) LN-ELA was primarily used for demo flights with a passenger to promote electric aircraft in Norway.

b) There were no stipulations in the aviation regulations against operating LN-ELA with passengers on board.

c) The Civil Aviation Authority Norway has established a working group, that will propose solutions so that the authority can ensure that passengers are able to make informed choices when deciding whether to be a passenger on non-commercial flights.

d) In the autumn of 2020, the Civil Aviation Authority Norway proposed a new flight operations regulation for non-commercial operations or air sports. One of the proposed rules is that all pilots will be obliged to give passengers sufficient information to enable them to decide whether or not to participate in the flight.

4. SAFETY RECOMMENDATIONS

The Norwegian Safety Investigation Authority has issued the following safety recommendations [15]:

Safety recommendation Aviation no. 2021/01T

On Wednesday 14 August 2019, a Pipistrel Alpha Electro suffered motor failure during its approach to Arendal Airport Gullknapp (ENGK). The probable cause of the motor failure was the power controller interrupting power to the motor. The reason for this was most likely overheating due to low fluid level and air pockets in the cooling system.

According to the flight manual, the coolant level should be checked prior to each flight. However, this is not possible without removing the top cowling. The investigation has

[15] The Ministry of Transport forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Section 8 of Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation.

shown that this is so impractical and time-consuming that pilots often chose not to perform this item on the checklist.

The Norwegian Safety Investigation Authority recommends that Pipistrel modifies the Alpha Electro model to make it easier to check the coolant level.

Safety recommendation Aviation no. 2021/02T

On Wednesday 14 August 2019, a Pipistrel Alpha Electro experienced motor failure during its approach to Arendal Airport Gullknapp (ENGK). The probable cause of the motor failure was the power controller interrupting power to the motor.

The investigation has shown that there was no complete and easily identifiable checklist for regaining motor power in situations like these. The relevant checklists are on different pages of the flight manual, and do not have unambiguous headings.

The Norwegian Safety Investigation Authority recommends that Pipistrel prepares a complete and easily recognizable checklist for regaining motor power should the aircraft's power controller cut power to the motor. This work should include an overall review of the flight manual to make it more unambiguous and easier to read in an emergency.

Safety recommendation Aviation no. 2021/03T

On Wednesday 14 August 2019, a Pipistrel Alpha Electro experienced motor failure during its approach to Arendal Airport Gullknapp (ENGK). The probable cause of the motor failure was the power controller interrupting power to the motor. The reason for this was most likely overheating due to low fluid level and air pockets in the cooling system.

In connection with a motor replacement, coolant was not optimally replenished. The procedure for this is not described in the maintenance manual. An insufficient amount of coolant was therefore replenished, and air was trapped in the system.

The Norwegian Safety Investigation Authority recommends that Pipistrel review the Aircraft Maintenance Manual with a view to improve the work description for replenishing coolant. The work description should also contain a cross-reference to the table for fluid quantity, which is in another section of the manual.

Safety recommendation Aviation no. 2021/04T

On Wednesday 14 August 2019, a Pipistrel Alpha Electro experienced motor failure during its approach to Arendal Airport Gullknapp (ENGK). The commander performed a successful emergency landing.

When the motor failure occurred, use of the ballistic rescue parachute was an alternative. The flight manual does not contain information about the minimum altitude for safe deployment of such a rescue parachute. Such information can be important when a pilot in an emergency situation has to decide whether to deploy the rescue parachute or not.

The Norwegian Safety Investigation Authority recommends that Pipistrel adds information about minimum altitude for safe deployment of the rescue parachute to its flight manual.

Norwegian Safety Investigation Authority

Lillestrøm, 15 March 2021

REFERENCES

EMSISO d.o.o. “emDriveH300A, s/n 300A5017005”, report dated 11 November 2019

The Norwegian Armed Forces’ chemistry and material technology laboratory service, FOLAT Chemistry and Material “Undersøkelser av kjølevæske fra el-fly” *(“Examination of coolant in electric aircraft”*), report no. 200309-03 dated 14 April 2020

Dutch Safety Board “Fatal loss of control accident with a Pipistrel Alpha Electro near Stadskanaal airfield”, report dated July 2020

APPENDICES

Appendix A – Abbreviations

Appendix B – Annex II to EU Regulation (EC) 216/2008

APPENDIX A – ABBREVIATIONS

AFIS	Aerodrome Flight Information Service
ASTM	ASTM International – standardization organization, formerly the American Society for Testing and Materials
BATT EN	Battery Enable Switch
BPRS	Ballistic Parachute Rescue System
BSL	"Bestemmelser for sivil luftfart" – Norwegian aviation regulations
CAMO	Continuing Airworthiness Management Organization
CS	Certification Specifications
CTR	Controller
dl	Deciliter
EASA	European Union Aviation Safety Agency
ENGK	Arendal Airport Gullknapp
EMRAX	Slovenian manufacturer of electric motors
EMSISO	Slovenian company for development and manufacture of electronic products, including power controllers for battery-operated electric motors.
EPSI 570	Electronic instrument for monitoring various operative motor parameters in Pipistrel Alpha Electro
FLARM	Flight Alarm
GPS	Global Positioning System
hp	Horsepower
hPa	Hectopascal
IGBT	Insulated-gate bipolar transistor
kW	Kilowatt
kWh	Kilowatt hour
LSA	Light Sport Aeroplanes
METAR	Meteorological Terminal Air Report
NLF	Norwegian Air Sports Federation
PtF	Permit to Fly

PWR	Power
PWR EN	Power Enable Switch
RPM	Revolutions per minute
SB	Service Bulletin
UTC	Universal Time Coordinated (formerly known as Greenwich Mean Time – GMT)
V	Volt

APPENDIX B – ANNEX II TO EU REGULATION (EC) 216/2008

Aircraft referred to in Article 4(4)

Article 4(1), (2) and (3) do not apply to aircraft falling in one or more of the categories set out below:

(a) historic aircraft meeting the criteria below:

(i) non-complex aircraft whose:

— initial design was established before 1 January 1955, and

— production has been stopped before 1 January 1975;

or

(ii) aircraft having a clear historical relevance, related to:

— a participation in a noteworthy historical event, or

— a major step in the development of aviation, or

— a major role played into the armed forces of a Member State;

(b) aircraft specifically designed or modified for research, experimental or scientific purposes, and likely to be produced in very limited numbers;

(c) aircraft of which at least 51 % is built by an amateur, or a non-profit making association of amateurs, for their own purposes and without any commercial objective;

(d) aircraft that have been in the service of military forces, unless the aircraft is of a type for which a design standard has been adopted by the Agency;

(e) aeroplanes, helicopters and powered parachutes having no more than two seats, a maximum take-off mass (MTOM), as recorded by the Member States, of no more than:

(i) 300 kg for a land plane/helicopter, single-seater; or

(ii) 450 kg for a land plane/helicopter, two-seater; or

(iii) 330 kg for an amphibian or floatplane/helicopter single-seater; or

(iv) 495 kg for an amphibian or floatplane/helicopter two-seater, provided that, where operating both as a floatplane/helicopter and as a land plane/helicopter, it falls below both MTOM limits, as appropriate;

(v) 472,5 kg for a land plane, two-seater equipped with an airframe mounted total recovery parachute system;

(vi) 315 kg for a land plane single-seater equipped with an airframe mounted total recovery parachute system;

and, for aeroplanes, having the stall speed or the minimum steady flight speed in landing configuration not exceeding 35 knots calibrated air speed (CAS);

(f) single and two-seater gyroplanes with a maximum take off mass not exceeding 560 kg;

(g) gliders with a maximum empty mass, of no more than 80 kg when single-seater or 100 kg when two-seater, including those which are foot launched;

(h) replicas of aircraft meeting the criteria of (a) or (d) above, for which the structural design is similar to the original aircraft;

(i) unmanned aircraft with an operating mass of no more than 150 kg;

(j) any other aircraft which has a maximum empty mass, including fuel, of no more than 70 kg.