



IN-FLIGHT SMOKE INCIDENT – INTRODUCTION, DISCLAIMER, and ACKNOWLEDGEMENT

INTRODUCTION:

On Feb. 8, 2017, an RV-8A experimental aircraft experienced smoke in the cockpit; in-flight. The following VAF posts describe this smoke incident in three parts: Incident, Technical, and Probable Cause with Recommendations. This incident report is being written in the spirit of promoting experimental aircraft safety. Specifically, the pilot/owner of the RV-8A wishes to share his experience with the experimental aircraft community so that we can all learn some valuable safety lessons and improve flight safety. Also, this incident report supports, expands, and supplements a recent VAF thread entitled “Overvoltage required for EarthX battery” initiated by “EarthX Lithium” (Kathy Nicoson) referring to this incident.

The authors, including the pilot, have done their best to write this report as accurately as possible, but we have the following disclaimer:

DISCLAIMER:

This report has not been written or compiled by professional accident/incident investigators and has not been reviewed, checked, endorsed, or recognized by any government agency (FAA, NTSB, etc.). This report is simply an attempt to state facts as accurately as possible in relation to this incident. The data, conclusions, and opinions offered in this report are solely those of the authors alone and should not be regarded as comprehensive, definitive, or precisely accurate.

This report is for consideration by the experimental aircraft community as they design, build, and fly their experimental aircraft. The authors are not responsible for any report omissions or inaccuracies or actions taken as a result of this report. Actions, if taken, are the individual responsibility of each individual reader who must determine his or her own conclusions and risk decisions. In other words, any liability is the reader’s alone; not the authors’.

ACKNOWLEDGEMENT:

The authors gratefully acknowledge the cooperation of EarthX, Inc. (including Kathy Nicoson, Global Sales Director and Reg Nicoson, Chief Technology Officer) in the development of this report. EarthX provided us with battery inspection results, data analysis, and technical data which greatly helped us understand what occurred during this incident. We must emphasize how fortunate the experimental aircraft community is to have a great company such as EarthX supporting us, communicating with us, educating us, and supplying us with the latest in battery technology . . . THANKS, EarthX.

Vans AF Web Page String November 2, 2017

PLEASE NOTE: It is not the intention of the authors, including the incident pilot, to respond to questions, corrections, opinions, or suggestions about this incident or provide additional information. What you read here is all we have to offer for your consideration. Please review this incident report in the spirit of experimental aircraft safety and draw your own individual conclusions. THANK YOU.

Bill Palmer
Chino Hills, CA

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#2

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Bill Palmer Bill Palmer is offline

Join Date: Apr 2006

Location: Chino Hills, CA

Posts: 385

Default IN-FLIGHT SMOKE – THE INCIDENT

INCIDENT REPORT:

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On February 8, 2017, the incident aircraft (an RV-8A purchased by the pilot from its original builder), departed Sedona Airport (KSEZ) on a return flight to Phoenix Deer Valley Airport (KDVT) with two pilots on board. Total time on the aircraft/engine was 880 hours since new. The pilot had owned the RV-8A for over 6 years and flown the aircraft over 320 hours without incident.

At the time of this incident, the aircraft had flown a total 6 flights and 2.7 hours since undergoing an instrument panel upgrade. A Dynon Skyview HDX system was installed in place of the standard "Six Pack" of instruments and Van's standard engine gauges. In addition to the Dynon HDX system, to save weight, an EarthX ETX-680 Lithium-Iron-Phosphate (LiFePO₄), battery was installed in place of the standard lead-acid battery. Both pilot (front cockpit) and copilot (rear cockpit) were experienced, current ATP pilots.

Approximately 16 minutes after takeoff, while accomplishing an in-flight compass calibration test, consisting of 360-degree turns at 7,500' MSL (3,000' AGL), both pilots noted a brief acrid smell (for about 2 seconds). Engine/electrical indications were reviewed, and no anomalies were noted. Specifically, volt and amp readings were observed to be within the normal range – 14.3 volts and 14 amps.

Approximately 18 minutes after takeoff a climb was initiated from 7500' to 9500' MSL along with a turn to the southwest toward less challenging terrain; just in case an emergency landing was required.

Approximately 1 minute later (19 minutes after takeoff), the voltage and amperage indications started to increase rapidly and fluctuate (voltage fluctuated between 19 and 25 volts, and amperage fluctuated between 40 and 44 amps). In addition, the electrically-powered fuel quantity indicator failed. Because the pilot thought he was experiencing a component electrical problem behind the panel, all electrical component switches were turned off; however, the Alternator/Battery Master Switch was inadvertently left on. The pilot acknowledges that he should have confirmed that the master switch was turned off when he first observed the high voltage and amperage fluctuations, however, he was focused on a "behind-the-panel" component failure; not an aircraft electrical power system failure. (Note: the alternator's main 35-amp breaker had not tripped).

Approximately 4 minutes later, while maneuvering the aircraft to an area where an off-field landing could be attempted, a strong "solvent type" odor was detected, and an immediate descent was initiated. Several seconds after initiating the descent, smoke entered the cockpit from behind and below the instrument panel. The source of the smoke confirmed to the pilot that he probably did have a behind-the-panel component failure. With the appearance of the smoke, a high-speed emergency descent was initiated via a Split-S maneuver. The copilot suggested opening the canopy, however, lacking any knowledge as to the ability to maintain structural integrity of the aircraft when opening the canopy in flight, the pilot initially elected not to open it. As the smoke intensified, visibility in the front cockpit was reduced to near zero, and it became very difficult for the pilot to breathe. The copilot in the rear cockpit had better, but limited, visibility and some fresh air from the rear air-vent sourced from the underside of the right wing. Having no other option, the pilot transferred aircraft control to the copilot, and the decision was made to open the canopy.

The pilot then attempted to open the canopy with one hand, but was initially unsuccessful. The canopy would not easily open as it normally does during ground operations. Using both hands on the canopy handle and much greater force than normal, the canopy slid aft approximately two feet. As fresh air flowed around the windshield, most of the smoke vented out of the cockpit via the canopy bottom skirt.

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Although smoke was still entering the lower portion of the cockpit, the pilot had recovered visibility and the ability to breathe. The pilot did not detect any heat or fire, and the copilot found that he could easily hold the canopy in the partially open position. Therefore, aircraft control was transferred back to the pilot while the copilot held the canopy to prevent it from sliding to the rear stop.

The pilot originally intended to land on a nearby stretch of interstate highway located approximately 5 miles ahead; however, the copilot observed a street pattern at 3 o'clock and less than a mile. The pilot circled to slow, and successfully landed on an uphill residential street, without any related damage to the RV-8A. The airplane was stopped, and the engine was shut-down approximately 27 minutes after takeoff and 3-to-4 minutes after the emergency descent was initiated. The descent covered approximately 5500 feet, and the descent rate averaged approximately 1600 feet per minute with peak descent in the neighborhood of 3000 feet per minute. TAS (true airspeed) during the emergency decent was recorded as high as 194 knots; with the canopy open.

After landing, smoke continued to enter the cockpit from behind the instrument panel. Halon was discharged underneath the panel, and the crew exited the aircraft. The forward baggage compartment was opened, the instrument (rear-access) panel was removed, and halon applied to the back of the instrument panel. At this point it was discovered that the source of the smoke was from the battery compartment located directly below the front baggage compartment, on the right side of the aircraft. This area was repurposed by the original builder as a battery compartment, complete with an access panel on top. The battery compartment access panel was removed, and the remaining halon applied directly to the battery. After the halon bottle was depleted, dirt from the roadside was used to completely extinguish the smoldering battery.

Note: No radio transmissions were made during this incident, since the radios were turned off to protect them.

The pilot was treated for smoke inhalation at a local hospital and has fully recovered. The pilot did not suffer from any burns or additional physical harm. The copilot did not suffer any physical harm. The FAA and NTSB were notified and classified this mishap as an unreported "incident", since there were no serious injuries or structural damage to this experimental aircraft. The RV-8A was dismantled and transported to a repair facility. Subsequently, the RV-8A has successfully returned to flight with no further problems.

Bill Palmer
Chino Hills, CA

Last edited by Bill Palmer : 10-18-2017 at 02:13 AM.
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#3

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Bill Palmer Bill Palmer is offline

Join Date: Apr 2006

Location: Chino Hills, CA

Posts: 385

Default IN-FLIGHT SMOKE – TECHNICAL

TECHNICAL REPORT:

The battery involved was an EarthX Model ETX-680 Lithium-Iron-Phosphate aviation battery with a dual-redundant Battery Management System (BMS). The EarthX battery was the aircraft's sole main battery. The EarthX battery was hard-mounted in the RV-8A's lower forward baggage compartment in place of a Concorde lead-acid aircraft battery; in the same location.

There is no record or evidence of an EarthX battery physical installation problem; however, EarthX's installation manual says: "Installation of the battery in the cockpit is not recommended, unless the battery is properly vented over-board." Technically, the battery was not mounted in the cockpit, but it was mounted in an enclosed compartment internal to the fuselage, aft of the firewall, and adjacent to the pilot's right foot and leg. The battery compartment had a top cover, but unfortunately did not include an overboard vent.

The EarthX battery's remote, discreet warning output (LED panel light or EFIS input) was not installed as recommended by EarthX. Since this installation seemed to be optional, the pilot/owner delayed the installation in favor of testing his new Dynon HDX system. The Dynon Skyview HDX EFIS was equipped with its own internal backup battery plus an advanced aircraft/engine instrumentation system which continued to record all flight, engine, and electrical data from takeoff until landing.

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The highest recorded peak voltage was 29.1 volts although it is very likely that the voltage greatly exceeded 30 volts as there was a two-second voltage data drop-out at that time. There was also an initial, half-second voltage data drop-out about 4 minutes earlier as the recorded voltage increased above 20 volts and fluctuated. The highest recorded peak amperage was 44.8 amps. The Dynon data shows that a simultaneous, average voltage / amperage level of 21 volts / 42 amps (approximately 880 watts) was applied to the aircraft electrical bus (and EarthX battery) for a total of approximately 5 minutes although all other components connected to the bus were switched off (disconnected from the aircraft electrical bus) as soon as the fluctuating excessive voltage (19 to 25 volts) and high amperage (40 to 45 amps) readings were initially observed. The master was left on, because the pilot was focused on a panel component failure; not an aircraft electrical power system failure.

Unfortunately, the aircraft had no automatic overvoltage protection circuit as “strongly recommended” by EarthX's installation manual (at the time of installation). When the RV-8A was purchased, the new pilot/owner was unaware that the aircraft was equipped with an automotive alternator/regulator with no overvoltage protection. Also, lacking a detailed aircraft electrical system schematic, the pilot/owner was unaware that the aircraft electrical system had no inherent, built-in overvoltage protection. Also, the installation of overvoltage protection seemed to be optional at the time (“strongly recommended”), so the pilot/owner did not inspect the alternator/regulator and aircraft electrical system to see if overvoltage protection was installed.

After the incident, the automobile-style alternator, a 35-amp-rated Bosch AL204X with integrated regulator/rectifier, was removed for bench testing and found to be non-functional. There was no output from the alternator. The Dynon data shows the alternator output starting to drop at 24 minutes after takeoff and the alternator output failing completely 1 minute later (2 minutes before landing). Please note that this bench test was only a functional test. There was no additional testing or detailed failure analysis to pinpoint the cause of alternator (regulator) failure. Also, there was no attempt to duplicate the high voltage and amperage recorded in-flight. The alternator was simply “dead.”

The alternator output breaker was rated at 35 amps, but did not trip during the incident despite the Dynon-recorded high voltage (21+) and amperage (42+) levels. The breaker was tested after the incident and tripped at less than 36 amps with 14.3 volts. After developing an aircraft electrical system schematic and reviewing it (including the Dynon shunt location in the alternator output between the alternator and the 35-amp breaker), the authors have no definitive explanation relative to why the breaker did not automatically trip in-flight and thus save the battery. There are several possible answers, but there is no information clearly pointing to one answer. The authors have decided not to pursue a more detailed analysis.

The damaged EarthX battery and the Dynon instrumentation data were sent to EarthX for analysis. Also, the authors subsequently communicated with EarthX to determine what EarthX discovered about the battery and the incident. Based on the Dynon data and inspection/analysis of the battery, EarthX concluded:

The battery was forced into thermal runaway for two reasons:

- (1) The alternator/regulator failed resulting in the application of sustained, excessive voltage and current to the battery which was above the rated limits of protection for the battery's Battery Management System (BMS). Battery inspection clearly showed physical evidence of extremely high voltage being applied to the battery which was above the rated limits of the BMS.

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Authors' Note: According to the Dynon data, the power applied to the battery was sustained at about 880 watts; peaking at well over a kilowatt (1,240 watts).

(2) The pilot/owner should have shut-off the master switch as soon as the fluctuating, excessive voltages and amperages were observed.

To quote EarthX:

"The aircraft voltage regulator failed and the battery was subjected to voltage greater than 20V charging with high amps for more than 7 minutes which caused the cells to reach thermal run-away. At a couple of points, the voltage spiked so high that the Dynon didn't record. Based on feedback from Dynon technical group, the voltage must have been above 30V. Our Battery management system indicated that the voltage exceeded 70V."

"An over-voltage protection circuit in the alternator regulator would have shut-down the alternator within 100ms in the event the voltage exceeded 16V, but this equipment was not installed on your aircraft."

Authors' Note: THE EARTHX BATTERY DID NOT CATCH FIRE. Although the battery over-heated in thermal runaway, the heat given off during thermal runaway event was not sufficient enough to burn the pilot's leg or foot through the thin aluminum battery compartment wall. The pilot does not recall detecting excessive heat from the battery compartment. The main effect of the thermal runaway event was the eventual emission of smoke as the battery overheated. The smoke was emitted through wiring grommets in the battery compartment wall as well as small gaps at the edges of the battery compartment. Smoke emission would be expected from any battery, lithium or lead-acid, experiencing a thermal runaway event.

Bill Palmer
Chino Hills, CA

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Old 10-18-2017, 02:01 AM

Bill Palmer Bill Palmer is offline

Join Date: Apr 2006

Location: Chino Hills, CA

Posts: 385

Default IN-FLIGHT SMOKE – PROBABLE CAUSE WITH RECOMMENDATIONS

PROBABLE CAUSE WITH RECOMMENDATIONS

NOTE: This PROBABLE CAUSE is SPECULATION . . . a definitive cause of this incident based on detailed technical analysis is UNKNOWN.

PROBABLE CAUSE (Automotive Alternator Regulator Failure):

The most likely probable cause of this in-flight smoke incident is alternator voltage regulator failure and the resultant direct application of extreme overvoltage and excessive amperage to the EarthX battery which was above the highest levels of the stated, rated design of the Battery Management System (BMS) protection and, thus, the battery was forced into thermal runaway; heating up and eventually emitting smoke as it failed.

RECOMMENDATIONS (CORRECTIVE ACTIONS):

1. Install an overvoltage protection system for each aircraft alternator, generator, or dynamo. The authors note that EarthX has amended their operation and installation manual to “require” overvoltage protection circuitry for alternators exceeding 20 amps of output. The authors agree that overvoltage protection is required.
2. Install the battery’s discreet warning output to either a panel LED or to an EFIS as shown in EarthX’s manual. This installation should also be viewed as required.
3. Install cockpit and/or battery ventilation to expel smoke overboard. The EarthX manual states: “Installation of the battery in the cockpit is not recommended, unless the battery is properly vented over-board.” Installation of overboard ventilation should be viewed as required.

4. Each EarthX battery and its integrated BMS are extensively tested at the factory before shipment, but field-testing of BMS functionality is not recommended. The authors' understanding from EarthX is that the BMS' overvoltage protection and charging current inhibiting features cannot be successfully field-tested without risking some residual damage to the battery. Thus, installation of overvoltage protection circuitry and the discreet warning output (LED or EFIS) is very important in lieu of being able to safely field-test and measure BMS functionality.

5. If it can be done safely, the aircraft's overvoltage protection system(s) should be tested after initial installation in the aircraft and then periodically. A sustained overvoltage beyond 16 volts should cause the overvoltage protection system to disconnect the source (alternator) from the aircraft electrical system and battery(s).

6. To protect against smoke emission in the cockpit, fire detection and suppression equipment should be installed if a battery (lithium or lead-acid) is mounted aft of the firewall. This equipment should be readily visible and accessible. For enclosed units like a battery, an injection port would be needed to apply the retardant. From the standpoint of a battery thermal runaway event, the application of fire retardant is most important for the prevention of smoke emission.

7. **IMPORTANT:** For Non-Builders Purchasing Experimental Aircraft: Make absolutely sure that you have a detailed, current schematic of the aircraft's electrical system. Carefully analyze the schematic and understand what it means in terms of aircraft electrical system operation, design, redundancy, and safety. Physically inspect the aircraft's alternator/generating system(s) and aircraft electrical system to confirm that overvoltage protection is installed. Also, if the battery manufacturer supplies a discreet warning output as EarthX does, definitely install it prior to any flight operations.

In summary, it is important to realize that if you purchase an experimental aircraft built or modified by someone else, you effectively become the aircraft's engineer and design decision maker; not just its pilot, owner, and maintainer. Buying an experimental aircraft is not like buying an FAA-certified aircraft whose design/build is formally reviewed, tested, and controlled. For an experimental aircraft, you must make sure that the aircraft's systems are acceptable to you based on your own design, cost, and flight risk decisions; not the builder's or modifier's. If you do not feel confident in your ability to properly assess an experimental aircraft's design, definitely find a respected, experienced aircraft builder to help you determine the aircraft's design, build condition, and relative level of safety. **DO NOT TAKE ANYTHING FOR GRANTED** or fail to analyze the aircraft's build quality and systems from a safety standpoint! In other words:

FLY KNOWLEDGEABLE AND FLY SAFE!

Bill Palmer
Chino Hills, CA