The National FAA Safety Team Presents

Topic of the Month
September, 2024

GA Aircraft Exhaust Systems

Presented to: AOPA Flying Clubs
By: Your Club Safety Officer
Date: Your Club's Monthly Safety Meeting

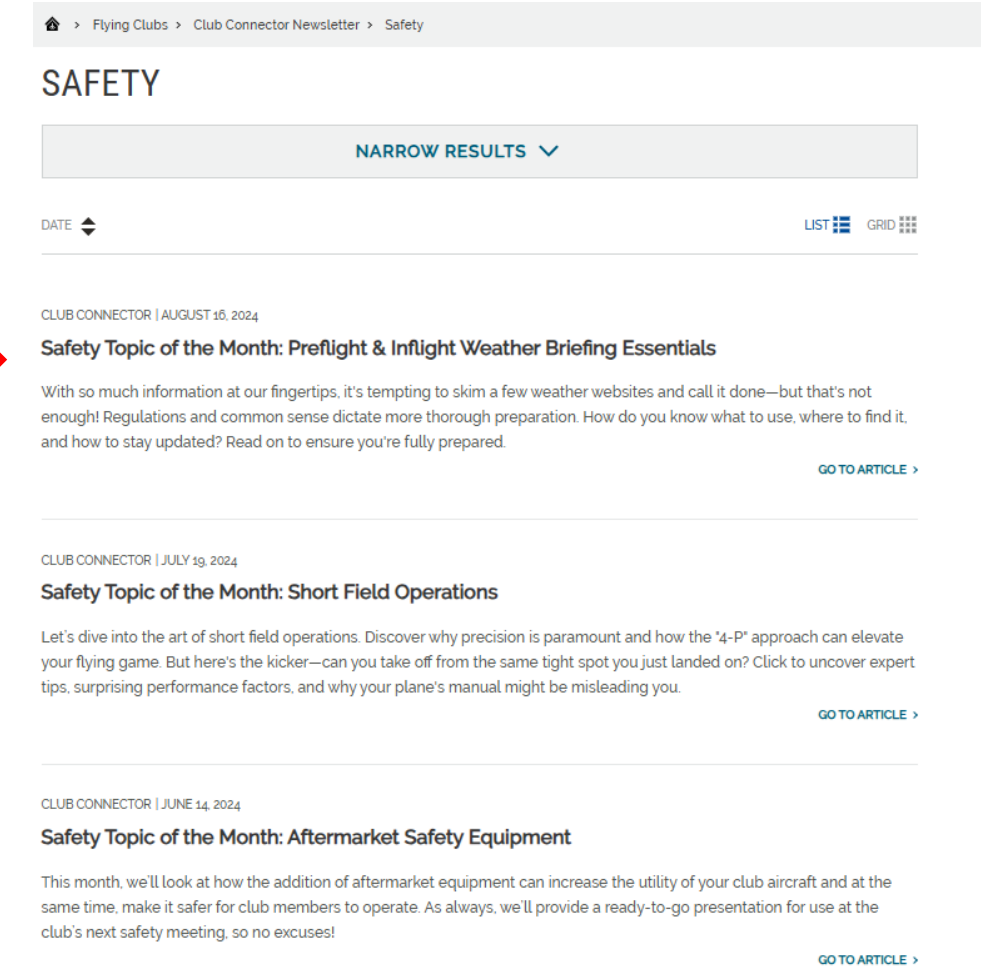
Produced by:
The National FAA Safety Team (FAASTeam)

Federal Aviation Administration

PDF Of These Slides Available For Your Further Study and Use

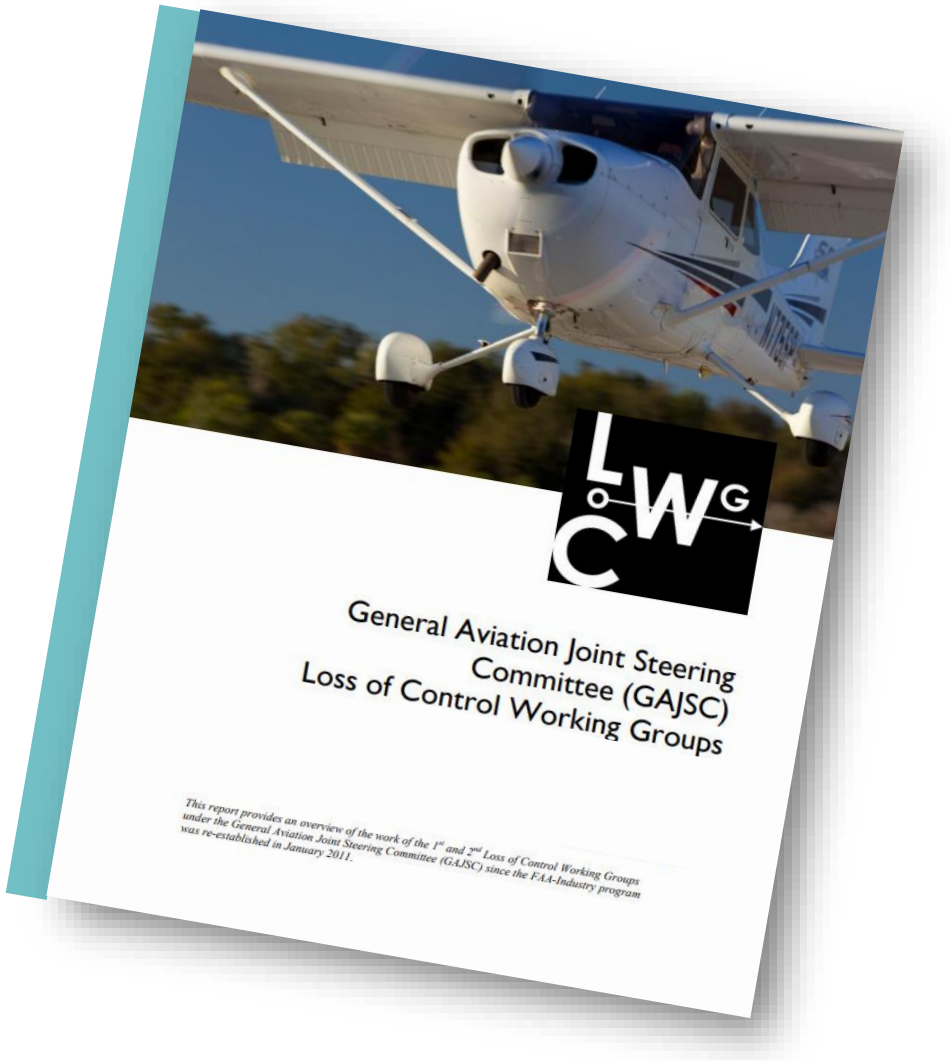
- **Slides post on the third Sunday of every month**
  https://bit.ly/ToMSafetyArticle

- **Or search for "AOPA Flying Clubs"**
  - Click on "Club Connector Newsletter"
  - Thanks to the AOPA Flying Clubs Initiative



Overview

- Types of exhaust systems
- Mufflers and heat exchangers
- Repairs and replacements
- Joint types V-band
  Flanges and gaskets
- Accident cases



Compendium of information from:
Stephen Bateman, Lead Representative
FAASTeam Topic of the Month/Quarter
Garry Mitcham, FAA *WINGS* SW17131756 "Aircraft Exhaust System Defects Can Lead to Accidents"

*** General Aviation Joint Safety Committee**

Q. What Am I…?

Cold…noxious gasses…hot…

Cold…noxious gasses…hot…
Cold…noxious gasses…hot…
Cold…noxious gasses…hot…
Cold…noxious gasses…hot…
Cold…noxious gasses…hot…
Cold…noxious gasses…hot…
Cold…noxious gasses…hot…
Cold…noxious gasses…hot…
Cold…noxious gasses…hot…

A. An engine exhaust system!

History

- **There have been many exhaust system failures that resulted in accidents, often fatal**
- **Some have prompted Airworthiness Directives as well as manufacturers' Service Bulletins**
- **Ignore SB's at your own peril**

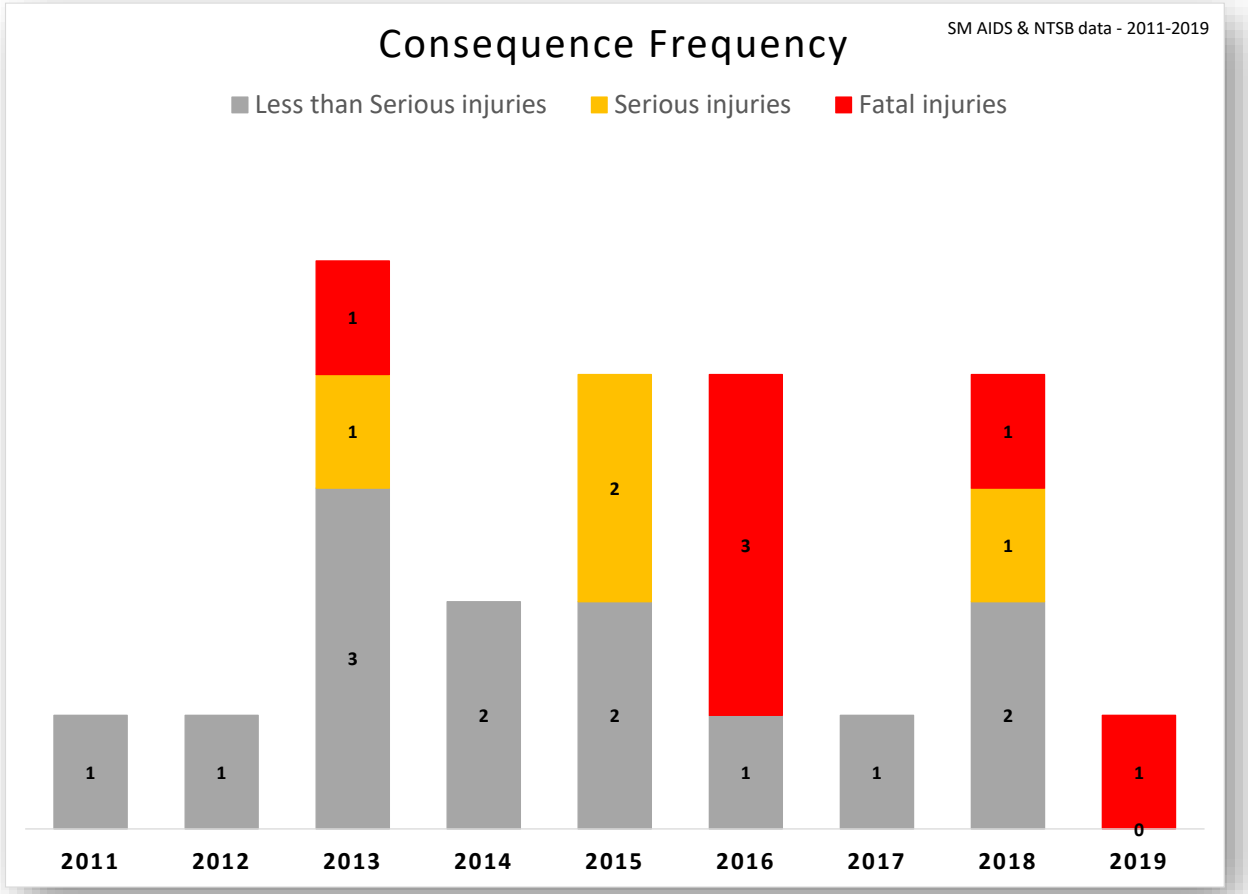
NTSB probable cause: The fatigue failure of the turbocharger exhaust band clamp.

The Problem in Numbers

2011 – 2019

23 accidents / incidents* involving GA exhaust system failures

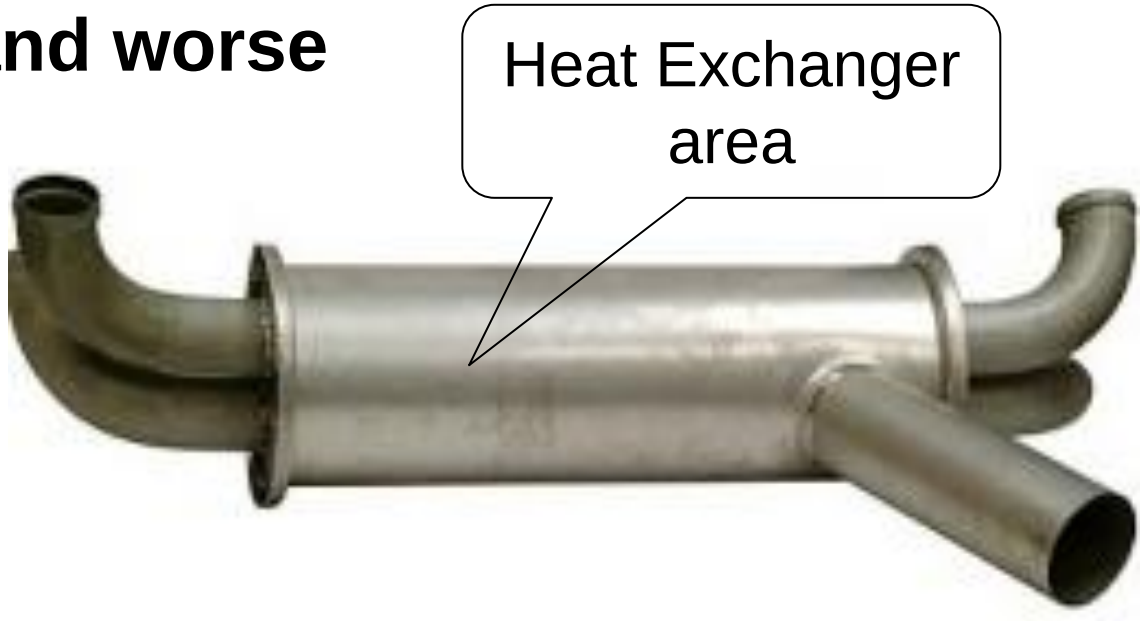
- Various aircraft models
- Various engine types
- High injury/fatality rate



* source: FAA AIDS / NTSB records

Muffler and Heat Exchangers Failures

- **Failures in the heat exchanger surface allow exhaust gases to escape directly into the cabin heat system**
- **CO poisoning: Befuddlement and worse**
- **Solution:**
  - Regular inspections
  - Replace rather than repair
  - Use a CO detector

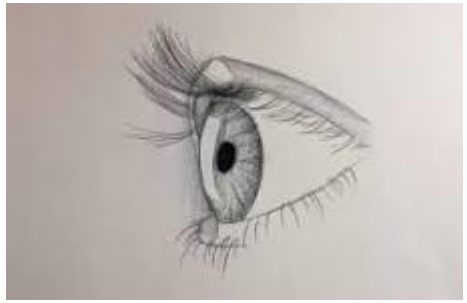


CO Detectors

- **Only useful if:**
  - In sight
  - Turned on (battery condition)
  - Valid (Dot detectors)
- **Built-in CO detector in some ADS-B IN receivers**

Inspection Tools:

- **Eyeballs**
- **Inspection mirror**
- **Borescope**
- **Flashlight**



Inspect Regularly

- **Not just during the annual**
- **Every time the cowls are off!**

Simple Pressure Test!

- Some testing can be done with a vacuum.
- AC 91-59A has information about performing this inspection.

- Use the “blow” side of the shop vac
- Use soapy water to check for leaks

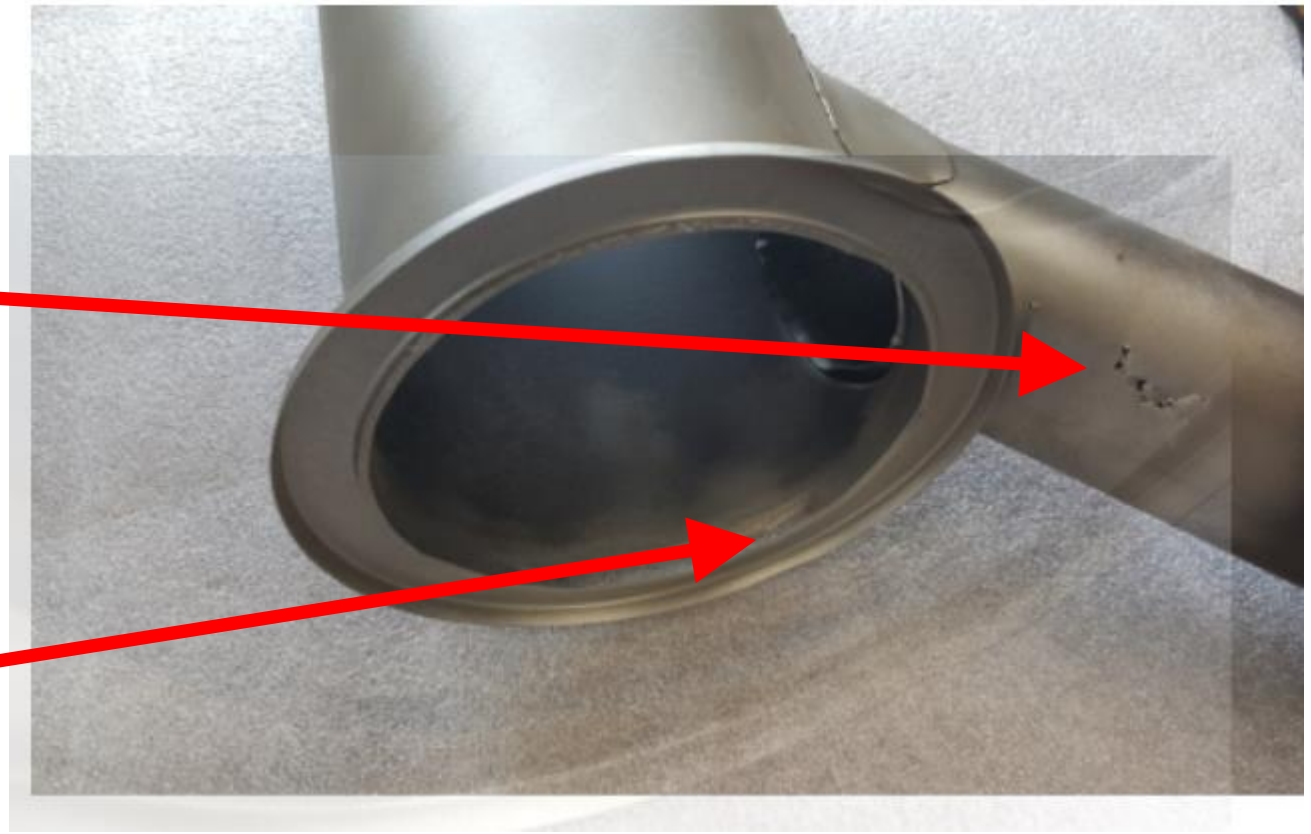
Look At The Complete System:

- **Check correct placement and condition of heat shields**

- **Condition of heat shield foils**
  - RV-12 fiberglass bottom cowl

Looks Corroded? (Then probably is…)

- **Bead blasting reveals pin holes from corrosion**
- **Also, flange issue**



Problem Types

The FAA is concerned about GA exhaust system failures continuing to contribute to accidents/incidents:

Muffler failures – internal baffles, external mounts

Exhaust system leaks – noxious fumes (CO poisoning)

Exhaust system cracks – heat impingement and fire

Exhaust Manifold and Stacks/Pipes

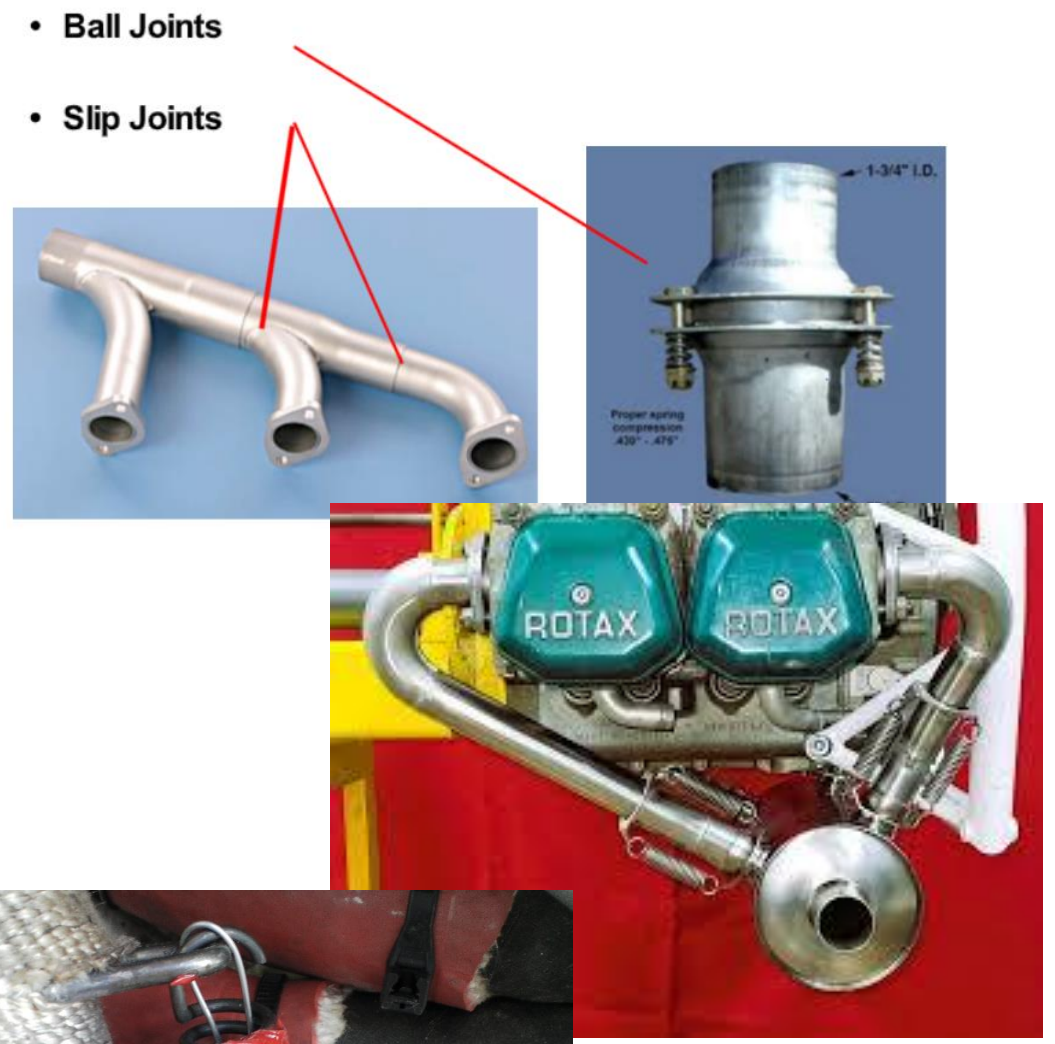
- **Exhaust manifold and stack failures are usually fatigue related at welded or clamped points**
- **These failures are fire hazards as well as the possibility of CO poisoning**

Exhaust Blow Torch:

- High pressures
- High temperatures
- At high altitudes, turbo working really hard maintaining sea level pressure
- Due to pressure differentials, leaks can result in a blow torch-like blast
- Melts things
- Fire hazard

Joints and Flanges:

- **Special attention areas**
- **Look for signs of leakage**
- **Check integrity of clamps and springs**
- **Springs loose or broken**
  - Springs allow for movement and expansion
- **Follow manufacturer's procedures:**
  - Anti-seize paste on ball joints to maintain joint flexibility
  - Safety wire retaining springs
  - RTV in/on springs for dampening



Signs Of Leakage at Joints and Flanges:

Replace or Repair?

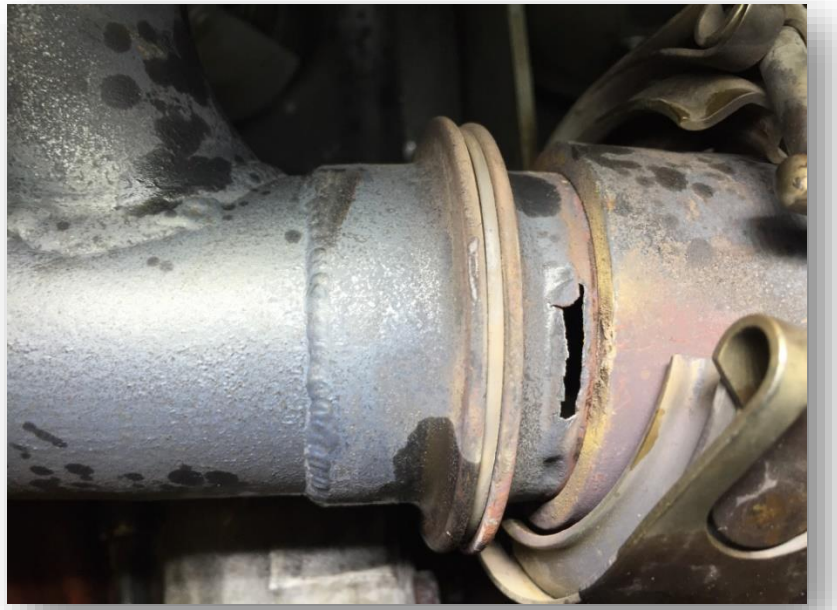
Replace!

- New or reconditioned components
- Qualified repair station
- Properly performed
- Correct return to service

- Every flight after maintenance is a test flight
- See “Preflight After Maintenance”
  - https://youcanfly.aopa.org/flying-clubs/flying-club-newsletter/2023/september/17/safety

Exhaust Components

- **Exhaust system components require special attention**
- **Might hide under clamps**
- **Look for streaks, discoloration…**

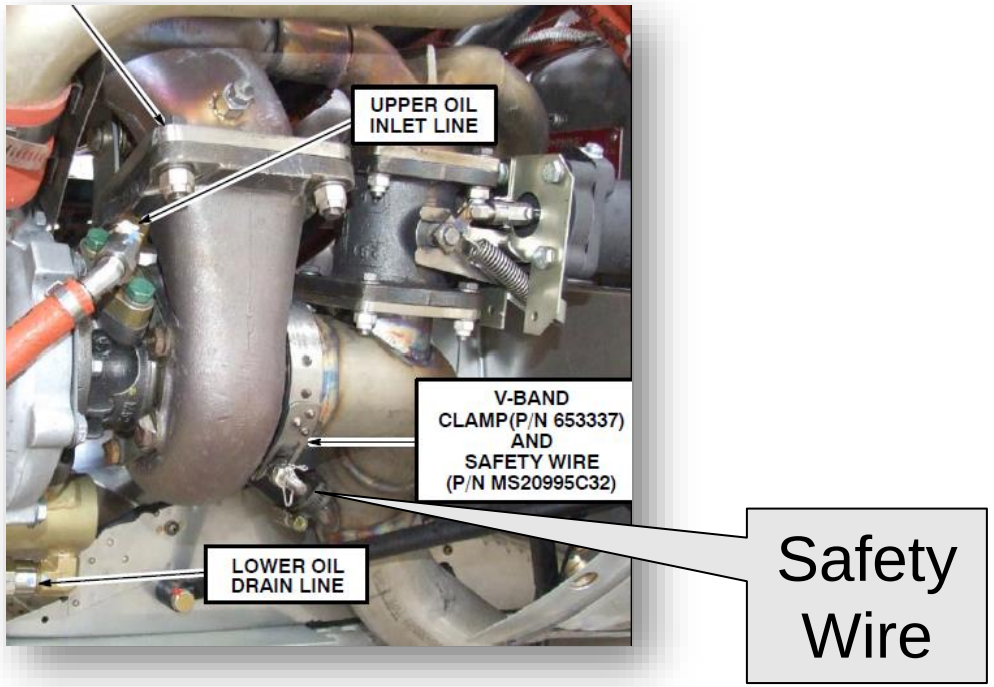


V-Bands

- V-band clamps are the preferred connection for many exhaust or intake systems
- A V-band applies uniform and equal closing force around the entire circumference of the flange
- Once tightened, friction between the flanges and V-retainer reduce the load on the bolt and clamp
- BUT, they can and do fail…

V-Band Gasket & Safety Wire

- **Comply with the manufacture's instructions for use of V-band gaskets**
- **Correct safety wire technique**



V-Band Cautions

- **Tubes and components of the coupling must be aligned before installing the coupling**
- **The flanges must be aligned correctly to prevent failures**

- **Ensure that the V-band does not bottom out on the flange before reaching the required torque**

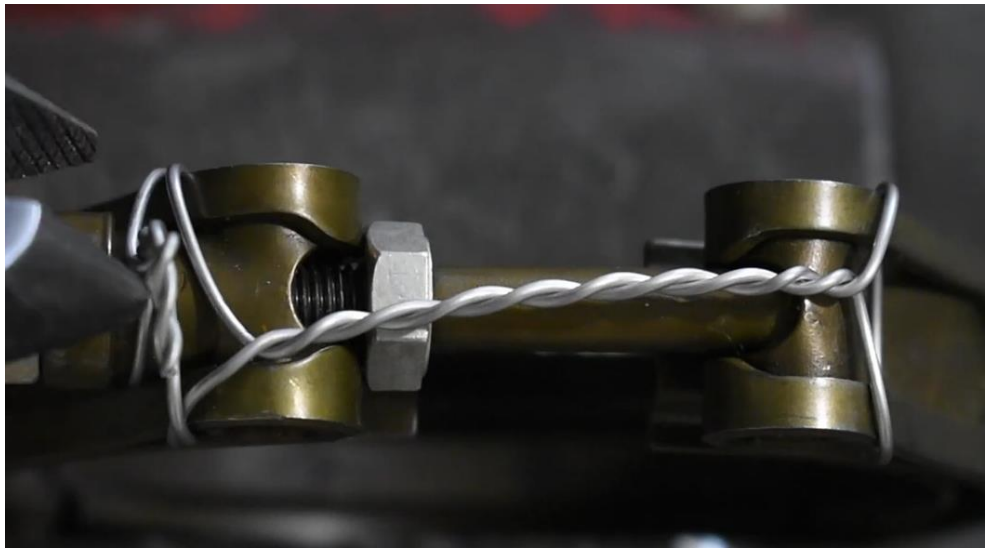
V-Band Cautions

- **The installation process includes proper torque, seating and retorquing the coupling until the torque value is stable**
- **Tapping the coupling with a rubber mallet can help seating the coupling while retorquing**
- **Safety wire!**

[All Engine Models - Installing V-Band Clamps - GE Aviation Maintenance Minute]

V-Band Cautions

- **Safety wire needed as directed**
- **Clamp held by safety wire if T-bolt fails**



[How to safety wire aircraft V-Band clamps information and live demonstration]

V-Band Cautions

- **Wrong…**
- **If T-bolt fails it will still fall apart**

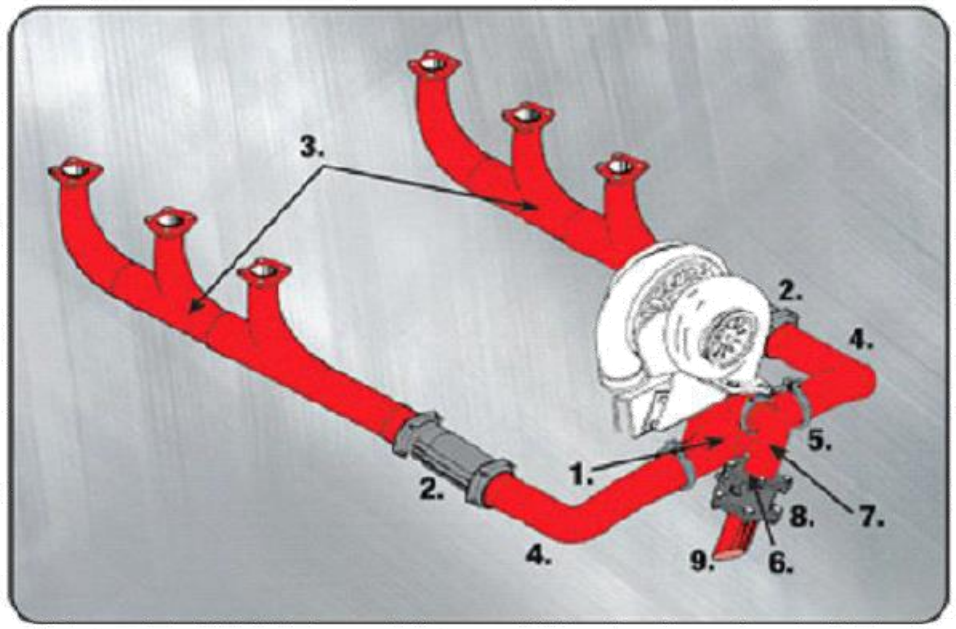
Special Emphasis Around Turbos

- **Turbos get hot!**

- **V-band clamp failure**

Exhaust Failures

- **With exhaust temperatures reaching up to 1,300 °F, the clamp assembly could quickly be compromised if exhaust leaks**
- **“Blow-torch” effect**



KEY

1. Wye duct, header assembly
2. Slip joint, ball joint
3. Riser
4. Elbow, manifold
5. Clamp
6. Waste-gate inlet
7. Wye to waste-gate elbow
8. Waste-gate valve
9. Waste-gate discharge

Sunriver, OR:

"Blockage on right muffler due to baffling turned 180^{o} and plugged muffler exhaust.", *NTSB*

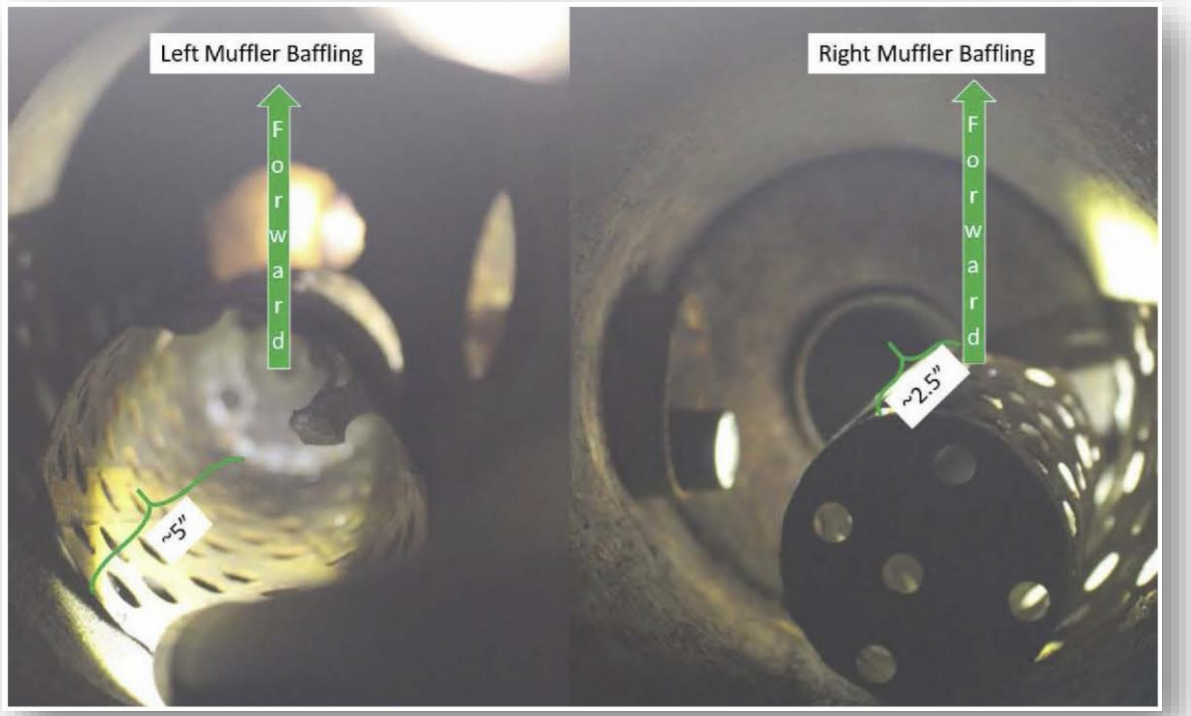


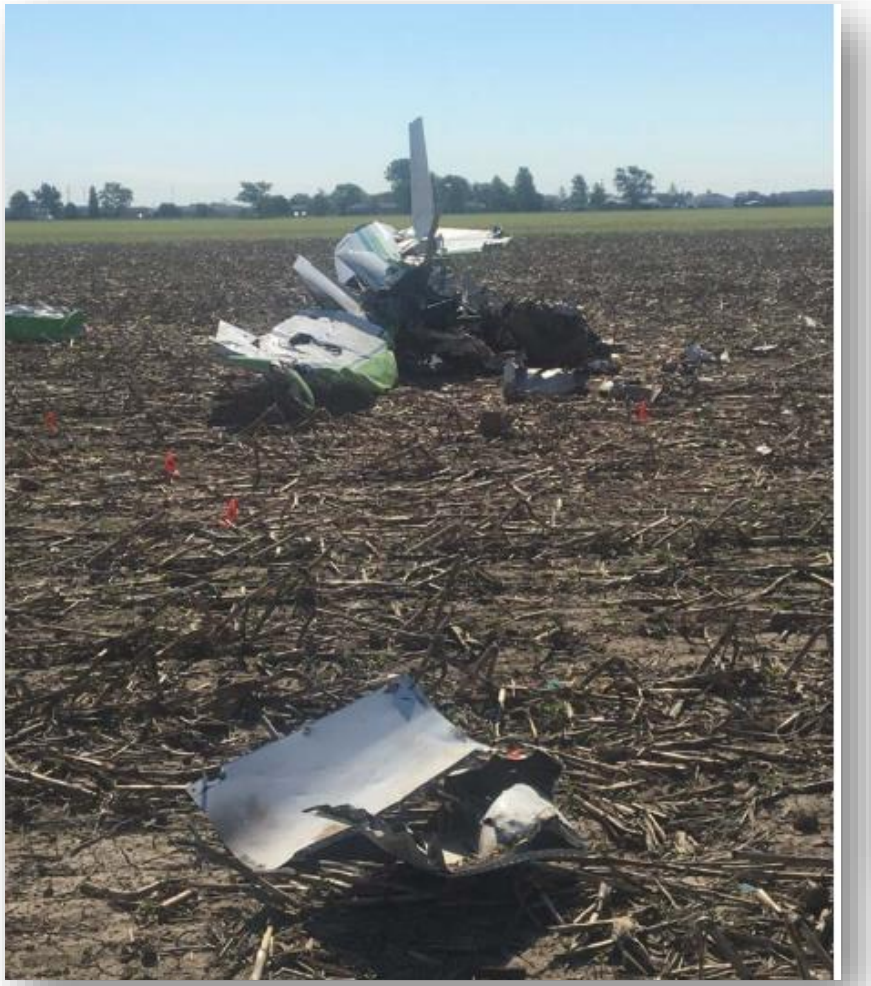
Photo credit: NTSB

"… available [exhaust] outflow reduction of 89%"

NTSB

Result: Exhaust back pressure and loss of engine power

22 Jun 2019, Sunriver, OR - 1 Fatal; 1 Serious injury *Photo: NTSB*



CEN17FA207 - Wreckage

CEN17FA207 – Heat Exchanger

CEN20LA256

Left exhaust system

Right exhaust system

- **Post crash investigation**
- **Both exhausts unairworthy**
- **Thin metal, cracks, holes**

Photos: Courtesy of Textron Aviation

- 2018 motor glider
- Taxied out, checked okay
- Took off
- Rough engine, burning smell
- Returned to airport
- Flames
- Fire consumed a/c
- Pilot existed safely

In addition to cracks, and holes, be sure to watch for loose/missing exhaust manifold Nuts and Studs

Photo 2 – View of hole in the muffler (Courtesy of FAA)

ERA18LA214

- **Day VFR**
- **E-AB on floats**
- **Nose pitched down in rapid descent**

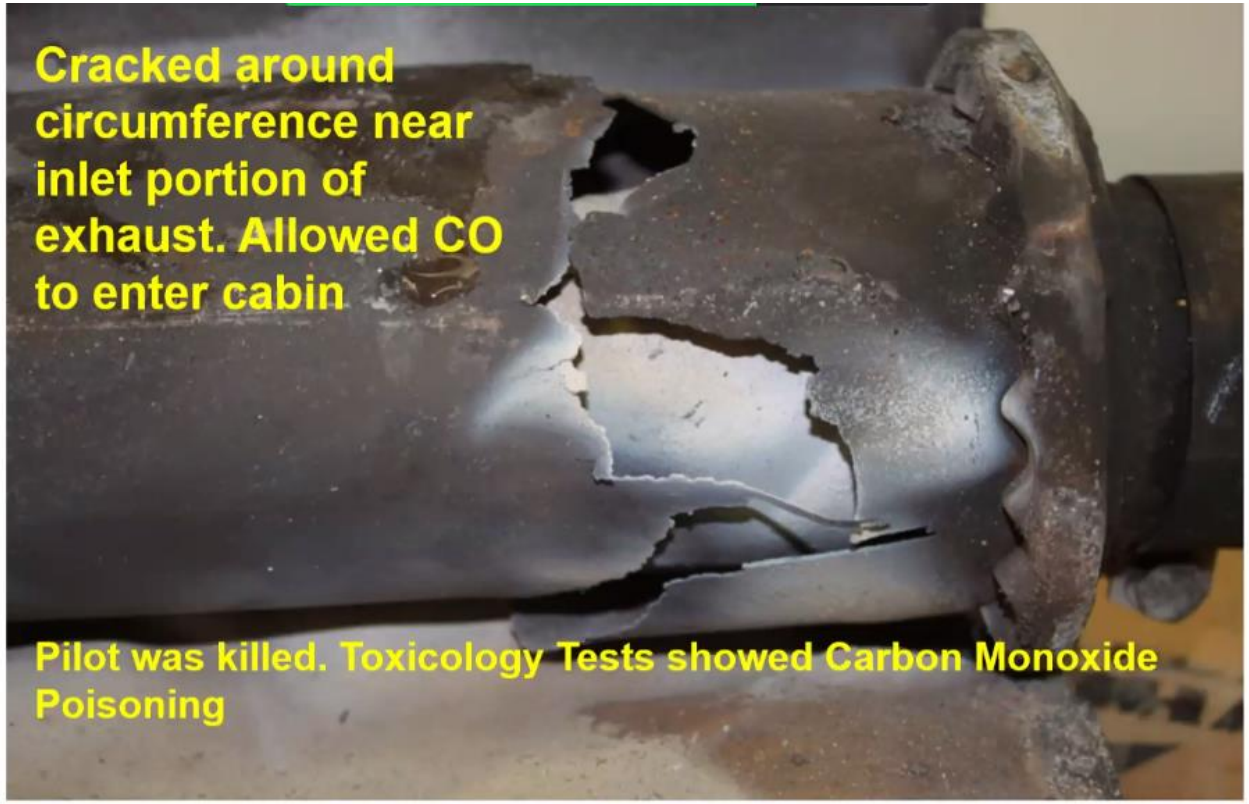


Photo 4 – Close-up View of Damaged Muffler Can

ANC16FA065

- Day VFR
- Nose pitched down in rapid descent

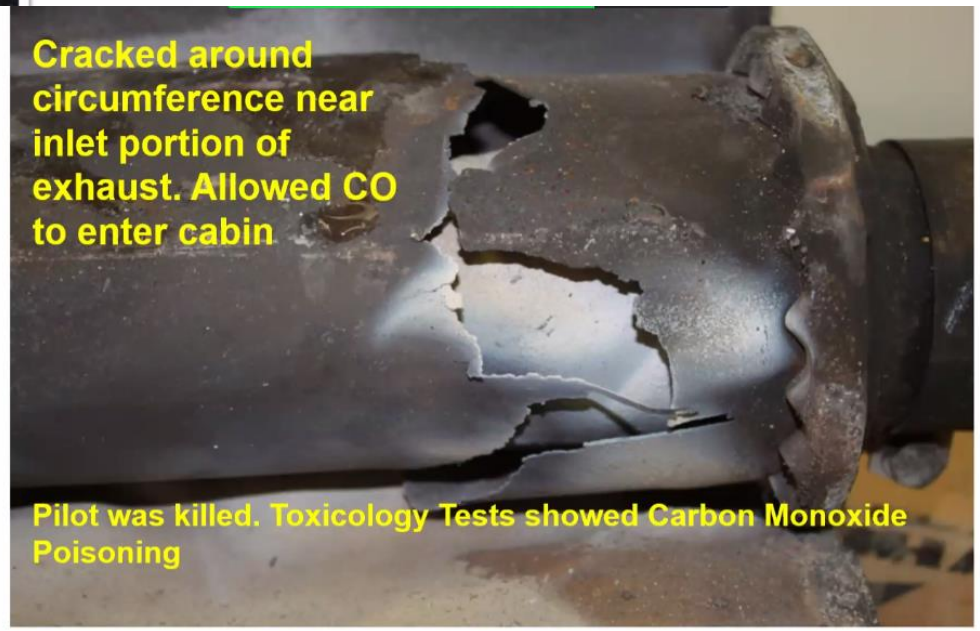


Photo 4 – Close-up View of Damaged Muffler Can

T206H Accident, Idaho Falls, 2015

In-flight fire during its initial climb from Idaho Falls. Pilot was able to return to airport and land.

Photo 1 – Fire Damage

Burn Through

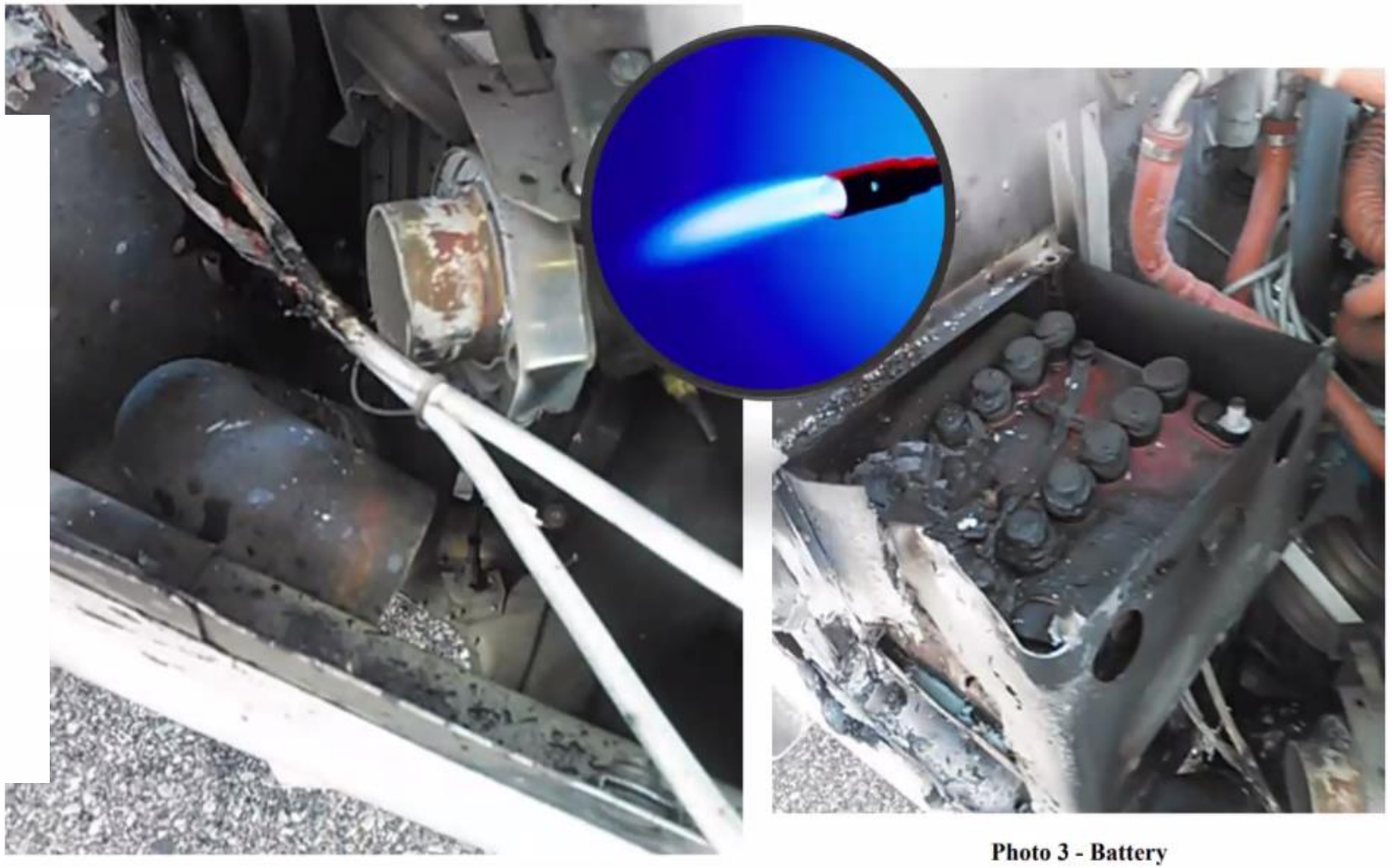


Photo 2 - Separated Tailpipe

Photo 3 - Battery

WPR15IA263 – Fire damage

Separated tailpipe

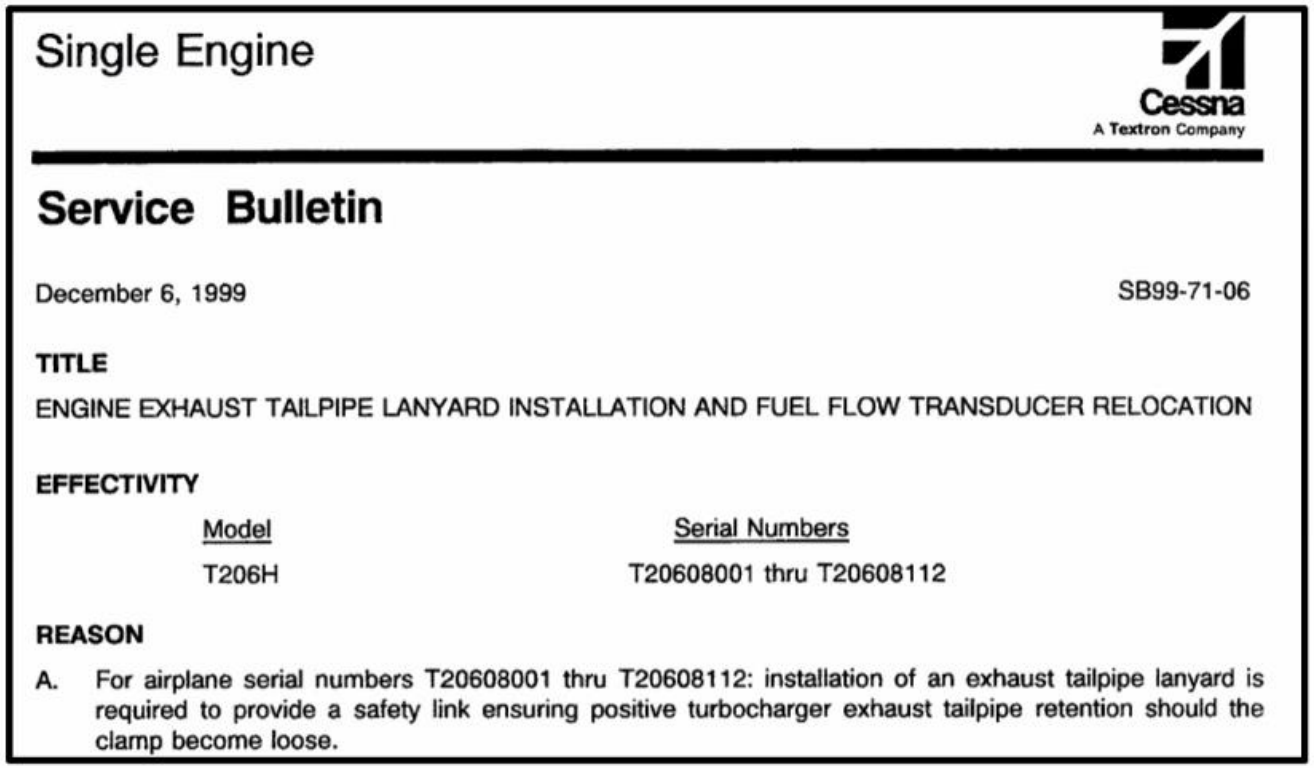
NTSB Probable Cause

An in-flight fire during initial climb due to the separation of the engine's turbocharger wastegate overboard exhaust tailpipe. Contributing to the accident was the owner's decision to not comply with a service bulletin that addressed the tailpipe separation.

Was the Owner Aware of the Service Bulletin?

Was the Mechanic Aware of the Service Bulletin?

SB missed for at last 15 Annuals…



Single Engine

Cessna
A Textron Company

Service Bulletin

December 6, 1999 SB99-71-06

TITLE

ENGINE EXHAUST TAILPIPE LANYARD INSTALLATION AND FUEL FLOW TRANSDUCER RELOCATION

EFFECTIVITY

Model	Serial Numbers
T206H	T20608001 thru T20608112

REASON

A. For airplane serial numbers T20608001 thru T20608112: installation of an exhaust tailpipe lanyard is required to provide a safety link ensuring positive turbocharger exhaust tailpipe retention should the clamp become loose.

No lanyard was found on the airplane, and no record in the maintenance logbooks indicated that the service bulletin had been complied with. Issued 16 Years before the Accident.

Historical Record

Accident Occurred Sept 21, 2015

Last Inspection was 45 Hours earlier

Six Months earlier, April 28, 2015, Tailpipe Separated and caused damage to Battery Cables. This would have been a good time to do the SB!

SB Affected 111 Airplanes. Cessna said they sold 91 units. So, 20 Owners opted not to do the Service Bulletin.

Service Bulletins are not mandatory, but many times they are a good idea

Experienced Wind Shear, elected to go around. Engine Loss of Power, Forced Landing, Collided with Fence and Tree

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The loss of engine power during go-around due to a failed muffler flame tube, which resulted in an exhaust blockage. Contributing to the accident was maintenance personnel's inadequate inspection of the exhaust system during the most recent maintenance.

Lodged in tail pipe

Photograph 11 - Inside muffler, flame tube lodged in tailpipe (Courtesy of NTSB)

- **Repair work…**

Could this have been Prevented?

The airplane maintenance logbooks revealed that, during a maintenance inspection on December 24, 1997 (3,523.42 hours total time and 1,260.42 hours since major overhaul), the exhaust system was inspected "for leaks and cracks. System found to be satisfactory."

On January 2, 1999 (3,556.5 hours total time and 1,293.50 hours since major overhaul), another maintenance inspection was conducted by the same mechanic and there was no mention of the exhaust system.

On March 21, 2000, the airplane's muffler was repaired and inspected by a separate exhaust system repair station. The work order for this muffler repair revealed that the muffler was to be inspected and repaired. The items replaced included: 3 tabs, the outer shell, 2 caps, 2 flame tubes, 2 elbows, 2 beaded ends, 2 end plates, and the tailpipe.

Repair Versus Replace

At what point do you replace, instead of repair?

According to the Federal Aviation Administration (FAA) FAA-H-8083-32B, Aviation Maintenance Technician Handbook – Powerplant:

It is generally recommended that exhaust stacks, mufflers, tailpipes, etc., be replaced with new or reconditioned components rather than repaired. Welded repairs to exhaust systems are complicated by the difficulty of accurately identifying the base metal so that the proper repair materials can be selected.

Beech Bonanza

Flame cone in the exhaust of a Beech Bonanza. Cone should be centered not sagging. It is easy to inspect for this fault by looking up the exhaust pipes.

Inspections

Beech maintenance and overhaul documents revealed that the exhaust system should be overhauled or replaced every 800 hours or when the condition warrants replacement. The exhaust muffler and shroud should be inspected every 100 hours. The documentation states, “It is recommended that at each 100 hour and/or annual inspection, all exhaust muffler shrouds be removed and the muffler thoroughly inspected for cracks, leaks and (if applicable) deterioration of the internal tubes which could cause a decrease in engine power due to blockage of the exhaust.

Photo 1 – Wreckage in Field

Photo 4 – Heat Exchanger (3)

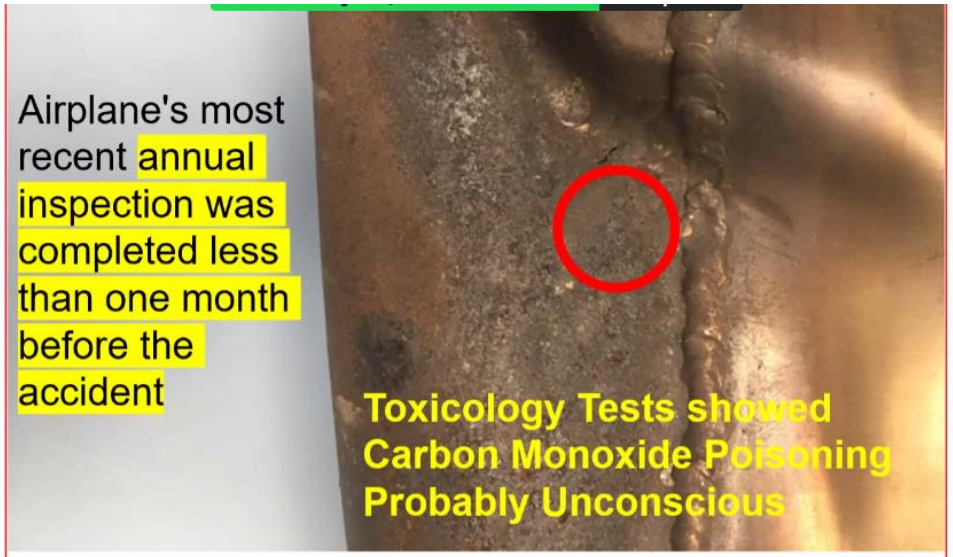


Photo 5 – Heat Exchanger (4)

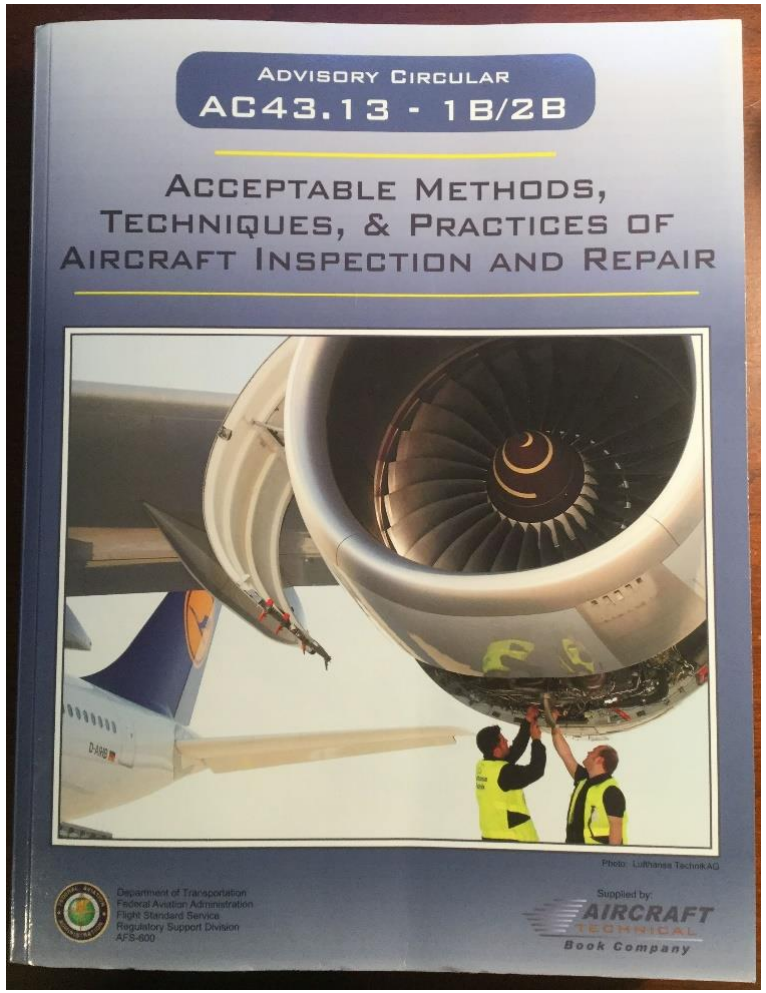
NTSB Probable Cause

The pilot's loss of control due to impairment from carbon monoxide poisoning. Contributing to the accident were the corrosion of the heat exchanger and the failure of maintenance personnel to adequately inspect and repair or replace the exchanger during the most recent annual inspection

Corrosion in the heat exchanger allowed carbon monoxide to enter the cabin

- **Downpipe rubbing on other structure**

AC 43.13-1B: Aircraft Inspection and Repair: Acceptable Methods, Techniques, and Practices



- **Chapter 8, Section 3: Exhaust Systems**

SECTION 3. EXHAUST SYSTEMS

8-45. GENERAL. Any exhaust system failure should be regarded as a severe hazard. Depending upon the location and type of failure, it can result in carbon monoxide (CO) poisoning of crew and passengers, partial or complete engine power loss, or fire. Exhaust system failures generally reach a maximum rate of occurrence at 100 to 200 hours' operating time, and over 50 percent of the failures occur within 400 hours.

8-46. MUFFLER/HEAT EXCHANGER FAILURES. Approximately one-half of all exhaust system failures are traced to cracks or ruptures in the heat exchanger surfaces used for cabin and carburetor air heat sources.

a. Failures in the heat exchanger's surface (usually the muffler's outer wall) allow exhaust gases to escape directly into the cabin heat system. The failures are, for the most part, attributed to thermal and vibration fatigue cracking in the areas of stress concentration; e.g., tailpipe and stack, inlet-attachment areas. (See figures 8-13 through 8-16.)

b. Failures of the spot welds which attach heat transfer pins, as shown in figure 8-14A, can result in exhaust gas leakage. In addition to the CO hazard, failure of heat exchanger surfaces can permit exhaust gases to be drawn into the engine induction system and cause engine overheating and power loss.

8-47. MANIFOLD/STACK FAILURES. Exhaust manifold and stack failures are also usually fatigue-type failures which occur at welded or clamped joints; e.g., stack-to-flange, stack-to-manifold, muffler connections, or crossover pipe connections. Although these failures are primarily a fire hazard, they also present a CO problem. Exhaust gases can enter the cabin via defective or inadequate seals at firewall openings, wing strut fittings, doors, and wing root openings. Manifold/stack failures, which account for approximately 20 percent of all exhaust system failures, reach a maximum rate of occurrence at about 100 hours' operating time. Over 50 percent of the failures occur within 300 hours.

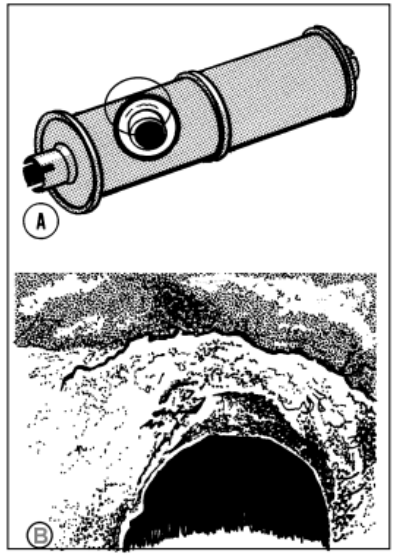


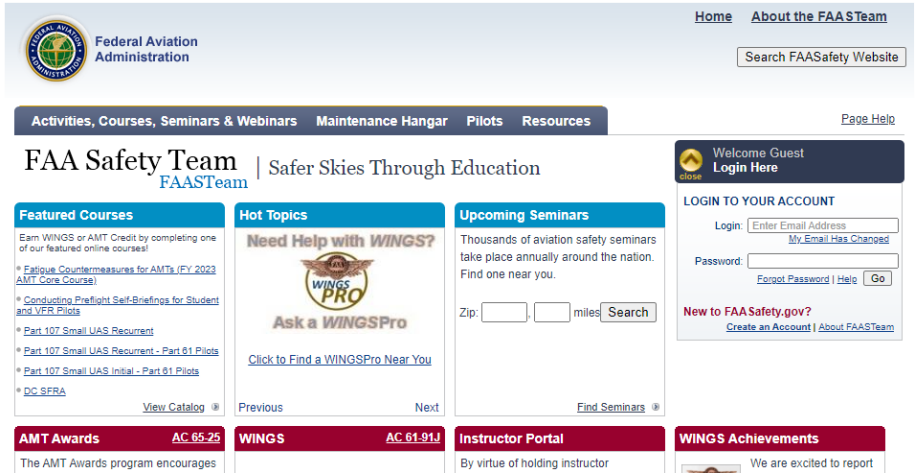
FIGURE 8-13. Typical muffler wall fatigue failure at exhaust outlet. (A. Complete muffler assembly with heat shroud removed; B. Detail view of failure.)

8-48. INTERNAL MUFFLER FAILURES. Internal failures (baffles, diffusers, etc.) can cause partial or complete engine power loss by restricting the flow of the exhaust gases. (See figures 8-17 through 8-20.)

AMT/WINGS Course:

The ALC-498 course “Aircraft Exhaust Systems” at FAASafety.gov:

- **Aircraft exhaust systems, types, repairs, and inspections**
- **Best practices for maintenance**

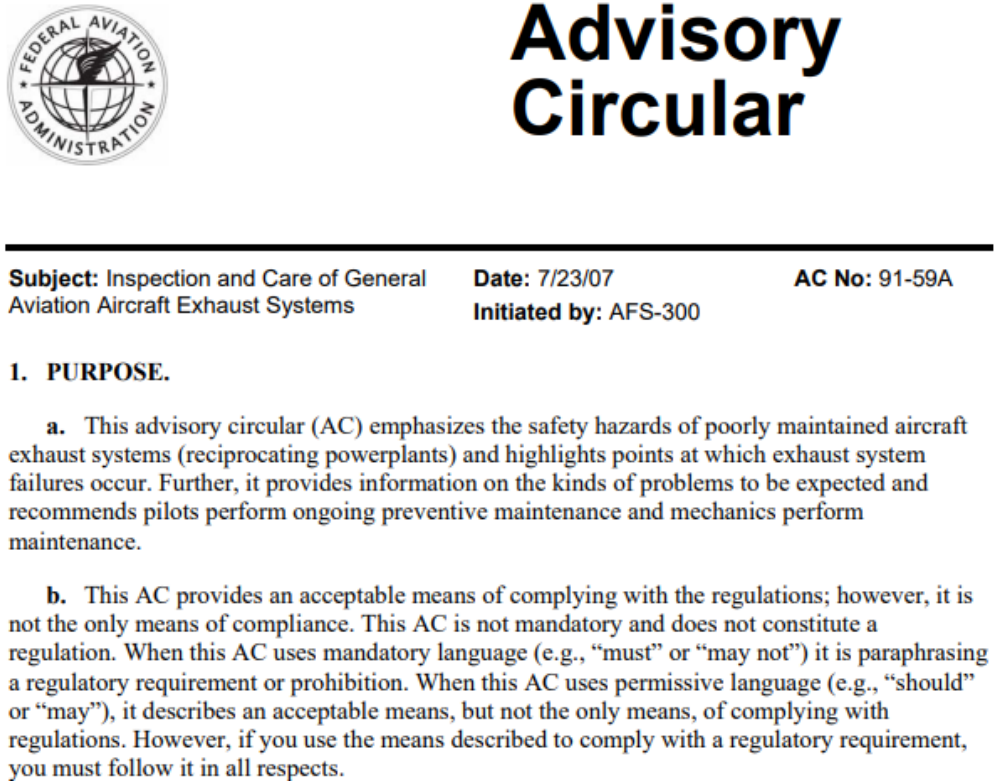


https://www.faasafety.gov/gslac/ALC/course_catalog.aspx

[Activities, Courses, Seminars & Webinars - Courses - FAA - FAASTeam - FAASafety.gov]

AC 91-59A:

Inspection and Care of General Aviation Aircraft Exhaust Systems



Advisory Circular

Subject: Inspection and Care of General Aviation Aircraft Exhaust Systems

Date: 7/23/07

Initiated by: AFS-300

AC No: 91-59A

1. PURPOSE.

a. This advisory circular (AC) emphasizes the safety hazards of poorly maintained aircraft exhaust systems (reciprocating powerplants) and highlights points at which exhaust system failures occur. Further, it provides information on the kinds of problems to be expected and recommends pilots perform ongoing preventive maintenance and mechanics perform maintenance.

b. This AC provides an acceptable means of complying with the regulations; however, it is not the only means of compliance. This AC is not mandatory and does not constitute a regulation. When this AC uses mandatory language (e.g., "must" or "may not") it is paraphrasing a regulatory requirement or prohibition. When this AC uses permissive language (e.g., "should" or "may"), it describes an acceptable means, but not the only means, of complying with regulations. However, if you use the means described to comply with a regulatory requirement, you must follow it in all respects.

References:

- **Aircraft Exhaust Systems Course ALC-498 on FAASafety.gov**
  - https://www.faasafety.gov/gslac/ALC/course_catalog.aspx
- **AC 43.13-1B: Aircraft Inspection and Repair: Acceptable Methods, Techniques, and Practices (See Chapter 8, Section 3: Exhaust Systems)**
  - https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/99861
- **AC 91.59A: Inspection and Care of General Aviation Aircraft Exhaust Systems**
  - https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/74468
- **Maintaining your Way to Greater Safety. FAA Safety Briefing, Mar/Apr 2010, pp 23-26**
  - https://www.faa.gov/sites/faa.gov/files/2022-01/MarApr2010.pdf
- **AOPA Pilot: Airframe and Powerplant—Exhausted and Often Forgotten**
  - https://www.aopa.org/news-and-media/all-news/2001/march/pilot/airframe-and-powerplant-(4)

Conclusions:

- **Knowledge is key to the maintenance of exhaust systems**
- **Have/use/comply with appropriate service information**
- **Inspect closely**
  - During service
  - On each preflight
- **When in doubt, get a second opinion**

- **Remember: Danger of fire and/or carbon monoxide if not maintained correctly**

Proficiency and Peace of Mind

- **Regular scenario training with your CFI**
- **Document in *WINGS***
- **Earn a phase: 3 + 3 in 12**
- **Progressive flight review**
- **Impress your insurance company**

Next Month's TOM:

The National FAA Safety Team Presents

Topic of the Month - October

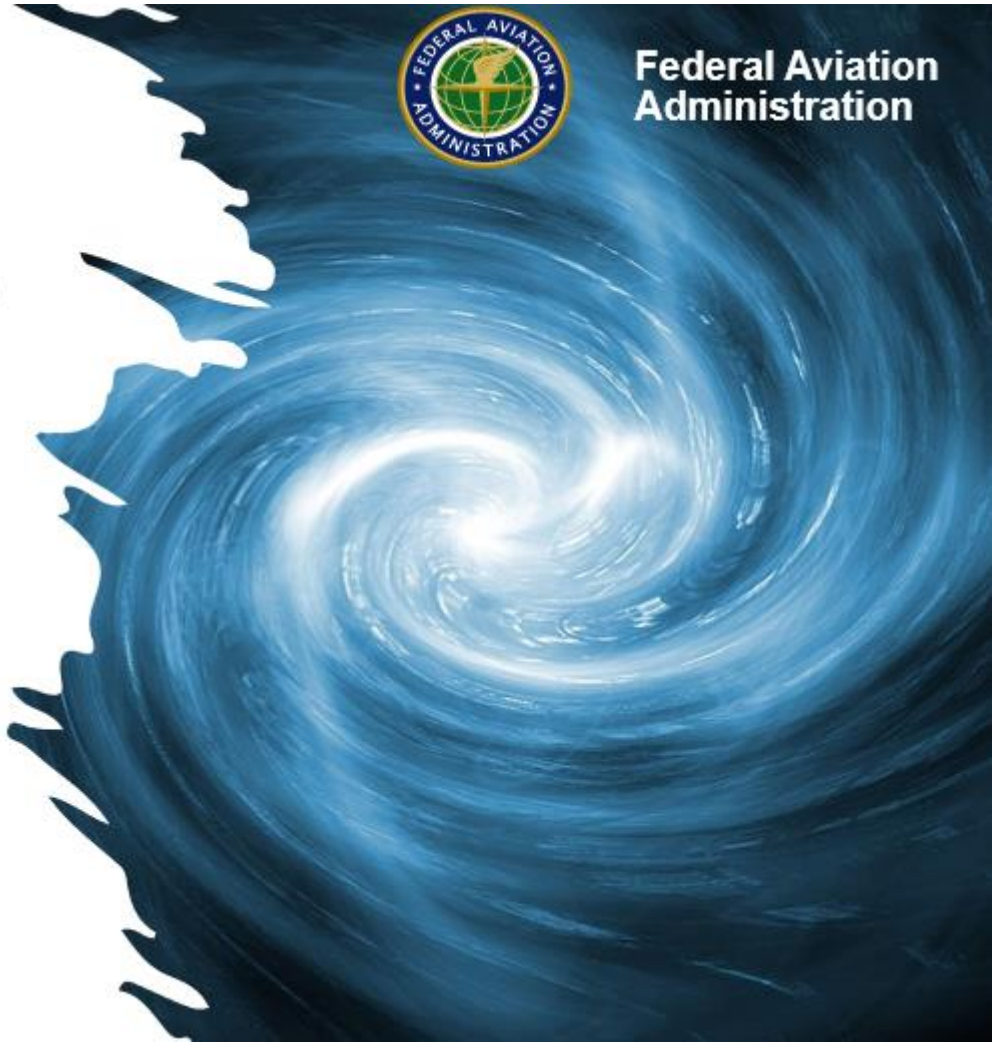
Vestibular Illusions

Presented to: AOPA Flying Clubs

By: Your Club Safety Officer

Date: Your Next Club Safety Meeting

Produced by:
The National FAA Safety Team (FAASTeam)



Thank you for attending!

You are vital members of our GA safety community!

PDF Of These Slides Available For Your Further Study and Use

- **Slides post on the third Sunday of every month**
  https://bit.ly/ToMSafetyArticle

- **Or search for "AOPA Flying Clubs"**
  - Click on "Club Connector Newsletter"
  - Thanks to the AOPA Flying Clubs Initiative