Turbocharged, Reciprocating Engine Powered Aircraft

Exhaust System
Turbocharger to Tailpipe
V-band Coupling / Clamp Working Group

Final Report

Reference:
JASC 8100 Exhaust Turbine System (reciprocating)
JASC 8120; Exhaust Turbocharger

January 2018

ABSTRACT

The General Aviation Joint Steering Committee established a working group to examine the causes of fatal general aviation accidents relating to System Component Failures – Power Plant (SCF-PP). The SCF-PP working group reviewed 70 *randomly* selected fatal accidents that took place between 2001 and 2010 and found three of the selected cases resulted from V-band coupling/clamp failures. The SCF-PP working group found that repeating data troubling and then prodded the GA-JSC to examine the feasibility of implementing fleet-wide inspection requirements and life-limits for V-band coupling/clamp on *all* turbocharged, reciprocating engine-powered aircraft not already covered by an existing Airworthiness Directive, regardless of make or model. A collaborative effort was initiated between the Small Airplane Directorate and the GA-JSC to study V-band coupling/clamp failures associated with turbocharged reciprocating aircraft and develop recommended corrective actions. The V-band Working Group was then formed comprised of aviation industry manufacturers, type/user groups, and government entities. The working group was tasked to examine the turbocharger to tailpipe interface and develop recommendations to enhance the safety of the fleet. The recommended corrective actions would then be assessed by the SAD for future implementation. Herein is the final reporting of the V-band Working Groups efforts.

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ACKNOWLEDGEMENTS

The FAA would like to thank the V-band Working Group and all those they reached out to that took the time and resources to provide any feedback to the working group process and the issues herein. This includes, but is not limited to the following entities:

- Aircraft Owners & Pilots Association – (AOPA)
- American Bonanza Society – (ABS)
- Continental Motors
- Eaton Industries
- FAA;
    - Aircraft Evaluation Groups – (AEG)
    - Aircraft Maintenance Division – (AFS)
    - Aviation Safety – (AVS & AVP)
    - Flight Standards District Office – (FSDO)
    - Small Airplane Directorate – (SAD)
    - Wichita Aircraft Certification Office – (ACO)
- General Aviation Manufacturers Association (GAMA)
- Lycoming Engines
- National Transportation Safety Board (NTSB)
- Textron Aviation, Inc. (Cessna & Beechcraft)

We would also like to thank all those that provided feedback, suggestions and solutions in responding to the Airworthiness Concern Sheet of November 11, 2016.

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EXECUTIVE SUMMARY

Accidents and serious incidents resulting from turbocharger to tailpipe V-band coupling/clamp failure have been a repetitive problem in turbocharged, reciprocating engine-powered aircraft. In fact, it was the relative repetitiveness of the problem that spawned this latest V-band coupling/clamp effort. Between the summer of 2014 and the winter of 2015, the General Aviation Joint Steering Committee (GA-JSC) developed a working group to examine the causes of fatal general aviation accidents relating to System Component Failures – Power Plant (SCF-PP) to determine what, if anything, could be done to eliminate certain accident causations. The SCF-PP working group reviewed 70 *randomly* selected fatal accidents that took place between 2001 and 2010[1] and found three of the selected cases resulted from V-band coupling/clamp failures. The SCF-PP working group found the repeating data troubling and as such, prodded the GA-JSC to examine the feasibility of implementing fleet-wide inspection requirements and life-limits for V-band coupling/clamp on *all* turbocharged, reciprocating engine-powered aircraft not already covered by an existing Airworthiness Directive (AD), regardless of make or model. Unfortunately, the completion of the GA-JSC SCF-PP working group effort coincided relatively closely with a tragic accident that took place on May 16, 2016 involving a Beech A36TC aircraft, prompting this focused effort.

This activity was undertaken as a result of the continued fatal accidents and incidents associated with the failure of V-band coupling/clamps which attach the exhaust tailpipe to the turbocharger exhaust outlet. Since the mid 1970's V-band coupling failures have resulted in a significant number of incidents, non-fatal and fatal accidents on both fixed wing aircraft and rotorcraft. Since 1974, National Transportation Safety Board (NTSB) accident/incident investigations have led to the development and issuance of at least (7) NTSB Safety Recommendations concerning exhaust systems and/or exhaust V-band coupling/clamps. The FAA dealt with those events by issuing (20) aircraft model specific Airworthiness Directives (AD) in which V-band coupling/clamps are included with (10) of those being V-band specific, providing guidance and recommendations in at least (10) Special Airworthiness Information Bulletins (SAIB), published numerous AC43-16A Maintenance Alert articles, and updated existing Advisory Circular guidance. Industry too has taken action to raise awareness of the concerns associated with V-band coupling/clamp failures by publishing articles in various trade magazines and user group newsletters, issuing installation guidance and clarifying installation requirements for V-band coupling/clamps. In spite of these efforts, failures continue to occur and the number of significant safety events continues to increase.

A collaborative effort was initiated between the Small Airplane Directorate (SAD) and the GA-JSC to study V-band coupling/clamp failures associated with turbocharged reciprocating engine-powered aircraft and develop recommended corrective actions. A V-band Coupling/Clamp Working Group was formed comprised of aviation industry manufacturers, type/user groups, and government entities. The working group was tasked to examine the turbocharger to tailpipe interface and develop recommendations to enhance the safety of the fleet. The recommended corrective actions would then be assessed by the SAD for future implementation.

One of the objectives of the working group was to ascertain the accident/incident history. NTSB and FAA representatives vetted V-band coupling/clamp failure data in the NTSB accident/incident

[1] Please see the GA-JSC SCF-PP report for more information. http://www.gajsc.org/document-center/

database and the FAA Service Difficulty Report (SDR) database. It should be noted FAA's SDR database is a voluntary system that does not require the submission of incident reports for Title 14, Code of Federal Regulations (CFR), Part 91 operations and the potential exists to have countless more V-band coupling/clamp failures than those in the database. Regardless, the vetted data obtained from the aforementioned databases was compelling, in that:

- Failures dated back to the 1970's with an average 3-5-year gap between accident/failures.
- Failures occurred across aircraft/engine product lines, and configuration, perhaps indicating that similar failures had yet to occur on certain make and model aircraft.
- The limited field data suggests that there is a time at temperature stress corrosion or stress rupture correlation.
- Certain coupling design features may lead to increased failure susceptibility, and
- Improper installation and maintenance issues can further aggravate the failure mechanism.

The working group developed a set of recommendations that contain both mandatory and non-mandatory corrective actions. To put things into perspective, the legacy fielded fleet is approximately 18,000 aircraft and there are at least eight turbocharged aircraft currently in production. There are 65 make/model single engine aircraft and 74 make/model twin engine airplanes that use a turbocharged reciprocating engine. The recommendations herein address existing in-service legacy aircraft and considerations for new designs incorporating turbocharged reciprocating engine(s). The working group recommended mandatory corrective actions that are tailored to the specific coupling types thereby minimizing the impact to owner/operators to the greatest extent possible. The mandatory actions impose a coupling replacement time (life) and annual inspection requirements. A summary of those actions are presented in Table I. The working group's goal was to develop mandatory action of a global nature which could be applied across product lines to multiple make/models, and type of aircraft (including small rotorcraft). The non-mandatory actions are tailored to aid and educate maintenance personnel in appropriate V-band coupling removal, installation, and inspection practices. Finally, recommendations for new designs incorporate a combination of the lessons learned from review of the in-service fleet. For new designs incorporating a V-band coupling immediately downstream of the turbocharger exhaust discharge, a replacement interval consistent with the in-service criteria is recommended to be incorporated in the Airworthiness Limitations sections of the maintenance manual. Additionally, the lessons learned and best practices contained in the non-mandatory actions (Best Practices Guide) should also be incorporated into the maintenance procedures.

REQUIREMENT	SPOT-WELD	RIVETTED	SINGLE-PIECE
Visual Inspection	At every annual inspection	At every annual inspection	At every annual inspection
Life-Limit	Initial replacement at 50 hrs., or within 500 hrs. depending on current part TIS from an A/C records review. Thereafter every 500 hrs.	Initial replacement at 50 hrs., or within 2000 hrs. depending on current part TIS from an A/C records review. Thereafter every 2000 hrs.	Initial replacement at 50 hrs., or within 2000 hrs. depending on current part TIS from an A/C records review Thereafter every 2000 hrs.

Table I
Recommended Mandatory Corrective Actions

1. INTRODUCTION

1.1 Objective

This report summarizes the work accomplished by the national V-band Coupling/Clamp Working Group (hereafter, "working group"), in support of the GA-JSC/SCF-PP initiative to investigate the continued failures of turbocharger exhaust to tailpipe V-band coupling/clamps. The working group was tasked to review, develop and provide the following:

- Coupling/Clamp Design, Standards, & Materials
- Historical Field Service Data
- Causal Analysis
- Laboratory Analysis
- Risk Analysis
- Existing Recommendations, Corrective Actions & Performance
- Targeted Outreach 2016
- Alternative Design Solutions
- New Design Approval Considerations
- Potential Future Corrective Actions
- Recommendations

1.2 Scope

The scope of this working group effort was broad and varied with respect to the type of products, configurations and issues involved in these events which included:

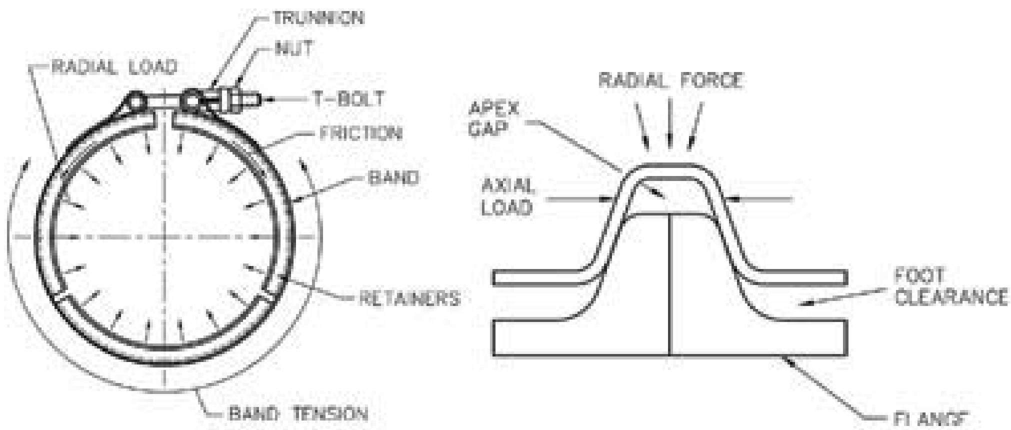
- A history dating from the 1970's
- Approximately 18,000 aircraft in the existing fleet
- At least eight turbocharged aircraft currently in production
- Single and multi-engine airplanes & single engine rotorcraft
- Type certificated (TC) products
- Supplemental type certificated (STC) products
- Multiple Original Equipment Manufacturers (OEM) of V-band coupling/clamps
- Parts Manufacturing Approval (PMA) replacement V-band coupling/clamps
- Textron Aviation, Inc. (formerly Cessna & Beechcraft) products
- Commander Aircraft products
- Continental Motors products
- Enstrom Helicopter products
- Lycoming Engines products
- Mooney Aircraft products
- Piper Aircraft products

The specific focus area of this working group was those V-band couplings and clamps used at the turbocharger exhaust exit to exhaust tailpipe interface only.

2. COUPLING / CLAMP DESIGN, STANDARDS, & MATERIALS

2.1 Coupling & Clamp Design

All turbocharger exhaust tailpipe V-band couplings or clamps are intended to couple and retain the exhaust tailpipe to the turbocharger housing, exhaust exit flange. The exhaust tailpipe V-band coupling/clamp do this by converting the radial load of the coupling band tension or clamp body to an axial load on the flanges due to the wedging action of the ‘V’ retainer segments or clamp body itself as shown below.



There are two types of exhaust tailpipe V-band <u>coupling</u> and one type of V-band <u>clamp</u> used to join the exhaust tailpipe to the turbocharger exhaust exit flange. The two types of V-band couplings are spot-welded, multi-segment V-band couplings and riveted, multi-segment V-band couplings. The one type of V-band clamp is called a single-piece V-band clamp. There are very distinct differences between the types, and their installations are not interchangeable per the applicable aircraft, engine or part Design Approval Holder (DAH), unless FAA approved. The following briefly explains the distinct differences in couplings and clamps.

Multi-segment exhaust tailpipe V-band <u>couplings</u> come in two varieties: spot-welded and riveted (aka; collared fastener). The two varieties typify the method of joining of the outer flat band to the inner v-retainer segments, and all other metal-to-metal joints on the coupling. These couplings come in either two or three segment varieties in this application. The segments are the number of v-retainer segments, which are attached to the outer band via spot-welds or rivets. Materials used throughout are various stainless steel alloys or Inconel’s. The single piece T-bolt may be straight or have a manufactured bend at the ‘T’ head by design. Couplings may also have a quick release latch to capture the T-bolt head. The self-locking nut is typically a high temperature steel alloy that is often silver coated. The self-locking nut is all-metal and the locking feature is a mechanical interference type with no polymer inserts. Couplings typically do not use washers under the nut as the trunnion housing is formed flat to act as a washer surface for the nut. Refer to Figures 1 through 5.

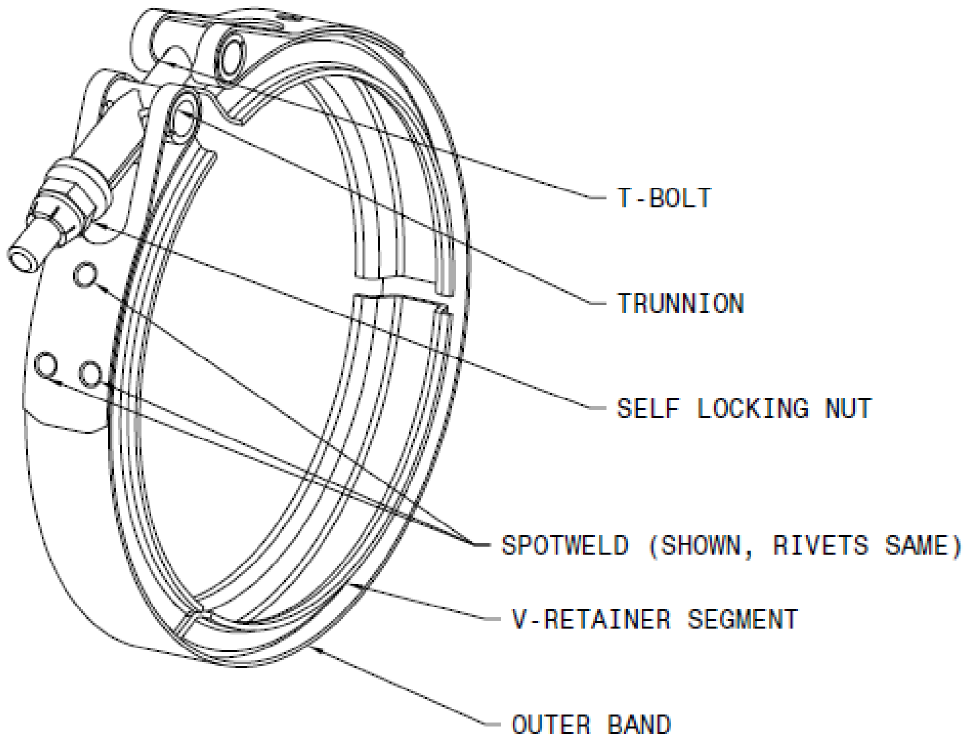


Figure 1

Multi-Segment, V-band *Coupling*
3-segment

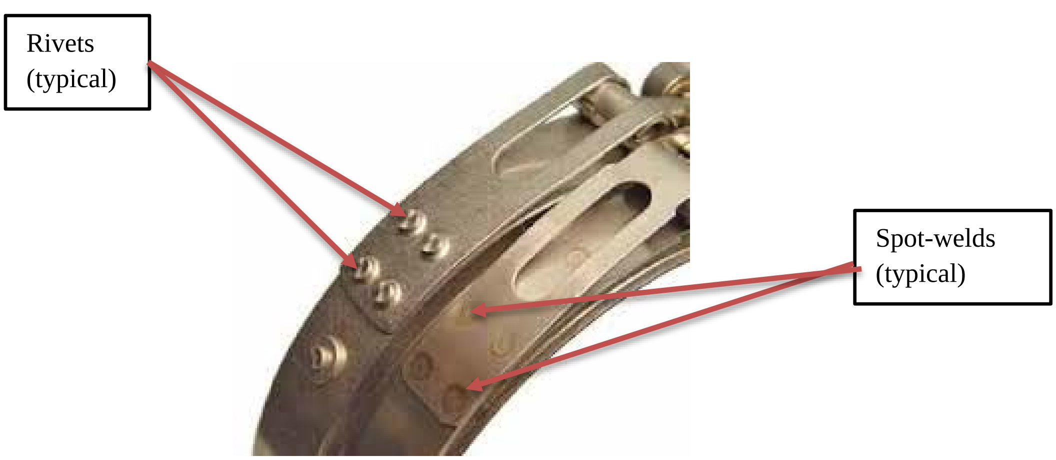


Figure 2

Multi-Segment, V-band *Couplings*
LH riveted (aka, collared fastener) & RH spot-welded

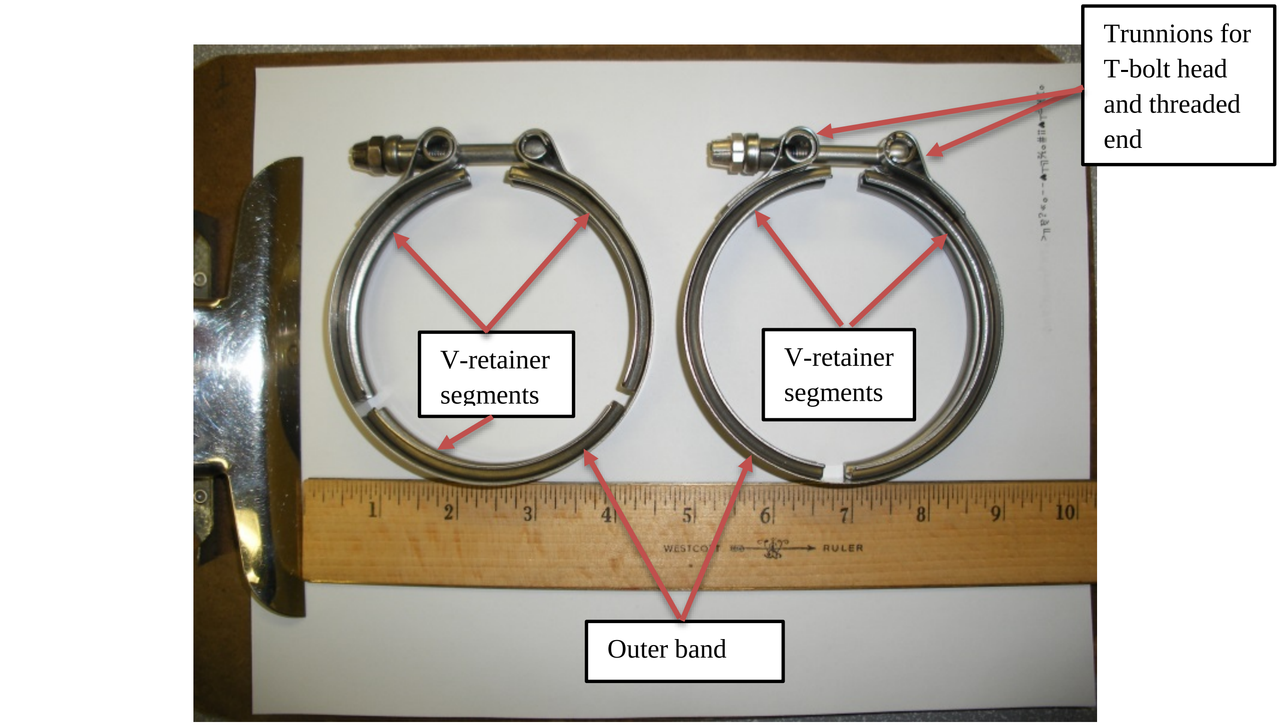


Figure 3

Spot-Welded, Multi-Segment, V-band *Couplings*
3-segment LH 2-segment RH

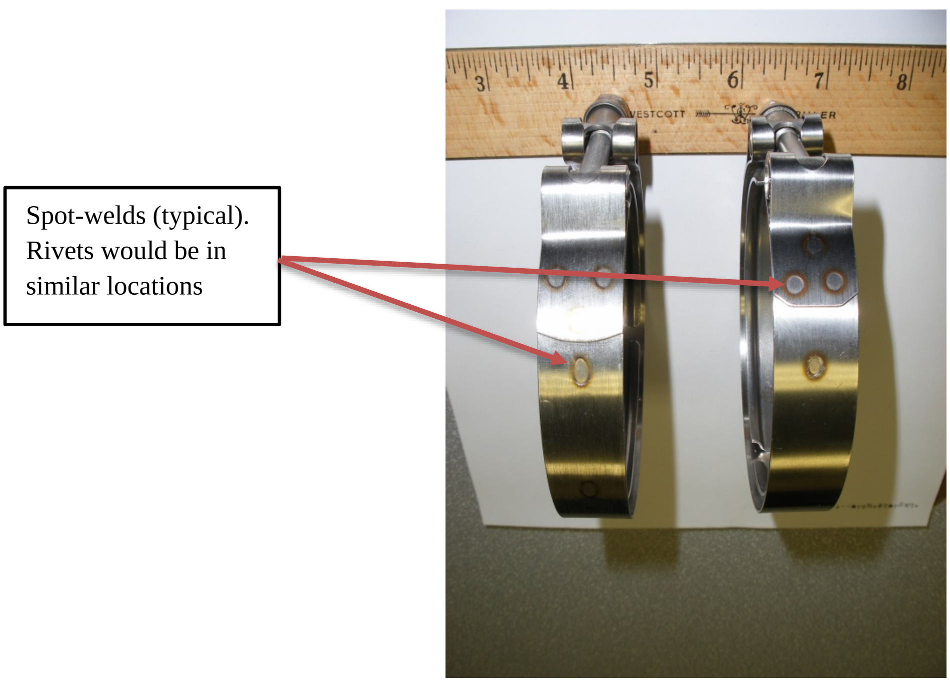
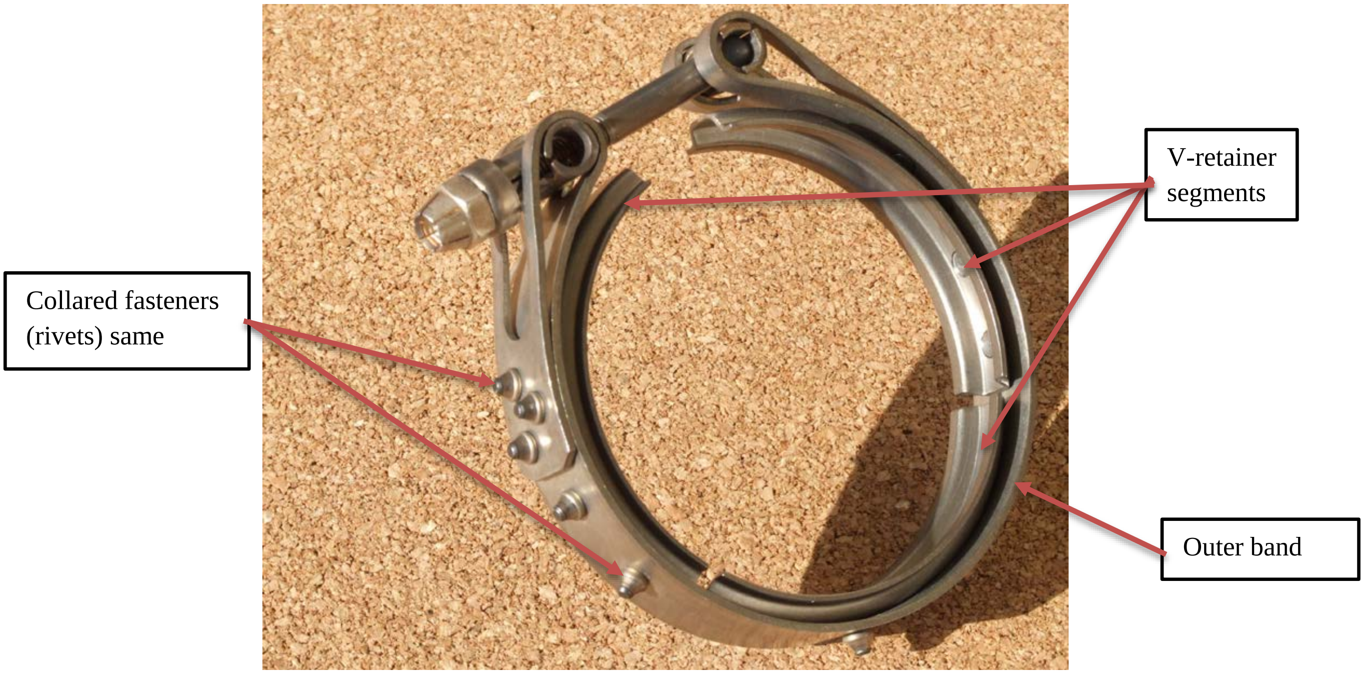


Figure 4

View looking at T-bolt head trunnion end
Spot-Welded, Multi-Segment, V-band *Couplings*

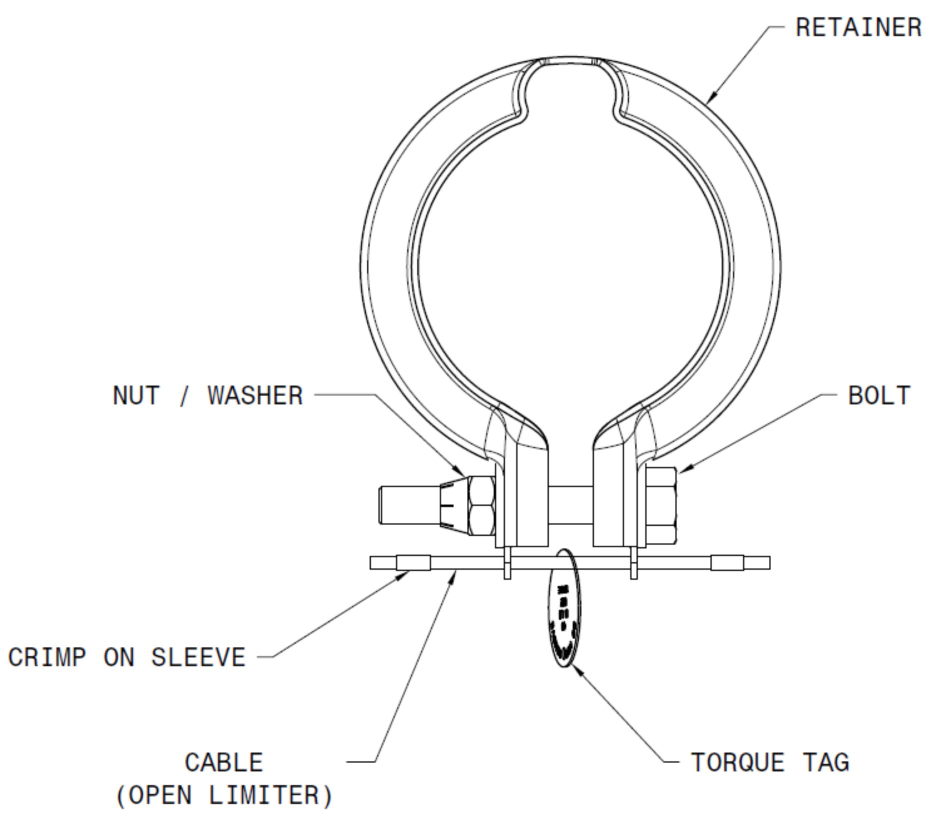


<u>Figure 5</u>

Riveted, (aka, Collared Fastener), Multi-Segment, V-band *Coupling*
3-segment

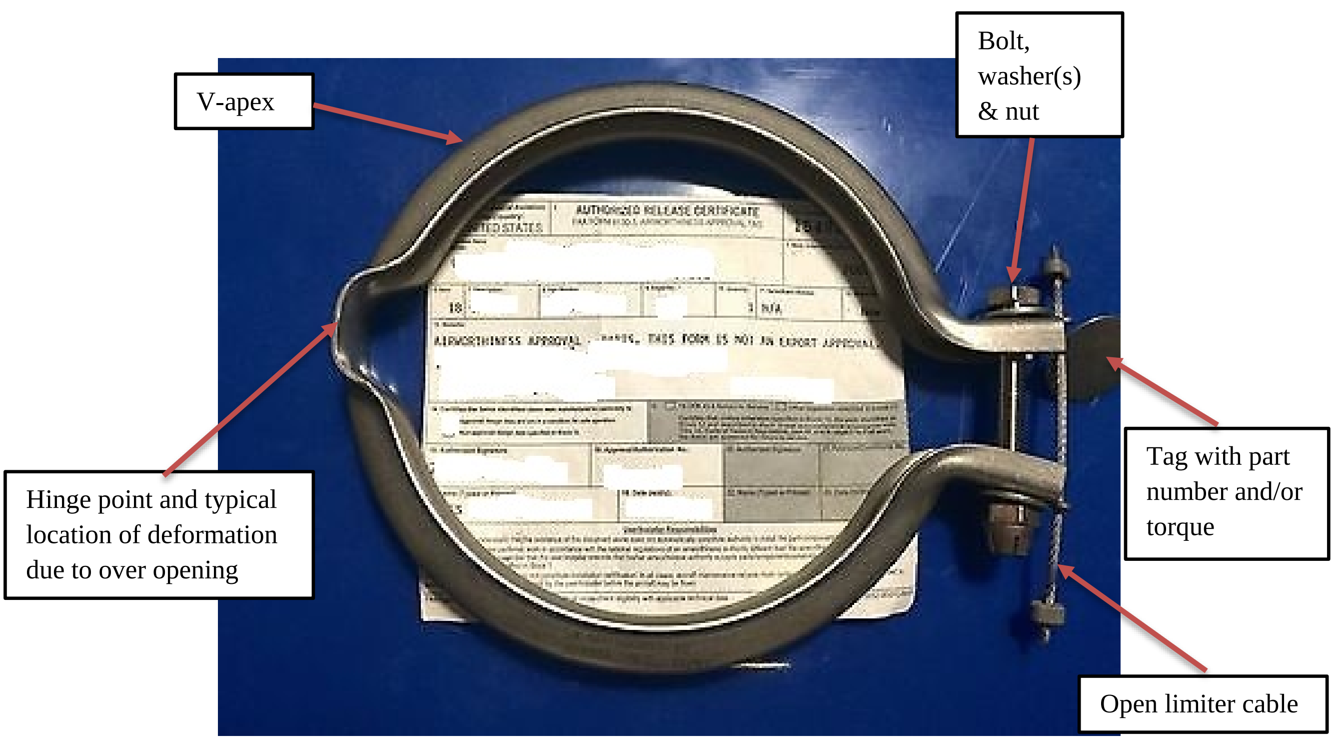
NOTE: Spot-welded and riveted couplings may look identical in all respects except the manufacturing method and may come in the exact same size and flange configuration as a similar spot-welded or riveted coupling. However, the couplings may or may not be legally interchangeable without an aircraft, engine or part FAA approval at the DAH level. Likewise, for a single-piece clamp versus any coupling type, these are also not interchangeable unless FAA approved in some manner as identified above.

Single-piece V-band <u>clamps</u> are stamped and roll formed from one single piece of base material. Materials used throughout are various stainless steel alloys or Inconel's. The single-piece straight (only) bolt is a stainless steel alloy. The self-locking nut is typically a high temperature steel alloy that is often silver coated. The self-locking nut is all-metal and the locking feature is a mechanical interference type with no polymer inserts. There is typically one washer under the bolt head and nut on these clamps. Refer to Figures 6 & 7.



<u>Figure 6</u>

Single-Piece, V-band *Clamp*



<u>Figure 7</u>

Single-Piece, V-band *Clamp*

NOTE: As noted above for multi-segment couplings, single-piece clamps may come in the exact same size and flange configuration and may look identical in all respects. However, clamps and any type of coupling may or may not be legally interchangeable without an aircraft, engine or part FAA approval at the DAH level.

2.2 Industry Standards

The following are the current aerospace industry standards for V-band coupling assemblies, their usage and installation:

SAE Aerospace Standards (AS)

AS1960:	Coupling Assembly, V-band, Sheet Metal Flange, Pneumatic Tube
AS1960/1:	Coupling Sheet Metal, 40 V-band, Standard Latch
AS1960/2:	Coupling Sheet Metal, 40 V-band, Quick Release (Optional Safety) Latch
AS1960/3:	Flange, Sheet Metal
AS1960/4:	Flange End, Design Standard

SAE Aerospace Information Report (AIR)

AIR869B:	V-couplings, Including V-band and V-Retainer Coupling Assemblies, Flange and Seal Design, Application of

2.3. Material Selection

Industry standards for material selection for turbocharger V-band coupling/clamps, components and flanges are contained in Table II.

Material	Specification	Commercial AISI Number
Corrosion and Heat Resistant Steels	AMS 5512 Comp Ti	321
Corrosion and Heat Resistant Steels	AMS 5511 Comp 301 ¼ Hard	301 ¼ Hard
Corrosion and Heat Resistant Steels		302
Corrosion and Heat Resistant Steels		303
Corrosion and Heat Resistant Steels	AMS 551 Comp 304	304
Corrosion and Heat Resistant Steels		305
Corrosion and Heat Resistant Steels	AMS 551 Comp 316	316
Corrosion and Heat Resistant Steels	AMS 5731	A286
Corrosion and Heat Resistant Steels	AMS 5732 or AMS 5737	A286
Alloy Steel	AMS 6322	8740
Corrosion and Heat Resistant Steels	MIL-S-18732	431ANL

Table II
Material Standards

3. HISTORICAL FIELD SERVICE DATA

3.1 NTSB & FAA Data Review

A team consisting of NTSB and FAA personnel was tasked to provide a historical perspective of turbocharger exhaust-to-tailpipe V-band coupling/clamp failures. Accident and incident data was reviewed from 1975 through September of 2017. The team's goals included:

- Capture V-band coupling/clamp failures
- Challenge and validate all data to at least one other data set, if possible
- Present the data in a chronological and logical manner

NOTE: The term "models" hereafter refers to all turbocharged single engine and multi-engine airplanes and helicopters. The term "event" can be construed as an accident, incident, or inspection item.

The NTSB generated a dataset from its sources, which the FAA then challenged for "relevant" failures. Relevant failures did not include items such as:

- Maintenance related (e.g. forgetting to torque the nut)
- Missing hardware (e.g. the self-locking nut)
- Bolt breakage (for undetermined cause)
- Unknown, or undetermined cause events
- Any narrative that did not offer physical proof of the statement(s)

The FAA then searched its SDR database for V-band coupling/clamp failure events. The initial search effort was revised to ensure pertinent data capture. The search was broadened to include items found during inspection, as many reported V-band coupling/clamp failures were not initially identified utilizing the original accident and incident event search criteria. Ultimately, the FAA SDR dataset was reviewed by the NTSB for relevancy and duplicity, resulting in a rigorously vetted dataset.

3.2 Results of Data Review

The data mining resulted in more than 14 NTSB investigated events and 19 FAA SDR incident reports all of which resulted in 13 fatalities. It must be clearly noted that this search result does not take into account the Cessna 300/400 series turbocharged multi-engine airplane events that culminated in approximately 28 fatalities and resulted in AD's 75-23-08 Revisions 1-5 and superseding AD 2000-01-16. Refer to Appendix A of this report for the dataset of the relevant V-band coupling/clamp failure events.

The dataset indicated that the V-band coupling/clamp failures can exist regardless of the product, manufacturer, detail design and/or installation differences between those products at the turbocharger/exhaust tailpipe interface. Since participation of the SDR reporting process is not mandatory the available data that comes out of the general aviation sector is produced and supplied on a voluntary basis. Therefore, it became apparent that the culminated data could not possibly provide a full and comprehensive history of this problem and all associated events. Consequently, the working group proceeded with caution and with the perspective that V-band coupling/clamp failures were more prevalent in the field then what has been presented herein.

4. CAUSAL ANALYSIS

4.1 Failure Modes

The following observed modes of failure were found in the dataset:

TYPE	OUTER BAND CRACK	V-RETAINER CRACK
Spot-welded, multi-segment coupling	YES	YES
Riveted, multi-segment coupling	1	UNK
Single-piece clamp	Not applicable	YES

4.2 Potential Causal Factors

These specific failure modes were then evaluated for potential causal factors:

- Transverse band cracking and separation (crack originating out of a spot weld)
- Circumferential crack in the v-retainer segment of a coupling or the clamp body itself

A summary of those failure modes and potential causes is presented below:

FAILURE MODE	POTENTIAL CAUSE	RECORDED
Transverse band crack	High thermal cycle load operations near material limits	YES
	Progressive stress corrosion cracking (pre-existing cracks)	YES
	Operating environment; heat/cool, vibratory	YES
	Installation; alignment/fit, torque, lack of inspection in the field	YES
	In-service usage; work hardening in a spot-welded area(s)	YES
	Known embrittlement in spot-welded areas during production	YES
	Material irregularity; physical damage in the materials in production	YES
	Process; poor spot-weld in production, heat/pressure issue.	NO

FAILURE MODE	POTENTIAL CAUSE	RECORDED
Circumferential V-retainer crack	Installation; alignment/fit, torque, lack of inspection in the field	YES
	Flange(s); warped, pitting/fissures, corrosive deposits	YES
	Flanges; incorrect flange on tailpipe to match turbocharger	YES
	High thermal cycle load operations near material limits	YES
	Progressive stress corrosion cracking	YES
	Operating environment, heat/cool, vibratory	YES
	Material irregularity; physical damage in the materials in production	NO

4.3 Findings

The following summarize the more significant repetitive findings from the review of the dataset:

- Multi-segment coupling transverse band cracking leads to total separation of the coupling
- Multi-segment coupling band cracks originate out of a spot weld
- Multi-segment couplings are not failing due to over opening.
- Two or three segment coupling failures are not discernable.
- Single-piece clamp cracking exists but does not lead to total failure as often now. However, many of these single-piece clamps and tailpipes are subject to AD repetitive inspections.
- Installation issues are a common thread.
- Materials are being operated at the high end of the material property limits.
- 300 series stainless steels or 700 series Inconel failures are not discernable.
- Similar operating conditions and environment for all make/model applications.
- Similar installations for all make/model applications.
- High probability for uncontrolled, in-flight fire, after cracking and separation of coupling.
- High severity of the event, typically hull loss at the least.
- In these cases, altitude is not necessarily conducive to continued safe flight.
- Potential exists to breach or bypass firewall exists.

4.4 Assumptions

The presented data allowed these assumptions to be made by the working group in order to proceed:

- This is currently not a coupling/clamp manufacturing or supplier issue.
- The product type designs are valid as is, having had no further detailed review.
- There are no PMA replacements parts involved in these events.
- There is no accounting for the effect of the many installation variables in the field.
- There is limited field service data on performance of the riveted multi-segment V-band coupling.

5. LABORATORY ANALYSIS

Results from the NTSB accident investigations and their lab examination of failed couplings and clamps were consistent between coupling and clamp failures. The multi-segment spot-welded couplings typically failed transversely across the outer band with crack initiations stemming from spot-welds that held the V-band segments and outer band together. Refer to Figures 1 through 4 and 8 through 13. The single-piece clamps typically failed along the apex or longitudinal axis of the "V". Refer to Figures 6, 7, 16 and 17. Findings from the compiled data included contributing factors such as pre-existing cracks, corrosion, lack of coupling/clamp inspection and timely replacement. Some of the failures occurred very shortly after an inspection or exhaust system maintenance activity in the general area. Table III contains a summary of the NTSB lab analyses.

EVENT	REPORT NO.	REPORT DATE	MAKE MODEL	DESCRIPTION	TYPE Coupling
WPR17IA198	TBD	08/22/2017 (event)	Enstrom F28F	Cracked but not separated, originates at a spot-weld with deformity present. Exhaust inlet, two-segment coupling.	Spot-welded
CEN16IA238	16-099	12/01/2016	Enstrom 280FX	Band separation due to failure at spot-weld(s) on the v-retainer segments.	Spot-welded
ERA16FA185	16-052	06/13/2016	Textron A36TC	Separated due to band crack at a spot-weld.	Spot-welded
WPR12LA414	13-068	08/30/2013	Textron T210N	Separated due to band crack at a spot-weld.	Spot-welded
WPR10FA056	10-008	01/25/2010	Textron A36 (STC)	Separated due to band crack at end of segments.	Spot-welded
LAX04FA001	04-058	05/25/2004	Piper PA-32R-301T	Separated due to band crack at a spot-weld, with pre-existing cracks.	Spot-welded
CHI02FA042	02-074	07/31/2002	Mooney M20M	Separated due to band crack at a spot-weld.	Spot-welded
FTW98FA325	99-60	01/20/1999	Commander 114TC	Separated due to band crack at a spot-weld, with pre-existing cracks.	Spot-welded
LAX91LA129	UNKNOWN	UNKNOWN	Textron 421B	Separation due to fatigue failure	Spot-welded
BFO91LA003	91-87	07/08/1991	Mooney M20M	Circumferential v-retainer cracking with deposits.	Spot-welded
LAX91FA001	UNKNOWN	UNKNOWN	Mooney M20K	Separated, due to cracking, intergranular.	Spot-welded
ATL86LA107	UNKNOWN	UNKNOWN	Piper PA-32R-300T	Separated	Spot-welded
LAX84LA035	UNKNOWN	UNKNOWN	Enstrom F28F	Separated due to crack at a spot-weld.	Spot-welded
DEN82DA110	83-44	08/31/1983	Piper PA-32RT-300T	Circumferential v-retainer cracking with deposits.	Spot-welded
MIA82IA110	UNKNOWN	UNKNOWN	Piper PA-31-350	Separated due to a brittle fracture, high temperature embrittlement, improper heat treatment of coupling during mfg. (several)	Spot-welded
KEY→ "UNKNOWN" means there was no lab report available and the description came from the narrative.					

<u>Table III</u>

Summaries of NTSB Laboratory Analysis

5.1 Failures Encountered

5.1.1 Failed; spot-welded, multi-segment, V-band couplings for reference.

Below are reference photographs of failed V-band couplings and clamps.

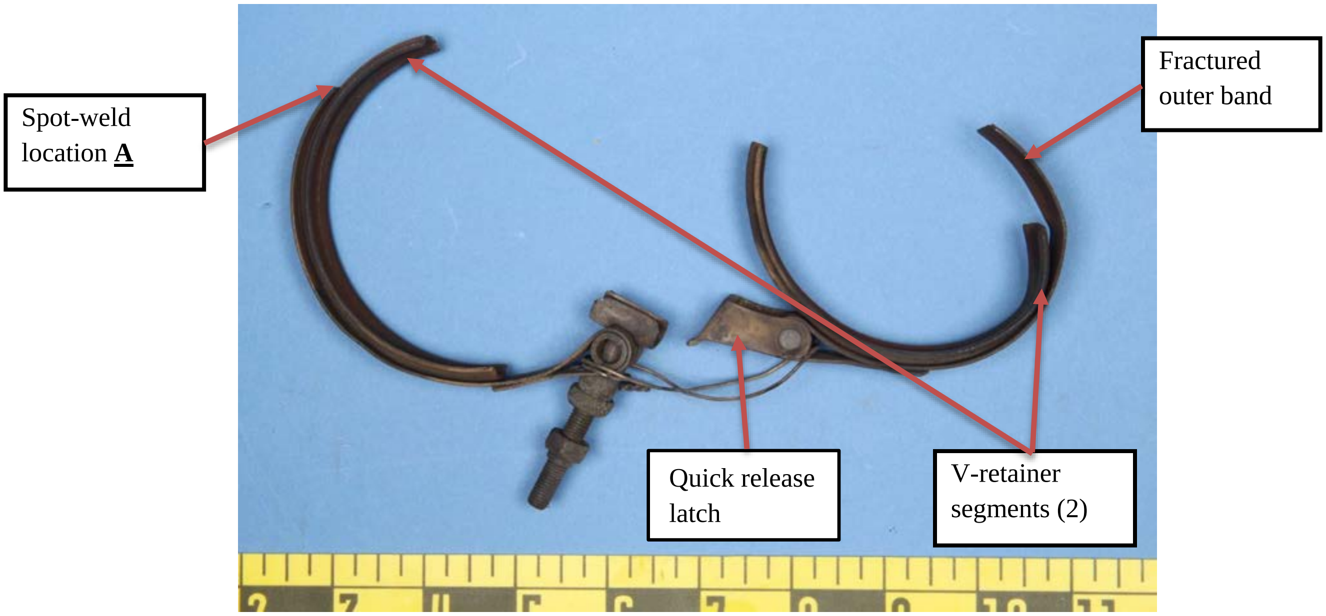


Figure 8

Spot-welded, 2-segment Coupling with Quick Release latch

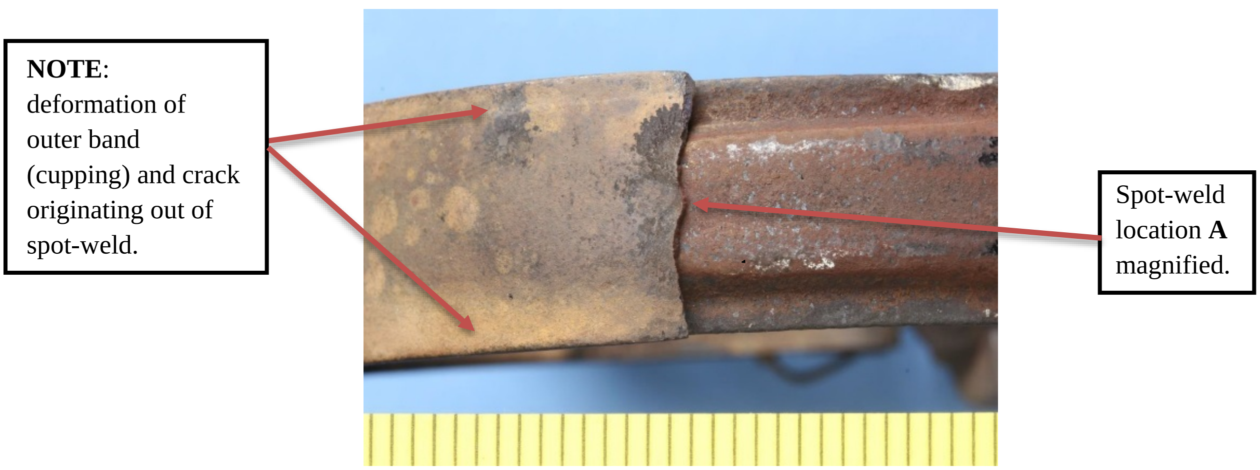


Figure 9

Same coupling above magnified

The above failure started as a crack that originated out of the spot-weld. The crack grew to a full transverse outer band crack that caused separation of the coupling. The above failure resulted in loss of the tailpipe, smoke in the cockpit, in-flight fire and fatalities. Note the safety wire is still in place.

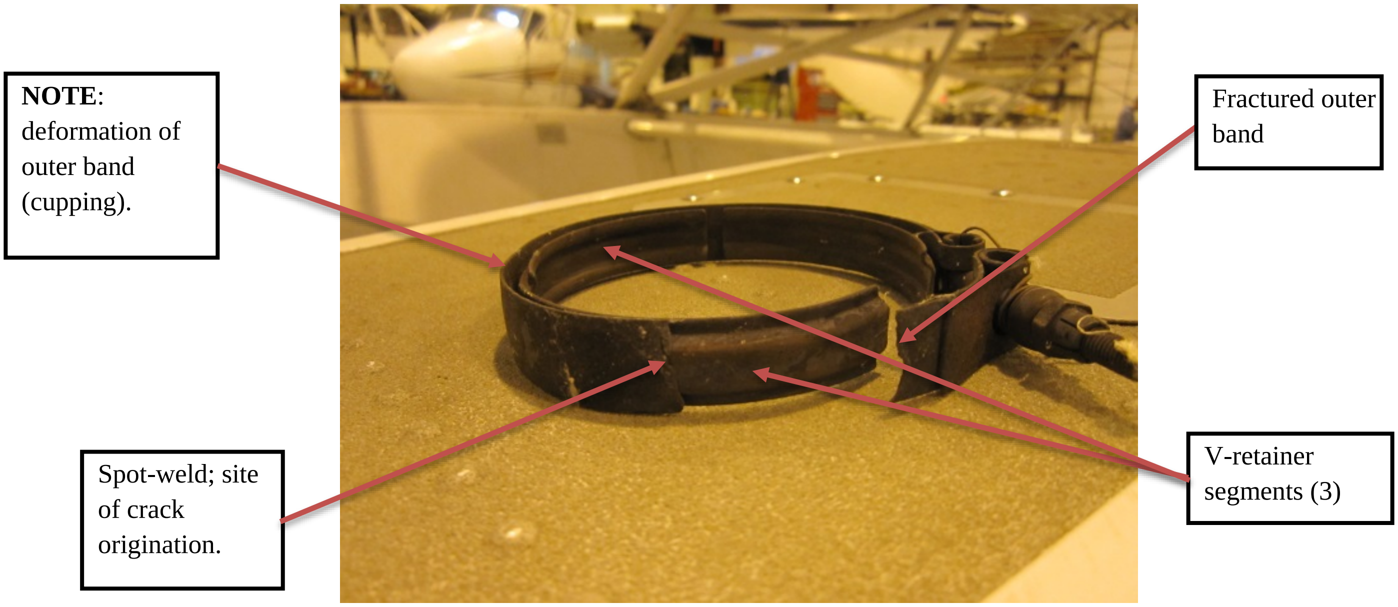


Figure 10
Spot-welded, 3-segment Coupling

The above failure started as a crack that originated out of the spot-weld. The crack grew to a full transverse outer band crack that caused separation of the coupling. The above failure resulted in loss of the tailpipe, smoke in the cockpit, in-flight fire and a very quick, direct in approach and landing on fire. There were no fatalities. Note again the safety wire is still in place.

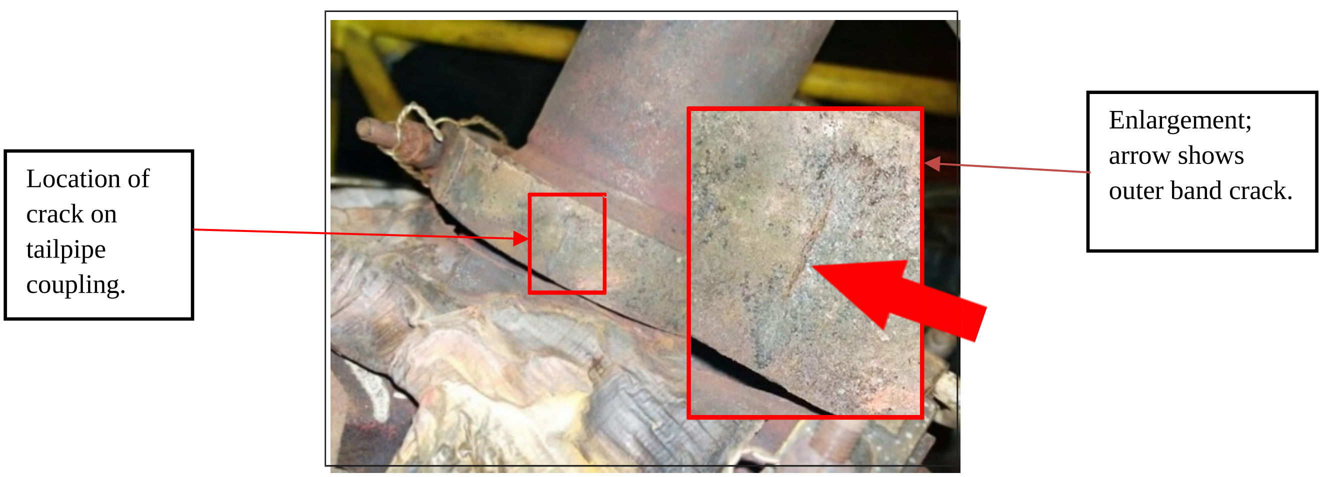
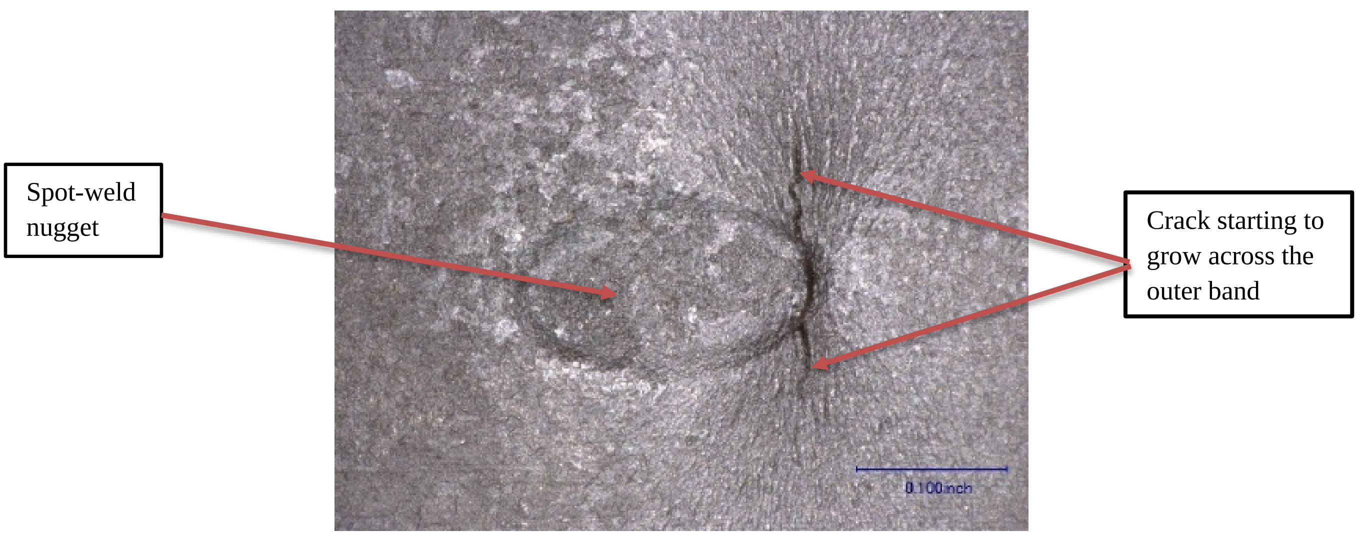


Figure 11
Spot-welded, Multi-segment Coupling

The above crack originated at a spot-weld. However, the crack had not grown across the outer band and the coupling had not separated yet. Found on inspection for another issue.

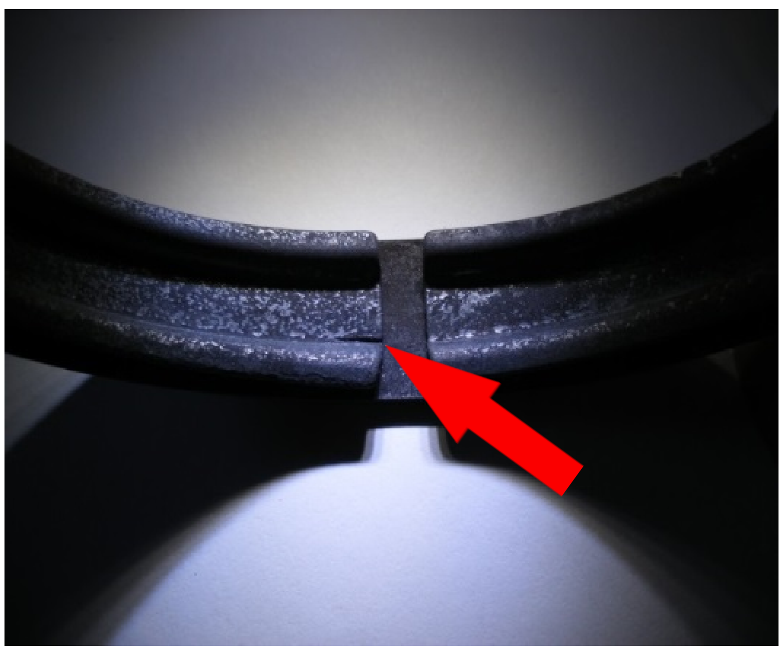
<u>Figure 12</u>
Spot-welded, 3-segment Coupling

The red arrow shows where the coupling is deformed at a spot-weld where the crack originates. The crack had not yet grown across the outer band and the coupling had not separated. Found on inspection for another issue.



<u>Figure 13</u>
Same coupling above magnified

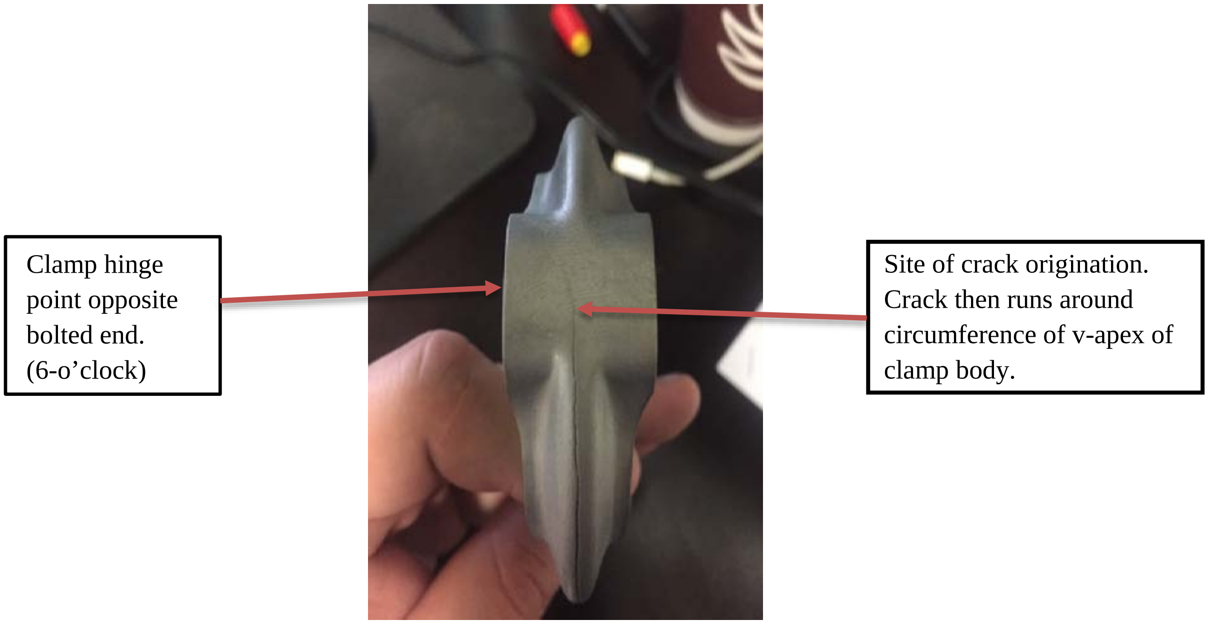
<u>Figure 14</u>
Spot-welded, 3-segment Coupling



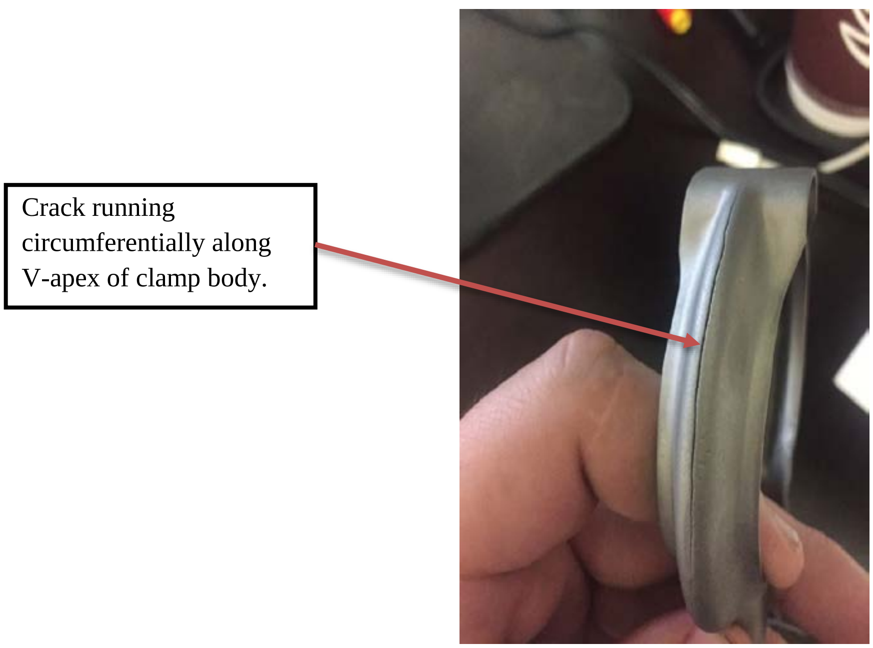
<u>Figure 15</u>
Spot-welded, 3-segment Coupling

Figure 15 is the same clamp as in Figure 14 above. This photograph was taken on a bench with a white top, using back lighting from a flashlight. There is a crack in the v-retainer segment inner corner radius. With the condition of the coupling, this crack was difficult to find with the coupling in-hand after tailpipe removal. This crack could not be found with the coupling installed. Found during inspection after tailpipe removal. Note the corrosion from salt water operations.

5.1.2 Failed; single-piece, V-band clamps for reference.



<u>Figure 16</u>
Single-Piece Clamp



<u>Figure 17</u>
Single-Piece Clamp

This crack was found during tailpipe removal and inspection which are required by AD.

5.2 Findings

In summary;

- The data covers turbocharged single and multi-engine airplanes and small rotorcraft from 8 of the largest manufacturers of these type products.
- The data indicates the problem is specific to the interface of the turbocharger exhaust to the exhaust tailpipe, regardless of the detail design and installation differences between those manufacturers.
- The results were consistent for multi-segment, V-band coupling and single-piece clamp failures:
  - Multi-segment coupling failures occurred regardless of the number of segments.
  - Spot-welded, multi-segment couplings typically failed laterally across the outer band (transverse), with crack initiation at the spot-welds that held the V-retainer segments to the outer band.
  - Spot-welded, multi-segment coupling outer band failure resulted in separation of the coupling and tailpipe from the turbocharger.
  - Single-piece clamps typically failed along the apex or longitudinal axis of the "V" segments.
  - Single-piece clamp cracks are often found during AD required tailpipe inspections.
- The compiled data included contributing factors such as corrosion, installation errors, and a lack of coupling/clamp inspection and timely replacement leading to the failures.

5.3 Conclusions

As can be seen in the data, the common denominator is the spot-welded, multi-segment V-band coupling. The majority of the reports indicated fatigue failure of spot-welded multi-segment V-band couplings, as a result of stress corrosion cracking, originating at or near a spot-weld. These are identical failure conditions identified in other multi-segment coupling AD actions. There is evidence of pre-existing cracking of the couplings. There is known embrittlement at the spot weld locations simply due to that manufacturing method. Outer band cupping on the multi-segment couplings was evident and is the result of age, over-use and potentially over-torqueing. It was also found that many of the couplings had safety wire across the bolt end. That safety wire could be helpful if there were a bolt or nut failure (extremely rare events), or the nut was missing. However, the safety wire is of no value when the failure is transverse band cracking and total separation at the spot weld, as seen in the data.

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6. RISK ANALYSIS,

6.1 Analysis

Small Airplane Risk Analysis (SARA) methods for wear-out and random failures (Ref. Figure 18) were used to evaluate individual and fleet V-band coupling/clamp quantitative risk when installed at the turbocharger exhaust exit.

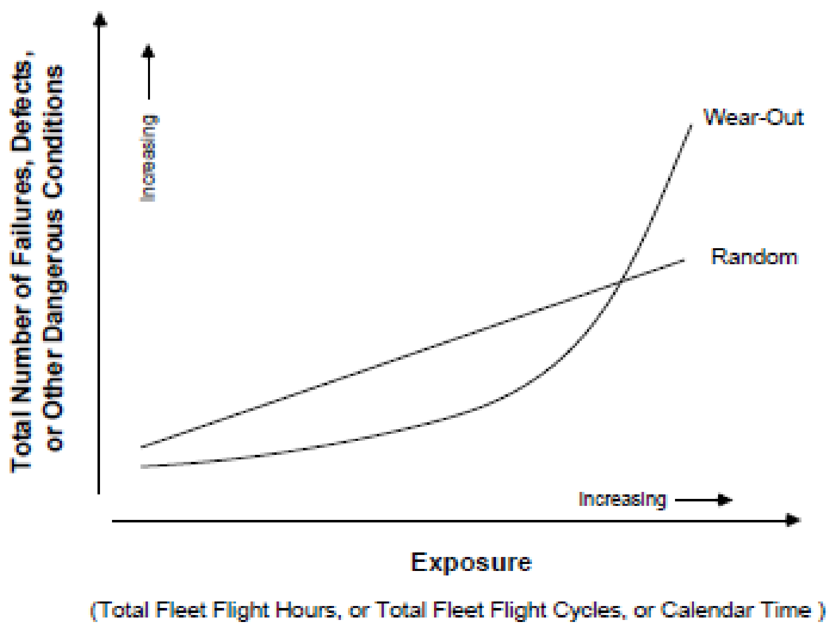


Figure 18
Time History of Random vs. Wear-Out Failures

As previously noted, there are two different designs of coupling/clamps; multi-segmented couplings and single-piece clamps, each displaying fatigue crack initiation and growth as the primary failure mechanism. Refer to Figures 1 through 5 for multi-segmented couplings and Figures 6 & 7 for single-piece clamps. Because of the displayed wear out failure characteristics, Weibull analysis was used to support the risk determination. Assumptions:

- There are approximately 18,000 aircraft with the V-band coupling/clamps of concern installed, including 10,000 single engine and 8,000 twin engine. The total fleet exposure is approximately 26,000 turbocharged engine powered aircraft exhaust systems that have V-band coupling/clamps installed.
- Average annual usage was estimated to be 140 flight hours per year.
- Failure data from NTSB and FAA datasets were used to determine the number of failures and hazard ratios.

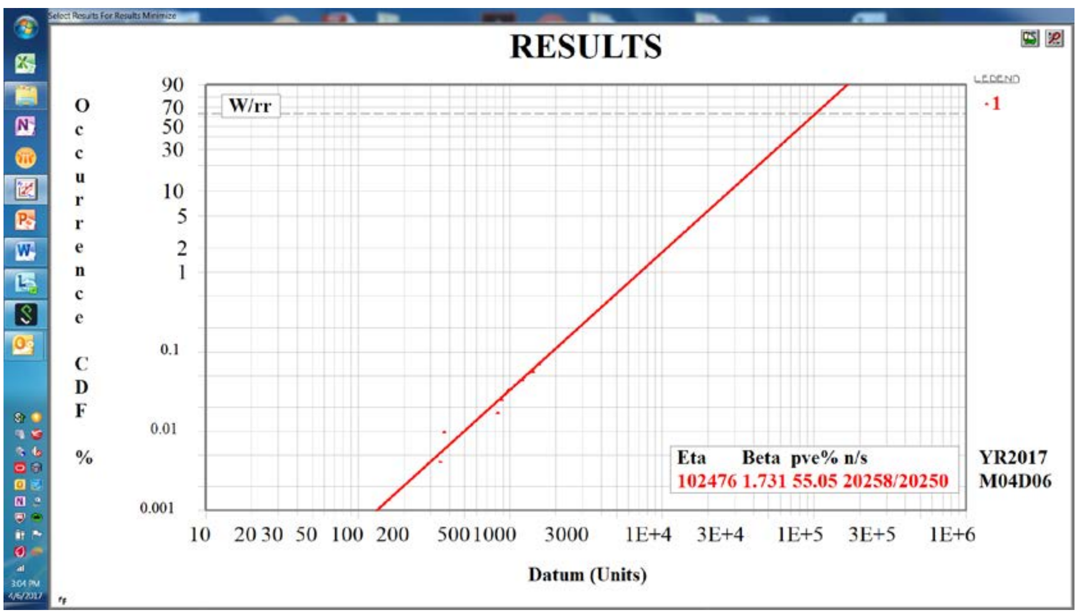
Because of the observed difference in coupling/clamp design, crack initiation points, and crack growth characteristics the population was divided into multi-segment coupling and single-piece clamp categories. A separate Weibull analysis was performed on data collected for the multi-segment couplings and single-piece clamps.

Multi-segment coupling failures and suspensions

From the recognized NTSB dataset of multi-segment coupling failures, 6 resulted in fatalities, including the May 2016 accident. To complete the Weibull analysis, suspensions or non-failed couplings in service, were estimated by assuming couplings are normally replaced at engine overhaul. The suspension population was evenly distributed throughout an overhaul cycle. Most engines have been overhauled. There are approximately 20,250 multi-segment turbocharger exhaust couplings installed in the affected fleet.

A Weibull analysis was done using the failure data and suspension estimate. The results are shown below.

Multi-segment coupling Weibull

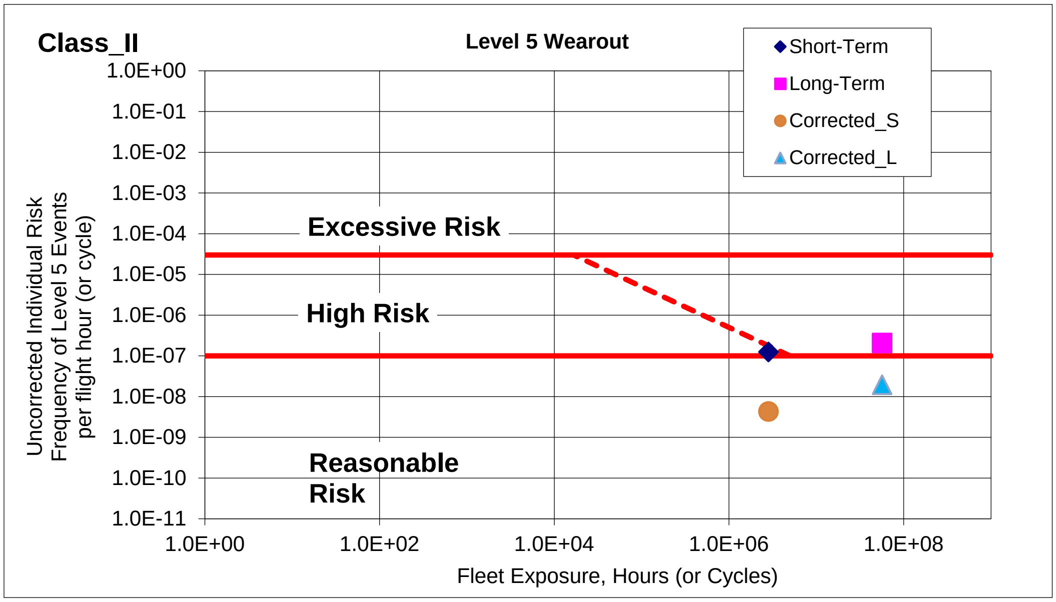


The Weibull analysis indicates a wear out failure mode (Beta > 1) for multi-segment couplings.

Combining the fleet demographic information, failure data, and Weibull results, the multi-segment coupling uncorrected and corrected individual and fleet risk were calculated using SARA methods and worksheets. Individual risk was based on as the predicted frequency of failures, and fleet risk is based on the predicted number of failures. Uncorrected risk is the projected future risk if no action is taken. Corrected risk is the projected risk if specific actions are taken to reduce risk.

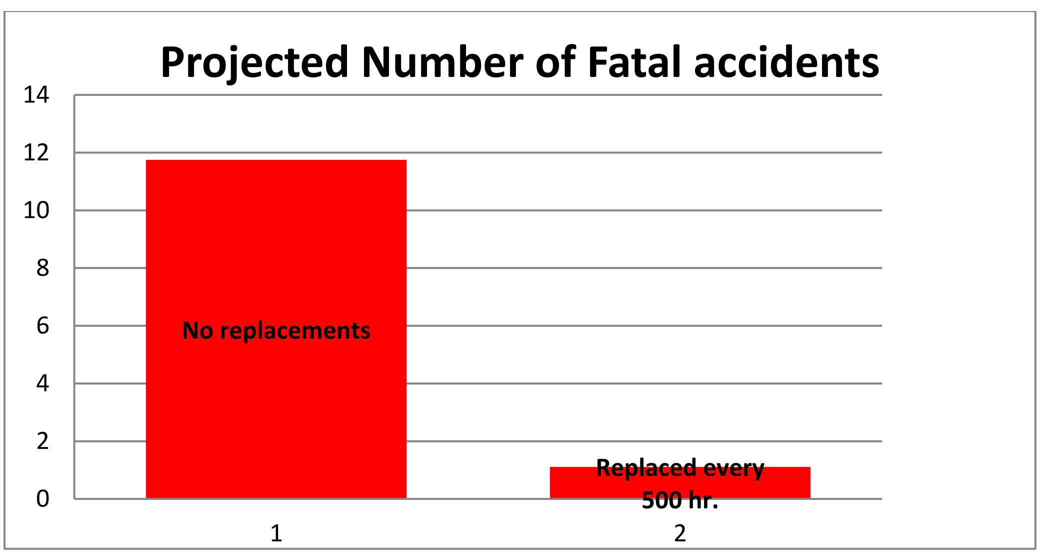
Calculated multi-segment coupling short term and long term individual risk was compared to SARA risk guidelines and is shown below.

Projected frequency of fatal accidents
No replacements (uncorrected) vs. 50 hour initial replacements, 500 hour repetitive replacements, and annual inspections (corrected)



Multi-segment coupling short term (1 year) and long term (20 years) fleet risk was determined and is shown below.

Multi-segment coupling fleet risk-
Projected number of fatal accident over the next 20 years
Uncorrected vs. Corrected



Multi-segment coupling failures have resulted in 6 fatal accidents. Data indicates multi-segment coupling replacements at 500 hrs. time in service (TIS) (e.g., life limit) combined with a fleet wide initial 50 hr. TIS replacement campaign, and an ongoing annual inspection reduces the individual risk below SARA guidelines for mandatory action, and the fleet risk is reduced to an acceptable level.

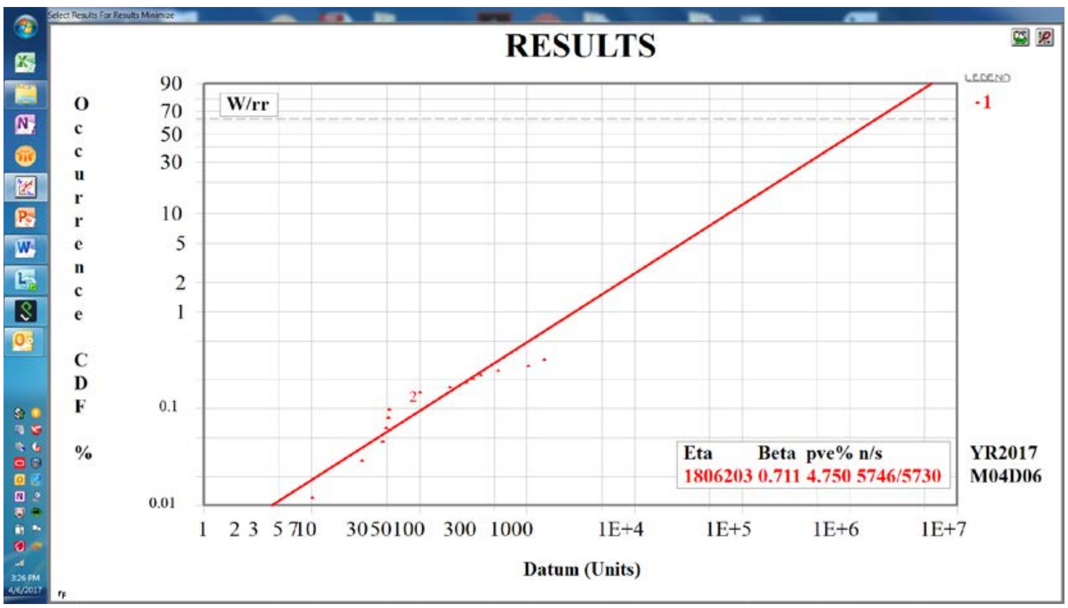
Single-piece clamp failures and suspensions

Historically, no fatal accidents have occurred due to a single-piece V-band clamp failure.

NOTE: the above statement is exclusive of the Cessna 300/400 series turbocharged multi-engine airplanes experiences prior to January of 2000. Prior to that time those airplanes experienced numerous coupling/clamp failures and fatal accidents. However, this was also prior to the development of AD 2000-01-16. AD 2000-01-16 has successfully managed the fleet risk with its mandatory actions for over 17 years now.

However, there have been several level 4 failure events recorded. Suspensions assume clamps are replaced at engine overhaul and the suspension population is evenly distributed throughout an overhaul cycle. Most engines have been overhauled. There are approximately 5,730 single-piece clamps installed in the affected fleet which are not currently effected by an AD.

Single-piece V-band clamp Weibull



The Weibull plot above signified overall infant mortality (Beta < 1) for single-piece clamps. The lower quality Weibull indicated the possibility of mixed failure modes. A review of failure reports showed some early failures likely due to installation technique, along with other traditional wear out failures. Field reports indicated that the single-piece clamp cracks are easier to find on inspection, and in most cases replaced before complete failure.

Predicted number of future single-piece clamp failures (no replacements)

Abernethy Risk (Standard) Quantity Expected Weibull

RESULTS, Set#1 1 M04-D06-YR2017
Present (Now) Risk=30.03341 Total / Suspension=5746/5730
Eta=1806203 Beta=0.7109287
Usage [Additional X-Value Age (Units) Each Month / Item]=12
No Renewal
Expected Additional Occur.(Cum.): Next Event[Month]=+4

Month	.........Risk	Month	.........Risk	Month	.........Risk	Month	.........Risk
6	1.46	96	20.15	186	35.96	276	50.25
12	2.874	102	21.27	192	36.95	282	51.16
18	4.251	108	22.38	198	37.94	288	52.07
24	5.596	114	23.47	204	38.92	294	52.97
30	6.913	120	24.56	210	39.89	300	53.87
36	8.206	126	25.64	216	40.86	306	54.77
42	9.476	132	26.71	222	41.82	312	55.66
48	10.73	138	27.77	228	42.78	318	56.55
54	11.96	144	28.82	234	43.73	324	57.43
60	13.17	150	29.86	240	44.68	330	58.31
66	14.37	156	30.9	246	45.62	336	59.19
72	15.55	162	31.92	252	46.56	342	60.06
78	16.72	168	32.94	258	47.49	348	60.93
84	17.88	174	33.96	264	48.41	354	61.79
90	19.02	180	34.96	270	49.33	360	62.65

Predicted number of future single-piece clamp failures (2,000-hr. replacements)

Abernethy Risk (Standard) Quantity Expected Weibull

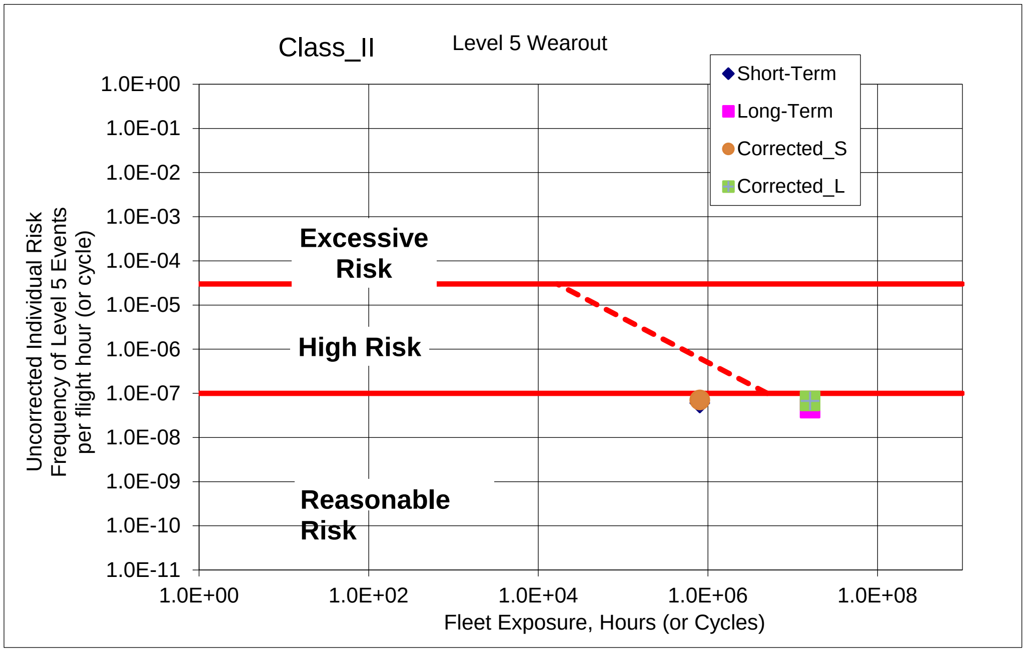
RESULTS, Set#1 1 M04-D06-YR2017
Present (Now) Risk=30.03341 Total / Suspension=5746/5730
Eta=1806203 Beta=0.7109287
Usage [Additional X-Value Age (Units) Each Month / Item]=12
2000 Un Replacement (F) : Renewal
Expected Additional Occur.(Cum.): Next Event[Month]=+4

Month	.........Risk	Month	.........Risk	Month	.........Risk	Month	.........Risk
6	1.736	96	25.86	186	50.69	276	74.6
12	3.406	102	27.5	192	52.3	282	76.2
18	5.115	108	29.01	198	54.02	288	77.78
24	6.755	114	30.66	204	55.62	294	79.37
30	8.452	120	32.17	210	57.33	300	80.96
36	10.07	126	33.83	216	58.91	306	82.54
42	11.76	132	35.37	222	60.61	312	84.14
48	13.37	138	37	228	62.19	318	85.9
54	15.05	144	38.56	234	63.69	324	87.61
60	16.65	150	40.32	240	65.14	330	89.46
66	18.16	156	42.02	246	66.76	336	91.12
72	19.62	162	43.87	252	68.28	342	92.89
78	21.22	168	45.56	258	69.89	348	94.51
84	22.73	174	47.32	264	71.44	354	96.25
90	24.35	180	48.96	270	73.04	360	97.85

The single-piece clamp uncorrected and corrected individual risk was calculated using SARA methods and worksheets.

Single-piece clamp individual risk is compared to SARA risk guidelines and is presented below.

Single-piece clamp individual risk for Class II airplanes-
Projected frequency of fatal accidents
No replacements (uncorrected) vs. 2,000-hour replacements (corrected)



With all factors considered, data indicated that single-piece clamp replacements before 2,000 hrs. (assumed approximate time for engine overhaul) may not be beneficial. However, replacement of single-piece clamps at approximate overhaul time, plus well defined periodic (annual) inspections, along with improved installation instructions and training may control risk to an acceptable level. Without other interventions such as annual inspections and additional training, risk associated with infant mortality failure modes usually increases with scheduled replacements.

6.2 Observations

- Multi-segment coupling failure is primarily transverse band cracking, and displays wear out characteristics.
- Multi-segment coupling risk may be substantially reduced with replacements at approximately 500 hr. TIS along with an initial replacement within 50 hours, and future annual inspections.
- Single-piece clamp failure is primarily circumferential V-retainer cracking and displays infant mortality failure characteristics. However, they may have a long term failure mode as well.
- Single-piece clamps may see limited risk reduction at replacements more frequent than at 2,000 hours or engine overhaul. However, annual inspections may help to further reduce risk.
- Existing mandatory AD actions which include repetitive inspections and/or life-limits have been effective in reducing risk in affected fleets.
- Riveted multi-segment couplings currently appear to have lower risk than those with spot welds. However, there is very little with regard to field service data on their performance.

7. EXISTING RECOMMENDATIONS, CORRECTIVE ACTIONS & PERFORMANCE

7.1 Government Formal Recommendations

7.1.1 National Transportation Safety Board (NTSB)

Since 1974, NTSB accident/incident investigations have led to the development and issuance of at least 7 NTSB Safety Recommendations concerning exhaust systems and/or exhaust V-band coupling/clamps. Many of those recommendations led to FAA mandatory AD action or recommendations in the form of FAA Special Airworthiness Information Bulletins (SAIB). Table IV contains a list of the NTSB safety recommendations:

NTSB Safety Recommendation	Description	Make/Model
A-90-166	Exhaust system	Piper PA-32RT-300T, PA-32R-301T
A-90-165	Exhaust system	Piper PA-32RT-300T, PA-32R-301T
A-90-164	Exhaust system	Piper PA-32RT-300T, PA-32R-301T
A-88-151	Exhaust system	Piper PA-32RT-300T
A-88-150	Exhaust system	Piper PA-32RT-300T
A-88-147	Exhaust system	Piper PA-32RT-300T
A-74-099	V-band engine exhaust clamp failures	Textron (Cessna) turbocharged 300/400 series

Table IV
NTSB Safety Recommendations

7.1.2 Federal Aviation Administration (FAA)

Since 1991, FAA Flight Standards District Office (FSDO) inspector accident/incident investigation support has led to the development and issuance of at least 11 FAA Safety Recommendations concerning exhaust systems and/or exhaust V-band coupling/clamps. Many of those recommendations led to FAA AD mandatory action or recommendations in the form of SAIB’s. Table V contains a list of the FAA safety recommendations:

FAA Safety Recommendation	Description	Make/Model
12.039	“V” clamp failure and inflight fire	Textron (Cessna) T206H
09.382	Lycoming engine clamp failure	Textron (Beech) A36 w/STC turbocharger
09.143	Aeroquip V-band exhaust clamps	Mooney M20M / Commander TC114
03.250	Turbocharger V-band clamp	Piper PA-23-250
03.105	Turbocharger clamp	Mooney M20M
03.055	Turbocharger exhaust systems	Mooney M20M
99.015	Turbocharger installation	Textron (Beech) A36 w/STC turbocharger
99.014	Turbocharger installation	Textron (Beech) A36 w/STC turbocharger
99.013	Turbocharger installation	Textron (Beech) A36 w/STC turbocharger
91.176	“V” clamps	Textron (Cessna) 421
91.175	“V” clamps	Textron (Cessna) 421

Table V
FAA Safety Recommendations

7.2 Government Mandatory Actions

7.2.1 FAA Airworthiness Directives (AD)

Since 1975, the FAA has developed and published 20 AD's (many of them as a result of NTSB/FAA safety recommendations) concerning exhaust systems and/or V-band couplings/clamps. Table VI contains a list of those AD's:

Airworthiness Directive (AD)	Description	Make/Model
2018-XX-XX	V-band Clamp	Textron (Beech) A36TC, B36TC, S35, V35, V35A, V35B
2014-23-03 (76-06-09)	Exhaust System Components	Piper PA-31P
2013-10-04 (82-16-05 R1)	Exhaust System Components	Piper PA-31, PA-31-325, PA-31-350
2010-13-07	V-band Clamp	Piper PA-32R-301T, PA-46-350P
2004-23-17	V-band Clamp	Mooney M20M
2001-08-08	V-band Clamp	Textron (Beech) 35-C33A, E33A, E33C,F33C, S35, V35, V35A,V35B, 36, A36
2000-11-04	V-band Clamp	Commander 114TC
2000-01-16 (75-23-08)	Exhaust System Components	Textron (Cessna) 300/400 series turbocharged twin engine airplanes
91-21-01	Exhaust System Components	Piper PA-32 and others
91-03-15	V-band Clamp	Mooney M20M
90-01-02	Exhaust System Tailpipe	Aerostar PA-60-600
89-25-05	Exhaust System Tailpipe	Aerostar PA-60-600
89-12-04	Exhaust System Components	Piper PA-32 and others
88-21-05	Exhaust System Components	Aerostar PA-60 all series
87-07-09	Exhaust System Components	Aerostar PA-60-600
82-16-05 R1	V-band Clamp Downstream Side of Turbo	Piper PA-31, PA-31-325, PA-31-350
81-23-03	Exhaust System; V-band Clamp; Emergency AD first	Textron (Cessna) (P210N
80-20-05	V-band Clamp; Emergency AD first	Piper PA-32RT-300T
76-06-09	Exhaust System; V-band Clamp	Piper PA-31P
75-23-08	Exhaust System Components	Textron (Cessna) 300/400 series twin engine airplanes
KEY → **(XX-XX-XX) = AD which has been superseded.**		

Table VI
FAA Airworthiness Directives

7.3 Other Recommendations

7.3.1 Design Approval Holder (DAH) Instructions for Continued Airworthiness (ICA)

The aircraft and engine type certificate (TC) DAH's have published numerous ICA's covering their products. Additionally, the STC and PMA DAH's have also published their own ICA's to address their approved modifications and approved parts. These ICA's include information about the procedures and processes required to properly maintain the product in the type design configuration over the life of the product. These ICA's can be in the form of:

- Maintenance Manuals
- Service Manuals
- Illustrated Parts Catalogs
- Service Bulletins
- Service Information Letters
- Field Notices
- Communiques
- other

The typical ICA's include things like the following:

- Airworthiness limitations (AWL)
- Life-limits or other time dependencies
- Inspection frequency and intervals
- Inspection procedures
- Procedures for proper installation and replacement of systems and components
- Trouble shooting guidance
- Part numbers and serial effectivity

Although in most cases there is no specific regulatory requirement to adhere to these ICA's, it is the FAA and DAH's expectation that the public use and adhere to the acceptable data found in those recommended procedures, practices, processes, etc. contained in the current DAH ICA's. Two exceptions to these expectations are regulatory requirements such as:

- regulatory action in the form of an AD or FAA approved AWL, etc.
- certificated operations being conducted under 14 CFR parts 121, or 135, etc.

The DAH's put forth numerous resources to generate, update and maintain current these ICA's even on legacy products that have been out of production for many years. It is FAA's expectation that the public conduct any servicing, maintenance or inspection activities using the current version of the applicable ICA.

7.3.1.1 Existing Maintenance Manual Practices

7.3.1.1.1 Inspections Requirements

The team reviewed existing AD's and other service information to build a matrix of existing maintenance requirements. This review included not only maintenance manuals but Service Bulletins and Service Letters as well. The review made apparent the wide range of information across the installed fleet. Some manuals had very detailed requirements while others had little information. Those aircraft models which had experienced cracked V-band coupling/clamps in the field tended to have more information included in their maintenance information. Additionally, newer models tended to have more details included in their maintenance information than legacy aircraft. Location of the maintenance information was inconsistent as well. Generally, if the maintenance manual contained information on V-band coupling/clamp installations it could be found in the airframe maintenance manual. However, occasionally the V-band coupling/clamp was part of the engine installation and the information was contained in the engine maintenance manual. The inspections called for in the maintenance procedures varied widely across the applications as well. Those ranged from general visual inspections every 100-hr./Annual inspection to very detailed and prescriptive, inspections every 25 hrs. time in service. Those with the more prescriptive inspections were those mandated via FAA AD.

7.3.1.1.2 Life-limits or other time dependencies

A review of the service information for V-band coupling/clamp installations shows there are some mandatory life limits on selected V-band coupling/clamp installations. These have been driven by FAA AD requirements. It was found that one manufacturer specified replacement of the V-band clamp at engine Time Between Overhaul (TBO) of 2,000 hr. TIS. However, engine TBO is legally only the engine manufacturers recommendation and 14 CFR part 91 operators which are the majority of General Aviation (GA) aircraft do not need to adhere to those recommendations. On the other hand, certificated operations under 14 CFR part 121 or 135 would have to adhere to those engine TBO requirements. Of note, there are also entities that now promote engine care "on-condition" and recommend that operators not adhere to the engine manufacturers published TBO. All other installations are an as required replacement for the V-band coupling/clamp based on inspection findings.

7.3.1.1.3 Installation guidance

As with the inspection requirements, installation guidance varied widely (in detail and location) across the installations. Legacy, out of production airplanes tended to have less information included in their maintenance manuals versus newer production aircraft. Service history also had an impact on the level of detail included in the maintenance manuals. Those airplanes with a history of V-band coupling/clamp separations tended to have more details and installation guidance than those with no history of separations. There were some common themes identified across manufacturers applicable to all V-band coupling/clamp installations. Many manuals stressed the importance of loosely fitting the exhaust components prior to torqueing, to insure all components were aligned properly and no preloads were introduced into the system. A few of the manuals also specified specific torqueing procedures for the V-band coupling/clamp to ensure even distribution of torque around the clamp.

7.3.2 FAA Special Airworthiness Information Bulletin (SAIB)

SAIB's are not mandatory in a regulatory nature. SAIB's are recommendations FAA prepares to alert the public of special aviation safety issues that arise. FAA takes input from any source such as the DAH, owners, operators, maintenance shops, technicians, inspectors, etc. to develop an SAIB. FAA strongly encourages owner/operators/technicians to read and heed the direction and recommendations provided in an SAIB. There have been 47 "exhaust system" related SAIB's over the years. Of those, 10 are germane to exhaust systems and V-band coupling/clamps specifically and are contained in Table VII.

SAIB	Subject
CE-18-07	V-band Couplings Used in Engine Exhaust Systems on Turbocharged Reciprocating
CE-13-45	Engine Exhaust; Tailpipe V-band Couplings
CE-13-07R1	Engine Exhaust; Tailpipe V-band Couplings Textron (Cessna) T206H
CE-13-07	Engine Exhaust; Tailpipe V-band Couplings Textron (Cessna) T206H
CE-10-33R1	Engine Exhaust
CE-10-33	Engine Exhaust
CE-09-11	Turbocharged Engines
CE-05-13	Mooney M20M AMOC to AD 91-03-15
CE-04-22	Exhaust System Components
CE-03-46	Mooney M20M V-band Clamps

Table VII
FAA Exhaust System SAIB's

7.4 Other Information

7.4.1 Advisory Circular 43-16A; Aviation Maintenance Alerts Articles

Up to November of 2012, the public, industry and FAA had the ability to submit for publication maintenance alerts articles. These articles, submitted by anyone, highlighted maintenance issues or concerns the author had been exposed to. This could have been through an inspection, overhaul, installation, servicing, etc. in the field. Oftentimes these articles included diagrams or photographs to further express the issue at hand. These articles compiled and edited for publishing by the FAA were presented in the Advisory Circular 43-16A, Aviation Maintenance Alerts. Since the inception of the Alerts back in the late 1990's numerous articles were presented by the public and FAA to alert owners, operators, and technicians about their findings from the field concerning exhaust systems and V-band couplings and clamps. There is no means to search the archival record to determine the exact number of these publications, and FAA Flight Standards Service cancelled the Alerts Article system in June of 2015. However, some archived Alerts Articles are still retained on the internet.

7.5 Performance Assessment

As can be seen above the FAA published 20 exhaust system AD's, (10 of which are V-band coupling/clamp specific) 10 comprehensive SAIB's, and numerous Maintenance Alert articles on exhaust systems and V-band couplings/clamps. In most cases, the AD's were developed in conjunction with industry developed ICA's designed to address findings from the AD investigations. Though the responses to the past V-band coupling/clamp failures were certainly commendable, the efforts were reactive in nature and did little in the way of accident prevention when it came to the broader turbocharger exhaust tailpipe V-band coupling/clamp utilization. The ADs that existed during this research effort only covered about 18% of the single-engine and 70% of the twin-engine turbocharged, reciprocating engine-powered aircraft, thus leaving a considerable population vulnerable to V-band coupling/clamp failures without mandatory inspection intervals and component life-limits.

Additionally, the working group reviewed the effectivity of the previously issued ADs in preventing accidents from V-band coupling/clamp failures at the turbocharger/exhaust tailpipe junction. Review of the data revealed that the previously mandated periodic inspections and life-limits were successful in preventing V-band coupling/clamp failure accidents in the covered fleets (e.g., AD 2000-01-16). The historic perspective and AD success, coupled with the fact that the V-band coupling/clamps at the turbocharger/exhaust tailpipe junction are exposed to similar operating conditions (e.g. exhaust gas temperatures, corrosive environments, etc.) regardless of aircraft make or model or engine/turbocharger combination, prompted the working group to support a global approach via mandatory action in the form of an AD that would address those aircraft that are not already covered by an existing AD. This can be accomplished using a similar approach as above, namely mandatory inspections and life-limiting of the V-band couplings and clamps.

8. TARGETTED OUTREACH 2016

8.1 Direct Airworthiness Concern Sheet Dissemination

The working group wanted to access the current state of V-band coupling/clamps in the field. The Small Airplane Directorate processes had a tool developed to do just that. It's called an Airworthiness Concern Sheet (ACS). This document is part of the SAD Monitor Safety Analyze Data (MSAD) processes that may be utilized to further investigate and research any safety concern or issue. The ACS process goal is to get real-time feedback from anyone that is exposed to or involved with a product's use, servicing, maintenance, inspection, etc. The ACS is used to try and engage the public to provide feedback as to what they are experiencing in the field. FAA can then use that information to assist in making informed decisions about future actions. The working group developed an ACS in hopes of garnering information without burdening the public significantly for resources. Refer to Appendix C for the complete ACS.

The working group performed targeted outreach in the distribution of the ACS to help ensure maximum participation and contributions from the public. The ACS was sent directly to those entities found in Table VIII for their feedback:

AOPA	Mooney Aircraft Pilots Assoc.	Piper Aircraft	Textron Aviation (Cessna/Beech)
GAMA	Piper Owner Society	Mooney Aircraft	Cessna Pilots Association
EAA	Tornado Alley Turbo	Lycoming Engines	Twin Cessna Flyer
Helicopter Association Intl.	Acorn Welding Ltd.	Continental Motors Intl.	Cape Air
Cessna Pilots Association	Piper Flyer Association	Eaton (Aeroquip)	Heliarc Welding Service, Inc.
American Bonanza Society	Knisley Welding Inc.	RAM Aircraft, LP	Aerospace Welding Minneapolis

Table VIII
Direct ACS Dissemination

Many of these entities took the initiative to further broadcast this request for information through their electronic/social media systems as well. In addition, the ACS was broadcast to the public on Twitter and re-tweeted mid-week as well as a Linkedln posting.

The feedback summary is as follows:

- 21 total responders
- 13 direct replies
- 55 comments
- 799 views
- 363 shares

The following types of feedback were received:

- anecdotal
- hypotheses
- “solutions”
- detailed (e.g., 3 pages of text)

The responses were a valuable and welcomed input to the working group to gain further field experience knowledge. The following represent the findings generated by the ACS. An [M] indicates there were multiple records of a similar nature:

- Poor or no detailed instructions, torques, tools, process, repeat [M]
- Some installations are much easier than others; install and inspection [M]
- High running torque leads to under torqueing [M]
- Tap around periphery during installation may or may not be possible [M]
- Unknown proper torque, certificate holder no longer exists [M]
- Use of power drivers averse to torque setting [M]
- Ability to see, and access to properly inspect [M]
- Opened too far, repeatedly
- Age, stress, corrosion
- New versus old components, coupling/clamp, flanges, seal, pipes don’t play well [M]
- Deposits leading to corrosion and rapid aging [M]
- Improper fitment, flat flanges, pipe insertion, hanging/support of tailpipe[M]
- Overuse of coupling/clamp; cupping, crowning [M]
- Tool marks, nick, gouge, tear in any part [M]
- Overuse of self-locking nut [M]
- Unapproved nut substitution, not high temp, or silver plated
- Lack of high temp, anti-seize usage [M]
- The operating environment itself

The following represent the suggestions made by responders to address various issues:

- Applicable OEM provide detailed instructions and inspections (including abandoned STC) [M]
- Define 'loose' installation of tailpipe, hangers, etc.
- Alignment is absolutely critical [M]
- Be careful in torqueing nut, don't use power tools[M]
- Liberal amounts of hi-temp anti-seize are good[M]
- Torque and re-check frequently, post engine run [M]
- Do not re-use nuts [M]
- Tap around the periphery is good but may not be possible, no more than twice in single torque sequence [M]
- Our standard remove & replace program controls the issues
- Don't over-torque to solve leaking/soot issue [M]
- Safety wire is good for bolt/nut failures [M]
- Add torque and p/n tag and open limiters on all coupling/clamps [M]
- Torque and open limiter required for airworthiness [M]
- Support the tailpipe a must, shorter the better [M]
- Use single-piece clamps instead [M]
- Use only new coupling/clamp for fit checks [M]
- Life limit is a good idea, cheap insurance
- Frequent inspection required after replacement [M]
- Bead blast and fluorescent penetrant inspection will find V-retainer cracks
- Inconel systems perform better
- Inspections should occur at:
  - Pre-flight with a tailpipe grab (it is a life saver)
  - 10/20/50 hr. after any removal or replacement (plus, do an engine run)
  - 50-hr. intervals, repetitively
  - Annual/100-hr. whichever occurs first
- Life-limits:
  - Use AD and OEM recommendations
  - 350-400 hr.
  - 400-hr.
  - 500-hr.
  - Overhaul; 1400/1600/1800/2000/2200 hours TIS, as applicable to the engine

The following potential solutions were recommended by responders:

- Use more expensive, higher tech cast/forged multi-segment coupling
- Use component similar to that specified for large Rolls Royce turbofan engines

The working group took all of the above information under consideration in developing the recommendations herein.

9. ALTERNATIVE EXISTING DESIGN SOLUTIONS EXAMINED

The working group looked at the historic and current state of the turbocharger to tailpipe interface. In the 1960's there was only one airplane that did not have a V-band coupling/clamp at the turbocharger to tailpipe interface. That airplane used an Army/Navy (AN) type, standard 4-bolt flange at both the turbocharger and tailpipe with a gasket. However, that interface combination was very short lived, as the very next model year of that airplane incorporated what is now the industry standard (for this application), a 40° V-band coupling/clamp interface. The current legacy fleet and production turbocharged reciprocating engine powered aircraft use the same V-band coupling/clamp interface.

9.1 Other existing new design couplings

The working group examined and discussed a variety of interface options. The primary driving characteristics for consideration in this aircraft market segment is cost. However, other characteristics also warrant consideration such as required interface changes, allowable installation flexibility, existing envelop constraints, and inspection ease. Many of these considerations manifest themselves as additional costs and those changes would have to be traded against the potential repetitive cost of imposing a coupling replacement and inspection interval. One general advantage to utilizing a V-band configuration is that the "V" formed by the flanges and that of the mating coupling is a standard 40°, which permits a variety of coupling configurations or a clamp to be used at the turbocharger/tailpipe interface. The working group examined a more robust (forged) machined coupling design such as the ones shown below in Figures 19 and 20.

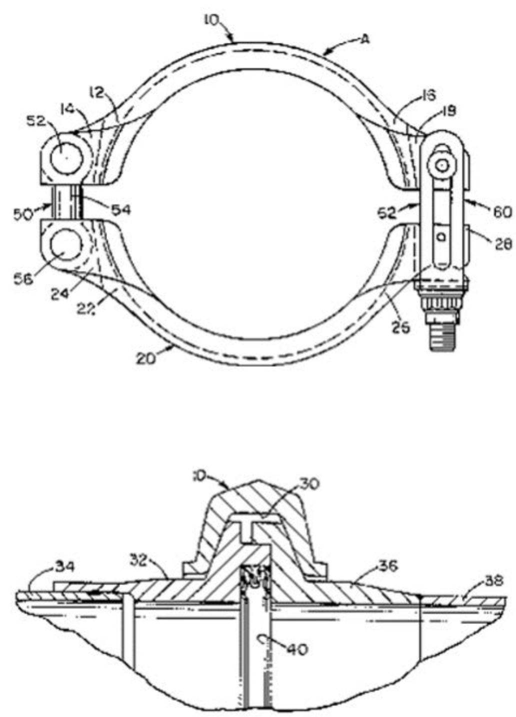


Figure 19
Forged and Machined Coupling

Figure 20
Forged and Machined Coupling

This type of coupling is typically used in large turbofan aircraft engines in a high pressure and temperature application, and could be a retrofit option with other potentially significant changes to the exhaust installation design (i.e., the turbocharger casting flange configuration). This type of coupling also comes from a much grander economic model (i.e., large transport aircraft) that may prove prohibitive to the General Aviation model. Coupling cost can also be two to four times more expensive than a traditional sheet metal coupling. This type of coupling works best with machined piloted flanges to help ensure tailpipe alignment which could require changes to flanges on both the tailpipe and turbocharger, which are also an industry standard on legacy and current production aircraft products using this configuration. Design aspects of this coupling could also exceed the envelope of the traditional sheet metal coupling making it a challenge for some confined applications. However, the possibility exists for this to be a one-time design change/replacement item with the other design changes noted above thereby potentially offsetting the overall cost. This type of coupling is not currently utilized in this application and would require FAA design approval activity for new production or retrofit applications.

9.2 Other existing approved coupling design

The working group also looked at an existing alternative to the high volume use of spot-welded couplings. As presented in Section 2 herein there are riveted couplings of almost identical design that are fully retrofit capable (with an FAA approval). Some of the products effected by the issues herein currently use a riveted V-band coupling. Riveted couplings are not as prevalent in current DAH configurations and thus the field performance data is very limited. However, riveted couplings have been used to replace spot-welded in past DAH approved changes which were then mandated by AD actions. It should be noted that riveted couplings come with their own nuances that could also potentially affect their service lives. For example, spot-welds are replaced with an equivalent number of upset or collared mechanical fasteners (rivets). Rivets require holes in the parent and joining material. Holes in aircraft structures often manifest themselves as sites of fatigue crack initiation and thus a riveted coupling may face the same predicament over time in the thermal cycles couplings experience. Riveting potentially also brings on other manufacturing issues that may affect service life such as hole drilling, punching, de-burr, etc. So any replacement of a spot-welded with a riveted coupling should be done with caution, and with an understanding of its potential limitations. However, all coupling/clamps come with their own specific set of nuances in their design and manufacture that must be taken into account when elected for use.

9.3 Other existing approved clamps

The working group also looked at another existing alternative design used on many of the legacy products, the simple, single-piece V-band clamp, aka a Marmon clamp. Refer to Figure 6 & 7. There are a significant number of single-piece clamps used in this application on legacy products (e.g. all Cessna turbocharged twins) and thus a substantial service history exists. The single-piece clamp service history indicates a potential for increased clamp service life. However, that has come with a commensurate mandatory repetitive inspection program mandated via AD actions (i.e., 2000-01-16). It is important to note that the use of single-piece clamps are typically in applications with either very short or supported tailpipes which help reduce the stresses typically taken up by the more substantial spot-welded/riveted couplings acting alone.

9.4 AN 4-bolt flange design

The standard AN/ANSI (American National Standards Institute) specification four-bolt flanged, gasketed interface is another existing option. However, for the flanged configuration to be used on legacy products it would require substantial changes to the turbocharger cast iron housing configuration and the tailpipe. As mentioned above the legacy product market and low volume new production market would be hard pressed to absorb the costs involved in such changes. This type of installation is also only viable where the installation envelope in the engine compartment has the space and clearances necessary to permit such an installation without generating other issues. However, with a clean sheet design for an aircraft product the manufacturer could specify the AN 4-bolt flange interface at their new turbocharger exhaust exit and for the tailpipe, thus eliminating the v-band coupling/clamp issues altogether. It is notable that FAA has worked with one applicant that elected to configure their new aircraft product turbocharger with the AN 4-bolt flange design because of their experiences on legacy products with v-band couplings/clamps over the years.

10. NEW DESIGN APPROVAL CONSIDERATIONS

10.1 Considerations

As discussed in the prior section there may be alternative design solutions. However, as also noted above, in this aircraft product market sector everyone is extremely cost sensitive, and the cost of anything aircraft related is extremely important to the public when investigating an aircraft purchase, ownership, operations, servicing and continued operational maintenance. The propensity of the affected fleet herein are legacy products most of which are 30-50 years old. Many of those products even with the best efforts of the OEM are very difficult to support. Unlike Detroit automakers, U. S. aircraft/engine manufacturers support their products much further into a life-cycle and often beyond what may have been envisioned to be a reasonable life of the product. Much of that stems from the fact that many of the legacy products are irreplaceable. There is not another aircraft/engine that can do the same job. As such, the owners and operators have in some cases gotten approval for changes to design or parts replacements to keep their aircraft flying while being cost conscious. For example, at least one OEM no longer supports the exhaust system components on their aircraft and that load has been taken up by FAA PMA replacement parts in total. However, that only works in the case where there is a viable economic model for the change.

10.2 Methods

There are two methods of getting FAA design approval for a spare or replacement part.

1) Aircraft or engine DAH (TC or STC) type design approval; new and spares
2) Design approval by Parts Manufacturing Approval (PMA); replacement parts

The process involved in achieving FAA approval in both cases above is essentially identical with both having to meet the applicable airworthiness requirements, with one exception that is highly unlikely on older legacy products. That one exception being PMA of a part through licensing agreement (literal identicality).

That being said, the working group is not aware of any PMA by licensing agreement for V-band couplings/clamps. The FAA is aware of only one PMA holder that exists for V-band coupling/clamps and they gained PMA approval based on a test & computations method.

Type design approval by the DAH (TC or STC) is essentially the same as PMA by test & computations. In both methods, the applicant must show proof that they meet the applicable airworthiness requirements. Once that is proven, the manufacturing approval aspects are controlled by the applicable Manufacturing Inspection division of FAA and those regulations.

The key to any of the above approvals being sought or ever happening is in whether there is an economic model that makes sense to the DAH. Can they manufacture and supply a high-quality part to the effected fleet and at the same time make money? This is the most significant aspect involved in getting high-quality cost effective spare or replacement parts to the field. Large legacy manufacturers with high overhead charges, that have not built the product for 30-50 years have great difficulty justifying any expense of resources on those products (even though to some there exists unwritten expectation that they support their certificated products ad infinity). The same economics hold true for the PMA seeker, namely, can they make enough high-quality parts, pay their bills and turn an acceptable profit? Safety comes with a real, significant expense on legacy products and the manufacturers are left to solve the problem as cost effectively as possible without the high-volume related to other industries. This cost/benefit struggle continues throughout all aspects of aviation long after production of the product, article or part by the OEM.

11. POTENTIAL FUTURE CORRECTIVE ACTIONS EXAMINED

The working group evaluated different forms of corrective action and developed options based on research findings. The following fundamental considerations were used for the working group's considerations:

- The data shows that failure of v-band couplings used to attach the tailpipe on the turbocharger exhaust exit flange continue to occur at an unacceptable rate.
- All current data points to fatigue failures in the form of transverse band cracking, which originates out of a spot-weld, on spot-welded, multi-segment, V-band couplings.

- Service history shows that without a mandate, inspections, discoveries and replacements are not being accomplished to preclude the next event.
- SDR data and ACS feedback indicate that mandatory inspection and life-limit requirements have mitigated risk in fleets that have an applicable V-band coupling/clamp AD.
- Current data shows that this failure is not prone to the V-band coupling/clamp at the wastegate-to-exhaust interface and thus is not part of these efforts.
- The failures occur across the DAH turbocharged reciprocating engine, make/model aircraft product lines, regardless of type design, installation variables, or operational usage between those products.
- Separation of the tailpipe from the turbocharger exhaust exit flange leads to rapid overheating and high probability of in-flight fire and fatalities.
- There are no other regulatory mitigations for such events (e.g. no requirement for fire detection/suppression on most affected products).

11.1 Options

The potential corrective actions can be grouped into one of two major categories, mandatory options required by regulation and non-mandatory options which are not supported by a regulation. Those can be further broken down into these potential choices:

- Non-Mandatory Options:
    - Recurring SAIB or similar
    - PMA for replacement of a coupling type or to a clamp, or all new coupling/clamp
    - DAH ICA (e.g. service bulletins, maintenance manual revision)
    - Outreach – public awareness
    - Industry Standards updates

- Mandatory Options (AD is the conveyance):
    - Design change required by 14 CFR part 21.99 such as:
        - New turbocharger to tailpipe interface
        - New turbocharger to tailpipe attachment methods
        - New exhaust system installation concepts
    - Coupling life-limit per Airworthiness Limitation
    - Inspection criteria requirements (recurrent inspection)
        - Visual with detailed instructions, methods & findings
        - Non-destructive of some type

11.1 1 Discussion on Non-Mandatory Options

The working group looked at the two potential corrective action categories with the historical perspective obtained through the research effort. Government has taken the non-mandatory path numerous times in the past and currently observes an unacceptable failure and accident rate on V-band couplings/clamps. Vehicles such as an SAIB may create a stir the moment they are published with a short-lived peak in awareness, but they are mostly ineffective in causing long-term change in the data.

Over the past few decades, DAH's developed and published numerous ICA's which are only recommendations to the majority of the owner/operators that do not have to comply with the inspection intervals or procedures in the ICA. Today, there are even advocates that preach against following the recommended overhaul intervals in the DAH ICA's, based on their experiences.

Outreach, another valuable tool in the working groups arsenal is usually well received, even more so with the expansion of social media; the ACS exposure proved that. We have also been very well received in our advocacy of these issues at FSDO Inspection Authorization (IA) seminars. As far as the industry standards are concerned, they have been in place for decades now and do not appear to be a significant part of the problem, nor are they currently a contributor to our fatal accident rate. There is really not much 'design' occurring on the systems and components involved herein. The contributor to the accident rate is the coupling/clamp itself and not the interface design.

Finally, there is the optional, non-regulatory required potential for PMA replacement parts. Again on legacy products, that economic model may not be viable. Currently, the solutions that are economically viable in PMA are coupling/clamps of very similar if not identical type design but offered by a different supplier/manufacture. With essentially the same type of design, the turbocharger/tailpipe interface is subject to the same type of failures, and we saw in the dataset that the failures occur across supplier lines. Changes in the type design say from a coupling to a single-piece clamp may be an improvement, but the economics must work out or those type of offerings will not come to fruition.

11.1.2 Discussion on Mandatory Options

The working group also looked at the mandatory action category. As presented earlier, new type design solutions come with a significant economic toll which is not readily absorbed by the legacy fleet manufacturers, owners, operators or maintainers. The majority of the products involved are 30-50 years old. There is no viable economic model that makes it readily possible for the DAH's that have not produced the product for over 30+ years to make a significant design change. The turbocharger to tailpipe interface involves a very expensive aviation component, the turbocharger. The standard interface since the 1960's has been the 40° 'V" flange to accept a 40° V-band coupling/clamp. The manufacturing and supply chain currently only has that configuration available as either a new part, over hauled or spares replacement. For all of that to change to something as simple as an AN 4-bolt flange design configuration would require a tremendous amount of effort and resources on the part of the manufacturers, owners, operators and maintainers which is not economically viable on products which have been out of production for a very long time.

Another mandatory action tool available to us is direct rulemaking. This could be in the form of new regulations which apply to the DAH products. Perhaps FAA could develop regulations with industry involvement (i.e., Special Conditions). If, for example, a new or amended, TC or STC applicant elected to use the standard 40° "V" flanged joint for the turbocharger to tailpipe interface in the future, they would have to show compliance to those new regulations. This could put in place the controls we know are necessary to manage this configuration effectively. Those special conditions might include things like:

- Specific design/installation constraints; type of coupling/clamp, alignment, support, etc.
- Specific installation criteria; procedures, torque, etc.
- Specific inspection criteria; intervals, methods, equipment, etc.
- Airworthiness Limitations (AWL) in the form of life-limiting, etc.

However, as we encountered previously, new regulations come with costs to all involved whether that be associated with the rulemaking, the cost/benefit to the public, the DAH and supplier costs to meet those new regulations, etc. Economic viability on 30+ year old products will again be at issue.

Another mandatory option discussed by the working group included life-limits and inspection intervals to be implemented via AD action. As noted earlier in this report, many of the coupling/clamp-related accidents occurred shortly after a 100-hour or annual inspection, which indicated that V-band coupling/clamps were not a focus of the inspection process. However, in aircraft where coupling/clamp inspection/replacement was mandated through AD action, the fatal accidents were eliminated. These two significant findings made mandatory inspection/replacement options rather attractive to the working group.

11.2 Action Selected

Given the aforementioned information, it became clear to the working group that mandatory action is the only practical, economically viable solution at this time, for this market sector. Since this issue is spread across all DAH turbocharged make/model products the working group looked at proposals from a "global" nature, without affecting already existing AD actions. Although this appears to be a simple and straightforward approach, it is unheard of in FAA mandatory action history due to the broad spectrum of affected make/model products. Currently, FAA mandates in the form of AD action are DAH make/model specific. However, the working group thought it in the best interest of aviation safety to treat all affected products in a fair and equitable manner and not wait until the next make/model accident. Thus, the "global" AD concept is the basis of the working groups specific proposals herein.

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The working group looked at the successful history of managing the unsafe condition on those products with an existing AD, which are summarized in Table IX.

Make / Model	Qty.	AD	Required Action
Commander Aircraft Model 114TC	149	2000-11-04	Within 25 hrs. time-in-service (TIS) replace spot-welded multi-segment coupling with a riveted coupling. Do not install a spot-welded coupling on affected airplanes.
Mooney M20M	261	2004-23-17 supersedes AD 91-03-15	Within 10 hrs. TIS replace spot-welded multi-segment coupling with a riveted coupling, replace the existing heat shield, and install a new heat shield deflector.
Piper PA-32R-301T series and PA-46-350P	1107	2010-13-07 supersedes AD 80-25-05 exhaust system inspection.	Within 25 hrs. TIS replace spot-welded multi-segment coupling with a riveted coupling. Do not install a spot-welded coupling on affected airplanes.
Piper PA-60	55	90-01-02	Prior to further flight after the effective date of this AD, and thereafter at intervals not to exceed 50 hrs. TIS, accomplish the dismantling and inspections in Part 1 of Piper SB No. 920.
Cessna 300 and 400 series	3546	2000-01-16 supersedes AD 75-23-08 R5	Exhaust system initial and repetitive inspections; 50 hr. TIS repetitive removal and inspection of the exhaust tailpipe and single-piece clamp, replacement of multi-segment V-band couplings within 500 hour TIS, and every 500 hours TIS thereafter.
Piper PA-31, PA-31-325, and PA-31-350	744	2013-10-04 supersedes AD 80-25-05	Perform required exhaust system inspections within 60 hrs. TIS and every 60 hrs. TIS thereafter.
Piper PA-31P	273	2014-23-03 supersedes AD 76-06-09	Perform required exhaust system inspections within 60 hrs. TIS and every 60 hrs. TIS thereafter. Replace 556-053 single segment coupling with a 557-369 riveted multi-segment coupling within 100 hours.
Beech 35, 33, 36 airplanes with Tornado Alley turbocharger installed (STC SA5223NM and SE5222NM	UNK	2001-08-08	Within 400 hrs. TIS after installing STC turbocharger, replace spot-welded multi-segment couplings with like couplings every 400 hrs. thereafter.
Piper PA-28, PA-34, PA-30, PA-39, Mooney M20 A-K, Lake LA-200 airplanes with a Rajay Model 325E10 and 3AT6EE10J2 turbocharger installed	UNK	82-27-03	Perform required exhaust system inspections within 50 hrs. TIS and every 50 hrs. TIS thereafter. Required inspections may be discontinued when the turbo housing is replaced

Table IX
Existing AD Requirements

The working group saw existing solutions to manage risk to acceptable levels in FAA's previous AD actions, if they were implemented (mandated). Existing AD performance history shows that with specific instructions, repetitive inspections and replacements, these events can be effectively managed and the risk of future events reduced. The working group based that on the following:

- No reported accidents since the effectivity of the latest currently applicable AD's. Refer to Table IX.
- A single report of a cracked riveted (collared fastener) multi-segment coupling being found on a Mooney M20M.
- Several reports of single-piece clamp cracking found during required repetitive inspections on the Cessna 300/400 series twin engine airplanes, with no separation failures in over 17 years.

11.2.1 Options

The working group proceeded to discuss options going forward to preclude the next event. The working group developed and evaluated six specific options for various forms of a global action, which are presented in Table X.

1. As soon as practical; inspect all tailpipe V-band coupling/clamp for airworthy condition defined in the Best Practices Guide (BPG). 2. Require mandatory replacement of coupling/clamp within XXX hours of the effective date. Require documentation in logbook for part TTIS in hours when coupling/clamp replaced with new. 3. Mandatory annual/100-hr. V-band coupling/clamp inspection. 4. Life-limit tailpipe V-band coupling/clamp at 500 hour TTIS. **A**	1. As soon as practical; inspect all tailpipe V-band coupling/clamp for airworthy condition defined in the BPG. 2. Require mandatory replacement of coupling/clamp within XXX hours of the effective date. Require documentation in logbook for part TTIS in hours when coupling/clamp replaced with new. 3. Mandatory annual/100 hr. V-band coupling/clamp inspection. 4. Life-limit tailpipe, multi-segment, V-band couplings to 500 hr. TTIS. (unless already life limited by existing AD) **B**	1. As soon as practical; inspect all tailpipe V-band coupling/clamps for airworthy condition defined in the BPG. 2. Require mandatory replacement of coupling/clamp within XXX hours of the effective date. Require documentation in logbook for part TTIS in hours when coupling/clamp replaced with new. 3. Mandatory annual/100-hr. V-band coupling/clamp inspection. 4. Life-limit tailpipe, multi-segment, V-band couplings to 500 hr. TTIS. (unless already life limited by any other AD) 5. Life-limit tailpipe, single piece V-band clamps to 1000 hr. TTIS. (unless already life limited by any other AD) **C**
1. As soon as practical; inspect all tailpipe V-band coupling/clamps for airworthy condition defined in the BPG. 2. Remove from service all multi-segment, V-band couplings within XXX hours of the effective date. 3. Install only single piece V-band clamp, as defined by the manufacturer, per their instructions for continued airworthiness. 4. Mandatory annual/100 hr. V-band clamp inspection. 5. Life-limit single piece V-band clamp to 1000 hr. TTIS. (unless already life limited by any other AD) **D**	1. Primary approval holders (PAH) define and FAA approve single piece clamp or new tech coupling (NTC) X. 2. Remove from service all V-band coupling/clamps within XXX hours of the effective date. 3. Install only NTC X coupling, as defined by the manufacturer, per their instructions for continued airworthiness. 4. Mandatory annual/100-hr. NTC X coupling inspection. 5. Life limit NTC X coupling to 2000 hr. TTIS, or at engine overhaul whichever occurs first. **E**	1. Go with one of **A** through **E,** *AND…* 2. Develop Best Practices Guide to assist the field in the proper installation, care and inspection of tailpipe V-band coupling/clamps. 3. Continue outreach to the shops, technicians and inspectors, to maintain focus on this issue. 4. Request FSDO national support in this activity. 5. Send a <u>*single*</u> consistent message to the field. 6. Fully supported by all PAH's.

<u>Table X</u>

Potential Requirements

11.2.2 V-band Working Group Concepts

The above options were then refined by the working group into the concepts in Table XI.

REQUIREMENT ↓	**SPOT-WELD COUPLING**	**RIVETED COUPLING**	**SINGLE-PIECE CLAMP**
Visual Inspection	At every annual inspection	At every annual inspection	At every annual inspection
Life-Limit	Initial replacement at 50 hrs., or within 500 hrs. depending on current part TIS from an A/C records review. Thereafter every 500 hrs.	Initial replacement at 50 hrs., or within 2000 hrs. depending on current part TIS from an A/C records review. Thereafter every 2000 hrs.	Initial replacement at 50 hrs., or within 2000 hrs. depending on current part TIS from an A/C records review Thereafter every 2000 hrs.
Brief Rationale	*Majority of data indicates this is the major problem. Both field history and Risk Analysis support this.*	*Concern; limited failure data, but materials and environment similarities support some type of life limit.*	*Clamps do crack. Life limit proposal consistent with Risk Analysis and AD field history with repetitive inspections.*

Table XI
Selected Action

11.2.3 V-band Working Group Consensus

The working group then voted on the above concepts which were converted into language more typical of a proposed mandatory field action which yielded the detailed recommendations found in Table XII.

The initial replacement plays a vital role in the working group proposed mandatory actions. That initial replacement requires a zero-time part be installed and record made in the aircraft maintenance records of the part number and installation time. This action establishes a known history for the new coupling/clamp installed. This will allow FAA to monitor the field performance of the new V-band coupling/clamps going forward to ascertain how they are performing in the field. Another benefit is the generation of more data to show how the riveted (collared fastener) style of coupling is performing in the field.

The working group also agreed that a Best Practices Guide (BPG) that would assist the public in installation and inspections, including methods, techniques and pass/fail criteria is warranted.

Type	Initial Replacement (establish field pedigree)	Replacement (Life-Limit)
Spot-Welded Coupling	*If from a review of the maintenance records you can positively identify that the hours TIS for the exhaust tailpipe V-band coupling is less than 500 hours TIS;* Do the initial replacement within 500 hours TIS for the exhaust tailpipe V-band coupling or within the next 50 hours TIS, whichever occurs later. *If from a review of the maintenance records you can positively identify that the hours TIS for the exhaust tailpipe V-band coupling is 500 hours TIS or more;* Do the initial replacement within 50 hours TIS. *If from a review of the maintenance records you cannot positively identify the hours TIS for the exhaust tailpipe V-band coupling;* Do the initial replacement within 50 hours TIS.	Replace repetitively thereafter at intervals not to exceed 500 hours TIS on the exhaust tailpipe V-band coupling.
Riveted Coupling (aka, collared fastener)	*If from a review of the maintenance records you can positively identify that the hours TIS for the exhaust tailpipe V-band coupling is less than 2000 hours TIS; Do the initial replacement within 2000 hours TIS for the exhaust tailpipe V-band coupling or within the next 50 hours TIS, whichever occurs later. If from a review of the maintenance records you can positively identify that the hours TIS for the exhaust tailpipe V-band coupling is 2000 hours TIS or more; Do the initial replacement within 50 hours TIS. If from a review of the maintenance records you cannot positively identify the hours TIS for the exhaust tailpipe V-band coupling; Do the initial replacement within 50 hours TIS.*	Replace repetitively thereafter at intervals not to exceed 2000 hours TIS on the exhaust tailpipe V-band coupling.
Single-Piece Clamp	*If from a review of the maintenance records you can positively identify that the hours TIS for the exhaust tailpipe V-band clamp is less than 2000 hours TIS;* Do the initial replacement within 2000 hours TIS for the exhaust tailpipe V-band clamp or within the next 50 hours TIS, whichever occurs later. *If from a review of the maintenance records you can positively identify that the hours TIS for the exhaust tailpipe V-band clamp is 2000 hours TIS or more;* Do the initial replacement within 50 hours TIS. *If from a review of the maintenance records you cannot positively identify the hours TIS for the exhaust tailpipe V-band clamp;* Do the initial replacement within 50 hours TIS.	Replace repetitively thereafter at intervals not to exceed 2000 hours TIS on the exhaust tailpipe V-band clamp.

<u>Table XII</u>

Selected Action Expanded

12. RECOMMENDATIONS

The working group positions and recommendations are as follows:

a. FAA must take the necessary action to prepare rulemaking of a global nature, that crosses DAH make/model product lines to implement the mandatory actions as outlined in Section 11.
b. Working group is to prepare a Best Practices Guide to assist the public in installation and inspections, including methods, techniques and pass/fail criteria.
c. The working group believes a required design change to the turbocharger to tailpipe interface is both impractical and not an economically viable solution for the effected fleet of mostly 30 to 50-year-old products.
d. In the interest of public safety FAA issue an SAIB to raise awareness and highlight the last (3) events which include a fatal accident. This was accomplished on December 14, 2017 with the publication of SAIB CE-18-07.
e. FAA should evaluate the efficacy and impact of new rulemaking controlling the use of multi-segment, V-band couplings for turbocharger to tailpipe applications on 14 CFR part 23 airplanes.
f. FAA should re-activate or replace the AC43-16A Aviation Maintenance Alerts reporting system to further outreach and presentation of safety issues identified by anyone. This system should function on a more real-time basis without delay in presentation of the issue to the public.
g. FAA and industry should continue their outreach campaigns on this and any significant safety issues.
h. The V-band Working Group believes that for legacy products this type of working group model was very conducive to gathering the facts, data, experiences, knowledge and input from as many effected entities as possible to ensure a more robust approach to dealing with the next safety issue on the General Aviation legacy fleet.

APPENDIX: A

NTSB / FAA DATA SET

APPENDIX A		**NTSB / FAA DATASET**												
ITEM	**Event or Effectivity**	**Description**	**One-time Initial**	**Rep. Insp.**	**V-band P/N used**	**Life Limited?**	**Hours on clamp**	**Injury**	**Reports; if any…**	**NTSB Event No. or FAA SDR No.**	**Airplane**	**Engine**	**V-band Coupling/Clamp ID?**	**NTSB Lab Report**
✈ 75-23-08 thru R5 2000-01-16	11/13/75 11/04/86 02/15/00	Exhaust system; including V-band clamp failure, one piece and multi-segment.	50 hr.	50 hr.	Same as original	YES: 400 hr. multi-seg. only 500 hr. multi-seg. only	☐	29F	14+	Numerous, back to '75'	Cessna 300/400 Series Twins	Continental TSIO-520 series	Couplings & Clamps	
Incident 82-16-05R1 [2013-10-04]	04/02/82	V-band clamp failure (later found to be high temp embrittlement due to mfg.)	100 hr.	100 hr.	Same as original	No		0	"reports"	MIA82IA110	Piper PA-31, Navajo PA-31-325, Navajo PA-31-350, Chieftain, N41045	Lycoming TIO-540-A1A, A1B, A2A, A2B, A2C TIO-540-F2BD, J2B, J2BD LTIO-540-F2BD, J2B, J2BD	557-369/ NH1005798-10 555-366/ MVT68049-450M	
Accident 80-20-05 Emer AD 1st	06/22/82	V-band clamp failure.	10 hr.	No	Same as original	No		2F		DEN82DA110	Piper PA-32RT-300T, N31912 Turbo Lance II	Lycoming TIO-540-S1AD		YES
Accident	10/26/83	V-band clamp failure out of spot weld, cracked through.						0		LAX84LA035	Enstrom F28F, N8621X	Lycoming HIO-360-F1AD	Enstrom LW13464 LW15768	
Accident	04/06/86	V-band clamp failure.						0		ATL86LA107	Piper PA-32R-300T, N22370	Lycoming TSIO-540-S1AD		
Incident	1980-1990	V-band clamp failure								?	Enstrom UNK			
Accident	10/03/90	V-band clamp failure, due to intergranular corrosion.				YES: engine TBO, 2000 hr.		1F	one	LAX91FA001	Mooney M20K, N231AX	Continental TSIO-360-GB		
Accident 91-03-15 [2004-23-17]	10/13/90	V-band clamp intergranular cracking failure.	25 hr.	No	New	No		2S		BFO91LA003	Mooney M20M, N987CM	Lycoming TIO-540-AF1A, AF1B		YES
Accident	03/11/91	V-band clamp failure from fatigue.						3S		LAX91LA129	Cessna 421B, N924MD	Continental GTSIO-520-H		
Incident	01/07/92	V-band clamp, found broken.						0		1992033100110	Beech 35-C33A, CE-53, 1966, N340LC with Colorado STC Dev. STC's: SA3817SW & SE3816SW	Continental; IO-520-B, BA or BB	S1921-1 Coupling	
Incident	01/28/93	V-band failure due to corrosion and worn severely.					(♦) 5291	0		1993939199934	Beech V35, D-8255, 1966, N7946M with STC: TBD	Continental O-520-X	NH1000897-40 Clamp	
Inspection	07/05/95	V-band cracked in V-retainer segment.					826	0		95ZZZX5125	Piper PA-31-325, 317612086, N117JP	TIO-540-F2BD	557584	
Incident	01/13/98	V-band clamp failure due to corrosion,						0		99ZZZX654	Beech S35, D-7668, N7WA with Rajay STC's: SA2556WE & SE57WE	Continental TSIO-520-D		

Accident2000-11-04	07/18/98	V-band clamp failure, pre-existing, brittle, cracked out of spot weld.	25 hr.	No	New	No	343	1F	(4) clamp failure	FTW98FA325	Commander114TC, 2001, 1997, N61174	LycomingTIO-540-AG1A		YES
Incident	02/08/99	V-band clamp found split, cracked.					545	0		99ZZZX952	Beech A36, E-1339, N2024Q with Engine Technology STC's: SA5223NM & SE5222NM			
Inspection	05/02/00	V-band clamp broke, it was safetied around bolt, possible out of spot weld.						0		20000531SH014	Mooney M20K, 250122, N231BT	Continental TSIO-360-GB	633358	
2001-08-08	06/07/01	V-band clamp failure.	25 hr.	400 hr. or 4 yrs. WOF +25 hr. allowance	Same as original	YES: 400 hr.		0	two		Beech 35-C33A, E33A, E33C, F33C, S35, V35, V35A, V35B, 36, A36 with Tornado Alley STC's: SA5223NM & SE5222NM	Continental IO-520-B, BA, BB or IO-550-B		
Accident 2004-23-17 [91-03-15]	11/27/01	V-band clamp failure, separated through the band, from fatigue.	10 hr.	No	New	No	1402	2F	one	CHI02FA042	Mooney M20M, 27-0011, 1989, N7775L	Lycoming TIO-540-AF1A, AF1B		YES
Inspection	01/15/03	V-band clamp found split around clamp, no safety cable, or torque stamp.						0		W532003F00000	Cessna 414, 4140643, N69917	Continental TSIO-520-E	NH1000897-50 Clamp	
Inspection	8/19/03	V-band clamp found failed during inspection.						0		CA030827007	Cessna 401	Continental TSIO-520-E	NH1000894-70 Clamp	
Accident	10/01/03	V-band failure after T.O., pre-existing crack out of spot weld.						2F		LAX04FA001	Piper PA-32R-301T, 3257081, 1999, N481CA	Lycoming TIO-540-AH1A	55677-340M	YES
Accident	10/23/03	V-band failure on takeoff, inflight fire.						0		2003FA0001113	Cessna P337G, P3370186, 1974, N4PF	Continental TSIO-360-C, front	S1921-1 Coupling	
Accident	6/23/04	V-band clamp found cracked ~50% around.						0		2004FA0000631	Cessna 340A, 340A0790, N346FS	Continental TSIO-520-N or NB	NH1000897-70 Clamp	
Inspection	3/14/05	V-band cracked at spot weld						0		2005FA0001251	Cessna T337G, P3370233	Continental TSIO-360-C, front	S1921-1 Coupling	
Inspection	12/12/06	V-band found cracked along circumference ~ 4" crack. Found same p/n clamp on other engine cracked seven hours ago as well.						0		2006FA0001178	Cessna 421, XXX, YYY	Continental GTSIO-520-X		
Accident	2/17/09	V-band clamp found cracked. ("new style")					368	0		OMKR2009-0001	Mooney M20M, 27-0282, 1999, N17RA	Lycoming TIO-540-AF1A	NH10009399-10 40D23255-340M Lycoming 3-segment Coupling	
Inspection	04/24/09	V-band clamp failed at bolt clamp support, found during walk around.					(♦) 2537	0		CA090506006	Cessna T206H, no S/N, new-build	Lycoming TIO-540-AJ1A	S1921-1 Coupling	
Accident	11/14/09	V-band clamp failure, crack with oxidation, pre-existing.						1F		WPR10FA056 2009FA0001013	Beech A36, 1977, E-1031, N17803 with Machen STC: SA762NW	Lycoming TIO-540-JB2D (MB)		YES
Inspection	03/09/10	V-band clamp found with 4.5" crack along circumference.						0		2010FA0000274	Cessna 421B, 421B0844, N1944G	Continental GTSIO-520-H	NH1000897-50 Clamp	

2010-13-07	07/28/10	V-band clamp, cracked.	25 hr.	No	New	No	(♦) 2255	0	"of spot-welded clamp failures"	?	Piper PA-32R-301T PA-46-350P	Lycoming TIO-540-S1AD TIO-540-AE2A	Spot-welded Lycoming 40D21162-340M or Eaton/Aeroquip 55677-340M replaced by Riveted Eaton/Aeroquip P/N NH1009399-10 or Lycoming P/N 40D23255-340M All Couplings	
Accident	02/17/12	V-band clamp failure, inflight fire, clamp and tailpipe found on runway					1000	2M		Foreign 700 hr. of marine ops	Cessna T206H, CAN, C-GTBB, new-build	Lycoming TIO-540-AJ1A	S1921-1 Coupling	
Inspection	05/07/12	V-band clamp found cracked through.					873	0		CA120508002	Cessna T206H, no S/N, new-build	Lycoming TIO-540-AJ1A	S1921-1 Coupling	
Accident	08/17/12	V-band clamp found installed with fractures in band, circumferential cracks, band necking, covered in oxides and sooty deposits.						3NF		WPR12LA414	Cessna T210N, 1978, 21063067, N6493N	Continental TSIO-520-R9B		
Inspection	08/24/12	V-band clamp found with 3" long crack along outer perimeter (.0625 wide)					1451	0		2012FA0000596	Cessna 421B, 421B0876, N678DB	Continental GTSIO-520-H		
2013-10-04 [82-16-05 R1	07/17/13	V-band coupling failures.	PTFF	60	Same as original	YES: 1000 hr.		0	"of forced landings"		Piper PA-31, Navajo PA-31-325, Navajo PA-31-350, Chieftain	Lycoming TIO-540-A1A, A1B, A2A, A2B, A2C TIO-540-F2BD, J2B, J2BD LTIO-540-F2BD, J2B, J2BD		
Incident	04/26/15	V-band clamp failure out of spot weld, cracked through.					(♦) 3147	0		NF2D2015FA0000205	Cessna TR182, R18201809, N423DK	Lycoming O-540-L3C5		
MSAD/SDRS	05/01/16	V-band clamp failed at the spot weld.					2800 hobbs				Mooney M20K, 1980, 25-0353, N321QC	Continental TSIO-360-GB		
Accident FAA S.R. 16.086 16.087	05/16/16	V-band clamp failure, found on ramp, failed at spot weld.					TBD	4F		ERA16FA185	Beech A36TC, 1980, EA-78, N60RW	Continental TSIO-520-U or UB	TCM: 642519 Natl. Utilities.: N4211-375M Voss: 5322C3752 Couplings	YES
Incident	06/27/16	V-band clamp failure via fractures at the two V-retainer segments originating out of spot welds.					533	0		CEN16IA238	Enstrom 280, 2003, 2101, N518EG	Lycoming HIO-360-SER		YES
KEY→	✈	**This dataset does not include the Cessna twins (14+) V-band coupling/clamp lamp failures, prior to AD 2000-01-16.**												
	(♦)	**The high number of hours above are very suspect and are potentially airplane total time in service (TTIS) and not V-band coupling/clamp TTIS.**												
	☐	**Cessna twins; TTIS from manual search of M or D reports found in AD75-23-08 file: 506, 1489, 1553, 1409, 105, 107, 600, 694, 1417, 607,**												

APPENDIX: B

BEST PRACTICES GUIDE

Best Practices Guide

for

Maintaining Exhaust System
Turbocharger to Tailpipe
V-band Couplings / Clamps

Reference:
JASC 8100 Exhaust Turbine System (reciprocating)
JASC 8120; Exhaust Turbocharger

January 2018

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LIST OF FIGURES

1. INTRODUCTION

1.1 Objective

This Best Practices Guide presents a summary of one of the recommendations developed during the national V-band Coupling/Clamp Working Group effort. It was driven by the General Aviation Joint Steering Committee (GAJSC) System Component Failures – Power Plant (SCF-PP) working group initiative to investigate the continued failures of turbocharger exhaust to tailpipe V-band coupling/clamps. This guide presents the “best practices” necessary to ensure airplanes equipped with turbocharged reciprocating engines fitted with turbocharger to tailpipe V-band coupling/clamps, remain in their original type design configuration. It will also help to effectively manage the risk associated with the use of V-band coupling/clamps in this application.

1.2 Scope

The national V-band Coupling/Clamp Working Group examined a wide range of products and configurations in developing this Best Practice Guide. The scope of the working group effort included:

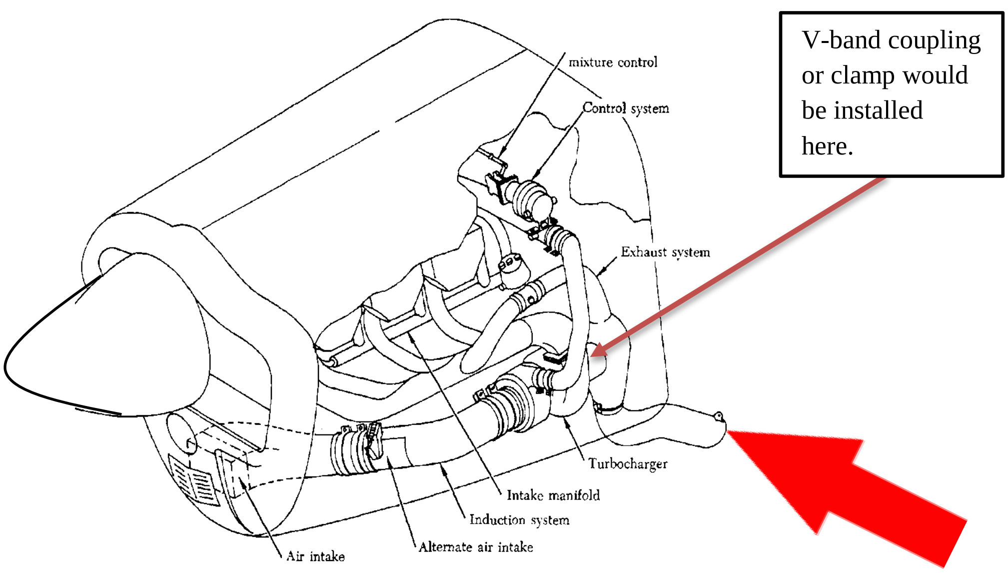
- A history of V-band coupling/clamp failures dating from the 1970’s
- Approximately 18,000 applicable aircraft in the existing fleet
- At least eight turbocharged reciprocating engine-powered aircraft currently in production
- Single and multi-engine airplanes & single engine rotorcraft from:
    - Commander Aircraft
    - Enstrom Helicopter
    - Mooney Aircraft
    - Piper Aircraft
    - Textron Aviation, Inc. (formerly Cessna & Beechcraft)
- Turbocharged reciprocating engines from:
    - Continental Motors
    - Lycoming Engines
- Type certificated (TC) products
- Supplemental type certificated (STC) products
- Multiple Original Equipment Manufacturers (OEM) of V-band coupling/clamps
- Parts Manufacturing Approval (PMA) replacement V-band coupling/clamps

1.2.1 Installations (typical)

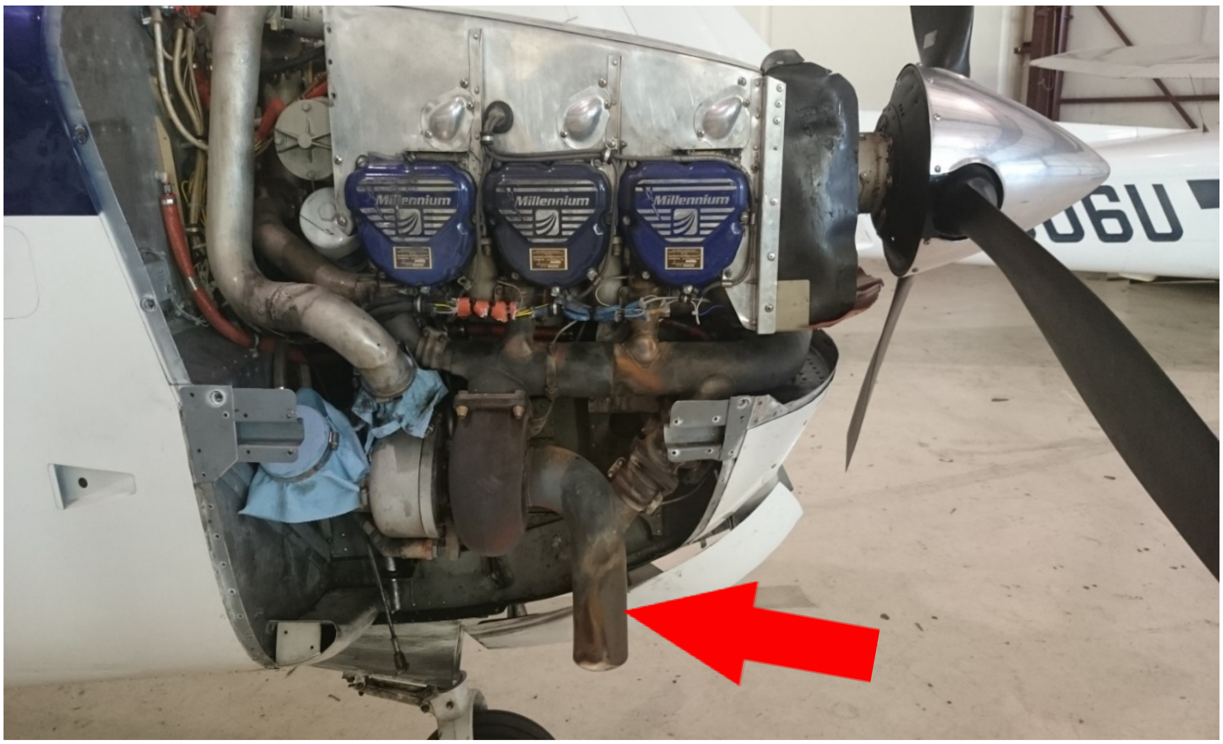
The specific focus area of this Best Practice Guide are those V-band couplings and clamps used at the turbocharger exhaust exit to exhaust tailpipe interface only. However, the installation and inspection recommendations herein may be applicable to any V-band coupling or clamp in any aircrafts exhaust system. The photographs and diagrams on the following pages present a very small sample of the various configurations that exist in the make/model of aircraft equipped with turbocharged reciprocating engines.

Below is a single engine airplane with engine cylinder exhaust ports located at the bottom of each cylinder. The upper cowl is open and a lower access panel is removed. As you can see the turbocharger in this application is not readily visible nor is the V-band coupling/clamp. The Design Approval Holder (DAH) also incorporated heat protection features in their type design to prevent exhaust heat from impinging on the surrounding area. The heat protection features typically include a set of sheet metal heat shields or fireproof foil type insulation in the form of a blanket or a combination thereof. The heat protection features that are a necessity also work well to obscure visibility of the turbocharger, and V-band coupling/clamps. The large red arrow denotes the tailpipe.

The diagram below depicts the turbocharger installation for the airplane above and the LH-side of the exhaust system. Notice none of the type design required heat protection features are shown installed. This is a typical retractable landing gear, single turbocharged engine airplane. The large red arrow denotes the tailpipe. The other arrow points to where the V-band coupling/clamp should be found. The V-band coupling/clamp in this application would not be readily visible during a pre-flight type inspection.

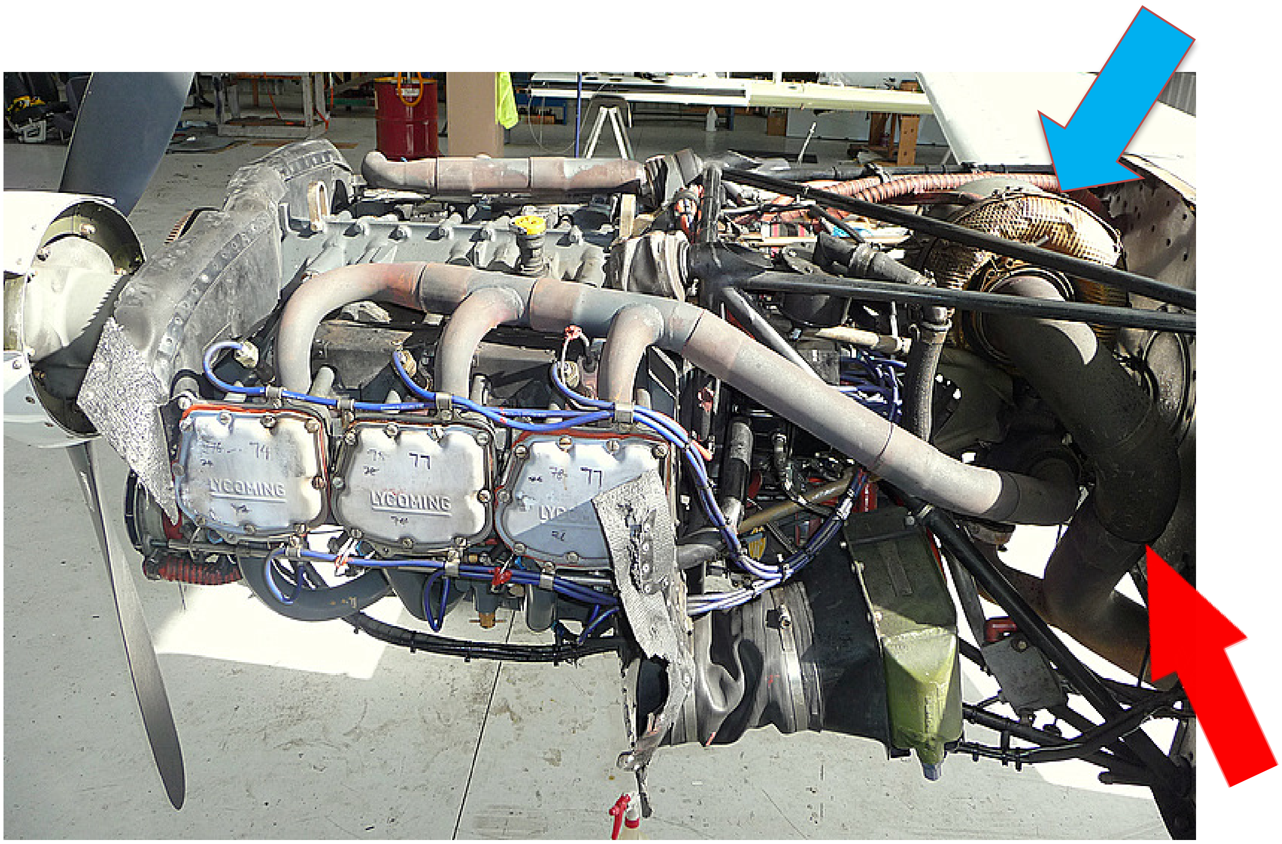


Another turbocharged single engine airplane, with engine cylinders with bottom exhaust ports is depicted below. The cowling has been removed. You can't see the turbocharger clearly with the lower cowling installed. The large red arrow denotes the tailpipe which is connected directly to the turbocharger exhaust exit flange just up and aft on the tailpipe. The tailpipe V-band coupling/clamp is not visible below. As you can see by the installation, the turbocharger in this application is not readily visible without a significant amount of maintenance activity, nor is the V-band coupling/clamp. In other words, this coupling /clamp installation would also not be readily accessible for pre-flight inspection.



In the two examples above, the interface to the turbocharger housing is such that the coupling partly resides within the turbochargers envelope. Seeing the turbocharger side of the coupling during inspection is not readily accomplished, even with a mirror and bright light. Turbochargers installed low on the engine (4 or 8 o'clock) like the two above make pre-flight viewing almost impossible. Inspection and maintenance of the turbocharger and tailpipe also have additional challenges, especially on retractable landing gear airplanes with non-removable lower cowlings and fixed structures.

Below is a twin turbocharged engine airplane with an engine with top exhaust ports. The lower red arrow denotes the large tailpipe, and the circular housing just inboard of the tailpipe is the turbocharger which in this application is under a heat insulation blanket. The upper blue arrow points to the threaded end of the T-bolt of the multi-segment V-band coupling attaching the tailpipe to the turbocharger. On this type of turbocharger installation, you may see more of the turbocharger and heat protection features when the cowling is removed for an annual/100-hr. inspection. However, even then one would be hard pressed to find a crack anywhere along the multi-segment, V-band coupling, V-retainer inner surface when installed.



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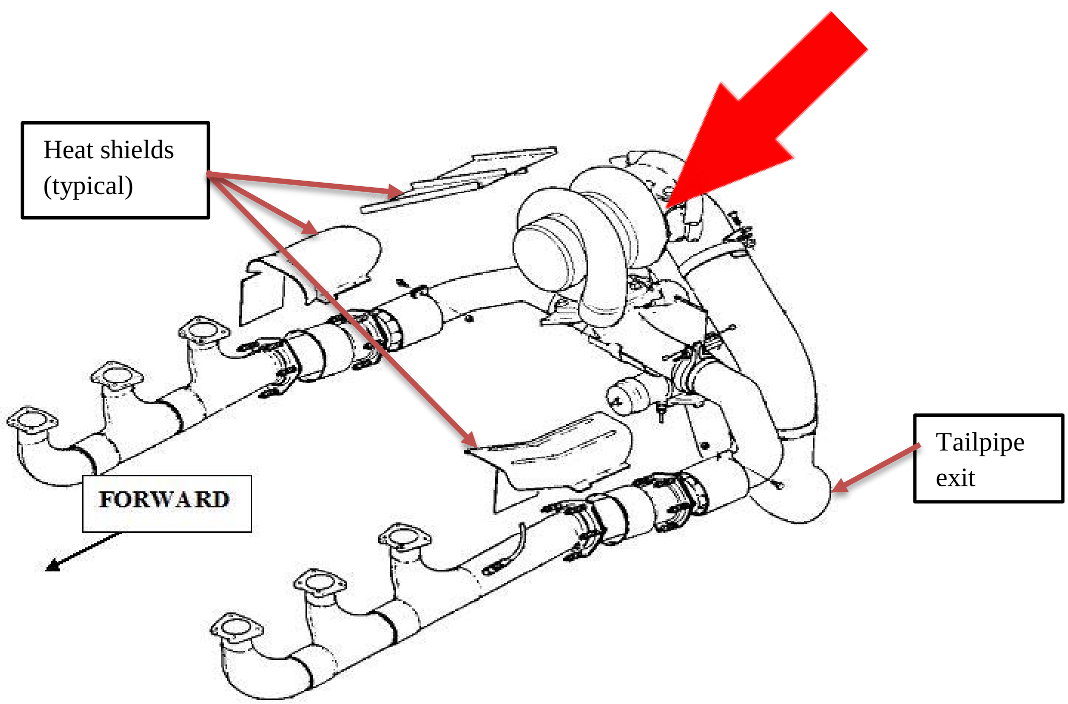
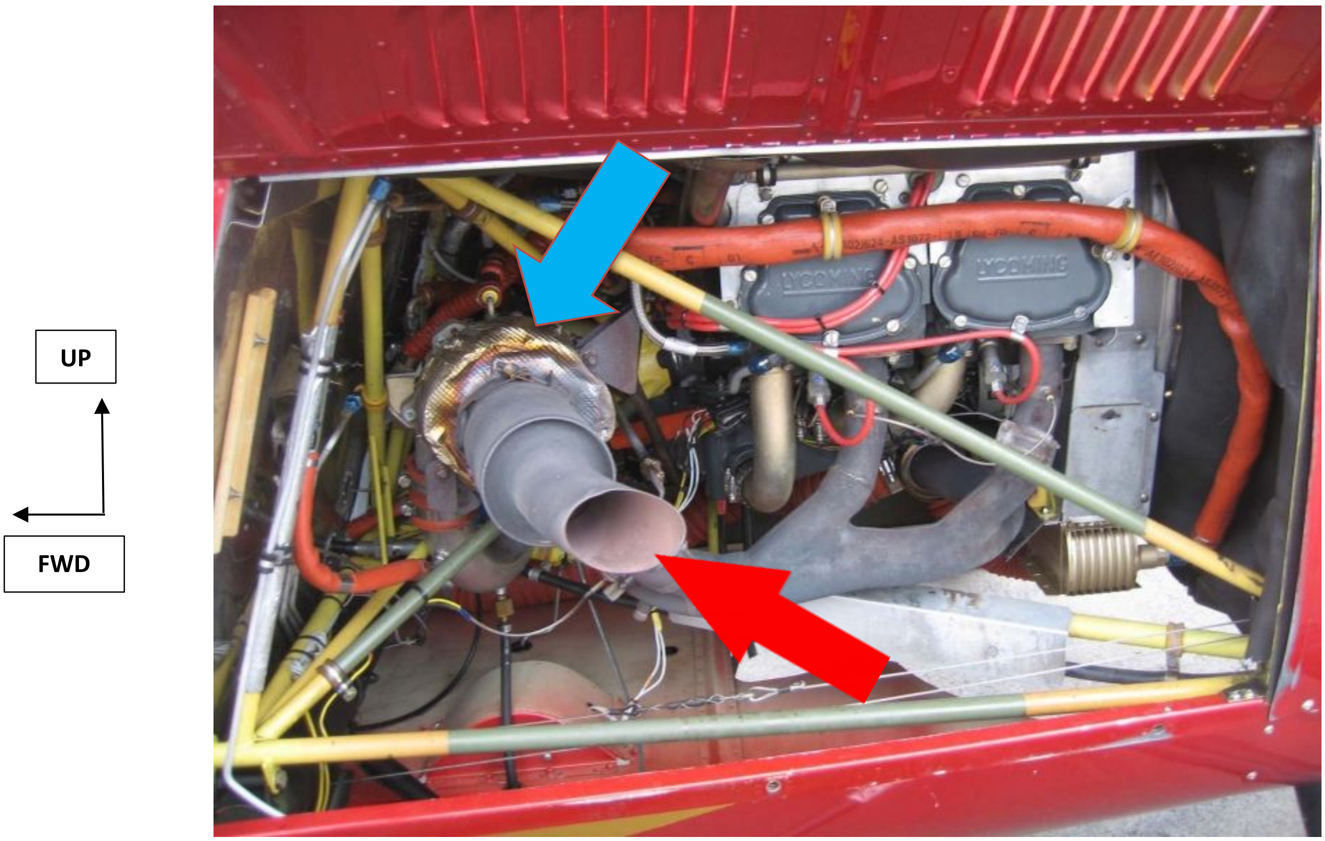
Another twin engine airplane with engine cylinders incorporating bottom exhaust ports is depicted below. The lower red arrow denotes the large tailpipe entrance. The circular housing just inboard of the tailpipe is the turbocharger under a heat shield and insulation blanket, denoted by the upper blue arrow.

Below is another full exhaust system for a twin engine airplane utilizing engine cylinders with bottom exhaust ports. The large red arrow would be the tailpipe coupling or clamp location. Some of the heat protection features are also shown below.



And finally, depicted below is a turbocharged engine used in a rotorcraft application with a LH forward turbocharger installation. The engine has cylinders with bottom exhaust ports. The hinged upper cowling door is open. The lower red arrow denotes the tailpipe/muffler assembly which is connected directly to the turbocharger exhaust exit flange just inboard of the muffler body on the tailpipe. The upper blue arrow points to the tailpipe multi-segment, V-band coupling just in front of the turbocharger heat insulation blanket. This type of installation may allow a very good pre-flight inspection of the tailpipe and coupling.



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1.2.2 Turbochargers (typical)

The photograph below is a typical new or freshly overhauled turbocharger assembly. The red arrow denotes the turbocharger exhaust exit flange where the tailpipe mates and is subsequently secured via a V-band coupling/clamp which is not shown in the photograph below. The tailpipe is attached to that flange on the RH cast iron side of the assembled turbocharger. The coupling that is shown below on the LH side of the turbocharger is used in this application to attach the compressor housing side of the turbocharger, which is not part of this Best Practice Guide. You will note that the exit flange is flush or already within the cast iron housings envelope. The upstream area of the exit flange is even further within that envelope. This is typical of the standard turbocharger found on many legacy aircraft products.

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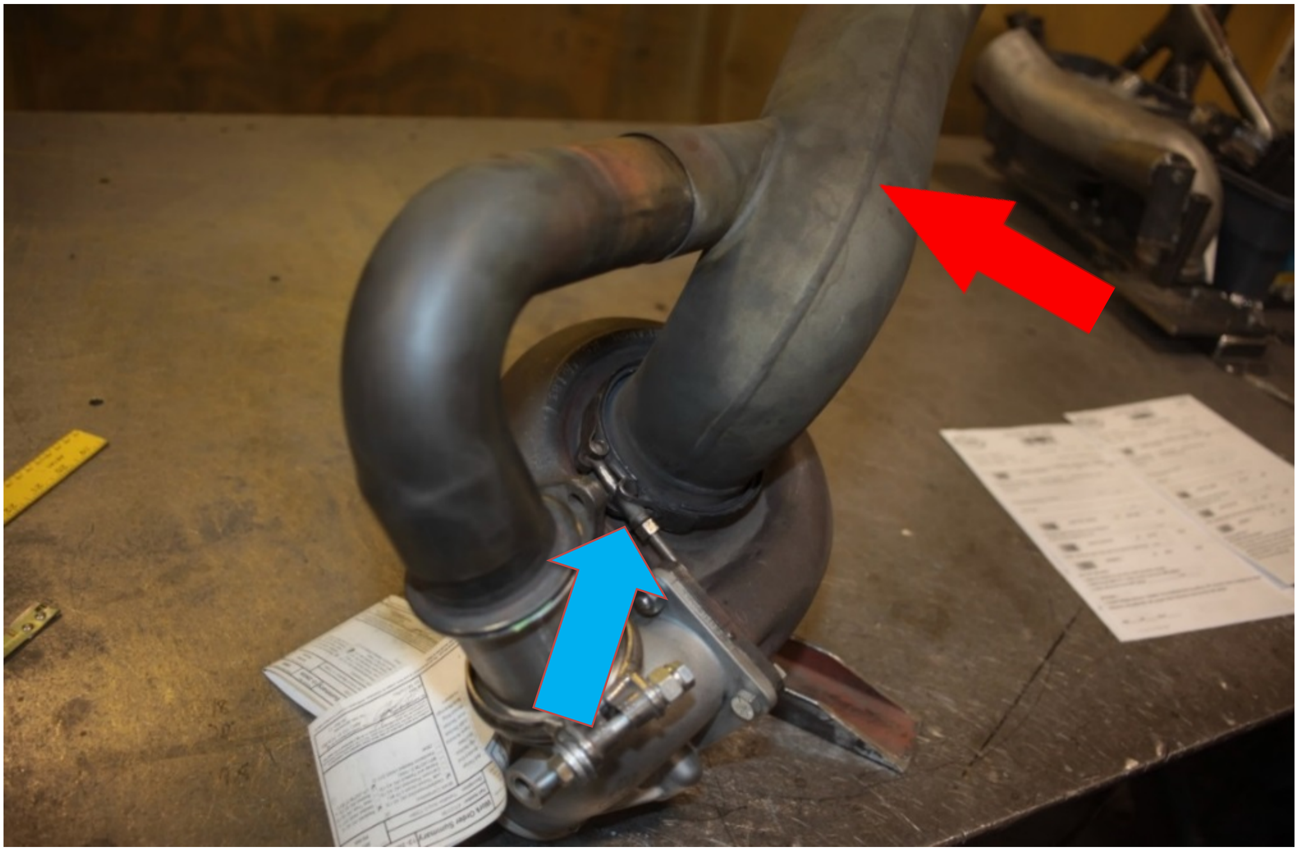
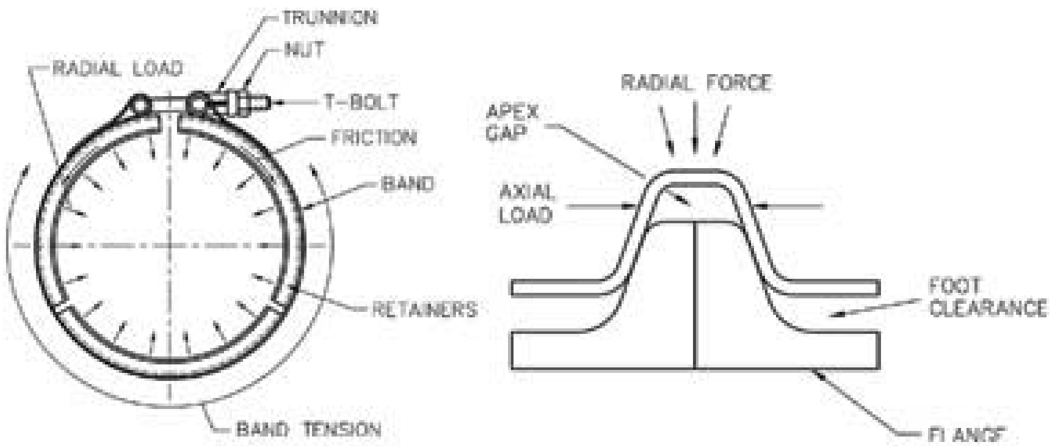
Another turbocharger assembly is depicted below (looking at the exhaust end on the bench). This version has the tailpipe (with a wastegate pipe and valve installed) installed on the turbocharger exhaust exit with a V-band coupling. The tailpipe is denoted by the upper red arrow and the multi-segment, V-band coupling is denoted by the lower blue arrow. Finally, even with the turbocharger assembly on the bench, a thorough inspection of the V-band coupling as installed is difficult. It is unlikely that one would be able to assess the interior of the coupling in hopes of finding a crack that lurks in a V-retainer inner radius on the coupling



As can be seen above in the variety of installation configurations and turbocharger assemblies, the turbocharger to tailpipe interface and V-band coupling/clamp are not readily visible. Unfortunately, the necessary heat protection features of the DAH type design (i.e. insulation blankets and heat shields) work well to obscure visibility of the turbocharger and V-band coupling/clamp and removal of those features has its own concerns. The interface to the turbocharger housing is also such that the coupling/clamp resides within the turbochargers cast iron housing envelope. Seeing the backside of the installed coupling/clamp is not readily accomplished, even with a bright light and mirror, and viewing the interior of the V-retainers is impossible. Therefore, it is understandable how things might be missed during an installation inspection. There are also valid concerns that come with the repetitive removal of the coupling/clamp which were not foreseen. However, that is to be expected anytime significant inspection or maintenance is accomplished, and that alone should not preclude anyone from performing a thorough inspection of the V-band coupling/clamp.

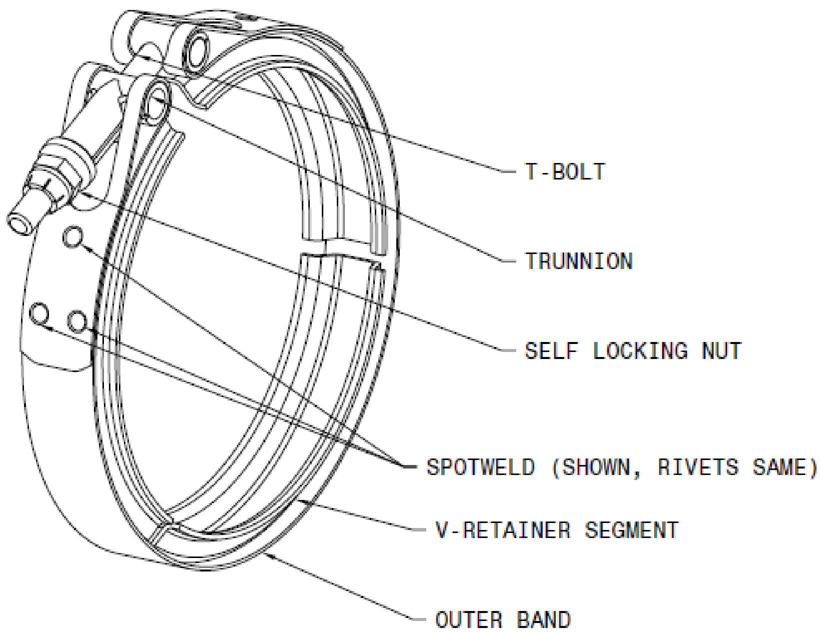
2. COUPLING & CLAMP DESIGN

All turbocharger exhaust tailpipe V-band couplings or clamps are intended to couple and retain the exhaust tailpipe to the turbocharger housing, exhaust exit flange. The exhaust tailpipe V-band coupling/clamp does this by converting the radial load of the coupling band tension or clamp body to an axial load on the flanges due to the wedging action of the 'V' retainer segments or clamp body itself, as shown below.

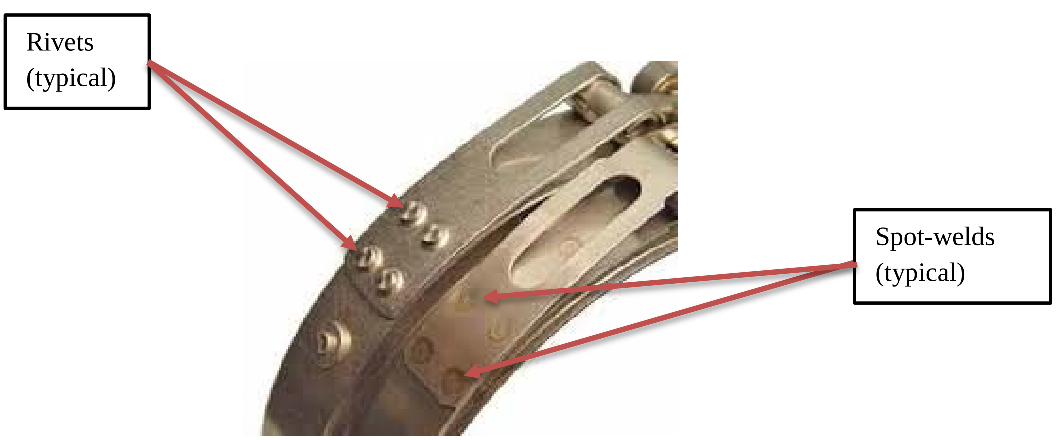


There are two types of exhaust tailpipe V-band coupling and one type of V-band clamp used to join the exhaust tailpipe to the turbocharger exhaust exit flange. The two types of V-band couplings are spot-welded, multi-segment V-band couplings and riveted, multi-segment V-band couplings. The one type of V-band clamp is called a single-piece V-band clamp. There are very distinct differences between the types and their installations are not interchangeable per the applicable aircraft, engine or part Design Approval Holder (DAH), unless FAA approved. The following briefly explains the distinct differences in couplings and clamps.

Multi-Segment, V-band *Couplings* come in two varieties: spot-welded and riveted (aka; collared fastener). The two varieties typify the method of joining of the outer flat band to the inner V-retainer segments, and all other metal-to-metal joints on the coupling. In this application, the couplings come in either two or three segment varieties. The segments are the number of V-retainer segments, which are attached to the outer band via spot-welds or rivets. Materials used throughout are various stainless steel alloys or Inconel's. The single-piece T-bolt may be straight or have a manufactured bend at the 'T' head by design. Couplings may also have a quick release latch to capture the T-bolt head. The self-locking nut is typically a high temperature steel alloy that is often silver coated. The self-locking nut is all-metal and the locking feature is a mechanical interference type with no polymer inserts. Couplings typically do not use washers under the nut as the trunnion housing is formed flat to act as a washer surface for the nut. Refer to Figures 1 thru 6.



<u>Figure 1</u>
Multi-Segment, V-band *Coupling*
3-segment



<u>Figure 2</u>
Multi-Segment, V-band *Couplings*
LH riveted (aka, collared fastener) & RH spot-welded

Although not as widely used as the spot-welded, multi-segment V-band couplings, riveted (aka; collared fastener) multi-segment, V-band couplings are approved on various make/model aircraft. A riveted coupling is almost identical with the exception of spot-welds being replaced with a similar number of rivets or collared fasteners to join the materials. Refer to Figure 1, 2, and 6.

NOTE: Spot-welded and riveted couplings may look identical in all respects except the manufacturing method and may come in the exact same size and flange configuration as a similar spot-welded or riveted coupling. However, the couplings may or may not be legally interchangeable without an aircraft, engine or part FAA approval at the DAH level. Likewise, for a single-piece clamp versus any coupling type, these are also not interchangeable unless FAA approved in some manner as identified above.

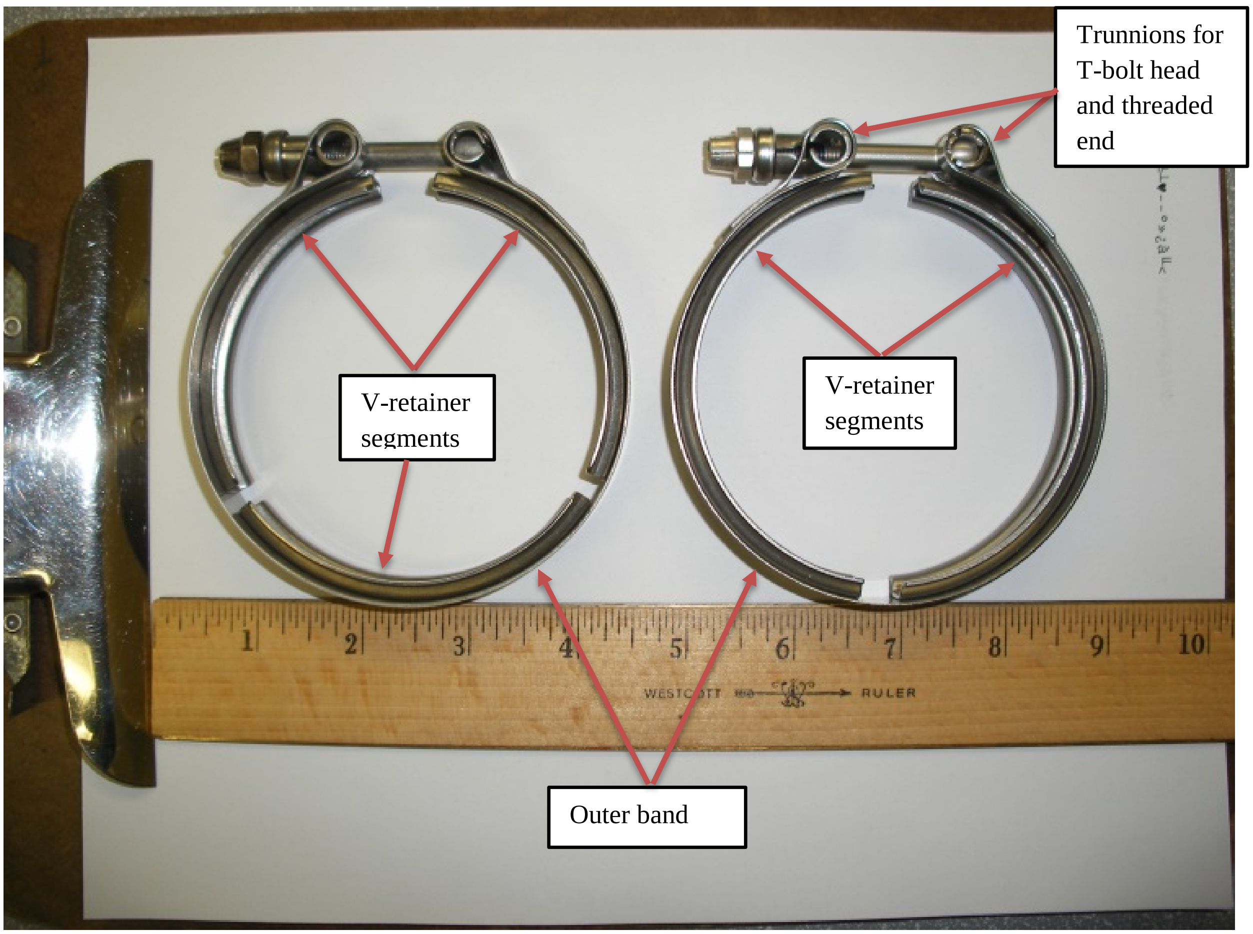
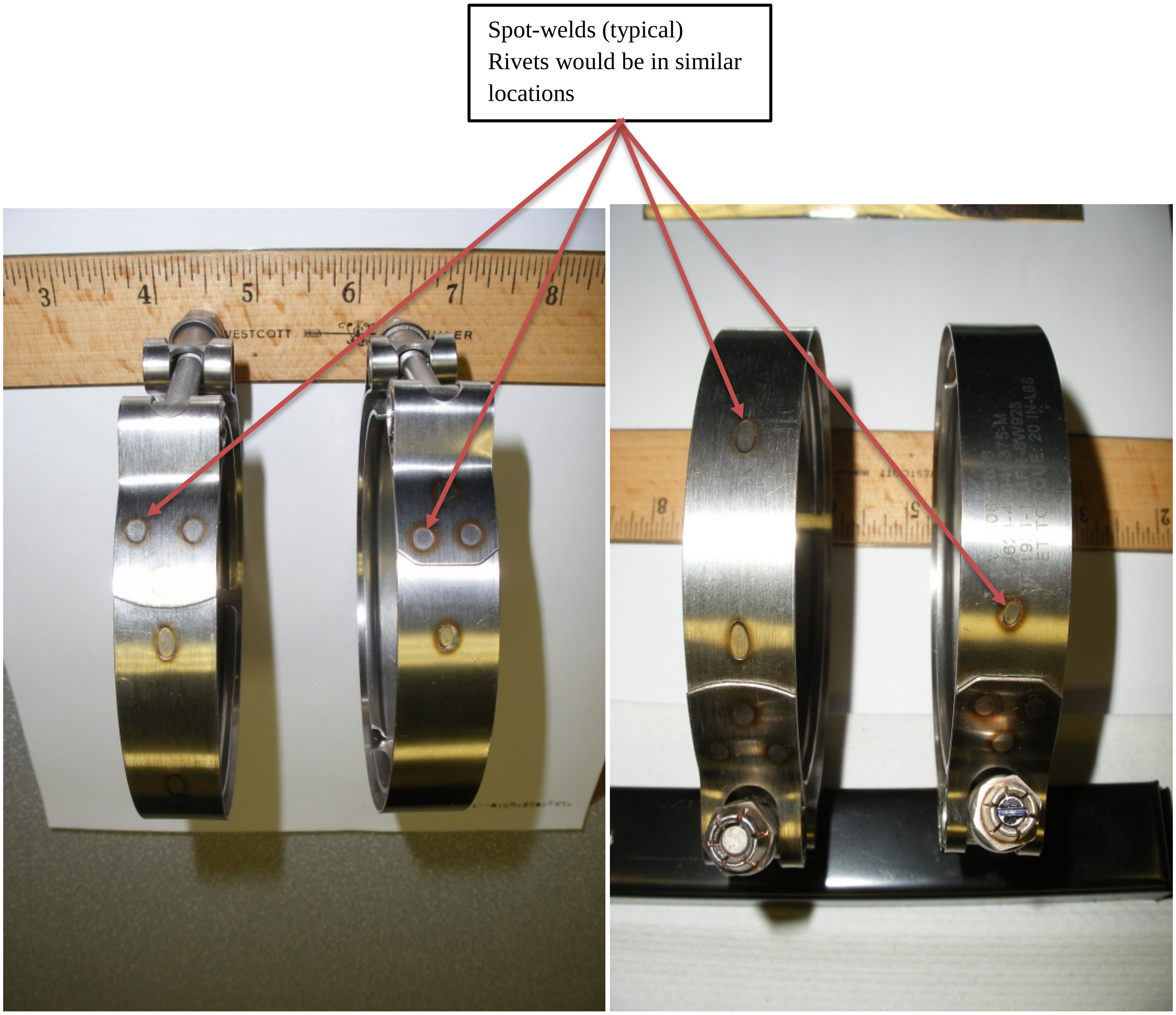


Figure 3

Spot-Welded, Multi-Segment, V-band *Couplings*
3-segment LH **2-segment RH**

3.750-inch size

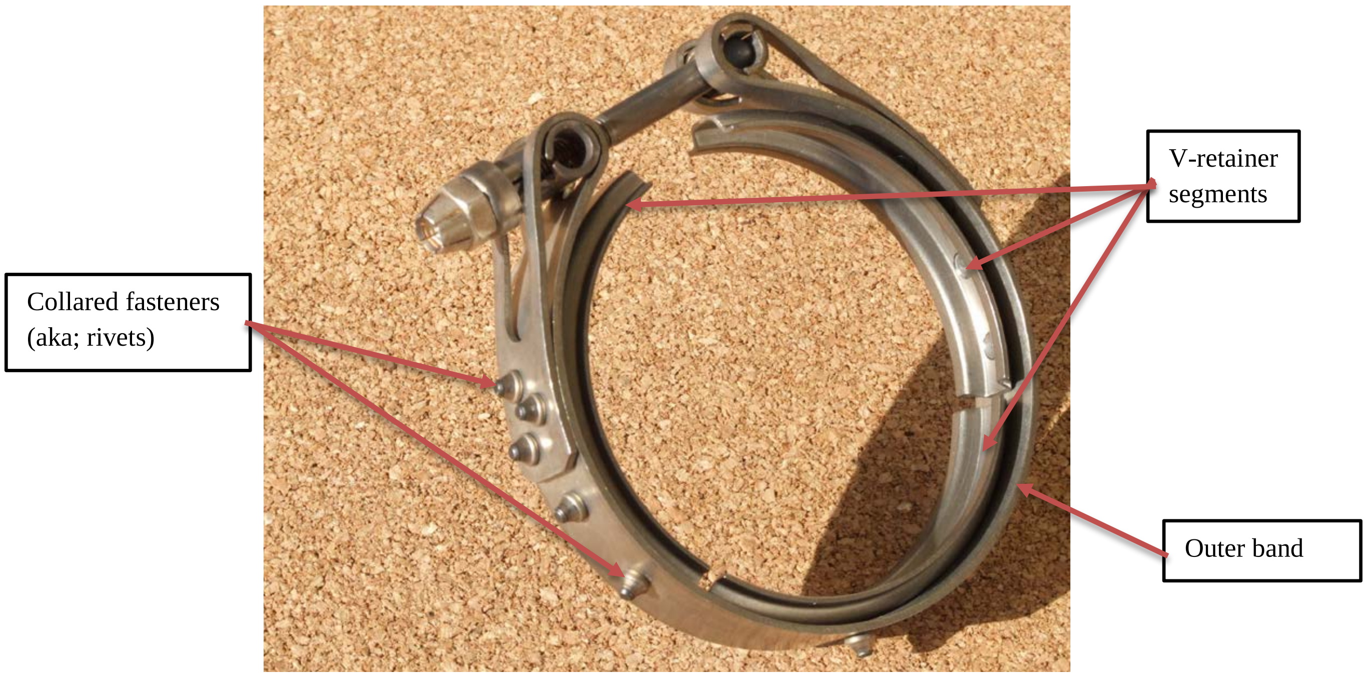


<u>Figure 4</u>
View looking at T-bolt head trunnion end

<u>Figure 5</u>
View looking at lock-nut trunnion end

Spot-Welded, Multi-Segment, V-band *Couplings*

3.750-inch size



<u>Figure 6</u>

Riveted, (aka, Collared Fastener), Multi-Segment, V-band *Coupling*

3-segment

Unknown size

Single-Piece, V-band *Clamps* are stamped and roll formed from one single-piece of base material. Materials used throughout are various stainless steel alloys or Inconel's. The single-piece straight (only) bolt is a stainless steel alloy. The self-locking nut is typically a high temperature steel alloy that is often silver coated. The self-locking nut is all-metal and the locking feature is a mechanical interference type with no polymer inserts. There is typically one washer under the bolt head and one washer under the nut on these clamps. They also typically come with a cable across the open end which acts as an open limiter. Installed on that cable is a tag with torque and/or part number and a pair of crimped on sleeves to limit opening. Lack of the cable (if applicable to the p/n), torque tag and/or crimp(s) that appear replaced should make the clamp suspect. Refer to Figure 7 and 8.

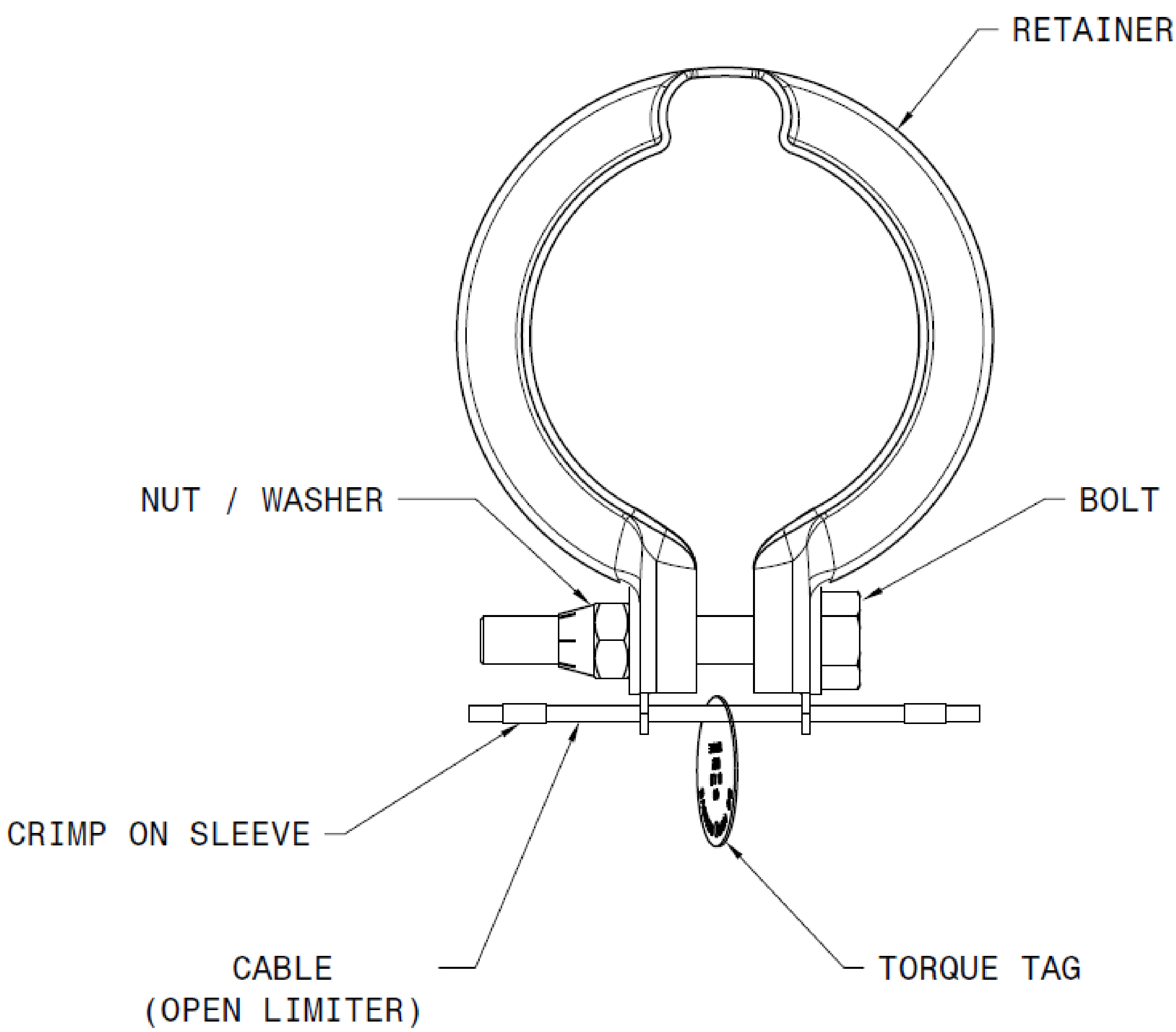


Figure 7

Single-Piece, V-band *Clamp*

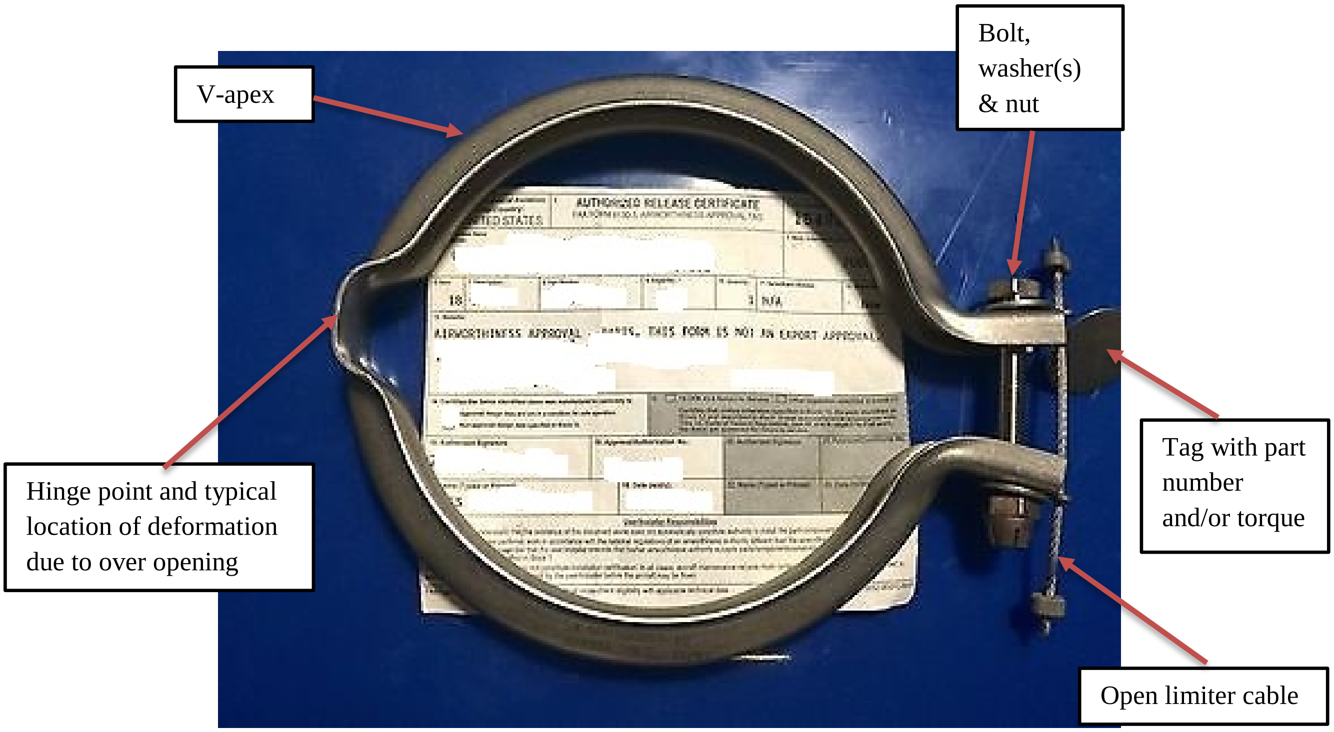


Figure 8

Single-Piece, V-band *Clamp*

NOTE: As noted above for multi-segment couplings, single-piece clamps may come in the exact same size and flange configuration and may look identical in all respects. However, clamps and any type of coupling may or may not be legally interchangeable without an aircraft, engine or part FAA approval at the DAH level.

3. INSTALLATION [Refer to Section 1.2.1 and Figures 1, 7, 9-14, 16 & 17]

3.1 Methods

The specific focus area of this Best Practice Guide are those V-band couplings and clamps used at the turbocharger exhaust exit to exhaust tailpipe interface only. However, the installation recommendations herein may be applicable to any V-band coupling or clamp in any aircrafts exhaust system.

CAUTION

SUBSTITUTION OF A COUPLING/CLAMP PART NUMBER, AND/OR TYPE (SPOT-WELDED, RIVETED, OR SINGLE-PIECE) FOR ANOTHER COUPLING OR A CLAMP OR VICE VERSA IS NOT ALLOWED WITHOUT A SPECIFIC FAA APPROVAL FROM THE DAH.

CAUTION

NO SERVICE LIFE EXTENSION SHOULD BE PERMITTED, AND NO SERVICE LIFE EXTENSIONS ARE ALLOWED WHEN MANDATED BY AIRWORTHINESS DIRECTIVE (AD) WITHOUT AN FAA APPROVED ALTERNATE METHOD OF COMPLIANCE (AMOC) TO THE SPECIFIC AD. ALSO CHECK THE AIRWORTHINESS LIMITATIONS.

WARNING

CRACKS AS WELL AS INCORRECT ASSEMBLY OR INSTALLATION OF THE TURBOCHARGER EXHAUST SYSTEM CAN ADVERSELY AFFECT ENGINE OPERATION, OR RESULT IN RELEASE OF HOT AND TOXIC GASES, WHICH CAN CAUSE DAMAGE TO NEARBY COMPONENTS, SYSTEMS OR A FIRE.

Inspect the turbocharger exhaust exit flange and the exhaust tailpipe flange interfaces for any un-flat (0.005 in. or greater) or wavy condition, corrosion, pitting, scaling or deposits (not easily removed) and correct per the manufacturer's recommendations. Refer to Figure 9.

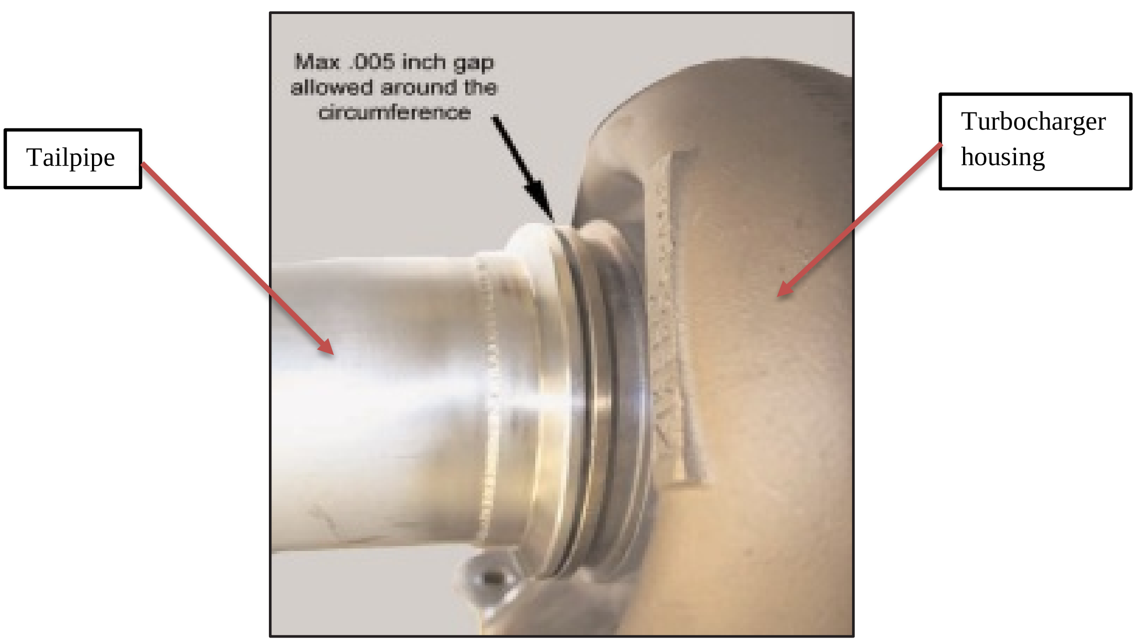


Figure 9

Typical turbocharger exhaust exit flange to tailpipe interface

CAUTION

USE CARE TO SUPPORT THE ENTIRE EXHAUST SYSTEM DURING INSTALLATION. DO NOT FORCE, PRY, OR BEND COMPONENTS DURING FINAL ALIGNMENT TO PREVENT DAMAGE TO THE PARTS.

CAUTION

THE SELF LOCKING NUT MUST HAVE A RUNNING TORQUE OF 1.8 TO 30.0 INCH-LBS. THE NUT SHOULD BE CAPABLE OF MULTIPLE ON-OFF CYCLES (MAXIMUM 10). HOWEVER, THAT IS VERY DEPENDENT ON THE NUT AND BOLT CONDITION(S), DEPOSITS, CONTAMINATION, ETC.

a. Conduct the installation when the engine is cool.
b. Prior to installation, ensure the coupling/clamp and attaching hardware is free from any physical damage to include but not limited to; cracks, gouges, tears, bulges and fractures.
c. Prior to installation, ensure the tailpipe and turbocharger exhaust exit flange are free from cracks, warps, gouges, nicks, grease dirt or deposits, including all weld areas. Refer to Figures 9 & 17.

CAUTION

WHEN INSTALLING EXHAUST SYSTEM COMPONENTS, INITIALLY TIGHTEN HARDWARE FASTENERS FINGER-TIGHT. ENSURE ALL COMPONENTS ARE ALIGNED PROPERLY BEFORE APPLYING FINAL TORQUE TO FASTENERS.

d. Assemble all tailpipe and interface exhaust components (i.e.; wastegate), hangers and supports loosely in order to receive final torque.

CAUTION

DURING ANY INSTALLATION, DO NOT TWIST OR OPEN THE COUPLING/CLAMP MORE THAN NECESSARY BECAUSE OVER-OPENING OR EXCESSIVE FLEXING CAN LEAD TO PHYSICAL DAMAGE, INEFFECTIVE SEALING AND EXHAUST GAS LEAKAGE. DO NOT OVER STRETCH OR OPEN BY PULLING THE SIDES APART ON ANY COUPLING/CLAMP.

e. Assemble the tailpipe exhaust flange on to the turbocharger exhaust flange, with a new gasket if applicable per the DAH type design configuration or current Instructions for Continued Airworthiness (ICA). Carefully twist the coupling/clamp over the flanges as if to follow the flanges as a nut would on a screw thread. Refer to Figure 10.
f. Ensure alignment of tailpipe flange and turbo exhaust exit flange with no gaps (maximum 0.005 in.), prior to coupling/clamp installation. Refer to Figure 9 & 10.

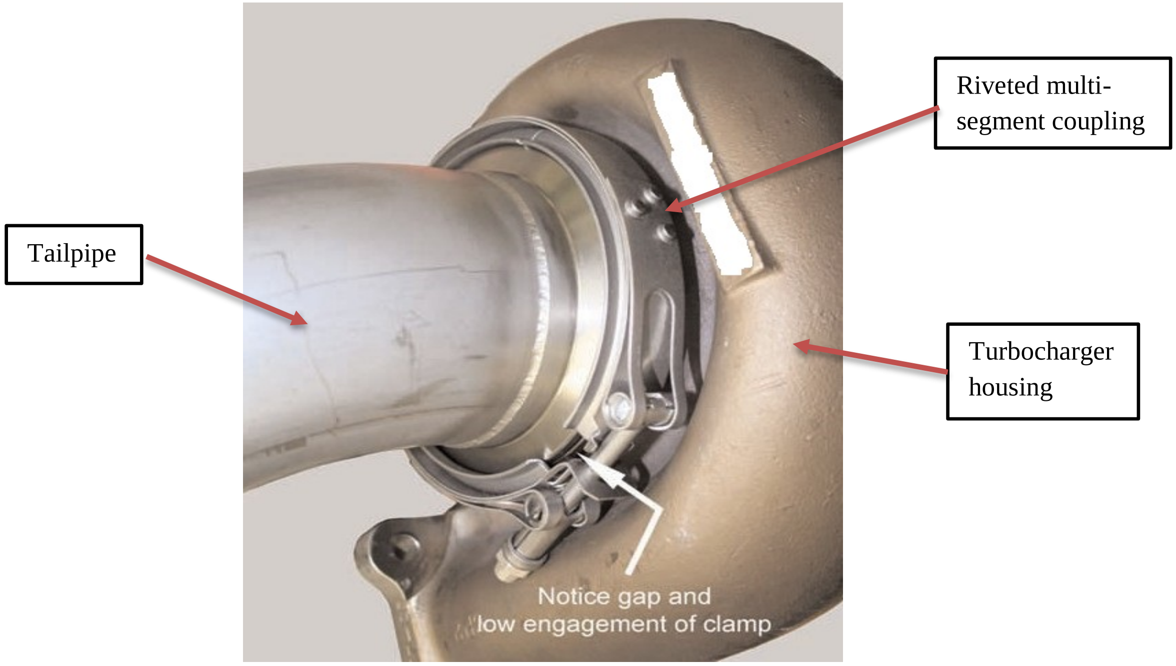


Figure 10

Typical installation of tailpipe and V-band coupling on turbocharger exhaust flange

CAUTION

WE DON'T RECOMMEND THE USE OF POWERED TOOLS. HOWEVER, IF USING A POWERED DEVICE TO INSTALL THE LOCKNUT DO NOT INSTALL AT GREATER THAN 120 RPM. EXCESSIVE NUT INSTALLATION SPEED CAN CAUSE THREAD DAMAGE AND INCORRECT FINAL TORQUE.

g. Preload 50-70% of total V-band coupling/clamp required final torque value, then if possible, lightly tap (not trying to deform) the coupling/clamp around the periphery with a soft faced mallet to ensure proper seating and even distribution of clamping stress. Do not rely on tightening alone for proper coupling/clamp seating.

CAUTION

THE COUPLING/CLAMP AT THE TURBOCHARGER EXHAUST EXIT FLANGE MUST BE CORRECTLY ALIGNED TO THE TAILPIPE FLANGE. **DO NOT USE THE V-BAND COUPLING/CLAMP TO BRING THE EXHAUST COMPONENTS INTO ALIGNMENT.** INCORRECT ALIGNMENT OF THE COUPLING/CLAMP IS AN INDICATION THAT THE EXHAUST SYSTEM IS NOT CORRECTLY INSTALLED. IF THE COUPLING/CLAMP DOES NOT ALIGN, ADJUST THE EXHAUST SYSTEM COMPONENTS UNTIL THE COUPLING/CLAMP IS IN CORRECT ALIGNMENT. A SLIGHT ADJUSTMENT TO THE TURBOCHARGER ORIENTATION MAY ALSO PERMIT CORRECT COUPLING/CLAMP ALIGNMENT.

h. Make sure there are no gaps at other exhaust system connections and all exhaust system components are correctly aligned before the final torque of all the exhaust system hardware.

i. Refer to the applicable DAH ICA's and their latest revisions for correct torque requirements for all exhaust system V-band coupling/clamps.
j. Ensure the turbocharger exhaust exit flange and exhaust tailpipe flanges are aligned, and then apply final, total 100% torque. Do not over-torque in an attempt to get things to fit together. If at 100% torque tailpipe fit is incorrect, disassemble the exhaust system as needed to determine the cause of the problem and correct it prior to proceeding with the installation.
k. Check the coupling V-retainer and clamp V-band apex gap and foot clearances. At full torque, a positive clearance must be maintained throughout to prevent the coupling/clamp from bottoming out on the flanges before the required loading has been achieved. Refer to Figure 11.
l. We recommend safety wire (minimum 0.032 in. stainless steel) per acceptable methods the bolt head to the nut end trunnion of the coupling as applicable to preclude opening of the coupling if the bolt or nut loosens, fails, or separates from the mating fastener after installation. Refer to Figures 12 & 13.
m. Properly install and torque as applicable the remaining exhaust system components, support clamps, hangers, and associated hardware.

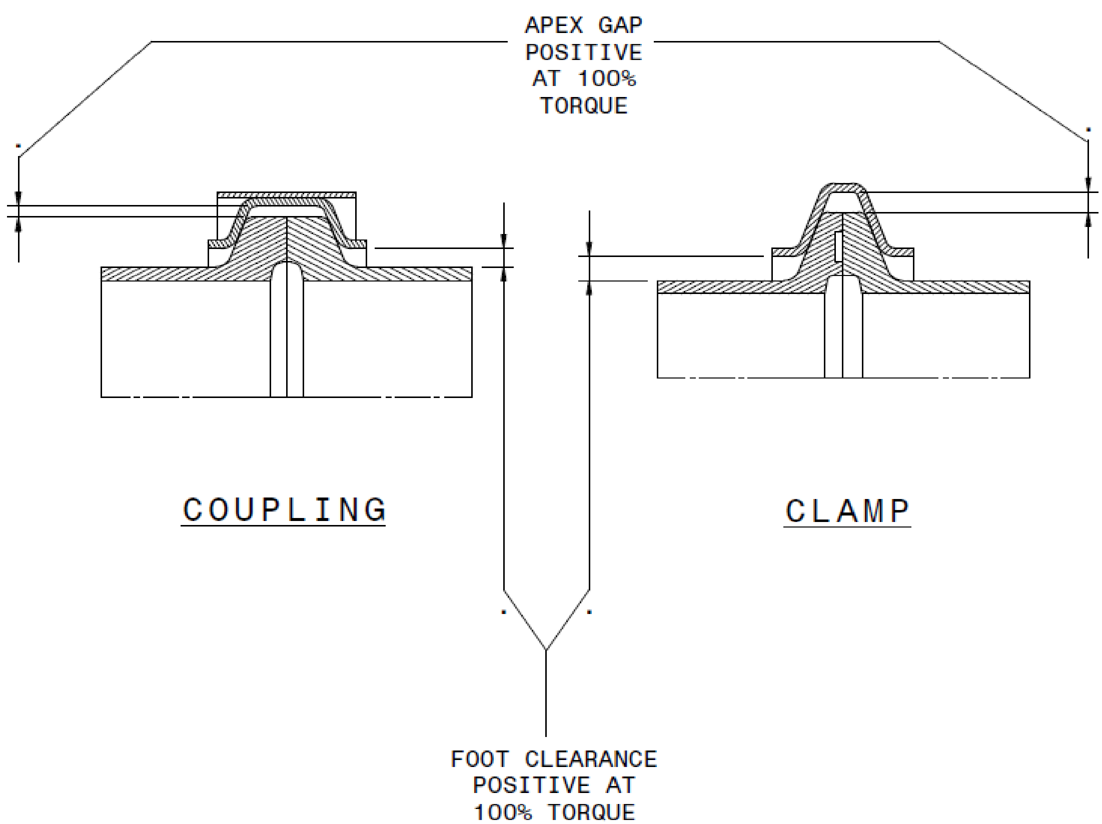
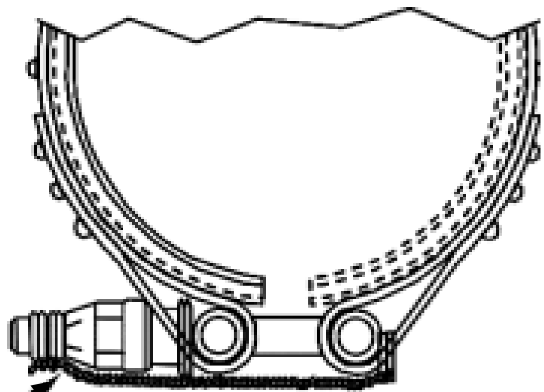


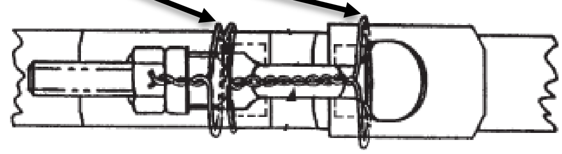
Figure 11

Coupling & Clamp Installation Clearances



<u>Figure 12</u>

Multi-Segment, Coupling Safety Wired



<u>Figure 13</u>

Multi-Segment, Coupling Safety Wired

n. After a coupling/clamp is installed/reinstalled and fully torqued, verify there is space between each V-retainer coupling segment, or verify there is space between both ends of a clamp. If there is no space between the V-retainer segment ends or clamp ends, a new coupling/clamp should be installed prior to further flight. Refer to Figures 14 & 16.
o. After a coupling/clamp is installed/reinstalled and fully torqued, check the coupling V-retainer and clamp V-band apex gap and foot clearances. A positive clearance must be maintained throughout to prevent the coupling/clamp bottoming out on the flanges. If there is no clearance in either location, a new coupling/clamp should be installed prior to further flight. Refer to Figure 11.
p. Relocate or reinstall any systems, cowling or access panels that have been previously removed.
q. After installation of any coupling/clamp, conduct an engine ground run with a full heating and cool down cycle and recheck the torque of the coupling/clamp after the engine has cooled. Adjust as necessary per Section 3.
r. Anytime a coupling/clamp is replaced with a new coupling/clamp, a record should be made in the maintenance records to include date of installation, the Time-In-Service (TIS) of the new coupling/clamp, manufacturer and part number.
S. Recheck the torque on any new or re-installed coupling/clamp after 25 hours TIS.

3.2 Tips & Hints

The following is a summary of some good do's and don'ts for V-band coupling/clamp installation:

a. Installation and fitment of components which are all new is often much better than a mix of old or worn components and new components.

b. Always minimize gaps and misalignment and align exhaust components prior to installation.

c. Soft-fit all components (including support brackets and clamps) loosely to assist in proper alignment and tailpipe support to preclude pre-loading the coupling/clamp inadvertently.

d. Do not attempt to align things using the coupling/clamp alone, get assistance from someone.

e. Ensure all required seals or gaskets as applicable (per the DAH ICA's) are airworthy and in their proper position.

f. Ensure the self-locking nuts are still serviceable and retain their locking capability, otherwise replace them.

g. Minimize opening, twisting or cycling of the coupling/clamp at any time.

h. Use of a hi-temp, nickel based, anti-seize compound on all interfaces may assist in the initial installation process.

i. Properly seat the coupling/clamp evenly around its circumference while tightening up exhaust installation fasteners (tailpipe, supports, hanger, etc.).

j. If accessible, a tap around the circumference with a soft mallet while tightening may help seat the coupling/clamp

k. Apply the proper torque as defined by the DAH Instructions for Continued Airworthiness.

l. More torque and subsequent over-torque is not better and will lead to deformation of the coupling/clamp and reduced service life.

m. In marine or saltwater environments or operations, be sure to include the V-band coupling/clamp in your airplane/engine washes and enhanced inspection programs.

n. If using blast media for cleaning a coupling/clamp, use only blast media that is non-abrasive, non-ablative and non-peening when cleaning any coupling/clamp per approved or acceptable methods.

4. INSPECTIONS

The specific focus area of this Best Practice Guide are those V-band couplings and clamps used at the turbocharger exhaust exit to exhaust tailpipe interface only. However, the inspection recommendations herein may be applicable to any V-band coupling or clamp in any aircrafts exhaust system.

WARNING

NEVER USE HIGHLY FLAMMABLE SOLVENTS ON ENGINE EXHAUST SYSTEMS. NEVER USE A WIRE BRUSH OR ABRASIVES TO CLEAN EXHAUST SYSTEMS. DO NOT USE ETCH TOOLS, GRAPHITE LEAD PENCIL, OR SCRIBE TO APPLY AN IDENTIFIER MARK ON EXHAUST PIPES. USE A NON-GRAPHITE MARKER.

CAUTION

DURING ANY INSPECTION OR REMOVAL, DO NOT TWIST OR OPEN THE COUPLING/CLAMP MORE THAN NECESSARY BECAUSE OVER-OPENING OR EXCESSIVE FLEXING CAN LEAD TO PHYSICAL DAMAGE. DO NOT OVER STRETCH OR OPEN BY PULLING SIDES APART ON ANY COUPLING/CLAMP.

If the coupling/clamp is removed, inspect the turbocharger exit flange and the tailpipe flange interfaces for any un-flat (0.005 in. or greater) or wavy condition, corrosion or deposits (not easily removed) and correct per the manufacturer’s recommendations. Refer to Figure 9.

4.1 Installed Inspection - Coupling/Clamp Installed

[Refer to Sections 1.2.1 and 5, and Figures 1 through 17]

The goal of the inspections is to find any of the Unsatisfactory Conditions presented in Section 5. These procedures do not require removal of the coupling/clamp, unless an Unsatisfactory Condition as defined in Section 5 is found or perceived to exist on any installed coupling/clamp. Conduct the inspection when the engine is cool.

a. First, inspect the turbocharger, tailpipe, and surrounding area in the as-received, installed condition. An inspection of the installed turbocharger area and surroundings may reveal Unsatisfactory Condition(s) or other issues with the installation such as sooting, signs of overheating, etc., that may be lost after a cleaning.

b. Remove any access panels or engine cowling as necessary to gain access and visibility to the installed turbocharger and tailpipe.

c. Remove any heat shields, insulation blankets, and any other readily removable exhaust system components that facilitate a better view of the exhaust tailpipe installation.

d. Loosen and/or relocate or remove any other systems that may impede your ability to inspect the tailpipe V-band coupling/clamp.

e. First check the installed torque of the self-locking nut to be sure it is to type design per the DAH ICA's and ensure there is no free-play in the coupling/clamp as received. If not torqued properly, this may explain movement at the tailpipe to turbocharger interface and potential wear marks on the V-retainers or V-band clamp body itself when the coupling/clamp is removed. This check may also reveal the condition of the self-locking nut and its ability to remain self-locking. If in doubt, about the nuts capability, replace the nut.

f. Use a bright light and mirror to inspect the areas that cannot be seen directly. Refer to Section 1.2.1 and Figures 14-17, 19, 21-23, 26, & 27. Pay particular attention to and carefully inspect the hard-to-see areas where the tailpipe attaches to the turbocharger exhaust exit flange. Inspect surrounding area for signs of exhaust stains, sooting or other evidence of exhaust leakage. These are grounds for removing the coupling/clamp and performing the Uninstalled Inspection per Section 4.2 herein.

g. Thereafter, if required, clean engine exhaust components per acceptable or approved methods using acceptable or approved materials. Pay particular attention to the outer band (flat) of a multi-segment V-band coupling, specifically at or near any spot-weld or rivet, and the outer surface of the V-band on a single-piece clamp. Refer to Figures 14-17, 19, 21-23, 26 & 27.

h. With the coupling/clamp properly torqued, visually inspect looking for any Unsatisfactory Condition as defined in Section 5. Refer to Figures 11, 14, 16 & 17.

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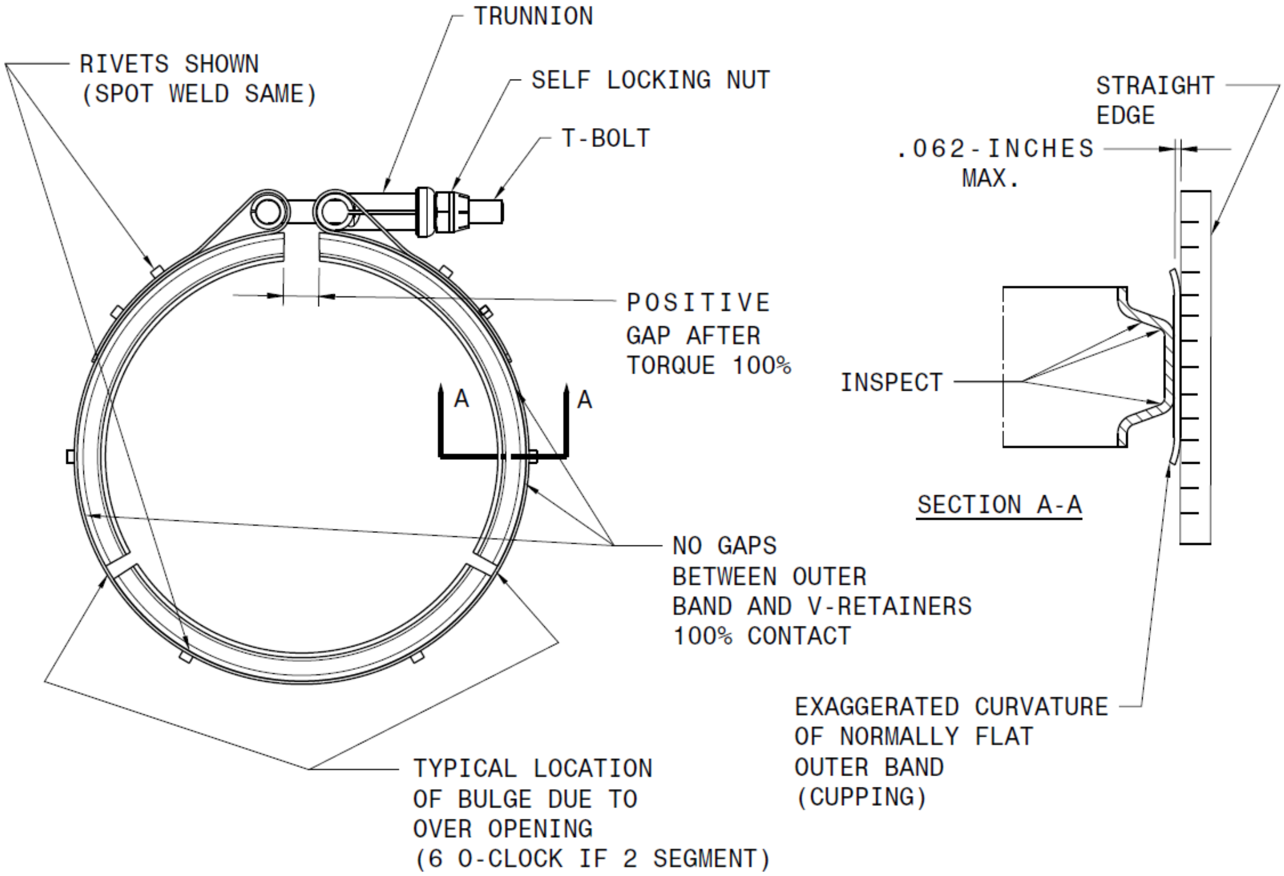

Figure 14

Multi-Segment, V-band *Coupling*

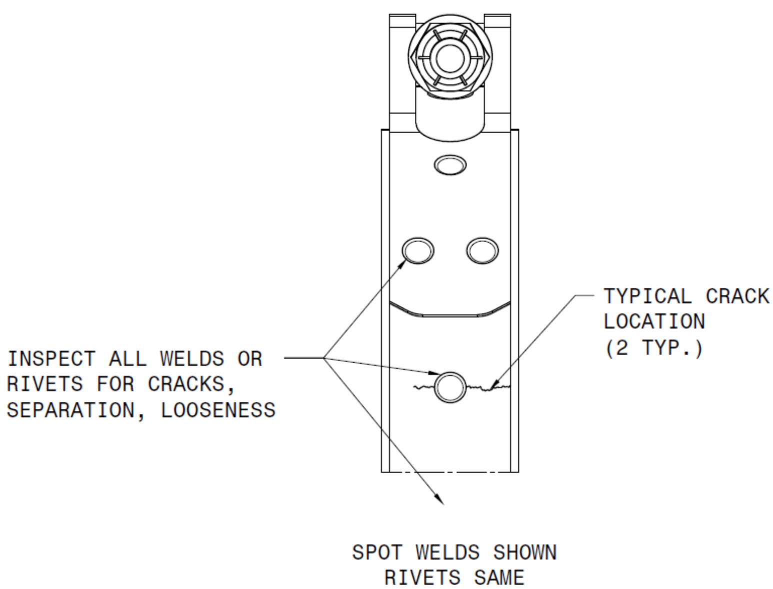

Figure 15

Multi-Segment, V-band *Coupling*

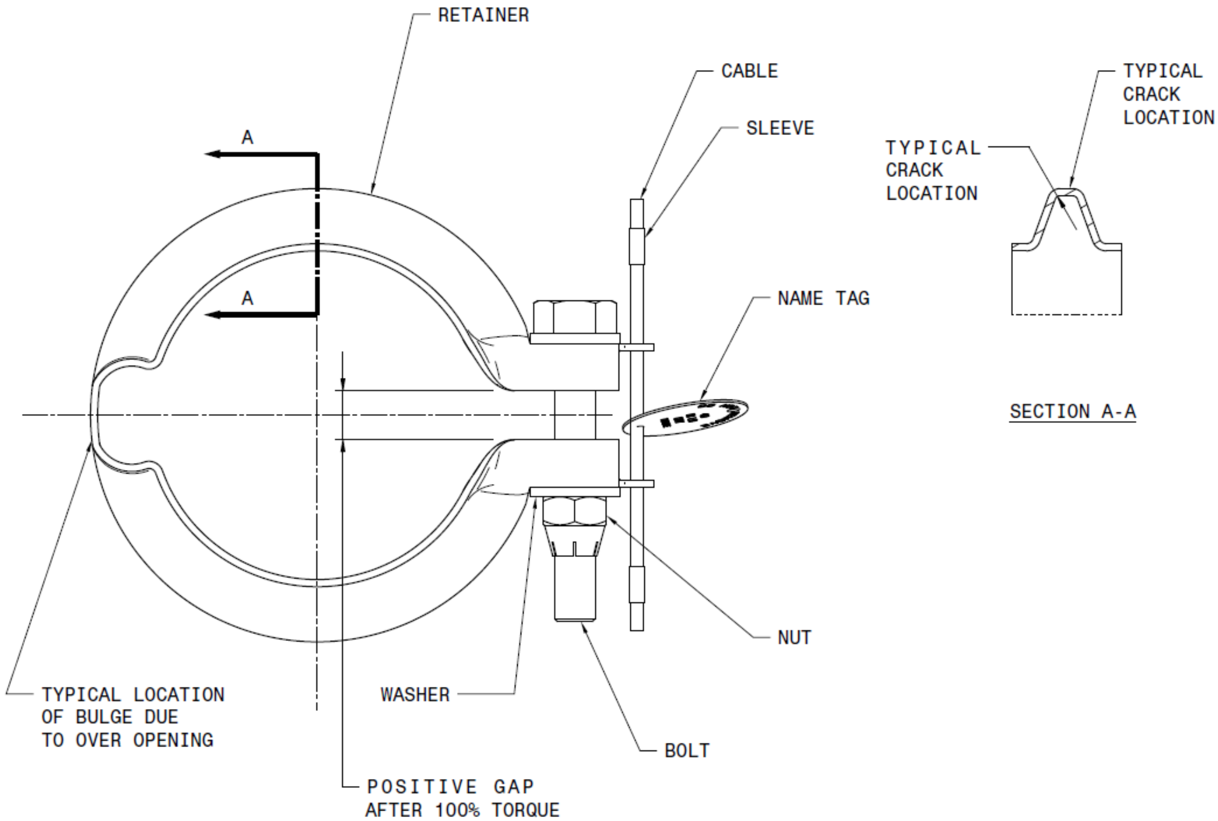

Figure 16
Single-Piece, V-band *Clamp*

4.2 Uninstalled Inspection - Coupling/Clamp In-hand
[Refer to Figures 1-8, 14-17, 19, 21-23, & 25-27.]

The goal of the inspections is to find any of the Unsatisfactory Conditions presented in Section 5. If the coupling/clamp has been removed for any reason, perform the following more detailed Uninstalled Inspection:

a. Hereafter, if required, clean engine exhaust components per acceptable or approved methods using acceptable or approved materials. Pay particular attention to the outer band (flat) of a multi-segment V-band coupling, specifically at or near any spot weld or rivet, and the outer surface of the V-band on a single-piece V-band clamp. Refer to Figures 4-6, 14-16, 19, 21-23, 26 & 27.

b. Use a 10X magnifier and bright lighting, backlighting may also be useful. Refer to Figures 14-17, 19, 21-23 & 25-27. Pay particular attention to the spot-welds or riveted areas on multi-segment couplings and the outer surface of the V-band on single-piece V-band clamps and areas that are initially hard to get to or see as installed, as these may have been neglected in prior inspections and may harbor problems.

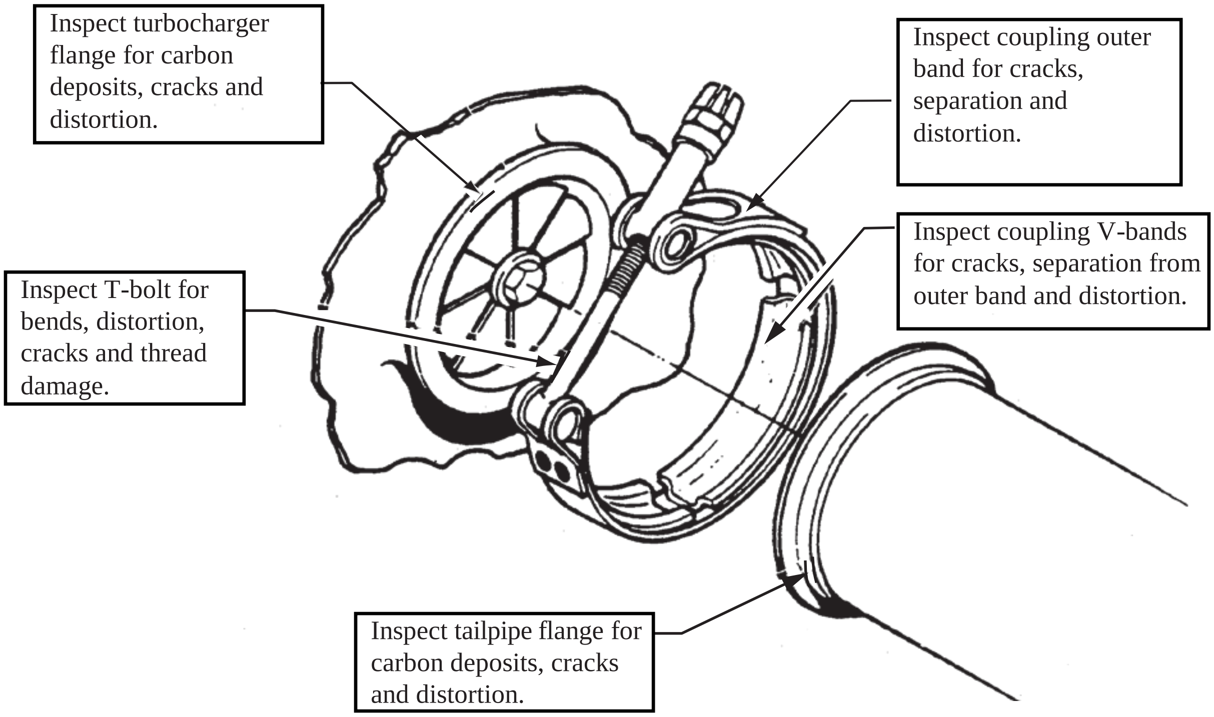

Figure 17
Typical Turbocharger to Tailpipe Interface Area

c. Visually inspect the coupling outer band for flatness using a straight edge. Lay the straight edge across the width of the outer band. The gap between the straight edge and the band must be less than 0.062 inches. Refer to Figure 14.

d. With the T-bolt in the 12 o'clock position, visually inspect the coupling for the attachment of the outer band to the V-retainer coupling segments. Inspect for gaps between the outer band and the V-retainer coupling segments at or in between any spot-weld or rivet that holds the outer band to the V-retainers. Placing the light source on the backside of the coupling may make this assessment easier. Refer to Figure 14 & 15.

e. Visually inspect the interior of the coupling V-retainers and the single-piece clamp V-band for indications of the exhaust flanges bottoming out in the V-apex of either. Refer to Figures 14, 16 & 25.

f. Visually inspect the inner bend radii of the coupling V-retainer segments or clamp V-band for cracks. Inspect the radii throughout the length of the segments and clamp. Back-lighting may assist here. Refer to Figures 14, 16 & 25-27.

g. Visually inspect the outer band and the V-retainer ends of a coupling or the V-band of any clamp opposite the bolt location (6 o'clock) for physical damage (i.e. distortion, creases, bulging, or cracks). Refer to Figures 14 & 16.

5. UNSATISFACTORY CONDITIONS

The following are definitions of Unsatisfactory Conditions for exhaust V-band couplings and clamps:

a. Crack in the coupling outer band (flat) material, potentially at or near a spot-weld or rivet. Refer to Figures 1, 2, 4, 5, 6, 15, 19, 21, & 22.
b. Cupping, bowing or crowning of the coupling outer band beyond 0.062 inches in depth. Refer to Figures 14, 19, 20 & 22.
c. Crack in any coupling V-retainer segment interior or exterior surface, e.g. at corner radii. Refer to Figures 14 & 25.
d. Looseness, separation of the outer band to V-retainer segment(s) at any spot-weld or rivet. Refer to Figures 14 & 15.
e. Less than 100% contact (i.e. gaps) between the V-retainer segments and the outer band at or between spot-welds or rivets on a coupling. Refer to Figures 14.
f. Crack in the clamp V-band exterior or interior surface along the V-apex, around the perimeter. Refer to Figures 16, 26 & 27.
g. Clamp open limiter cable (if applicable to the specific part number of clamp) missing or detached. Refer to Figures 7, 8 & 16.
h. Clamp part number and/or torque tag (if applicable to the specific part number of clamp) missing or detached. Refer to Figures 7, 8 & 16.
i. Contact of the V-retainer segments ends or clamp ends at any location (e.g. bolt area). Refer to Figures 14 & 16.
j. Lack of positive clearance at either the apex gap or foot clearance locations at full torque. Refer to Figure 11.
k. Bolt shank bent, bowed, or deformed (not at the T-bolt head end, as there are some which are manufactured with a slight angle to it.)
l. Bolt threads damaged or missing.
m. Self-locking nut thread damage or a nut that has lost self-locking capability and can be installed without preload (i.e. less than a minimum running torque of 1.80 inch-lb.).
n. Peening (flattening, curling) of material on the V-retainer segment ends or clamp ends from contact with each other, at any location (e.g. bolt area). Refer to Figures 14 & 16.
o. Corrosion that is not easily removed with a polymer abrasive pad from any component of the coupling/clamp.
p. Pitting of any component of the coupling/clamp base material.
q. Permanent deformity to include, but not limited to, out of round, bowed or wavy condition (un-flat), twisted, and/or re-formed by any method.
r. Physical damage to any coupling/clamp component to include but not limited to; cracks, gouges, notches, tears, bulges, bumps, fractures.
s. Any repairs or any indications of past repairs.
t. Unapproved hardware or any material or hardware substitution.

NOTE: It is understood that many of the unsatisfactory conditions above may not be readily accessed with the coupling/clamp installed. If coupling/clamp condition is suspect for ***any*** reason, you should always remove the coupling/clamp for a more detailed examination.

6. REPETITIVE INSPECTION & LIFE-LIMITING

CAUTION

IF THERE EXISTS AN AIRWORTHINESS DIRECTIVE AGAINST THE PRODUCT WHICH ESTABLISHES A LIFE-LIMIT AND/OR REPETITIVE INSPECTION INTERVAL, THAT MANDATE TAKES PRECEDENCE OVER THE INFORMATION HEREIN, UNLESS APPROVED BY AMOC TO THE SPECIFIC AD. ALSO CHECK THE AIRWORTHINESS LIMITATIONS.

a. Inspect annually the coupling/clamps per Section 4. The repetitive inspection may be conducted with the coupling/clamp installed per Section 4.1. If the installed condition is suspect or inspection or conditions indicate removal of the coupling/clamp is necessary to determine the coupling/clamp condition from the installed inspection, the coupling/clamp should always be removed and the inspection in Section 4.2 should be performed.

b. Spot-welded, multi-segment V-band couplings should be life limited to 500 hrs. total TIS with no life extensions permitted.

c. Riveted (collared fastener), multi-segment V-band couplings should be life limited to 2000 hrs. total TIS with no life extensions permitted.

d. Single-piece V-band clamps should be life limited to 2000 hrs. total TIS with no extensions permitted.

e. Coupling/clamp life limits are applicable to only one engine and aircraft installation and coupling/clamps should not be swapped between engines or aircraft or re-used in any other aircraft application.

f. If any Unsatisfactory Conditions per Section 5 is found to exist on any coupling/clamp, the coupling/clamp should be considered un-airworthy and should be removed and replaced prior to further flight with a new, zero hours TIS, FAA approved coupling/clamp as applicable.

g. Satisfactory completion of any inspection in Section 4 or the lack of finding any Unsatisfactory Condition as presented in Section 5 should not alter or terminate any repetitive inspection or restart the hours TIS for any coupling/clamp.

h. If the coupling/clamp passes all of the inspections in Section 4, you should only re-install the same coupling/clamp on the same aircraft, engine, tailpipe and turbocharger combination from which the coupling/clamp was removed.

i. After any coupling/clamp is re-installed on the same engine only and torqued as required per Section 3, verify there is space between the ends of each V-retainer coupling segment or between the ends of the clamp. If there is no space between any V-retainer coupling segment, or between the ends of the clamp, before further flight, you should install a new coupling/clamp and restart the hours TIS for the repetitive replacement of the coupling/clamp. Refer to Figures 11, 14 & 16.

j. After a coupling/clamp is installed/reinstalled and fully torqued, check the coupling V-retainer and clamp V-band apex gap and foot clearances. A positive clearance must be maintained throughout to prevent the coupling/clamp bottoming out on the flanges. If there is no clearance in either location, a new coupling/clamp should be installed prior to further flight. Refer to Figure 11.

k. If no Unsatisfactory Condition(s) per Section 5 are found the coupling/clamp, may remain installed or be re-installed on the same engine per Section 3 until the airworthiness condition of the coupling/clamp warrants the removal, the next inspection is due, or the TIS limits have been reached.

l. Anytime a coupling/clamp is replaced with a new coupling/clamp, a record should be made in the maintenance records to include date of installation, the TIS of the new coupling/clamp, manufacturer and part number.

m. All V-band coupling/clamps removed from service should be permanently destroyed and not used on any other engine, aircraft or other aircraft application.

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7. V-BAND COUPLING & CLAMP FAILURES

7.1 Spot-welded, Multi-segment, Coupling Failures Encountered

Below are reference photographs of failed V-band couplings.

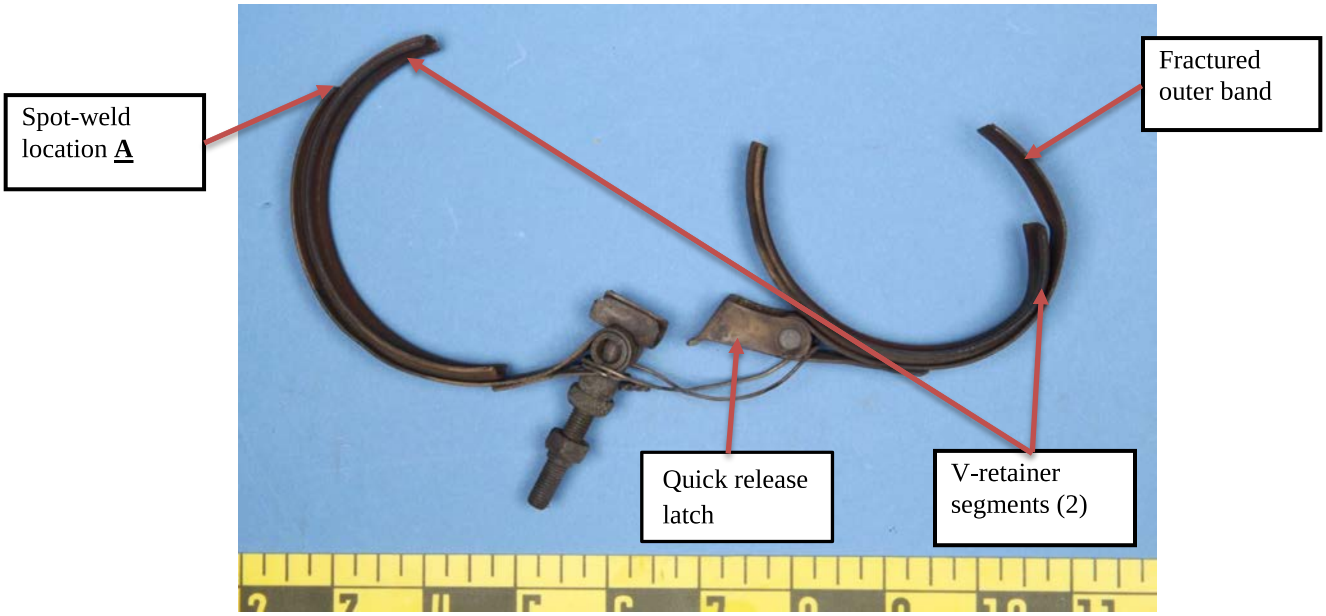


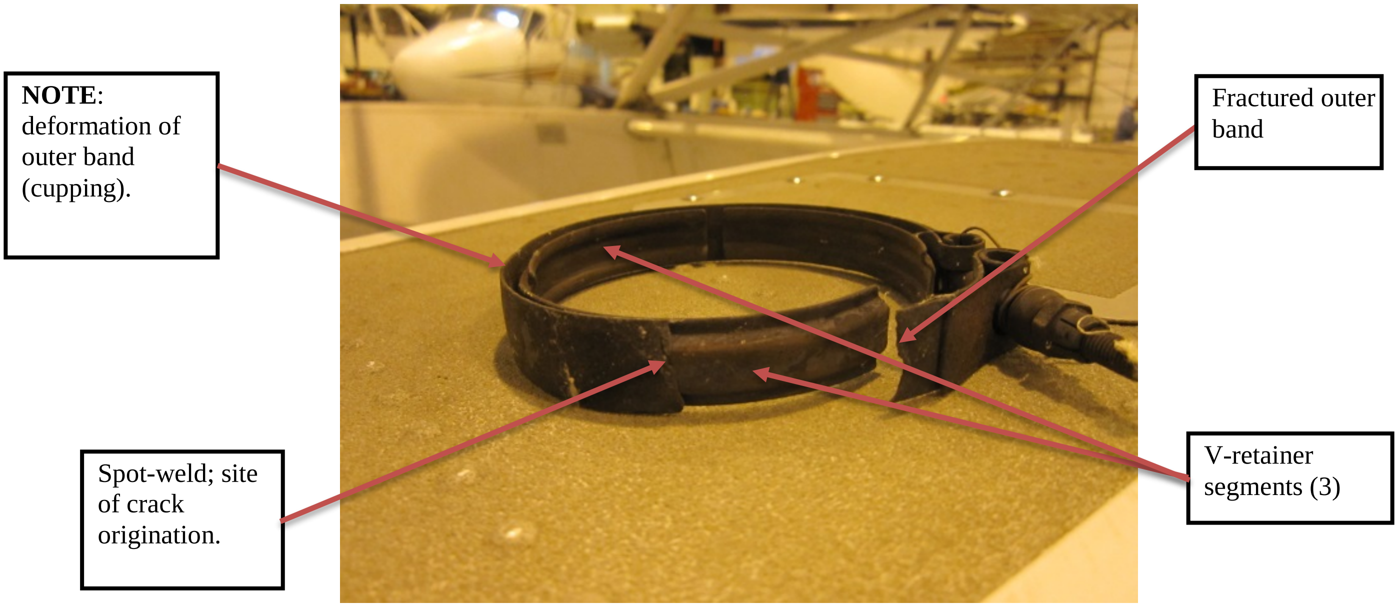
Figure 18

Spot-welded, 2-segment Coupling with Quick Release Latch

Figure 19

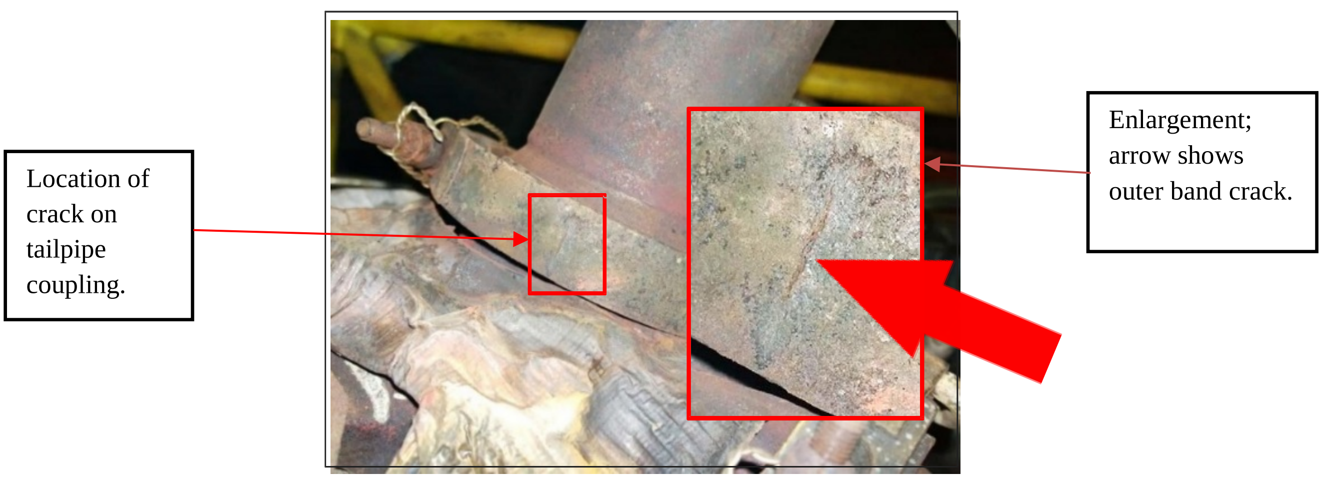
Same coupling above magnified

The above failure started as a crack that originated out of the spot-weld. The crack grew to a full transverse outer band crack that caused separation of the coupling. The above failure resulted in loss of the tailpipe, smoke in the cockpit, in-flight fire and fatalities. Note the safety wire is still in place.



<u>Figure 20</u>
Spot-welded, 3-segment Coupling

The above failure started as a crack that originated out of the spot-weld. The crack grew to a full transverse outer band crack that caused separation of the coupling. The above failure resulted in loss of the tailpipe, smoke in the cockpit, in-flight fire and a very quick, direct in approach and landing on fire. There were no fatalities. Note again the safety wire is still in place.

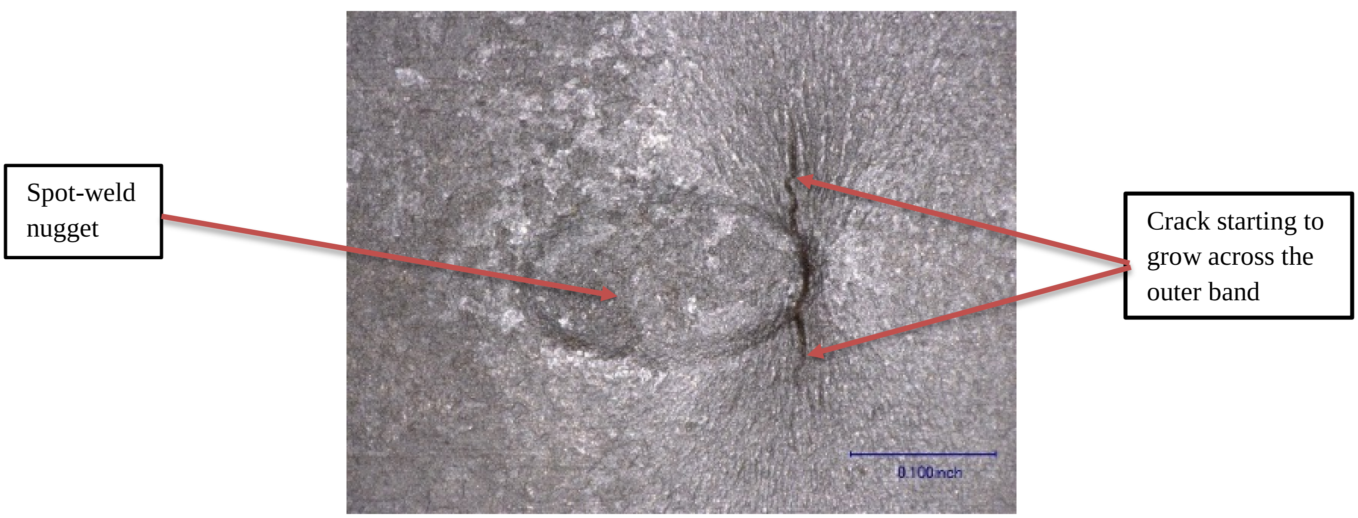


<u>Figure 21</u>
Spot-welded, Multi-segment Coupling

The above crack originated at a spot-weld. However, the crack had not grown across the outer band and the coupling had not separated yet. Found on inspection for another issue.

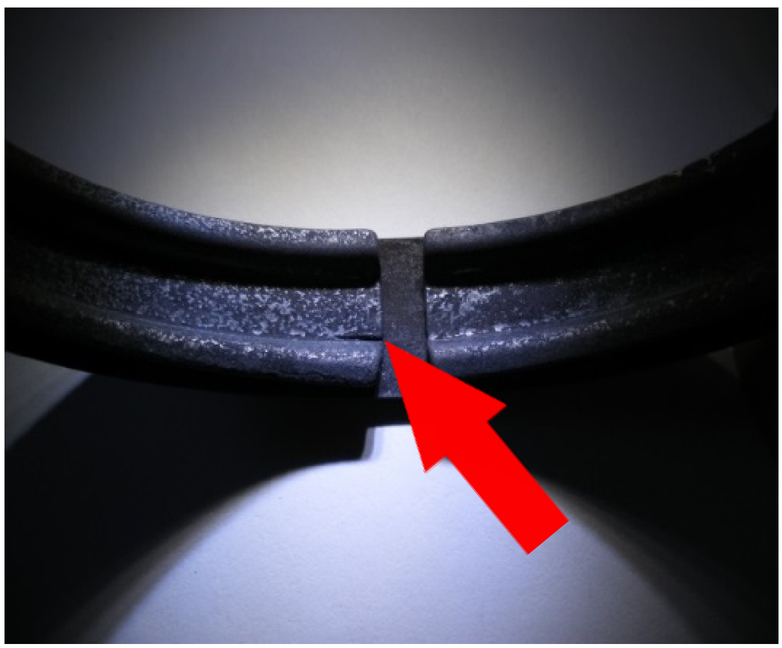
<u>Figure 22</u>
Spot-welded, 3-segment Coupling

The red arrow shows where the coupling is deformed at a spot-weld where the crack originated. The crack had not yet grown across the outer band and the coupling had not separated. Found on inspection for another issue.



<u>Figure 23</u>
Same coupling above magnified

<u>Figure 24</u>
Spot-welded, 3-segment, Coupling



<u>Figure 25</u>
Same coupling above magnified

Figure 25 is the same coupling as in Figure 24 above. This photograph was taken on a bench with a white top, using back lighting from a flashlight. There is a crack in the V-retainer segment inner corner radius. With the condition of the coupling, this crack was difficult to find with the coupling in-hand. This crack could not be found with the coupling installed. Found during inspection after tailpipe removal. Note the corrosion from salt water operations.

7.2 Single-piece, Clamp Failures Encountered

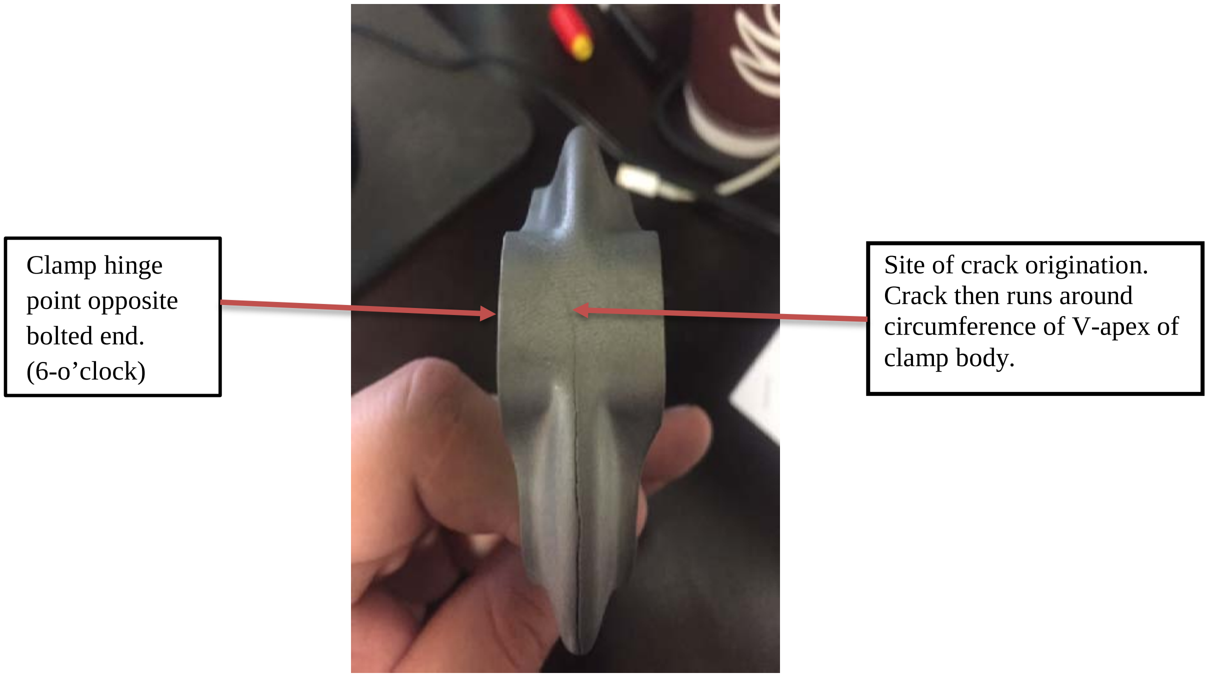


Figure 26
Single-Piece Clamp

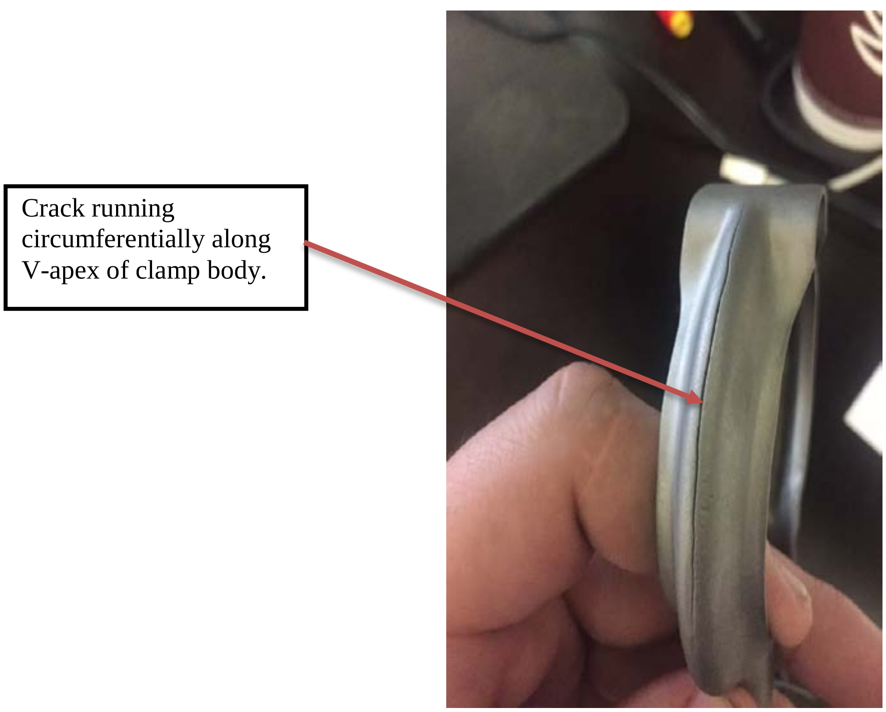


Figure 27
Single-Piece Clamp

APPENDIX: C

AIRWORTHINESS CONCERN SHEET

U.S. Department
of Transportation

**Federal Aviation
Administration**

Airworthiness Concern Sheet

Date: November 22, 2016

Reply to: **Name:** David Hirt **Title:** Aerospace Engineer **Office:** ACE-113 **Street Address:** 901 Locust, Room 301 **City, State, ZIP:** Kansas City, MO 64106 **Telephone:** (816) 329-4050 **Electronic Mail:** david.hirt@faa.gov	**Make:** All turbocharged reciprocating engine powered aircraft **Model / Series:** **Serial Numbers:** **Reason for Airworthiness Concern:** Failure of the Turbocharged Exhaust Tailpipe V-Band Coupling

Federal Aviation Administration (FAA) Description of Airworthiness Concern

V-Band coupling failures on turbocharged reciprocating engines at the turbocharger exhaust tailpipe interface continue to result in incidents and accidents. Separation of the turbo/tailpipe interface can potentially lead to engine bay in-flight fires, smoke/fumes in the cockpit, and engine power loss. These events are not unique to any specific brand of aircraft, engine, or coupling manufacturer. This problem affects both rotary and fixed wing aircraft.

The FAA has dealt with these events by issuing numerous (18) aircraft model specific Airworthiness Directives, providing guidance and recommendations in at least seven Special Airworthiness Information Bulletins, issued approximately six AC43-16A Maintenance Alert articles, and updated existing Advisory Circular guidance. Industry too has taken action to raise awareness of the concerns associated with V-Band coupling failures by publishing articles in various trade magazines and user group newsletters, issuing installation guidance and clarifying installation requirements for v-band couplings.

In spite of previous corrective action attempts problems continue to persist. The most recent fatal accident occurred in May 2016 resulting in four fatalities. The FAA and Industry have established a working group to examine this continued safety issue. The working group is looking at this airworthiness concern from a comprehensive perspective to develop safety enhancing corrective actions. We seek your assistance in obtaining in-service data to help drive corrective action decisions.

Request for Information (For example: Proposed alternate inspection or repair procedures, cost impact, etc. Your comments or replies to the AA need to be as specific as possible. Please provide specific examples to illustrate your comments or concerns.)

The public is asked to provide the following information concerning your experience with these turbocharger/tailpipe V-band couplings:

- V-Band Coupling Inspection Frequency
- Type of inspection conducted (e.g., Preflight tailpipe looseness check, general visual inspection without coupling removal)
- Inspection criteria utilized (e.g., Airplane Maintenance Manual, etc.)
- Typical replacement criteria (e.g., excessive corrosion, cracks, outer band cupping, etc.) encountered to cause V-band coupling replacement
- Observations on related components (Turbo Flange, Exhaust pipe flanges, etc.
- Observations of the condition of couplings at replacement (include photographs if available)
- Coupling inspection/replacement difficulty (e.g., was it difficult to gain access or difficulty)
- Total coupling time-in service at time of inspection
- Total coupling time in-service prior to replacement
- V-band clamp part number and design features (e.g. riveted vs. spot weld construction, single piece vs. multi-segment, opening limiter cable, etc.)
- Airplane Make, Model, and Serial Number
- Airplane total time-in-service
- Airplane operating environment (e.g., coastal or humid environment, etc.)
- Corrective Action Recommendations (e.g., improved processes and guidance, inspection/replacement criteria, design changes, etc.)

- If available, please send any removed turbocharger to exhaust pipe couplings to: Mr. Jeff Janusz, Wichita Aircraft Certification Office; 1801 Airport Road, Room 100; Wichita, KS 67209

This Airworthiness Concern Sheet (ACS) is intended as a means for FAA Aviation Safety Engineers to coordinate airworthiness concerns with aircraft owners/operators through associations and type clubs. At this time, the FAA has not made a determination on what type of corrective action (if any) should be taken. The resolution of this airworthiness concern could involve Airworthiness Directive (AD) action or a Special Airworthiness Information Bulletin (SAIB), or the FAA could determine that no action is needed at this time. The FAA's final determination will depend in part on the information received in response to this ACS.

The FAA endorses dissemination of this technical information to all manufacturers and requests association and type club comments.

Attachments:	**Transmittal:**	**Response Requested By:**
☐ Service Difficulty Report ☐ Accident/Incident Data System ☐ Service Letter / Bulletin ☐ Special Airworthiness Information Bulletin ☐ Federal Aviation Administration or National Transportation Safety Board Safety Recommendation ☐ Airworthiness Directive ☐ Alternate Means of Compliance ☐ Risk Analysis	☐ Federal Aviation Administration ☒ Airplane Owners and Pilots Association ☐ Experimental Aircraft Association ☒ Type Club ☒ Type Certificate Holder ☒ Other:	☐ Emergency (10 days) ☐ Alert (30 days) ☒ Information (90 days)