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U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Weld Repair of Aluminum Crankcases and Cylinders of Piston Engines

Date: 12/20/94

AC No. 33-6

Initiated by: ANE-110

Change:

1. PURPOSE. This advisory circular provides guidelines for the development of repair procedures for weld repairs on crankcases and cylinders of piston engines.

a. It addresses development of weld repairs which are not contained in the engine manufacturer's "Instructions for Continued Airworthiness" (Maintenance Manual). It provides guidance to clarify the areas which should be addressed by an applicant's repair procedure, and/or substantiating data when seeking an approval for weld repair on crankcases or cylinders.

b. This advisory circular also includes information on critical areas of welding, qualifications of welder's, inspection techniques, the thermal processes, and technical data required. This advisory circular references industry and military specifications which are acceptable for use by repair stations as approved data.

2. RELATED FAR SECTIONS.

a. FAR Part 21, Certification Procedures for Products and Parts.

b. FAR Part 33, Airworthiness Standards: Aircraft Engines.

c. FAR Part 43, Maintenance, Preventive Maintenance, Rebuilding, and Alteration; particularly sections 43.9 and 43.13.

(1) Section 43.9 describes the maintenance records required to approve a part for return to service. These records shall include "a description (or reference to data acceptable to the Administrator) of the work performed." This should indicate what work was performed and the manner in which it was accomplished. References to documents containing the description

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of the manner are acceptable. These may be manufacturer's manuals, advisory circulars, or other documents or references containing data acceptable to the Administrator. If documents other than types which are in common use are referenced, the document should be made part of the maintenance record, as required under section 43.9(a)(1).

(2) Section 43.13 describes the requirements for performing work and using materials that will return the item to a condition equal to its original, or properly altered state. The regulation requires that maintenance be done using methods, techniques, and practices in the manufacturer's "Instruction for Continued Airworthiness." However, some may be found in advisory circulars published by the FAA or other industry standards. The regulation requires that the necessary tools, equipment, and test apparatus be used. Normally, these are listed in the manufacturer's maintenance manual, but may be shown to conform to accepted industry standards. Any special equipment recommended by the manufacturer, or its equivalent acceptable to the Administrator, must be used.

d. FAR Part 145, Repair Stations. The holders of mechanic and repairman certificates, persons under the supervision of these mechanics and repairmen, and repair stations certificated under Part 145, are authorized to perform maintenance. In accordance with section 145.51, "A certificated domestic repair station may maintain or alter any airframe, powerplant, propeller or accessory, or part thereof for which it is rated." However, major repairs or alterations must be done in accordance with technical data approved by the Administrator. Caution must be taken in that functions which appear to be simple tasks may, in fact, be quite complicated, and applicants for process specifications should ensure that the task is within the repair station's capabilities.

3. RELATED READING MATERIAL.

a. Directive. FAA Order 8300.10, Airworthiness Inspector's Handbook (11/88).

(1) Volume 2, Chapter 1 describes requirements for approved data; and

(2) Volume 4, Chapter 7 specifically addresses repairs on reciprocating engines and lists welding of crankcases as major repair. (This advisory circular defines as major repair, any weld repair done on a crankcase or cylinder).

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b. Advisory Material. When incorporated and substantiated properly in the applicant's process specification, the following may be considered data acceptable to the Administrator:

(1) Advisory Circulars:

(i) AC 33-2B, Aircraft Engine Type Certification Handbook (06-30-93).

(ii) AC 43-3, Non-Destructive Testing in Aircraft (5-11-73).

(iii) AC 43-9B, Maintenance Records (1-9-84).

(iv) AC 43.9-1E, Instructions for Completion of FAA Form 337 (OMB No. 2120-0020), Major Repair and Alteration (Airframe, Powerplant, Propeller, or Appliance) (5-21-87).

(v) AC 43.13-1A, Acceptable Methods, Techniques, and Practices -- Aircraft Inspection and Repair (4-17-72). (With Errata Sheet).

(vi) AC 145-3, Guide for Developing and Evaluating Repair Station Inspection Procedures Manuals (2-13-81).

(2) Manufacturer service letters, service instructions, service bulletins, repair manuals, overhaul manuals, and tables of limits. Industry specifications, including but not limited to:

(i) Aerospace Materials Specifications (AMS):

(A) AMS 2630, Room Temperature Tensile Properties of Castings.

(B) AMS 2635, Radiographic Inspection.

(C) AMS 2645, Fluorescent Penetrant Inspection.

(D) AMS 2646, Contrast Dye Penetrant Inspection.

(E) AMS 2694, Repair Welding of Aerospace Castings.

(F) AMS 2771, Heat Treatment of Aluminum Alloy

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Castings.

(G) AMS 2804, Identification, Castings.

(H) AMS 4214, Castings Aluminum Alloy, Sand.

(ii) American Welding Society (AWS):

(A) AWS A5.10-88, Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods.

(B) AWS B2.1-84, Standard for Welding Procedure and Performance Qualification.

(iii) Military Specifications, including, but not limited to:

(A) MIL-I-25135E, Inspection Materials, Penetrants.

(B) MIL-H-6088F, Heat Treatment of Aluminum Alloys.

(C) MIL-W-45208, Welding of Aerospace Aluminum Castings.

(iv) Military Standards, including, but not limited to:

(A) MIL-STD-271F, Requirements for Nondestructive Testing Methods.

(B) MIL-STD-1595A, Qualification of Aircraft, Missile and Aerospace Fusion Welders.

(C) MIL-STD-2219, Fusion Welding for Aerospace Applications.

c. Reference Publications. For the purposes of this advisory circular, the following publications are considered reference materials, and should not be used to limit repairs discussed in this document:

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(1) Welding Alcoa Aluminum, Alcoa Aluminum.

(2) Welding Handbook, American Welding Society.

(3) How to do Heliarc Welding, Linde-Electrical Welding

Instruction.

(4) SAE Handbook, Vol 1, Society of Automotive Engineers.

4. BACKGROUND. The Federal Aviation Administration (FAA) is aware that there are many repair stations in the aviation industry that have talented and knowledgeable personnel who are performing a much needed service in repairing otherwise unserviceable parts. However, the FAA has been made aware of repaired crankcases and cylinders which have failed in-service, resulting in accidents.

a. Major weld repair procedures not contained in the manufacturer's maintenance manuals have been developed and used by repair stations in a non-uniform manner. Before weld repair procedures may be added to the operation specifications of a repair station (with a specialized Service Rating for Welding), a process specification, based upon substantiating data approved by the Administrator, must be developed.

b. This advisory circular is meant to standardize the procedure for development of approved data for weld repair specifications for piston engine crankcases and cylinders.

5. DEFINITION. For the purpose of this advisory circular, the following definitions will be used in conjunction with all applicable airworthiness requirements:

a. Acceptable Data. Technical data which was examined and accepted by the FAA. Data that may be used on an individual basis to obtain approval are: FAA Advisory Circulars; Manufacturer's technical information (for example, manuals, bulletins, kits, etc.); Mil Specs; and FAA Field Approvals.

b. Approved Data. Technical data which was examined and approved (for major repairs and alterations) through applicable FAA authority, or previously approved documents such as advisory circulars or manufacturers' service bulletins. This includes: Type Certificate Data Sheets, Supplemental Type Certificates

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(STCs), Airworthiness Directives, Manufacturer's FAA approved data, Designated Engineering Representative (DER) approved data, and Designated Alteration Station (DAS) approved data developed for alterations performed by that station only.

c. Repair. A procedure performed on a product or component part that does not change its form or function.

(1) Major Repair. A repair that: if improperly done, might appreciably affect weight, balance, structural strength, performance, powerplant operation, flight characteristics, or other qualities affecting airworthiness; or is not done according to accepted practices or cannot be done by elementary operations.

(2) Minor Repair. Any repair that is not classified as a major repair.

d. Technical Data. Information necessary to define and substantiate a repair procedure, in compliance with applicable airworthiness standards, including the following: drawings, sketches, and/or photographs; stress analysis; engineering orders; and operating limitations.

6. DISCUSSION.

a. Welding Criteria. The applicant's process specification should contain criteria for determining the area and nature of the weld repair. The criteria must be sufficient to determine the nature of the weld and extent of the repair necessary, to assure the applicable procedure will return the component to airworthy condition. This criteria will include a procedure for determining when repairs cannot be effected. The following areas are considered to be of critical importance and require special consideration in analyzing the supporting data used for substantiation of these repairs. Weld repairs in the following areas, unless approved by the engine manufacturer, must be substantiated by a detailed analysis of the repair that ensures the airworthiness of the part. Substantiation may include dimensions (locations and alignments of critical areas), hardness tests (before and after welding), full scale engine block test, in-service tests which include periodic inspections (on similarly repaired cylinders or crankcase), military specifications, industry standards, fatigue testing, and engineering analyses.

(1) Crankcase:

(i) Crankcase bores.

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(ii) Supports, webs, and fillets of the crankcase bearing bores.

(iii) Areas on or adjacent to any stud holes, or cylinder decks, or mating flanges.

(iv) Cracks in any areas, if they are in excess of three and one-half inches long.

(2) Cylinders:

(i) Crack(s) through a seat boss.

(ii) Crack(s) between two seats.

(iii) Crack(s) through the guide boss.

(iv) Circumferential crack(s) in the head area.

(v) Broken pieces built up by welding, such as, rocker arm shaft bosses.

(vi) Dome cracks over three-eighths of an inch depth.

(vii) More than two cracks emanating from any port.

(viii) Crack(s) over one and one-quarter inch in length.

(ix) More than three welded cracks.

(x) Port crack(s), if exhaust port crack(s) exceeds one and one-quarter inch in length, or one-quarter inch in depth; or is within one-quarter inch of valve seat boss.

(xi) Welding or machining of cylinder attach flange, other than routine lapping to obtain flatness and to remove scratches and burrs.

b. Inspection Criteria. The applicant's process specification must contain criteria for inspection of the part, pursuant to data approved by the Administrator. Procedures must include visual and dimensional inspections prior to repair, to determine the extent of the repair necessary. Procedures must also include criteria for determining whether a repair is within the capabilities of the applicant to perform under its process.

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(1) Welds shall be limited to those which can be inspected, in accordance with approved procedures, i.e., Non-Destructive Inspection (NDI). Procedures must include post-weld inspection criteria necessary to determine the airworthiness of the component, after approved repairs have been accomplished.

(2) Guidance for developing inspection criteria may be obtained by referring to the visual and dimensional limitations contained in manufacturers' maintenance documents. Guidance for developing non-destructive testing procedures may be obtained from referenced industry, and military standards and specifications on inspection and heat treatment techniques. The most common inspection techniques include Dye Penetrant Inspection (DPI) and Fluorescent Penetrant Inspection (FPI) per AMS 2645 or MIL-I-6866. Personnel performing NDI must be trained and qualified in the disciplines being performed.

(3) Preheating the case or cylinder to approximately 200 degrees F before inspection will enhance crack detection.

(4) After welding and stress relief, repeat dimensional and crack inspection.

c. Preparation of Weld Area.

(1) Disassembly and Removal Procedures. The applicant's process specification must contain necessary disassembly instructions to permit proper cleaning of the component. These instructions, if required, must specify those parts to be removed and their method of removal.

(2) Cleaning Procedures. The process specification must have an acceptable method of cleaning components. Cleaning must be performed in order to permit proper inspection, as well as to assure welding which is free of foreign material contamination. Care should be taken to ensure that cleaning solutions are not entrapped in the component being cleaned.

(i) Cleaning agents used shall be limited to those which can be shown to be compatible with the materials being cleaned. Compatibility is defined as those agents which do not cause embrittlement or corrosion of the component material.

(ii) Where solid media blasting is used for cleaning, compatibility requirements as described above shall apply. Additionally, methods employed for media blasting must provide for complete removal of all blasting media. Blasting methods must be shown not to cause peening of material, so as to

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close surface cracks or to excessively distort machined surfaces.

d. Preparation for welding.

(1) Inert gas arc welding is the most common method used for this type of welding. A process specification for inert gas arc welding that uses filler material, must address methods for preparation of the area to be welded. These preparation methods should address the following areas:

(i) Cleaning of the area necessary to obtain a high quality weld (use of solvent and steel wire brush).

(ii) Method by which cracked or damaged material is removed to permit welding.

(iii) Inspection method for determining that all cracked or damaged material has been removed prior to welding.

Where other welding technologies that do not add filler material are used in the process specifications, preparation methods must be shown to produce a high quality weld.

(2) Preheating aluminum prior to welding is normally required because:

(i) Aluminum casting is porous and tends to become saturated with oil that would contaminate the weld.

(ii) Preheating brings the oil to the surface of the material.

(iii) Aluminum is very conductive, and preheating prevents heat from conducting away from weld area.

(3) If a welding method, other than the Inert Gas Arc, is used and preheating is determined not to be advantageous, the substantiating data should include the reason for this determination.

(4) Where preheating is determined advantageous in producing the best quality weld for the process specification, the preheat time and temperature must be shown to be adequate for the parent material, filler material, and specific welding process.

(i) The procedure must include a method for determining the temperature of the component, the tolerances of

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the preheat temperature, and the method for maintaining the temperature during the welding process.

(ii) A preheat temperature of 450 to 475 degrees F, for two to four hours, has been found acceptable for Lycoming cases. A preheat temperature of 375 to 400 degrees F, for two to four hours, has been found acceptable for Teledyne Continental cases.

e. Weld Procedure Criteria. The applicant's process specification shall set forth weld procedures that are demonstrated to return the component to airworthy condition.

(1) The equipment requirements shall be those necessary to accomplish the welding process. Maintenance and record of such machinery shall comply with equipment manufacturer's recommendations or acceptable industry standards.

(2) If the process specification requires filler material, the filler shall be demonstrated to be compatible with the parent material and not affect the airworthiness of the component. Guidance for determining filler material compatibility may be found in the military and industry standards for welding aerospace aluminum castings.

(3) The process specification should address the method by which distortion is minimized during the weld procedure. In certain instances, it has been helpful to constrain the component in a proper fixture during preheating, welding, and stress relief.

(4) Weld rod of AMS 4190 (AA 4043) is acceptable for all aluminum alloys; except AMS 4031, AMS 4143, or AMS 4313, which require weld rod of equivalent material.

f. Stress-Relief Criteria. The applicant's process specification shall contain procedures for assuring that post-weld stress relief shall be performed in a manner that ensures the component is restored to an airworthy condition.

(1) Post-weld stress relief by heat treatment shall be performed in such a manner, and provide for time and temperature requirements, necessary to ensure the component is returned to an airworthy condition. The procedure shall be substantiated by reference to acceptable military or industry specifications or by metallurgical analysis.

(2) If it is determined that post-weld heat treatment is

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not required, either because of the weld procedure incorporated or another method of stress relief is used, the process specification must include the reasons for this determination.

g. Post-Weld Machining Criteria. The applicant's process specification shall set forth an inspection procedure which shall determine the extent and nature of machining necessary to correct any misalignment or distortion of areas adjacent to the weld repair. This procedure can allow for the installation of approved undersized or oversized parts.

(1) The process specification shall have methods by which approved dimensions are determined and conformed to. The dimensions may be obtained from manufacturers' manuals, service bulletins, or other technical publications, or by specifications established by the applicant and approved through the FAA by analysis, testing, or other acceptable methods.

(2) The process specification shall set forth the method of machining which shall be demonstrated to return the component to airworthy condition. Hand-finishing and blending of non-machined cast areas shall be shown to conform to in-service limits for approval for return to service. Surface-finish limits shall conform to manufacturers' published data or acceptable data established by the applicant to be equivalent.

h. Qualification of Personnel. The applicant shall set forth the method by which personnel necessary to perform the tasks shall be qualified, trained, and re-trained.

(1) Personnel shall demonstrate the ability to perform the necessary operations upon the material and by the methods set forth in the process specifications.

(2) The applicant may refer to the criteria set forth in the repair station manual for qualifying, training, and re-training the welding personnel. Guidance for developing adequate training may be obtained from industry and military standards.

i. Approved Data Criteria. The applicant's process specification must be accompanied by a detailed analysis of the complete process, sufficient to document the ability to assure the airworthiness of the component.

(1) The detailed analysis shall be accomplished in such a manner and include dimensions, tolerances, alignments, hardness specifications, surface finishing specifications, and other

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technical data necessary to assure that the component's integrity meets its properly altered condition approved by the Administrator.

(2) Technical data may be obtained from such sources as:

(i) Manufacturer design drawings which have been issued for an engine having a type certificate.

(ii) Manufacturer overhaul manuals, service bulletins, and tables of limits.

(iii) Military specifications, government specifications and other industry standards.

(iv) Data obtained on the basis of analytical testing, such as, metallurgical evaluation, fatigue testing, and engineering analysis.

(v) Data supported by a block test or a model test that simulates a specified test period.

(vi) Data supported by in-service testing.

(vii) Data which is consistent with a documented service history that demonstrates reliability and viability of the repair, including drawings, dimensional charts, and clearances.

j. Markings. All crankcases and cylinders that have been weld repaired shall be permanently marked, in order to identify the station which performed the work. For the benefit of consistency among the various repair stations, it is recommended that the following marking procedure be used:

(1) One-eighth inch letters; a "W" to indicate a weld, followed by the repair station certificate number, and ending with the date. For example: W-XXXX-XXXX-3/18/91.

(2) For crankcase halves; the marking may be steel stamped, electrolytic etched, or vibration peened, along the top mating surface.

(3) For cylinders; the marking may be vibration peened or electrolytic etched, on the top surface of the uppermost fin area, above the exhaust port.

/s/ J. C. Jones

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