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Advisory Circular

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Subject: CONTINUING STRUCTURAL INTEGRITY PROGRAM FOR LARGE TRANSPORT CATEGORY AIRPLANES

1. PURPOSE. This Advisory Circular (AC) provides guidance material to manufacturers and operators of transport category airplanes for use in developing a continuing structural integrity program to ensure safe operation of older airplanes throughout their operational life. This guidance material applies to large transport airplanes which were certified under the fail-safe and fatigue requirements of Civil Air Regulations (CAR) 4b or 14 CFR part 25 of the Federal Aviation Regulations (FAR), prior to Amendment 25-45, and which have a maximum gross weight greater than 75,000 pounds. Guidance material on this subject for other transports is provided in AC 91-60. The procedures set forth by this AC are applicable to the large transport category airplanes operated under Subpart D of part 91, and parts 121 and 125.

2. CANCELLATION. Advisory Circular AC 91-56, Supplemental Structural Inspection Program for Large Transport Category Airplanes, dated May 6, 1981, is canceled.

3. RELATED FAR SECTIONS. Section 25.571 of part 25, as amended by Amdts. 25-45, 25-54, and 25-72; Section 91.403 of part 91; and Section 43.16 of part 43.

4. RELATED ADVISORY CIRCULARS. Advisory Circular 91-60, "The Continued Airworthiness of Older Airplanes," dated June 13, 1983.

5. BACKGROUND. Service experience has demonstrated that there is a need to have continuing updated knowledge concerning the structural integrity of transport airplanes, especially as they became older. The structural integrity of these airplanes is of

concern since such factors as fatigue cracking and corrosion are time dependent and knowledge concerning them can best be assessed on the basis of real time operational experience and the use of the most modern tools of analysis and testing.

The Federal Aviation Administration (FAA), manufacturers, and operators have continually worked to maintain the structural integrity of older airplanes. Traditionally, this has been accomplished through an exchange of field service information and subsequent changes to inspection programs, and by the development and installation of modifications on particular aircraft. However, increased utilization, longer operational lives, and the high safety demands imposed on the current fleet of transport airplanes indicate the need for a program to ensure a high level of structural integrity for all airplanes in the transport fleet. Accordingly, the inspection and evaluation programs outlined in this advisory circular are intended to ensure a continuing structural integrity assessment by each airplane manufacturer and the incorporation of the results of each assessment into the maintenance program of each operator.

6. SUPPLEMENTAL STRUCTURAL INSPECTION PROGRAMS. The manufacturer, in conjunction with operators, is expected to initiate development of a supplemental structural inspection program for each airplane model. Such a program must be implemented before analysis, tests, and/or service experience indicates that a significant increase in inspection and/or modification is necessary to maintain structural integrity of the airplane. In the absence of other data as a guideline, the program should be initiated no later than the time when the high-time or high-cycle airplane in the fleet reaches one half its design service goal. This should ensure that an acceptable program is available to the operators when needed. The program should include procedures for obtaining service information, and assessment of service information, available test data, and new analysis and test data. A Supplemental Inspection Document (SID) should be developed, as outlined in Appendix 1 of this AC, from this body of data.

a. The recommended supplemental inspection program, along with the criteria used and the basis for the criteria, should be submitted to the cognizant FAA Aircraft Certification Office for review and approval. The supplemental program should be adequately defined in the SID and presented in a manner that is effective. The SID should include the type of damage being considered, and likely sites; inspection access, threshold, interval, method and procedures; applicable modification status and/or life limitation; and types of operations for which the SID is valid.

b. The FAA review of the SID will include both engineering and maintenance aspects of the proposal. Since the SID is applicable to all operators and is a safety concern for older airplanes, it will be made mandatory under the existing Airworthiness Directive (AD) system. In addition, any service bulletin or other service information publications found to be essential for safety during the initial SID assessment process should be implemented by AD action. Service bulletins or other service information publications revised or issued as a result of in service findings resulting from implementation of the SID should be added to the SID or implemented by separate AD action, as appropriate.

c. In the event an acceptable SID cannot be obtained on a timely basis, the FAA may impose service life, operational, or inspection limitations to assure structural integrity.

d. The manufacturer should revise the SID whenever additional information shows a need. The original SID will normally be based on predictions or assumptions (from analyses, tests and/or service experience) of failure modes, time to initial damage, frequency of damage, typically detectable damage, and the damage growth period. Consequently, a change in these factors sufficient to justify a revision would have to be substantiated by test data or additional service information. Any revision to SID criteria and the basis for these revisions should be submitted to the FAA for review and approval of both engineering and maintenance aspects.

7. AGING AIRCRAFT MODIFICATION PROGRAM. [Reserved]

8. CORROSION PREVENTION AND CONTROL PROGRAM. [Reserved]

9. REPAIR EVALUATION PROGRAM. [Reserved]

10. EVALUATION FOR WIDESPREAD FATIGUE DAMAGE. The manufacturer, in conjunction with operators, is expected to initiate development of a Widespread Fatigue Damage (WFD) prediction and verification technique with the intent of precluding operation in the presence of WFD. Such a program must be implemented before analysis, tests, and/or service experience indicates that widespread fatigue damage may develop in the fleet. To ensure that an acceptable program is available to the operators when needed, development of the program should be initiated no later than the time when the high-time or high-cycle airplane in the fleet reaches three quarters of its design service goal.

a. The results of the WFD evaluation should be presented to the cognizant FAA Aircraft Certification Office for review and approval. Since the objective of this evaluation is to eliminate WFD from the fleet, it is expected that the results will include recommendations for the verification or removal of WFD as appropriate. In the case of verification inspections, the very small size of critical WFD cracks may dictate the use of new inspection techniques. It is expected that the manufacturer will work closely with operators to assure that the expertise and resources for such inspections are available when needed.

b. The FAA review of the WFD evaluation results will include both engineering and maintenance aspects of the proposal. Since WFD is applicable to all operators and is a demonstrated safety concern for older airplanes, identified inspection or modification programs will be made mandatory. In addition, any service bulletins or other service information publications revised or issued as a result of in-service WFD findings resulting from implementation of these programs may require separate AD action.

c. In the event an acceptable WFD evaluation is not completed on a timely basis, the FAA may impose service life, operational limitations, or inspection requirements to assure structural integrity.

d. The manufacturer should update the WFD evaluation as the fleet continues to age, and as additional information shows a need. It is expected that the original recommended actions stemming from a WFD evaluation will be focused on those structural items determined to be prone to WFD that have passed, or are soon expected to reach, the age at which WFD is predicted to occur. As the fleet ages, more areas of the airplane may reach that point, and the recommended actions should be updated accordingly. Also, new service experience findings, improvements in the prediction methodology, better load spectrum data, or a change in any of the factors upon which the WFD evaluation is based may dictate a revision to the evaluation. Accordingly, associated new recommendations for service action should be developed and submitted to the FAA for review and approval of both engineering and maintenance aspects.

11. IMPLEMENTATION. Once a SID AD is issued, operators will be in a position to amend their current structural inspection programs to comply with and account for the applicable AD. The same will be true for WFD AD's that require special inspections. WFD AD's that require structural modification would be handled separately. In all cases, compliance will be required in accordance with the applicable regulations.

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APPENDIX 1

GUIDELINES FOR DEVELOPMENT OF THE SUPPLEMENTAL INSPECTION DOCUMENT

1. GENERAL.

a. The transport airplanes subject to this appendix to AC 91-56A were certified prior to Amendment 25-45 of Section 25.571, which emphasizes damage-tolerant design. However, the structure to be evaluated, the type of damage considered (fatigue, corrosion, service, and production damage), and the inspection and/or modification criteria should, to the extent practicable, be in accordance with the damage-tolerance principles of the current Section 25.571 standards.

b. It is essential to identify the structural parts and components that contribute significantly to carrying flight, ground, pressure, or control loads, and whose failure could affect the structural integrity necessary for the continued safe operation of the airplane. The damage tolerance or safe-life characteristics of these parts and components must be established or confirmed.

c. Analyses made in respect to the continuing assessment of structural integrity should be based on supporting evidence, including test and service data. This supporting evidence should include consideration of the operating loading spectra, structural loading distributions, and material behavior. An appropriate allowance should be made for the scatter in life to crack initiation and rate of crack propagation in establishing the inspection threshold, inspection frequency, and, where appropriate, retirement life. Alternatively, an inspection threshold may be based solely on a statistical assessment of fleet experience, provided that it can be shown that equal confidence can be placed in such an approach.

d. An effective method of evaluating the structural condition of older airplanes is selective inspection with intensive use of nondestructive techniques and the inspection of individual airplanes, involving partial or complete dismantling ("tear-down") of available structure.

e. The effect of repairs and modifications approved by the manufacturer should be considered. In addition, it may be necessary to consider the effect of repairs and operator-approved modifications on individual airplanes. The operator has the responsibility for ensuring notification and consideration of any such aspects.

2. DAMAGE-TOLERANT STRUCTURES

a. The damage tolerance assessment of the airplane structure should be based on the best information available. The assessment should include a review of analysis, test data, operational experience, and any special inspections related to the type design. A determination should then be made of the site or sites within each structural part or component considered likely to crack, and the time or number of flights at which this might occur.

b. The growth characteristics of damage and interactive effects on adjacent parts in promoting more rapid or extensive damage should be determined. This study should include those sites that may be subject to the possibility of crack initiation due to fatigue, corrosion, stress corrosion, disbonding, accidental damage, or manufacturing defects in those areas shown to be vulnerable by service experience or design judgment.

c. The minimum size of damage that it is practical to detect and the proposed method of inspection should be determined. This determination should take into account the number of flights required for the crack to grow from detectable to the allowable limit, such that the structure has a residual strength corresponding to the conditions stated for fail-safe qualification under Section 25.571.

NOTE: In determining the proposed method of inspection, consideration should be given to visual inspection, nondestructive testing, and analysis of data from built-in load and defect monitoring devices.

d. The continuing assessment of structural integrity may involve more extensive damage than might have been considered in the original fail-safe evaluation of the airplane, such as:

(1) A number of small adjacent cracks, each of which may be less than the typically detectable length, developing suddenly into a long crack;

(2) Failures or partial failures in other locations following an initial failure due to redistribution of loading causing a more rapid spread of fatigue; and

(3) Concurrent failure or partial failure of multiple load path elements (e.g., lugs, planks, or crack arrest features) working at similar stress levels.

3. INFORMATION TO BE INCLUDED IN THE ASSESSMENT.

a. The continuing assessment of structural integrity for the particular airplane type should be based on the principles outlined in paragraph 2 of this appendix. The following information should be included in the assessment and kept by the manufacturer in a form available for reference:

(1) The current operational statistics of the fleet in terms of hours or flights:

(2) The typical operational mission, or missions assumed in the assessment;

(3) The structural loading conditions from the chosen missions; and

(4) Supporting test evidence and relevant service experience.

b. In addition to the information specified in paragraph 3a, the following should be included for each critical part or component:

(1) The basis employed for evaluating the damage tolerance characteristics of the part or component;

(2) The site or sites within the part or component where damage could affect the structural integrity of the airplane;

(3) The recommended inspection methods for the area;

(4) For damage tolerant structures, the maximum damage size at which the residual strength capability can be

demonstrated and the critical design loading case for the latter; and

(5) For damage tolerant structures, at each damage site the inspection threshold and the damage growth interval between detectable and critical, including any likely interaction effects from other damage sites.

NOTE: Where reevaluation of fail-safety or damage tolerance of certain parts or components indicates that these qualities cannot be achieved or can only be demonstrated using an inspection procedure whose practicability or reliability may be in doubt, then replacement or modification action may need to be defined.

4. INSPECTION PROGRAM. The purpose of a continuing airworthiness assessment in its most basic terms is to adjust the current maintenance inspection program, as required, to assure continued safety of the airplane type.

a. In accordance with paragraphs 1 and 2 of this appendix, an allowable limit of the size of damage should be determined for each site such that the structure has a residual strength for the load conditions specified in Section 25.571, as defined in paragraph 2c. The size of damage that it is practical to detect by the proposed method of inspection should be determined, along with the number of flights required for the crack to grow from detectable to the allowable limit.

b. The recommended inspection program should be determined from the data described in paragraph a above, giving due consideration to the following:

(1) Fleet experience, including all of the scheduled maintenance checks;

(2) Confidence in the proposed inspection technique; and

(3) The joint probability of reaching the load levels described above and the final size of damage in those instances where probabilistic methods can be used with acceptable confidence.

c. Inspection thresholds for supplemental inspections should be established. These inspections would be supplemental to the normal inspections, including the detailed internal inspections.

(1) For structure with reported cracking, the threshold for inspection should be determined by analysis of the service data and available test data for each individual case.

(2) For structure with no reported cracking, it may be

acceptable, provided sufficient fleet experience is available, to determine the inspection threshold on the basis of analysis of existing fleet data alone. This threshold should be set such as to include the inspection of a sufficient number of high-time airplanes to develop added confidence in the integrity of the structure (see paragraph 1c of this appendix). Thereafter, if no cracks are found, the inspection threshold may be increased progressively by successive inspection intervals until cracks are found. In the latter event, the criteria of paragraph (1) above would apply.

5. THE SUPPLEMENTAL STRUCTURAL INSPECTION DOCUMENT.

a. The Supplemental Structural Inspection Document should contain the recommendations for the inspection procedures and replacement or modification of parts or components necessary for the continued safe operation of the airplane. The document should be prefaced by the following information:

(1) Identification of the variants of the basic airplane type to which the document relates;

(2) A summary of the operational statistics of the fleet in terms of hours and flights, as well as a description of the typical mission, or missions;

(3) Reference to documents giving any existing inspections or modifications of parts or components;

(4) The types of operations for which the inspection program is considered valid; and

(5) A list of service bulletins (or other service information publication) revised as a result of the structural reassessment undertaken to develop the SID, including a statement that the operator must account for these service bulletins.

b. The document should contain at least the following information for each critical part or component:

(1) A description of the part or component and any relevant adjacent structure, including means of access to the part;

(2) The type of damage which is being considered (i.e., fatigue, corrosion, accidental damage);

(3) Relevant service experience;

(4) Likely site(s) of damage;

(5) Recommended inspection method and procedure and alternatives;

(6) Minimum-size of damage considered detectable by the method(s) of inspection;

(7) Service bulletins (or other service information publication) revised or issued as a result of in-service findings resulting from implementation of the SID (added as revision to the initial SID);

(8) Guidance to the operator on which inspection findings should be reported to the manufacturer;

(9) Recommended initial inspection threshold;

(10) Recommended repeat inspection interval;

(11) Reference to any optional modification or replacement of part or component as terminating action to inspection;

(12) Reference to the mandatory modification or replacement of the part or component at given life, if fail safety by inspection is impractical; and

(13) Information related to any variations found necessary to "safe lives" already declared.

c. The Supplemental Inspection Document should be checked from time to time against current service experience. Any unexpected defect occurring should be assessed as part of the continuing assessment of structural integrity to determine the need for revision of the document. Future structural service bulletins should state their effect on the SID.

APPENDIX 2

GUIDELINES FOR THE DEVELOPMENT OF A PROGRAM TO PREDICT AND ELIMINATE WIDESPREAD FATIGUE DAMAGE

1. GENERAL.

a. The likelihood of the occurrence of fatigue damage in an airplane's structure increases with the number of repeated load cycles the airplane experiences. During the design process the manufacturer selects a design service goal (DSG) in terms of flight cycles/hours for the airframe. The manufacturer designs the airplane to keep the probability of cracking to a minimum up to the design service goal. It is expected that any cracking that occurs during this period will occur in isolation, originating from a single source, such as a random manufacturing flaw (e.g., a misdrilled fastener hole). Because the manufacturing flaws are randomly distributed throughout the structure, it is considered unlikely that they will result in cracks that will interact strongly as they grow.

b. Uniformly loaded structure may develop cracks in adjacent fasteners, or in adjacent similar structural details, which interact to reduce the damage tolerance of the structure in a manner which may not be readily detectable. Widespread fatigue damage (WFD) is characterized by the simultaneous presence of cracks at multiple structural details that are of sufficient size and density whereby the structure will no longer meet its damage tolerance requirement, Section 25.571 (e.g., not maintaining required residual strength after partial structural failure). Multiple Site Damage (MSD) is a source of WFD characterized by the simultaneous presence of fatigue cracks in the same structural element (e.g., fatigue cracks that may coalesce with or without other damage leading to the loss of the residual strength). Multiple Element Damage (MED) is a source of WFD characterized by the simultaneous presence of fatigue cracks in similar adjacent structural elements. The development of cracks at multiple locations (both MED and MSD) may result in strong interactions that can affect subsequent crack growth, in which case the predictions for local cracking would no longer apply. An example of this situation may occur at a fuselage skin lap joint. Simultaneous cracking at many fasteners along a common rivet line may reduce the residual strength of the joint below required levels before the cracks are readily detectable during routine maintenance.

c. The methods used to date to develop structural inspection programs have generally considered only localized interactions between fatigue cracks. Since a few cracks of a size which may not be reliably detected by Non Destructive Testing (NDT) can cause unacceptable reduction in the structural strength below the residual strength requirements of the damage tolerance regulations, no widespread fatigue damage should be allowed within the original or extended design service goal of an airplane. Unless there is a high confidence in the ability to detect and rectify WFD in its early subcritical stages, continued safe operation of the airplane is jeopardized; therefore, it is necessary to take appropriate action in the aging fleets to preclude it. The manufacturers should conduct evaluations to determine where and when WFD may occur and provide instructions for the verification and removal of WFD in the airplane structure.

d. The occurrence of corrosion, or other structural degradation, can couple with fatigue cracking and reduce the effectiveness of an airplane's routine structural maintenance program.

2. STRUCTURAL EVALUATION FOR WFD.

a. General. The evaluation has three objectives:

(1) Identify primary structure susceptible to WFD (see paragraphs 2b(1) and 2b(2) of this appendix).

(2) Predict when it is likely to occur (see paragraph 2c of this appendix).

(3) Establish additional maintenance actions, as necessary, to ensure continued safe operation of the airplane (see paragraph 2d of this appendix).

b. Structure Susceptible to WFD. Susceptible structure is defined as that which has the potential to develop WFD. Such structure typically has the characteristics of similar details operating at similar stresses where structural capability could be affected by interaction of similar cracking. The generic types of susceptible structure include the following.

(1) Fuselage.

(a) Longitudinal skin joints, frames, and tear straps (MSD, MED),

(b) Circumferential joints and stringers (MSD, MED);

(c) Fuselage frames (MED);

(d) Aft pressure dome outer ring and dome web splices (MSD, MED);

(e) Other pressure bulkhead attachment to skin and web attachment to stiffener and pressure decks (MSD, MED);

(f) Stringer to frame attachments (MED);

(g) Window surround structure (MSD, MED);

(h) Over-wing fuselage attachments (MED);

(i) Latches and hinges of nonplug doors (MSD, MED);

(j) Skin at runout of large doubler (MSD);

(2) Wing and Empennage.

(a) Skin at runout of large doubler (MSD);

(b) Chordwise splices (MSD, MED);

(c) Rib to skin attachments (MSD, MED);

(d) Stringer runout (MED, MSD).

c. Determination of WFD. The time in terms of hours and/or flights to the occurrence of WFD should be established. The evaluation should include a complete review of the service history of the susceptible areas, relevant full-scale and component fatigue test data, teardown inspections, and any fractographic analysis available. The evaluation of test results for the reliable prediction of the time WFD occurs in each susceptible area should include appropriate test-to-structure factors and a scatter factor.

(1) Each susceptible area should be evaluated to establish the size and extent of multiple cracking that could cause the residual strength to degrade below certification levels.

(2) Each susceptible area should be evaluated for a discrete source damage event due to uncontained failure of engines, fan blades, and high-energy rotating machinery.

(3) Each susceptible area should be evaluated to establish the time WFD is expected to occur.

(a) This initial estimate may be analytically determined, supported by existing test or service evidence.

(b) Revised estimates of the time of WFD occurrence should be made based on additional information from the continuing assessment of the fleet-demonstrated capability and one or more of the following:

1 Additional fatigue and/or residual strength tests on a full-scale airplane structure or a full-scale component, followed by detailed inspections and analyses.

2 Testing of new or used structure on a smaller scale than full component tests (i.e., sub-component and/or panel tests).

3 Tear-down inspections (destructive) that could be done on structural components that have been removed from service.

4 Local teardown by selected, limited (non-destructive) disassembly and refurbishment of specific areas of high-time airplanes.

d. Maintenance Actions.

(1) For all areas that have been identified as susceptible to WFD, the current maintenance program should be evaluated to determine if adequate structural maintenance and inspection programs exist to safeguard the structure against unanticipated cracking or other structural degradation. The evaluation of these inspections should typically be done as follows:

(a) Determine the level (inspection threshold, repeat interval, and methods) of the inspection for each susceptible area that is necessary to maintain the required level of safety.

(b) Review the existing maintenance programs to determine if they provide the required level of safety.

(2) For airplanes approaching the estimated occurrence of WFD, a program should be developed and recommended to the FAA that provides for replacement or modification of the susceptible structural area.

e. Period of Evaluation Validity. The initial evaluation of the complete airframe should cover a significant forward projection of airplane usage beyond the design service goal. Typically an assessment through at least an additional twenty-five percent of the design service goal would provide a realistic forecast with reasonable planning time for necessary maintenance action. However, it may be appropriate to vary the evaluation validity period depending on issues such as:

(1) The projected useful life of the airplane at the time of the initial evaluation (could increase or decrease the validity period).

(2) Expectations of improved Non Destructive Inspection (NDI) technology (could decrease the initial validity period, pending new methods becoming available).

(3) Airline advance planning requirements for introduction of new maintenance and modification programs.

(4) Providing sufficient forward projection to identify all likely maintenance/modification actions essentially as one package.

Subsequent evaluations should follow similar validity period guidelines as the initial evaluation.

3. DOCUMENTATION.

a. The manufacturers should revise the SID as necessary and/or prepare Service Bulletins that contain the recommendations for inspection procedures and replacement or modification of parts or components necessary to preclude Widespread Fatigue Damage. Since WFD is applicable to all operators and is a safety concern for older airplanes, identified inspection or modification programs will be made mandatory. In addition, any service bulletins or other service information publications revised or issued as a result of in-service WFD findings resulting from implementation of these programs may require separate AD action.

b. If the manufacturer chooses not to update the SID or prepare Service Bulletins, it should develop a WFD document containing recommendations for inspection procedures and replacement or modification of parts or components necessary to preclude WFD. The document should be prefaced by the following:

(1) Identification of the variants of the basic airplane type to which the document relates;

(2) Summary of the operational statistics of the fleet in terms of hours and flights;

(3) Description of the typical mission, or missions;

(4) The types of operations for which the inspection program is considered valid;

(5) Reference to documents giving any existing

inspections, or modification of parts or components; and

(6) Duration of evaluation validity.

c. The document should contain at least the following information for each critical part or component:

(1) Description of the primary structure susceptible to WFD

(2) The estimated threshold of MSD/MED and subsequent occurrence (hours/cycles) of WFD;

(3) Recommended initial inspection threshold;

(4) Recommended repeat inspection interval;

(5) Recommended inspection method and procedure and alternatives;

(6) Any optional modification or replacement of the structural element as terminating action to inspection;

(7) Any mandatory modification or replacement of the structural element;

(8) Service bulletins (or other service information publication) revised or issued as a result of in-service findings resulting from the WFD evaluations (added as a revision to the initial WFD document); and

(9) Guidance to the operator on which inspection findings should be reported to the manufacturer.

4. RESPONSIBILITY. It is expected that the evaluation will be conducted in a cooperative effort between the operators and manufacturers with participation by airworthiness authorities during the evaluation.