Task Assignment

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Subcommittee; Small Transport and Commuter Airworthiness Assurance Working Group

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of establishment of the small transport and commuter airworthiness assurance working group.

SUMMARY: Notice is given of the establishment of a Small Transport and Commuter Airworthiness Assurance Working Group by the Transport Airplane and Engine Subcommittee.

DATES: William J. (Joe) Sullivan, Executive Director, Transport Airplane and Engine Subcommittee, Aircraft Certification Service (AIR-3), 800 Independence Avenue, SW., Washington, DC 20591, Telephone: (202) 267-9954; FAX: (202) 267-5364.

SUPPLEMENTARY INFORMATION: The Federal Aviation Administration (FAA) established an Aviation Rulemaking Advisory Committee (ARAC) (56 FR 2190, January 22, 1991 (which held its first meeting on May 23, 1991 (56 20492, May 3, 1991). The Transport Airplane and Engine Subcommittee was established at that meeting to provide advice and recommendations to the Director, Aircraft Certification Service, FAA, regarding the airworthiness standard for transport category airplanes, engines, and propellers in parts 25, 33 and 35 of the Federal Aviation Regulations (14 CFR parts 25, 33, 35).

Before the establishment of the Aviation Rulemaking Advisory Committee, the agency's Research, Engineering, and Development Advisory Committee established a Transport Airplane Safety Subcommittee. In turn that subcommittee established the Airworthiness Assurance Task Force to deal with issues arising out of the tragic aircraft accident in Hawaii involving an Aloha Airlines B-737. The ARAC Transport Airplane and Engine Subcommittee was tasked with assuming jurisdiction over the Airworthiness Assurance Task Force. This was accomplished, and a notice of establishment renaming the Task Force and restating its tasks is published elsewhere in this issue of the **Federal Register.**

After discussing the Airworthiness Assurance Task Force, the subcommittee identified a need to establish a similar working group to deal with similar airworthiness assurance issues for airplanes typically operated by regional and commuter airlines. These airplanes generally weigh less than 75,000 pounds maximum certificated takeoff weight, and they do not have supplemental inspection programs based on damage tolerant criteria or equivalent. Based on these considerations, the subcommittee recommended and the FAA agreed to form this parallel group. This notice establishes the Small Transport and Commuter Airworthiness Assurance Working Group to consider those issues.

Specifically, the Small Transport and Commuter Airworthiness Assurance Working Group's tasks are:

Task 1. Develop criteria, requirements, and guidance to set operational limits on airplanes of less than 75,000 maximum certificated takeoff weight type used in scheduled air carrier or commuter service, which were not certificated to damage-tolerance criteria or do not have approved supplemental inspection programs or equivalent.

Task 2. Develop criteria, requirements and guidance necessary to operate beyond the operational limits established under task 1. These may be presented as a rule, an advisory circular, or a combination of them, and may include guidance for supplemental inspection programs.

Reports

A. Recommend time line(s) for completion of each task, including rationale, for Subcommittee consideration at the meeting of the subcommittee held following publication of this notice.

B. Give a detailed conceptual presentation to the Subcommittee before proceeding with the work stated under item C, below.

C. Draft a Notice of Proposed Rulemaking proposing requested or modified new or revised requirements, a supporting economic analysis, and other required analysis, with any other collateral documents (such as Advisory Circulars) the Working Group determines to be needed.

D. Give a status report on each task at each meeting of the Subcommittee.

The Small Transport and Commuter Airworthiness Assurance Working Group will be comprised of experts from those organizations having an interest in the task assigned to it. A working group member need not necessarily be a representative of one of the organizations of the parent Transport Airplane and Engine Subcommittee or of the full Aviation Rulemaking Advisory Committee. An individual who has expertise in the subject matter and wishes to become a member of the working group should *write* the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire, describing his or her interest in the task, and the expertise he or she would bring to the working group. The request will be reviewed with the subcommittee chair and working group leader, and the individual advised whether or not the request will be accommodated.

The Secretary of Transportation has determined that the information and use of the Aviation Rulemaking Advisory Committee and its subcommittees are necessary in the public interest in connection with the performance of duties imposed on the FAA by law. Meetings of the full committee and any subcommittees will be open to the public except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the Small Transport and Commuter Airworthiness Assurance Working Group will not be open to the public, except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of working group meetings will be made.

Issued in Washington, DC, on November 19, 1992.

William J. Sullivan,

Executive Director, Transport Airplane and Engine Subcommittee, Aviation Rulemaking Advisory Committee.

[FR Doc. 92-28935 Filed 11-27-92; 8:45 am]

BILLING CODE 4910-13-M

Recommendation Letter

Jean

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

July 14, 1994
B-T01B-GRM-94-050

Mr. Anthony J. Broderick
Associate Administrator for Regulations and Certification, (AVR-1)
Department of Transportation
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington DC 20591
Tele: (202) 267-3131
Fax: (202) 267-5364

BOEING

Dear Mr. Broderick:

On behalf of the Aviation Rulemaking Advisory Committee, I am pleased to submit the enclosed recommendation for publication on the following subject:

AC 91-XX Continuing Airworthiness of Older Small Transport and Commuter Airplanes

The enclosed package is in the form of a final draft AC. The package was developed by the Small Transport & Commuter Airworthiness Assurance Working Group chaired by Bill Keil of the Regional Airline Association. The membership of the group is a good balance of interested parties in the U.S. and Europe. This group can be available if needed for docket review.

The members of ARAC appreciate the opportunity to participate in the FAA rulemaking process and fully endorse this recommendation.

Sincerely,

Gerald R. Mack

Gerald R. Mack
Assistant Chairman
Transport Airplane & Engine Issues Group
Aviation Rulemaking Advisory Committee
Tele: (206) 234-9570, Fax: 237-0192, Mailstop: 67-UM

Enclosure

cc: M. Borfitz (617) 238-7199
B. Keil (202) 223-4579
S. Miller (206) 227-1100

Acknowledgement Letter

U.S. Department
of Transportation

**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

AUG 31 1994

Mr. Gerald R. Mack
Aviation Rulemaking Advisory Committee
Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

Dear Mr. Mack:

Thank you for your July 14 letter forwarding the Aviation Rulemaking Advisory Committee's (ARAC) recommendation in the form of a draft final Advisory Circular on Continuing Airworthiness of Older Small Transport and Commuter Airplanes.

I would like to thank the aviation community for its commitment to ARAC and its expenditure of resources to develop the recommendation. We in the Federal Aviation Administration (FAA) pledge to process the document expeditiously as a high-priority action.

Again, let me thank the ARAC and, in particular, the Small Transport and Commuter Airworthiness Assurance Working Group for its dedicated efforts in completing the task assigned by the FAA.

Sincerely,

Anthony J. Broderick
Associate Administrator for
Regulation and Certification

Recommendation

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

DRAFT WORKING MATERIAL--NOT FOR PUBLIC RELEASE

Subject: CONTINUED AIRWORTHINESS OF OLDER SMALL TRANSPORT AND COMMUTER AIRPLANES; ESTABLISHMENT AND EXTENSION OF OPERATIONAL LIMITS

Date: JUN 1 3 1994
Initiated by: ACE-100

AC No: 91-XX
Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance regarding an acceptable means, but not the only means, of showing compliance with the operational requirements of the Federal Aviation Regulations (FAR) applicable to the establishment of Operational Limits and the extension of the Operational Limit. It is for guidance purposes and provides an example of a method of compliance that has been found acceptable. Because the method of compliance presented in this AC is not mandatory, the terms "shall" and "must" used in this AC apply only to an applicant who chooses to follow this particular method without deviation. The applicant may elect to follow an alternate method provided the alternate method is also found acceptable by the FAA. This advisory circular provides guidance for fleet-wide limits. Individual operators seeking limits different than the fleet-wide limits may use this guidance in support of their application.

2. APPLICABILITY. The following guidelines are intended for use in setting and extending Operational Limits for:

a. airplanes of less than 75,000 pounds maximum certified takeoff weight, which are used in scheduled air carrier or commuter service; and

b. the airplane type is not certified to damage tolerance criteria; and

c. the airplane type does not have an approved supplemental inspection program or equivalent.

3. RELATED REGULATIONS AND DOCUMENTS.

a. Regulations.

§ 121.212 - Aging Airplane Limitation

§ 129.20 - Aging Airplane Limitation

§ 135.168 - Aging Airplane Limitation

b. Advisory Circulars. The AC's listed below may be obtained from the U.S. Department of Transportation, General Services Section, M-443.2, Washington, DC 20590:

AC 25.571-1A	Damage-Tolerance and Fatigue Evaluation of Structure
AC 91-56	Supplemental Structural Inspection Program for Large Transport Category Airplanes
AC 91-60	Continued Airworthiness of Older Airplanes

4. BACKGROUND. Service experience indicates that as an airplane ages, increasing care is required in the maintenance process and more frequent inspections or parts replacement of the structure may be needed to maintain the required level of safety. These added inspections should be directed at detecting degradation caused by environmental deterioration and fatigue.

To ensure the continued safe operation of airplanes used in scheduled air carrier service, an "Operational Limit" must be established beyond which operation is not permitted unless specific work is carried out to justify an extension of that limit. At the Operational Limit, the existing maintenance requirements may not be sufficient to allow the airplane to continue to operate in scheduled air carrier service.

5. DEFINITIONS.

a. Operational Limit. That point in the life of the airplane where additional maintenance action is required to assure the continued airworthiness of the airplane's principal structural elements.

b. Fatigue Evaluation. The evaluation for the prediction of fatigue damage that can be performed by test or analysis based on, but not limited to, Crack Propagation (Fracture Mechanics), S/N (Miner's Rule) or ε/N (Neuber's Rule).

c. Damage tolerance. The attribute of the structure that permits it to retain its required residual strength for a period of usage after the structure has sustained specific levels of fatigue, corrosion, accidental, or discrete source damage.

d. Principal Structural Elements (PSE). An element of structure that contributes significantly to the carrying of flight, ground, and pressurization loads and whose integrity is essential in maintaining the overall structural integrity of the airplane.

6. CONTINUED AIRWORTHINESS. The continued airworthiness of the structure of airplanes addressed by this AC can be achieved by the implementation of an Operational Limit for each type of airplane. The maintenance program and the continued airworthiness information currently provided should ensure the continued airworthiness of the airplane for the service period between manufacture and the Operational Limit. When the airplane reaches the Operational Limit, an evaluation of the airplane should occur, any needed parts replacements or modifications should be accomplished, and the airplane should be placed on an inspection and maintenance program that will ensure the continued airworthiness of the airplane for the service period between the Operational Limit and the Extended Operational Limit. The Extended Operational Limit can be re-extended as many times as desired if the condition of the airplane, the additional maintenance, and the information provided to justify the extension are sufficient to ensure the continued airworthiness of the airplane for the extended service period.

a. Development of an Operational Limit. The manufacturer, in conjunction with the operators, is expected to establish an Operational Limit for each airplane type. The Operational Limit should be based on an evaluation of the crack propagation behavior and/or the fatigue durability of all PSE's. The Operational Limit must be set at a value which provides adequate assurance that neither PSE failure nor Widespread Fatigue Damage will occur before the Operational Limit is reached. Life-limited parts requiring replacement prior to the Operational Limit should be replaced as scheduled. Appendix 1 describes detailed guidelines for setting an Operational Limit.

b. Extension of the Operational Limit. The Operational Limit may be extended for a specified period based on FAA approved actions to ensure continued airworthiness for the specified period. The end of this specified period is the Extended Operational Limit. Appendix 2 describes detailed guidelines to extend an Operational Limit.

To operate to the Extended Operational Limit, additional specific FAA approved actions may be required. The specific actions may include, but are not limited to:

(1) One-time special inspections.

APPENDIX 1 - GUIDELINES TO SET AN OPERATIONAL LIMIT

The guidelines given apply to airplanes of conventional construction using conventional metallic materials. The following is a suggested procedure for this evaluation; however, any alternative procedure that is acceptable to the Federal Aviation Administration (FAA) may be used. The procedure given below is based on the assumption that limited fatigue/fracture data are available for the airplane being evaluated. Portions of this work may not be needed if some data are already available. Guidelines for the extension of Operational Limits are given in appendix 2.

The possibility of Widespread Fatigue Damage must be considered when setting an Operational Limit.

1. DEFINE AIRPLANE USAGE. The average usage is defined by the number and the frequency of typical flight profiles. Since an aging airplane has been in service for a considerable period, such utilization data should be readily available from a survey of typical operators. Each flight profile should be defined in terms of the typical flight parameters: stage length, flight time, take-off weight, fuel load, altitude, climb-cruise-descent speeds, flap settings, etc.

The average usage may be applicable to all airplanes of the same airplane type. However, if individual airplanes of a particular airplane type are used in specialized roles that differ significantly from the average usage or environment for the type, then a separate evaluation for this operation may be needed.

Decisions on Operational Limits should be based on average fleet usage. The Federal Aviation Administration (FAA) may choose to impose specific additional requirements prior to the Operational Limit threshold on those airplanes used in specialized roles.

2. DETERMINE "GLOBAL" LOAD SPECTRA. A "global" spectrum is one that specifies the occurrence frequency of fatigue loads expressed in terms of flight load factor, ground load factor, gust velocity, or landing sink rate. As a minimum, spectra should be developed to specify the loading conditions (a. through f.) listed below. The spectra must be derived to reflect the airplane usage specified by the usage profile. If spectrum data have been recorded for the airplane type under consideration (ideally during operation representing typical service), this data should be used in preference to handbook data.

The reference sources of loads data and analysis methods listed here are provided as information on acceptable methods. Alternative data acceptable to the FAA may be used.

a. Vertical and lateral gust loads.
SOURCES: FAA Report No. AFS-120-73-2
PSD Gust Spectrum Analysis, Part 25, Appendix G
ESDU 69023
DOT/FAA-CT-91/20 General Aviation Aircraft Normal Acceleration Data Analysis and Collection Project
NOTE: ESDU data contain maneuver as well as gust loads. For some airplane types it may be unnecessary to add maneuver loads separately.

b. Maneuver loads.
SOURCES: MIL-A-8866B
FAA Report No. AFS-120-73-2
TM-84660
DOT/FAA-CT-91/20 General Aviation Aircraft Normal Acceleration Data Analysis and Collection Project

c. Taxi loads.
SOURCES: ESDU 75008
FAA Report No. AFS-120-73-2
MIL-A-8866B

d. Landing loads.
SOURCES: MIL-A-8866B
FAA Report No. AFS-120-73-2

e. Pressurization loads (if applicable). In considering fatigue of pressure cabins, full normal operating differential pressure plus external aerodynamic pressure shall be assumed to occur once per flight unless the usage profile specifically defines a Pressurization spectrum.

f. Empennage Loads.
SOURCES: FAA Report No. ACE-100-01 entitled Fatigue evaluation of Empennage, Forward Wing, and Winglets/Tip Fins on Part 23 airplanes.

3. IDENTIFY ALL PRINCIPAL STRUCTURAL ELEMENTS. Typical examples of components that should be considered for PSE designation are:

a. Items with a significantly severe fatigue stress spectrum and/or a low static reserve factor in tension, e.g., wing lower skin panels, stabilizer skin panels, and fuselage pressure shell panels (including pressure bulkheads and domes).

b. Items of primary structure incorporating a design feature which, based on analysis, test, or service experience, could be prone to cracking during the service life of the airplane. Structural discontinuities such as skin panel, spar cap and stringer splices, shell cut-outs, highly loaded fittings (in wing/fuselage joints, stabilizer attachment joints and flap track attachment joints) and flight compartment window posts and door stops or latches (on pressurized airplanes) are examples.

c. Engine mountings, landing gear, and attaching structure.

d. Components exposed to propeller wakes.

All designated PSE's should be listed and subjected to the evaluation detailed below. The determination of the extent of the structure to be covered by each PSE would be influenced by the fatigue evaluation method used to establish an Operational Limit (see paragraph 5 below). For example, if a full scale test of the complete wing is carried out, the entire wing might be declared as one PSE. On the other hand, if analysis is used, multiple PSE's, chosen on the basis of the above guidelines, would be required.

Those PSE's that have existing mandatory replacement times, either identified at certification or by Airworthiness Directive (AD), should not necessarily be used to set the initial Operational Limit. Any parts (e.g., safe-life parts) requiring replacement prior to the Operational Limit should continue to be replaced as scheduled.

4. ESTABLISH "LOCAL" STRESS SPECTRA FOR EACH PSE. Unless stress or local load spectra are available from flight records, stress or local load spectra for each PSE must be determined from the global load spectra by analysis. A means to transform the global load parameters of load factor, gust velocity and landing sink rate into stress or local load at each PSE site must be available. Satisfactory "global load"-to-"stress" (or "global load"-to-"local load") transformations should be possible if internal stresses (or loads) are determined by finite element analysis (or classical methods as applicable) for each of the following unit fatigue cases. These cases should be run for a typical airplane

configuration (weight, c.g. position, etc.) as applicable to each PSE.

a. A 1g level flight case for each significant flight phase in the usage profile (e.g., a case for each flap setting used may be required).

b. A unit vertical gust case (e.g., a 2.0g vertical acceleration) for each significant flight phase in the usage profile.

c. A unit lateral gust case for a nominal lateral gust velocity (e.g., 10 ft./sec.).

d. A 1g on-ground case.

e. A landing case for a sink rate not less than the average sink rate in the fatigue spectrum.

f. A unit cabin pressure case, if the airplane is pressurized.

As an alternative, internal stresses could be obtained from a strain gauge survey under flight conditions that correspond to the above cases. If analysis is used to transform global loads to internal stresses, then some strain gauging may be needed to validate the analysis methods used.

For wing components, in absence of better data, the load-to-stress transformation using internal stresses determined for the above fatigue cases may be accomplished by assuming a linear relationship (1g stress versus stress/g) between stress and vertical load factor, stress and lateral gust velocity, and stress and landing sink rate.

In the generation of the local stress spectra, ground-air-ground cycle loading must be accounted for where significant.

5. DETERMINE LIFE FOR EACH PSE. Fatigue life for each PSE must be determined once a stress spectrum is available. Fatigue life may be determined by one of the methods itemized below:

a. Fatigue Test and/or Analysis. When using fatigue test and/or analysis to establish fatigue life for a PSE, the procedure outlined by the flow chart in Figure 1 should be used (see page 7, Appendix 1). In addition, for PSE's associated with Single Load Path Structure, care should be exercised when considering their structural performance - particularly PSE's made of materials with low fracture toughness. These Single Load Path PSE's should be reviewed to consider their structural integrity as a result of accidental, environmental, and fatigue damage.

(1) Fatigue Tests.

(i) Full Scale Fatigue Test. Results from a full scale fatigue test of a complete airframe or a major component (e.g., a complete wing or fuselage) using a representative fatigue spectrum such as that determined with the above guidelines may be utilized to establish a fatigue life. An appropriate spectrum simplification may be acceptable to expedite the test. Fatigue life would be taken as time to detectable cracking or test termination if no cracking occurs. Use of a full scale fatigue test may preclude the need for local stress spectra.

(ii) Fatigue Test of Representative Specimens. Results from a detail fatigue test of the local structure covered by a PSE being evaluated (e.g., a wing spar joint) using a representative fatigue spectrum such as that determined with the above guidelines, may be utilized to establish a fatigue life. An appropriate spectrum simplification may be acceptable to expedite the test. Fatigue life would be taken as time to detectable cracking or test termination if no cracking occurs.

(2) Fatigue Analysis. When performing fatigue analysis, the Crack Propagation Analysis method described below (paragraph 5.a.(2)(i) of Appendix 1) is preferred.

(i) Crack Propagation Analysis. Fatigue life may be calculated by crack propagation (fracture mechanics) analysis assuming the existence of a small crack to represent a manufacturing flaw located at the most critical site in the structure covered by the PSE being evaluated. The analysis should be carried out using a representative fatigue spectrum such as that determined using the above guidelines. Analysis should commence with a crack of appropriate size and location. Fatigue life is the time taken for this crack to propagate to the largest size at which the structure can still sustain required residual loads (usually limit loads).

Linear elastic (unretarded) crack propagation analysis may be used, because this method is conservative for most transport airplane fatigue spectra. If crack growth retardation analysis is used, appropriate test validation must be provided. Crack propagation (da/dN) data and fracture toughness data may be taken from acceptable references (such as MCIC-HB-01R, MIL-HDBK-5, or ESDU sheets), or the data may be generated by appropriate coupon testing. Crack geometry factors for most configurations are available (or can be derived by superposition or compounding) from the following references:

(A) D. P. Rooke & D. J. Cartwright, "Stress Intensity Factors."

(B) H. Tada, P. Paris, G. Irwin, "The Stress Analysis of Cracks Handbook."

(C) Murakami Y., "Stress Intensity Factors Handbook," Vols. 1 & 2.

(ii) Analysis Using Constant Amplitude S-N Data. In some cases, fatigue life may be determined using constant amplitude S-N data and linear cumulative damage calculation (Miner's Rule). This method should be restricted to structure made of fracture tough materials where the S-N data has been obtained from testing of structure that is of the same type as the PSE being evaluated. Handbook S-N data obtained from typical coupon type test specimens would not normally be acceptable for such analysis.

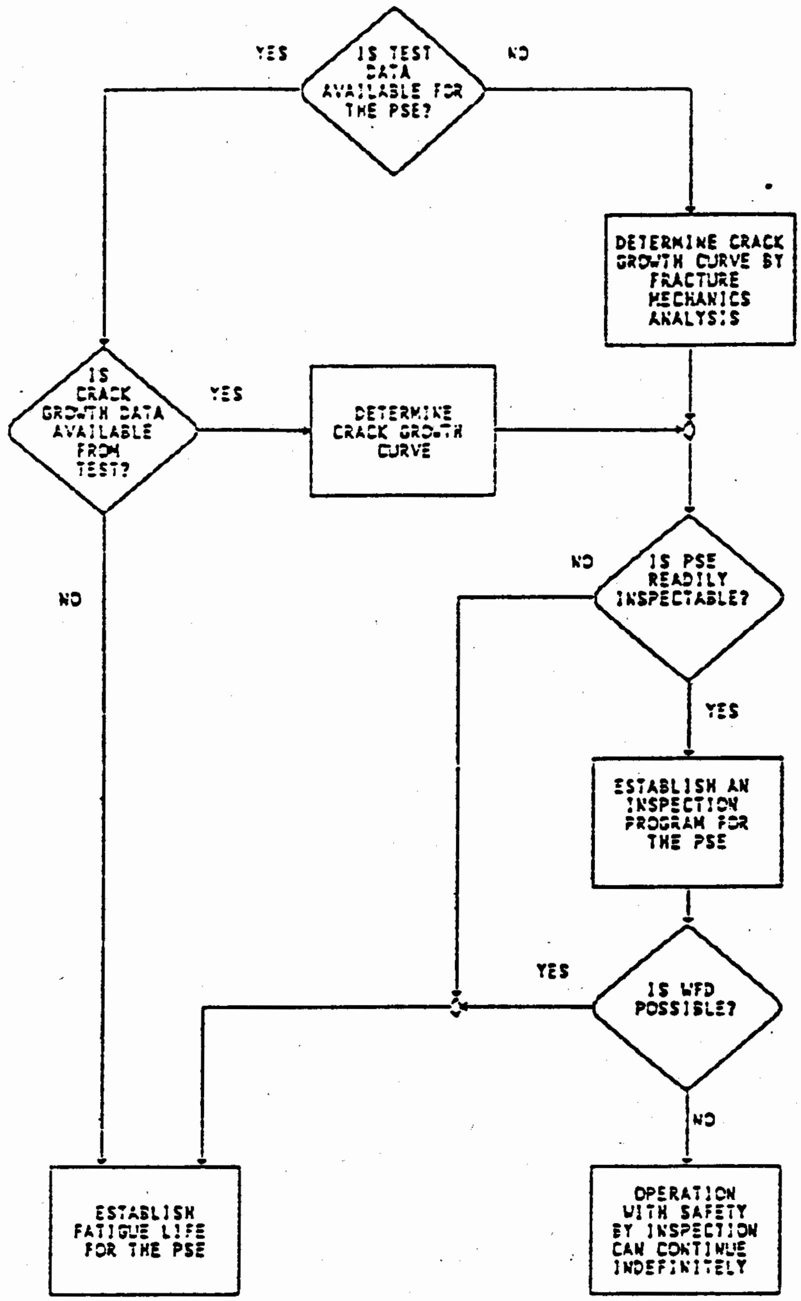

Figure 1 - PSE LIFE/INSPECTION DETERMINATION BY ANALYSIS AND TEST

b. Comparison with Similar Structure. Fatigue life may be derived by demonstrating a quantitative relationship with similar structure for which a fatigue life has already been established by test. That is, the structural and load spectrum differences between the PSE being evaluated and a similar component for which a fatigue life is already available may be sufficiently small to justify life adjustment by analysis to account for those differences. This adjustment could be made by comparative fatigue damage calculation (a procedure sometimes termed the "Relative Miner Rule"), or by comparative crack propagation (fracture mechanics) analysis.

c. Use of a Fleet Based Limit. If life determination by any of the above methods is not practical, it may be acceptable to establish a life from the service time accumulated by individual members of the fleet. An evaluation of the accumulated service times using an acceptable statistical analysis method would have to be carried out to obtain fleet life for a confidence and probability level agreed to by the FAA. Life determined in this manner would have to be divided by the K1 factor specified in paragraph 6 below to obtain the factored life. If an Operational Limit is to be based on fleet accumulated time, it is highly desirable that high time airplanes be inspected to establish their cracking, corrosion and repair status. Also, fleet utilization records should be examined to confirm that past fleet usage is sufficiently representative of present and intended future usage. The extent of any inspections carried out and the results of the fleet utilization review are factors that should be considered in the choice of K1 magnitude. It should be noted that life based on fleet accumulated time would be significantly lower than the time accumulated by the fleet leader.

6. DETERMINE THE FACTORED LIFE OF EACH PSE. A factored life should now be determined for each PSE from:

$$\text{FACTORED LIFE} = \frac{\text{FATIGUE LIFE}}{\text{K1}}$$

where,

FATIGUE LIFE equals the PSE Fatigue Life determined by any of the methods 5a to 5c of Appendix 1, and K1 represents a reduction factor that accounts for the variability of the method chosen and the quality of the available data.

a. <u>K1 VALUES</u>. A range of K1 values for each method are given below:

K1	=	2.0 to 5.0	if life established using method 5a(1)(i)
	=	3.0 to 7.0	if life established using method 5a(1)(ii)
	=	2.0 to 4.0	if life established using method 5a(2)(i)
	=	6.0 to 10.0	if life established using method 5a(2)(ii)
	=	2.0 to 5.0	if life established using method 5b
	=	1.0 to 1.5	if life established using method 5c

b. <u>DISCUSSION OF K1 VALUES</u>. The range of K1 values provided above are given for guidance purposes only and are subject to acceptance by the FAA for the structure being evaluated. Any test based lives previously approved by the FAA and the factors on which they were based, i.e., life obtained using above method 5a(1) of this Appendix, would qualify for acceptance without change, provided that the spectrum loading on which the test based lives are based is still relevant.

The following is a discussion of the above K1 values and the industry precedents and practices.

(1) <u>Full Scale Fatigue Tests, Method 5a(1)(i)</u>: Factors between 2.0 and 5.0 have been accepted in military and civilian certifications. The lower bound, 2.0, has been used as a service life indicator for damage tolerant or multi-load path structure. A full scale fatigue test to two times the proposed limit may be assumed to account for the possibility of widespread fatigue damage.

A factor of 3.0 has been accepted in FAA certification of safe life structure such as landing gears and multi-element structure (i.e., many replicates of similar design details in the same test article) such as pressure cabins. The upper bound of 5.0 has been applied (especially in Europe) to increase confidence levels in cases where the inservice load or stress spectra have not been based on measured data. FAA Engineering Report, AFS 120-73-2, "Fatigue Evaluation of Wing and Associated Structure on Small Airplanes," recommends between 3.0 and 5.0, with the lower number applied when supported by knowledge of critical crack locations and inspectable crack growth rates.

(2) <u>Representative Specimen Tests, Method 5a (1)(ii)</u>: Factors between 5.0 and 7.0 have been used in certification of fatigue lives based on specimen testing. Typically 6.0 or 7.0 has been used based on specimen test results, and as low as 5.0 when test results were backed up with flight measured strain data. Lower factors could be applied when specimen test results include

applicable crack growth results. FAA Engineering Report, AFS 120-73-2, "Fatigue Evaluation of Wing and Associated Structure on Small Airplanes," recommends between 5.0 and 7.0.

Certifications of single load path structure by other airworthiness authorities have used factors of: 3.33 for material scatter; 1.0-1.5 for fleet usage scatter; and 1.0-2.0 for test quality scatter. In the case of multiple load path structure the 3.33 factor may be reduced to a factor of 2.0. These factors are then multiplied together to give an overall factor (K1). Thus for representative test specimens a factor between 3.0 and 5.0 is likely to result.

(3) Crack Propagation Analysis, Method 5.a.(2)(i): A K1 value of 2.0 for multiple load path structure, and 3.0 for single load path structure, has usually been applied in defining a replacement life or inspection threshold based on fracture mechanics calculations or crack growth test results that take into account the possibility of manufacturing or maintenance induced flaws in critical locations.

(4) Analysis Using Constant Amplitude S-N Data, Method 5.a.(2)(ii): For fatigue analysis not supported by test results or flight measured data, higher K1 values are required. FAA Engineering Report, AFS 120-73-2, "Fatigue Evaluation of Wing and Associated Structure on Small Airplanes," recommends 8.0 for analysis alone and possibly 7.0 when analysis is supported by flight measured data and/or comparison to successful similar designs. Following the philosophy of 6.b.(2), the applicable factor for other Regulatory Authorities has been between 6.0 and 10.0.

(5) Comparison With Similar Structure, Method 5b: Where design details, stress levels, load spectra, etc. are similar between those of a new design and a proven successful design, then a proposal may be made in which the K1 factor is also based on the value applied in the successful design.

(6) Fleet Based Limit, Method 5c: Where fleet history data are available, a K1 factor may be applied to the statistically derived number of hours that represents a low probability of the presence of fatigue cracks.

7. WIDESPREAD FATIGUE DAMAGE. Widespread Fatigue Damage (WFD) in a structure is characterized by the simultaneous presence of multi-site cracks that are of sufficient size and density to degrade strength of the structure below its damage tolerance requirement. Such cracks are initially independent and usually non-uniform, but

may interact to increase in size. This could result in a significant increase in crack propagation rate and/or a reduction in residual strength capability. Because these cracks are relatively small and therefore difficult to detect, there is the risk of sudden coalescence that could possibly lead to total structural failure without adequate prior warning.

Widespread Fatigue Damage may occur either as Multiple Site Damage (MSD) or as Multiple Element Damage (MED)

a. Multiple Site Damage: Multiple Site Damage is characterized by the simultaneous presence of fatigue cracks in the same structural element. Simultaneous cracking at multiple locations can occur because a particular feature is replicated many times, with equal or very near equal stress exposure at all locations (a fuselage longitudinal skin joint is an example of such structure).

b. Multiple Element Damage: Multiple Element Damage is characterized by the simultaneous presence of fatigue cracks in similar adjacent structural elements in a multi-load path component (a control surface hinge consisting of side-by-side duplicated members is an example of such structure).

Most airplanes contain at least some structure of a design, which could lead to WFD. For such structure, the possibility of WFD must be considered in the determination of the Operational Limit. In many instances this can be achieved by an appropriate choice of K1 factor (see paragraph 6).

Further guidelines for the evaluation of WFD are given in the following references:

a. "A Report of the Airworthiness Assurance Working Group Industry Committee on Widespread Fatigue Damage," Final Report dated July 1993.

b. "Damage Tolerance, Facts and Fiction", Ulf Goransen, 17th ICAF, June 1993.

c. "Widespread Fatigue Damage Monitoring-Issues and Concerns", Tom Swift, Proceedings from 5th International Conference on Structural Airworthiness of New and Aging Aircraft. June 16-18, 1993.

8. <u>DETERMINATION OF THE OPERATIONAL LIMIT</u>. The Operational Limit for the airplane is determined by the lowest factored life established in Paragraph 6 Appendix 1.

OPERATIONAL LIMIT = MINIMUM FACTORED LIFE

However, the operational limit should never be set higher than the time at which WFD can be expected to occur.

If a PSE is kept in service using safety by inspection (see appendix 2) and the PSE is prone to WFD, the Operational Limit for that PSE is determined by the development of WFD.

APPENDIX 2 - GUIDELINES TO EXTEND AN OPERATIONAL LIMIT

The guidelines given apply to airplanes of conventional construction using conventional metallic materials. The following is a suggested procedure for this evaluation; however, any alternative procedure that is acceptable to the Federal Aviation Administration (FAA) may be used. The procedure given below is based on the assumption that limited fatigue/fracture data are available for the airplane being evaluated. Portions of this work may not be needed if some data are already available.

Using these methods, the Operational Limit can be extended to the time when the life of the next critical PSE is reached. It may also be extended to the highest time of the lives of a group of PSE's when the inspection, modification, and/or replacement actions due between the Operational Limit and the Extended Operational Limit are accomplished.

1. METHODS FOR EXTENDING THE OPERATIONAL LIMIT. The Operational Limit can be extended by any of the following methods:

When an airplane or component (wing, fuselage, stabilizer, etc.) operational limit is extended by treatment of PSE's by any of the methods described in sections 1a, 1b, or 1c of Appendix 2, the potential for widespread fatigue damage in other parts of the affected components must be evaluated in accordance with appendix 1, paragraph 7; except, under paragraph 1b when the affected components have been tested to the equivalent of two times the extended operational limit.

a. PSE Replacement or Modification. Since the Operational Limit is determined by the PSE with the shortest factored life, the limit can be extended by replacement of this PSE, or by a modification that extends its fatigue life. The new Operational Limit would then be set by the PSE with the next lowest factored life or the factored life of the modified/replaced PSE, whichever is lower.

b. Further Testing or Analysis. Further testing and/or analysis in accordance with the guidelines given in paragraph 5a to 5e of appendix 1 may be undertaken if the potential exists to justify longer lives than those determined by the first evaluation. For example, a fatigue test may have been terminated for economic reasons before the development of Widespread Fatigue Damage and/or any significant fatigue failures had occurred. In that case, an extended test could justify a longer fatigue life.

c. Re-Evaluation of Data Used to Establish the Initial Operational Limit. The Operational Limit may have been established as a result of initial assumptions. A re-examination of these assumptions may lead to an Extended Operational Limit.

For example, the aircraft may have had an Operational Limit set on the basis of an assumed usage. Over time, the actual usage may be determined. A re-evaluation of the original data using the actual usage may result an Extended Operational Limit.

d. Continued Operation with Safety by Inspection. The Operational Limit can be extended beyond the currently declared value if it is shown that safe operation is possible by implementation of an appropriate inspection program. The inspection program should ensure that if any cracks occur, they will be detected by mandatory inspections before the required residual strength is lost. Extension of the Operational Limit by this method is feasible only for structure which is inspectable for cracking. The detectable crack size must be substantiated for each Principal Structural Element (PSE) to be evaluated by this method. A crack propagation analysis (or test) must be carried out to determine the time (flights or flight hours) for a detectable crack to reach the maximum permitted size, i.e., the largest size where the structure can still sustain required residual load. This is the available crack detection time.

If analysis is used, the guidelines in paragraph 5a of Appendix 1 for crack propagation analysis apply, except that the analysis is commenced from a detectable flaw size. For crack propagation analysis in a pressure shell, the crack geometry factors used must account for pressure bulging effects. For multi-load path structure, detectable crack size may include the total failure of one element. The available crack detection time is then the time taken for cracking in the secondary path(s) to reach maximum permitted size.

For crack propagation analysis purposes, it is acceptable to assume that given a primary path failure, cracking in the secondary path(s) continues from a 1/4 circular corner crack of size $a_o+\delta a$, where a_o is the typical imperfection flaw size and δa is the amount by which a crack of size a_o would propagate with all load paths intact during a period equivalent to the primary path crack propagation.

The maximum permissible crack size, as defined above, can be determined either by residual strength test or by fracture mechanics analysis using representative fracture toughness data.

Inspection interval for each PSE then becomes:

$$\text{REPEAT INSPECTION INTERVAL} = \frac{\text{AVAILABLE CRACK DETECTION TIME}}{\text{K2}}$$

where, K2 = 3.0 for single-load path structure
2.0 for multi-load path structure

Any item cleared by the above procedure for continued operation through safety by inspection may continue in service indefinitely, provided that the item is not prone to WFD in accordance with Appendix 1, paragraph 7. Such items no longer need to be considered to determine an Operational Limit; the Operational Limit would be determined by the lowest life of the remaining items not cleared for continued operation through safety by inspection. The Operational Limit can therefore be extended progressively by revalidating more of the lowest life components using the safety by inspection method, provided that the components are inspectable and that assessments made prior to extension validate that WFD of any such component is not a concern during the Operational Limit extension interval.

2. INSPECTION PROCEDURE FOR SAFETY BY INSPECTION. For any structure evaluated by the procedure specified in paragraph 1c, Appendix 2, an inspection procedure that can reliably detect cracks of the assumed detectable size must be developed and documented. The following inspection procedures are commonly used:

a. Visual.

b. Eddy current (usually paint removal is not required).

c. Visual with fluorescent dye penetrant (paint removal is usually required).

d. Ultrasonic (for non-accessible structure where crack can be approached from the side).

e. Radiographic - this is not a preferred method. The probability of detection is dependent on crack opening (more than crack length), on beam orientation, and on operator judgment.

f. Magnetic Particle

Detectable crack size depends on factors such as:

(i) Inspection technique.

(ii) Structure geometry, accessibility, and the amount of structure to be inspected.

(iii) Inspection specificity (i.e., is the inspection directed at a specific point?).

(iv) Damage location indicators (i.e., fuel leaks, pressure loss, and working fasteners).

3. <u>OPERATIONAL LIMIT EXTENSION CRITERIA</u>. A document should be prepared that defines the requirements for the operation of the airplane to its Extended Operational Limit. The document should be in a form that can be added to the existing maintenance program of the airplane, or it can be in a "stand alone" document to supplement the existing maintenance program.

4. <u>REVISE MAINTENANCE PROGRAM TO INCLUDE INSPECTIONS</u>. The inspections identified for any PSE evaluated in accordance with paragraph 1c of this appendix shall be incorporated into the operator's approved maintenance program. Any extensions of these inspection intervals must be approved by the responsible FAA Aircraft Certification Office (ACO).

FAA Action: Continued Airworthiness of Older Small Transport and Commuter Airplanes; Establishment of Damage-Tolerance-Based Inspections and Procedures; Advisory Circular