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20 May 1987
SUPERSEDING
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(See 6.4)

MILITARY SPECIFICATION

AIRPLANE STRENGTH AND RIGIDITY RELIABILITY REQUIREMENTS, REPEATED LOADS, FATIGUE AND DAMAGE TOLERANCE

This specification is approved for use within the Naval Air Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification defines the strength and rigidity requirements for repeated loading condition applicable to Navy procured airplanes.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and Standards. The following specifications form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

MILITARY

MIL-D-8708	-	Demonstration Requirements for Airplanes.
MIL-A-8860	-	Airplane Strength and Rigidity, General Specification for.
MIL-A-8861	-	Airplane Strength and Rigidity Flight Loads.
MIL-A-8863	-	Airplane Strength and Rigidity Ground Loads for Navy Procured Airplanes.
MIL-A-8867	-	Airplane Strength and Rigidity Ground Tests.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Naval Air Engineering Center, Systems Engineering and Standardization Department (Code 93), Lakehurst, NJ 08733-5100, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

AMSC N/A FSC 1510

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SPECIFICATIONS

MILITARY (cont'd)

MIL-A-8868	-	Airplane Strength and Rigidity Data and Reports.
MIL-A-8870	-	Airplane Strength and Rigidity, Vibration, Flutter, and Divergence.
MIL-L-22589	-	Launching System, Nose Gear Type, Aircraft.

STANDARD

MILITARY

MIL-STD-2066	-	Catapulting and Arresting Gear Forcing Functions for Aircraft Structural Design.

(Copies of specifications and other Government documents (publications) required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.1.2 Other publications. The following document forms a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the document which are DOD adopted shall be those listed in the issue of the DODISS specified in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS shall be the issue of the non-government documents which is current on the date of the solicitation.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM Test Method E399-83	-	Test for Plane Strain Fracture Toughness of Metallic Materials.

(Application for copies of ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

2.2 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein (except for associated detail specifications, specification sheets or MS standards), the text of this specification shall take precedence. Nothing in this specification, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 General. The structural design of the airplane shall be such that repeated loads shall not cause failure or permanent deformation of any part of the airplane, interfere with it's mechanical operation, or affect its aerodynamic characteristics. Further, the design shall not require repair, inspection, or replacement of components other than as specifically approved by the contracting activity. The above requirements apply to the planned service life of the airplane for the repeated loads environment resulting from ground and flight operations, including loads and load combinations associated with maneuvers, field and carrier arrested landings , gusts, buffeting, dynamic response, pressurization (fuel and cockpit), aeroacoustics, vibration, store installation and release, catapulting, taxiing, operation of devices, and exposure to a chemical or thermal environment.

3.2 Service life. The service life of the airplane shall not be less than that specified by the contracting activity in terms of the following (as applicable):

a. Flight hours
b. Ground-air-ground cycle.(flights)
c. Field taxi runs
d. Field takeoffs
e. Catapult launches
f. Landings
   (1) Field
   (2) FCLP (Field Carrier Landing Practice)
   (3) Carrier arrested
   (4) Carrier touch-and-go

3.3 Fatigue.

3.3.1 Spectra. The airplane usage spectra for analysis and test shall include repeated loads from all types of ground and flight operations as noted in 3.1 and shall be supplemented, as required, to ensure that each airplane component is designed and tested to the proper repeated loadings. Consideration shall be given to the effects of load sequence, load truncation, load induced residual stress, and other factors as appropriate to assure that usage spectra for analysis and test provide the most conservative fatigue life. Ordering and frequency of loads within the usage spectra shall be random, consistent with flight-by-flight airplane operation, load exceedance and occurrence rates, and planned service life values.

3.3.2 Compliance. Compliance with 3.1 shall be demonstrated by the fatigue analysis of MIL-A-8868 and the fatigue tests of MIL-A-8867 utilizing crack initiation as the primary failure criterion. Specifically, the structural design of the airplane shall be such that the usage spectra will not cause structural defects (cracks, deformations, loss of modulus, delaminations, disbonds, etc.) or failure, within 4 times service life based upon analysis and 2 times service life based upon full scale tests. If any part of the airplane should fail to demonstrate compliance with the above requirements, that part shall be redesigned and then shown by analysis and test to be compliant. No inspections shall be required as a function of design within two service lifetimes. For both fatigue analysis and tests, the use of fatigue life-enhancing mechanical processes (such as shot peening, roller burnishing, etc.), other than split sleeve cold working and interference fit, are prohibited in demonstrating compliance.

3.3.2.1 Analysis. For analysis purposes, substantiation of fatigue life shall be in accordance with prediction methods as approved by the contracting activity. For approved interference fit and/or cold working enhancements, fatigue analysis shall indicate the airplane will be free from structural defect for at least 1 service life without the benefit of interference fit and/or cold working.

3.3.2.2 Test. Testing shall continue beyond 2 times service life until catastrophic failure, or until 4 times service life has been sustained by the test article. At test conclusion, the test article shall be subjected to a complete destructive teardown inspection, including fractographic examination, to identify all failures. All repairs made to the test article prior to 2 times service life, and all repairs for cracks or failures concluded to have been initiated prior to 2 times service life, shall be incorporated into all forward- and retrofit-production airplanes, provided the repairs have demonstrated compliance by analysis and test. For fatigue life certification of composite structure by test, accounting for variability and environmental factors shall be relatable to and confirmable by the results of the design development pre-production component and static tests of MIL-A-8867.

3.3.3 Low frequency vibratory loads. The airframe structure shall have unlimited life due to low frequency vibratory loadings. When these low frequency vibratory loadings are combined with the other various airplane loading conditions (i.e., pullups, banks, high angle of attack (AOA), gusts, etc.), the vibratory loadings shall not cause the stuctural fatigue life to be degraded from that which results when separately applying the other various loading conditions to the airframe structure.

3.4 Damage tolerance. The design and construction of the airframe structure, and the selection of materials to be used shall include provision for damage tolerance. Damage tolerant material shall be chosen on the basis of available, confident data. Damage tolerance shall be in addition to, rather than in lieu of, provision for adequate structural fatigue characteristics, and shall serve as a means for preventing catastrophic structural failure loss of control of the aircraft after a predefined limit of structural damage has occurred.

3.4.1 Analysis. All areas of structural components established as primary or critical shall be analyzed using the methods of linear elastic fracture mechanics, as a minimum, to identify the character and dimensions of defects which could grow to critical size in time periods as limited by aircraft inspection periods or wing required lifetime, as applicable. These analyses shall assume the presence of crack-like defects and/or delaminations placed in the most unfavorable orientation with respect to the material properties and applied stress consistent with the aircraft loads environment, and shall predict the growth behavior of the chemical, thermal, and sustained and repeated-loads environment to which the component will be subjected.

3.4.2 Compliance.

3.4.2.1 Metals. For all primary or critical structures, crack growth under sustained and repeated loads shall not occur at a rate such that initial flaws can reach critical size at the residual strength requirement load in one lifetime of expected service usage. For purposes of these analyses, the initial flaw size shall be .010 inches minimum in metals, and at failure not smaller than 0.25 inches (surface length). Critical flaw sizes shall be determined using the appropriate critical fracture toughness values determined on a valid statistical basis in accordance with the procedures of the American Society for Testing and Materials Test Method E399-83 entitled "Test for Plane Strain Fracture Toughness of Metallic Materials." The analysis shall identify plane strain, plane stress, or mixed mode conditions at the onset of rapid crack propagation, and shall include all crack growth rate and critical crack length data on which the analysis was based. The effect of sheet thickness on fracture resistance shall be proposed by the contractor and accepted by the contracting activity.

3.4.2.2 Composites. Damaged (e.g., delamination) structure, at or below the threshold of being clearly visible, shall be capable of fully compensated ultimate load statically with no damage growth under sustained and repeated loads for one service lifetime . Demonstration of requirement shall be by test, or as proposed by the contractor and specifically approved by the contracting activity, accounting for the effects of variability and environment as relatable to and confirmable by the results of the design development, pre-production component and static tests of MIL-A-8867.

3.5 Maneuver loads. For determination of loads, the airplane shall be at the critical speed and altitude which results in the minimum life on the component being considered. The spectrum of loads shall include symmetric pull-ups and push-overs, and asymetric rolling pull-outs, roll reversals, and level rolls. Except for level rolls, the maneuvers shall have the number of positive and negative exceedances of vertical load factor as specified by the contracting activity. The percentage of asymmetric maneuvers at each load level as well as the total number of level rolls shall be proposed by the contractor and approved by the contracting activity.

3.6 Gust loads. The gust load spectra shall encompass the anticipated mission usage of the airplane and be approved by the contracting activity. The usage shall include at least 4 percent of the airplane's life at V_H at sea level. The fatigue analysis shall include at least the dynamic response in the rigid-body modes of pitch and translation, for elastic modes as appropriate to the structural characteristics and configuration, and the modes of any autopilot or artificial stability devices. The dynamic response shall be determined for the power spectral density of atmospheric turbulence in accordance with MIL-A-8861 continuous turbulence aproach of 3.5.2.

3.7 Ground loads.

3.7.1 Catapult takeoff. The weight shall be the maximum design gross weight. The off-center spotting eccentricity of the airplane at release shall be half of that resulting from the criteria of MIL-L-22589. Half of the takeoffs shall be to the right and half to the left. For each takeoff the sequence and magnitude of load application shall be as follows:

a. Two cycles of buffing load. Each cycle shall be from zero to 80 percent of the release load of MIL-A-8863. At the end of each cycle the load shall drop to zero.

b. Tensioning load of MIL-A-8863.

c. Release load including the effects off-center spotting.

d. External and internal loads that result during the catapult run, including bending moments that result from eccentricities of the launch bar with respect to the shuttle as well as loads due to tire and steering friction in off-center takeoffs. The applied tow force shall be the maximum catapult tow force of MIL-A-8863, except that for ten percent of the takeoffs the tow force shall be equal to the upper 90-90 envelope boundary of MIL-STD-2066.

3.7.2 Landings. For all landings the applicable design gross weight shall apply.

3.7.2.1 Landing impact loads. The airplane loads shall be determined by a rational combination of sinking speeds of Table I with variations in landing attitudes (pitch and roll) and engaging speeds, including arresting and drift landing loads. For loads on the nose gears for carrier arrested landings, one tenth of all landings at each sinking speed shall be considered free-flight engagements unless it can be shown by analysis that free-flight engagements cannot occur within the specified distribution of landing conditions.

3.7.2.2 Arresting loads. The horizontal component of the arresting hook force shall be equal to the limit load for 90 percent of the arrestments. For 10 percent of the arrestments it shall be equal to the force corresponding to the upper 90-90 probability envelope of MIL-STD-2066. The side force shall be 0.6W for 90 percent of the arrestments and 1.0W for 10 percent of the arrestments, where W is the carrier loading design gross weight. The resultant P, of the arresting hook force shall be applied through a point located at a distance equal to half of the radius of the cable groove from the centerline of the hook shank. The resultant P shall be applied as follows:

$$0 \longrightarrow P \longrightarrow .5P \longrightarrow P \longrightarrow .5P \longrightarrow P \longrightarrow 0$$

3.7.3 Ground maneuvering loads. The loads shall include vertical, drag and lateral loads resulting from braking turning pivoting and taxiing. Hard braking with maximum braking effect (0.8 coefficient of friction) shall occur twice per taxi run and medium braking with half maximum effect shall occur an additional five times per run. Turning with total side loads of 0.4 times the airplane weight applied as inboard and alternately as outboard loads shall occur five times per taxi run. Pivoting with 1/2 limit torque load shall occur once per three taxi runs. The vertical response resulting from runway roughness shall be as specified in Table II.

3.7.4 Miscellaneous ground loads.

3.7.4.1 Sudden extension. The number of applied cycles shall be equal to the number of touch-and-go landings and catapult takeoffs. The applied loads shall be determined for the conditions of MIL-A-8863.

3.7.4.2 Extension and retraction and braking wheels in air. The number of applied cycles shall be equal to the number of ground-air-ground cycles. The applied load for each phase of operation shall be determined as specified in MIL-A-8863. The sequence of each cycle shall be as follows:

a. Landing gears in the extended and locked position

b. Braking wheels in air

c. Full retraction of landing gears in the locked position

d. Extension of landing gears in the locked position. Actuation shall be by a normal power system.

TABLE I

DISTRIBUTION OF SINKING SPEEDS PER 1000 LANDINGS

CARRIER LANDINGS, FCLP, AND FIELD LANDINGS (NON-FLARED)		FIELD LANDINGS (FLARED)	
SINKING SPEEDS	FREQUENCY	SINK SPEED (FPS)	FREQUENCY
$\bar{V}_v$	122*	10	0.5
$V_v \pm 0.31\sigma$	116*	9	1.5
$\bar{V}_v \pm 0.62\sigma$	101	8	7
$\bar{V}_v \pm 0.93\sigma$	80	7	22
$\bar{V}_v \pm 1.24\sigma$	58	6	66
$\bar{V}_v \pm 1.55\sigma$	38	5	153
$\bar{V}_v \pm 1.86\sigma$	23	4	252*
$\bar{V}_v \pm 2.17\sigma$	13	3	271
$\bar{V}_v \pm 2.48\sigma$	5	2	170
$\bar{V}_v \pm 2.79\sigma$	3	1	57
$\bar{V}_v \pm 3.10\sigma$	2	-	-

Notes:

1. The value of σ for each type of landing shall be as defined in MIL-A-8863

2. The landings indicated by an asterisk shall include drift landing loads for which the following apply:

   a. The side load shall be 0.4 times the maximum vertical load for the main gear and 0.2 times the maximum load for the nose gear.

   b. The side load shall act in combination with the maximum vertical load.

   c. The shock strut stroke and the drag load shall correspond to those occurring at the instant of maximum vertical load.

TABLE II. Number of times per thousand runway landings that load factor n_z is experienced.

n_z	Number of applications
1 ± 0.05	300,000
1 ± 0.15	165,000
1 ± 0.25	27,000
1 ± 0.35	2,000
1 ± 0.45	90
1 ± 0.55	4
1 ± 0.65	0.15
1 ± 0.75	0.005

3.8 Cockpit or cabin pressurization. Pressurized cabins of land-based transport, cargo, AEW, and other large airplanes similar to those of commercial airline transports shall be pressurized 20,000 times. Other types shall be pressurized a number of times equal to twice the number of landings specified in 3.2. The pressure to be applied shall be the maximum value obtained from tests of at least 10 relief valves of the type to be used, or the value obtained by adding the maximum relief valve setting governing acceptance of the valve in its acquisition specification to the maximum permissible tolerance on this valve. The flight loads to be applied shall include those resulting from gust penetrations and maneuvers consistent with the missions.

3.9 Aeroacoustics and vibration. Structural design requirements to preclude fatigue cracking initiation or delamination or any other fatigue failure of the airframe structure or structural components induced by vibrations, aeroacoustics and other oscillatory loads for the service life of the airplane shall be in accordance with MIL-A-8870.

3.10 Repeated operation of devices. Particular attention shall be given to the impact loads as well as the operational and residual loads that may occur when doors, landing gear, controls, wing folds, and other devices (which open, close, extend, retract, or rotate) are operated consistent with planned usage of the airplane. Under normal operating conditions, repeated actuation shall not adversely affect the mechanical operation of any part of the airplane and shall not fail or deform any part or element of any device, system, or structure.

3.11 Integral fuel tanks. Integral fuel tanks shall not leak under repeated loads resulting from taxiing, takeoff, flight (including buffeting), and landings. This requirement shall be aptly demonstrated by laboratory tests which simulate these repeated loadings for an extended period of operation and for several periods of operation. For design purposes, fighters and attack airplanes shall have two periods of operations in their service life; other classes shall have three periods.

3.12 Loads on balance weight attachments. Refer to MIL-A-8870 paragraph 3.2.1.2.1.3 for design load requirements.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Also unless specified in the contract or purchase order, the contractor may use his own or any other facilit-
ies suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items must meet all requirements of section 3. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of assuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, and does not commit the Government to accept defective material.

4.2 Methods of inspection.

4.2.1 Design data. Structural design and analyses data shall be in accordance with MIL-A-8868.

4.2.2 Laboratory tests. Laboratory tests shall be in accordance with MIL-A-8867.

4.2.3 Flight tests. Navy flight test demonstrations shall be in accordance with MIL-D-8708.

5. PACKAGING

This section is not applicable to this specification.

6. NOTES

6.1 Intended use. The requirements of this specification are intended for use in the structural design and substantiation of airplanes.

6.2 Ordering data.

This paragraph is not applicable to this specification.

6.3 Definitions. For definitions of terms used in this specification see section 6 of MIL-A-8860.

6.4 Supersession data. See supersession data in section 6 of MIL-A-8860. This specification supersedes MIL-A-8866(ASG). It also supersedes, in part, MIL-A-008866B(USAF), although MIL-A-008866B(USAF) will remain in effect until cancelled by the Air Force.

6.5 Subject term (key word) listing.

Airplane
Arresting
Cabin pressurization
Carrier-based airplanes
Catapulting
Fatigue
Flight maneuver loads
Flight tests
Gust loads
Loads
Reliability requirements
Repeated loads
Rigidity
Service life
Sinking speeds
Strength
Taxi ground loads
Trainers
Turbulence
Vibration

6.6 Changes from previous issue. Asterisks or vertical lines are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - AS

(Project 1510-N025)

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NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-A-8866C(AS)	Airplane Strength and Rigidity Reliability Requirements, Repeated Loads, Fatigue and Damage Tolerance

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION (Mark one)
	☐ VENDOR
	☐ USER
b. ADDRESS (Street, City, State, ZIP Code)	☐ MANUFACTURER
	☐ OTHER (Specify):

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER (Last, First, MI) – Optional	b. WORK TELEPHONE NUMBER (Include Area Code) – Optional
c. MAILING ADDRESS (Street, City, State, ZIP Code) – Optional	8. DATE OF SUBMISSION (YYMMDD)

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