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SUPERSEDING
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MILITARY SPECIFICATION

FLYING QUALITIES OF PILOTED AIRPLANES

This specification is approved for use by all
Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification contains the requirements for the flying and handling qualities, in flight and on the ground, of U.S. Military, manned, piloted airplanes except for flight at airspeeds below V_{con} (MIL-F-83300). It is intended to assure flying qualities that provide adequate mission performance and flight safety regardless of design implementation or flight control system mechanization. The structure of the specification allows its use to guide these aspects in design tradeoffs, analyses and tests.

1.2 Application. The flying qualities of all airplanes proposed or contracted for shall be in accordance with the provisions of this specification. The requirements apply as stated to the combination of airframe and related subsystems. Stability augmentation and control augmentation are specifically to be included when provided in the airplane. The automatic flight control system is also to be considered to the extent stated in MIL-F-9490 or MIL-C-18244, whichever applies. The requirements are written in terms of cockpit flight controls that produce essentially pitching, yawing and rolling moments. This approach is not meant to preclude other modes of control for special purposes. Additional or alternative requirements may be imposed by the procuring activity in order to fit better the intended use or the particular design.

1.3 Classification of airplanes. For the purpose of this specification, an airplane shall be placed in one of the following Classes:

Class I   Small, light airplanes such as
- Light utility
- Primary trainer
- Light observation

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASD/ENESS, Wright-Patterson AFB, OH 45433 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 15GP

Class II Medium weight, low-to-medium maneuverability airplanes such as
Heavy utility/search and rescue
Light or medium transport/cargo/tanker
Early warning/electronic countermeasures/airborne command, control, or communications relay
Antisubmarine
Assault transport
Reconnaissance
Tactical bomber
Heavy attack
Trainer for Class II

Class III Large, heavy, low-to-medium maneuverability airplanes such as
Heavy transport/cargo/tanker
Heavy bomber
Patrol/early warning/electronic countermeasures/airborne command, control, or communications relay
Trainer for Class III

Class IV High-maneuverability airplanes such as
Fighter/interceptor
Attack
Tactical reconnaissance
Observation
Trainer for Class IV

The procuring activity will assign an airplane to one of these Classes, and the requirements for that Class shall apply. When no Class is specified in a requirement, the requirement shall apply to all Classes. When operational missions so dictate, an airplane of one Class may be required by the procuring activity to meet selected requirements ordinarily specified for airplanes of another Class.

1.3.1 Land- or carrier-based designation. The letter -L following a Class designation identifies an airplane as land-based; carrier-based airplanes are similarly identified by -C. When no such differentiation is made in a requirement, the requirement shall apply to both land-based and carrier-based airplanes.

1.4 Flight Phase Categories. The Flight Phases have been combined into three Categories which are referred to in the requirement statements. These Flight Phases shall be considered in the context of total missions so that there will be no gap between successive Phases of any flight and so that transition will be smooth. In certain cases, requirements are directed at specific Flight Phases identified in the requirement. When no Flight Phase or Category is stated in a requirement, that requirement shall apply to all three Categories. Flight Phases descriptive of most military airplane missions are:

Nonterminal Flight Phases:

Category A - Those nonterminal Flight Phases that require rapid maneuvering, precision tracking, or precise flight-path control. Included in this Category are:

a. Air-to-air combat (CO)

b. Ground attack (GA)

c. Weapon delivery/launch (WD)

d. Aerial recovery (AR)

e. Reconnaissance (RC)

f. In-flight refueling (receiver) (RR)

g. Terrain following (TF)

h. Antisubmarine search (AS)

i. Close formation flying (FF).

Category B - Those nonterminal Flight Phases that are normally accomplished using gradual maneuvers and without precision tracking, although accurate flight-path control may be required. Included in this Category are:

a. Climb (CL)

b. Cruise (CR)

c. Loiter (LO)

d. In-flight refueling (tanker) (RT)

e. Descent (D)

f. Emergency descent (ED)

g. Emergency deceleration (DE)

h. Aerial delivery (AD).

Terminal Flight Phases:

Category C - Terminal Flight Phases are normally accomplished using gradual maneuvers and usually require accurate flight-path control. Included in this Category are:

a. Takeoff (TO)

b. Catapult takeoff (CT)

c. Approach (PA)

d. Wave-off/go-around (WO)

e. Landing (L)

When necessary, recategorization or addition of Flight Phases or delineation of requirements for special situations, e.g., zoom climbs, will be accomplished by the procuring activity.

1.5 Levels of flying qualities. Where possible, the requirements of section 3 have been stated in terms of three values of the stability or control parameter being specified. Each value is a minimum condition to meet one of three Levels of acceptability related to the ability to complete the operational missions for which the airplane is designed. The Levels are:

Level 1	Flying qualities clearly adequate for the mission Flight Phase
Level 2	Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists
Level 3	Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate, or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed.

2. APPLICABLE DOCUMENTS

2.1 Issues of documents. The following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

SPECIFICATIONS

MILITARY

MIL-D-8708	Demonstration Requirements for Airplanes
MIL-A-8861	Airplane Strength and Rigidity Flight Loads
MIL-F-9490	Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification for
MIL-C-18244	Control and Stabilization Systems, Automatic, Piloted Aircraft, General Specification for
MIL-F-18372	Flight Control Systems, Design, Installation and Test of, Aircraft (General Specification for)
MIL-W-25140	Weight and Balance Control Data (for Airplanes and Rotorcraft)
MIL-F-83300	Flying Qualities of Piloted V/STOL Aircraft
MIL-S-83691	Stall/Post-Stall/Spin Flight Test Demonstration Requirements for Airplanes

STANDARDS

MIL-STD-756	Reliability Prediction

(Copies of specifications and standards required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer).

3. REQUIREMENTS

3.1 General requirements

3.1.1 Operational missions. The procuring activity will specify the operational missions to be considered by the contractor in designing the airplane to meet the flying qualities requirements of this specification. These missions will include all associated Flight Phases and tasks, such as takeoff, takeoff abort, landing and missed approach. Operational missions include the entire spectrum of intended usage to include aircrew upgrade and training.

3.1.2 Loadings. The contractor shall define the envelopes of center of gravity and corresponding weights that will exist for each Flight Phase. These envelopes shall include the most forward and aft center-of-gravity positions as defined in MIL-W-25140. In addition, the contractor shall determine the maximum center-of-gravity excursions attainable through failures in systems or components, such as fuel sequencing, hung stores, etc., for each Flight Phase to be considered in the Failure States of 3.1.6.2. Within these envelopes, plus a growth margin to be specified by the procuring activity, and for the excursions cited above, this specification shall apply.

3.1.3 Moments and products of inertia. The contractor shall define the moments and products of inertia of the airplane associated with all loadings of 3.1.2. The requirements of this specification shall apply for all moments and products of inertia so defined.

3.1.4 External stores. The requirements of this specification shall apply for all combinations of external stores required by the operational missions. The effects of external stores on the weight, moments of inertia, center-of-gravity position, and aerodynamic characteristics of the airplane shall be considered for each mission Flight Phase. When the stores contain expendable loads, the requirements of this specification apply throughout the range of store loadings. The external stores and store combinations to be considered for flying qualities design will be specified by the procuring activity. In establishing external store combinations to be investigated, consideration shall be given to asymmetric as well as to symmetric combinations.

3.1.5 Configurations. The requirements of this specification shall apply for all configurations required or encountered in the applicable Flight Phases of 1.4. A (crew-) selected configuration is defined by the positions and adjustments of the various selectors and controls available to the crew except for pitch, roll, yaw, throttle and trim controls. Examples are: the flap control setting and the yaw damper ON or OFF. The selected configurations to be examined must consist of those required for performance and mission accomplishment. Additional configurations to be investigated may be defined by the procuring activity.

3.1.6 State of the airplane. The State of the airplane is defined by the selected configuration together with the functional status of each of the airplane components or systems, throttle setting, weight, moments of inertia, center-of-gravity position, and external store complement. The trim setting and the positions of the pitch, roll and yaw controls are not included in the definition of Airplane State since they are often specified in the requirements.

3.1.6.1 Airplane Normal States. The contractor shall define and tabulate all pertinent items to describe the Airplane Normal (no component or system failure) State(s) associated with each of the applicable Flight Phases. This tabulation shall be in the format and shall use the nomenclature specified in 6.2. Certain items, such as weight, moments of inertia, center-of-gravity position, wing sweep, or thrust setting may vary continuously over a range of values during a Flight Phase. The contractor shall replace this continuous variation by a limited number of values of the parameter in question which will be treated as specific States, and which include the most critical values and the extremes encountered during the Flight Phase in question.

3.1.6.2 Airplane Failure States. The contractor shall define and tabulate all Airplane Failure States, which consist of Airplane Normal States modified by one or more malfunctions in airplane components or systems; for example, a discrepancy between a selected configuration and an actual configuration. Those malfunctions that result in center-of-gravity positions outside the center-of-gravity envelope defined in 3.1.2 shall be included. Each mode of failure shall be considered. Failures occurring in any Flight Phase shall be considered in all subsequent Flight Phases.

3.1.6.2.1 Airplane Special Failure States. Certain components, systems, or combinations thereof may have extremely remote probability of failure during a given flight. These failure probabilities may, in turn, be very difficult to predict with any degree of accuracy. Special Failure States of this type need not be considered in complying with the requirements of Section 3 if justification for considering the Failure States as Special is submitted by the contractor and approved by the procuring activity.

3.1.7 Operational Flight Envelopes. The operational flight envelopes define the boundaries in terms of speed, altitude and load factor within which the airplane must be capable of operating in order to accomplish the missions of 3.1.1. Envelopes for each applicable Flight Phase shall be established with the guidance and approval of the procuring activity. In the absence of specific guidance, the contractor shall use the representative conditions of table I for the applicable Flight Phases.

3.1.8 Service Flight Envelopes. For each Airplane Normal State the contractor shall establish, subject to the approval of the procuring activity, Service Flight Envelopes showing combinations of speed, altitude and normal acceleration derived from airplane limits as distinguished from mission requirements. For each applicable Flight Phase and Airplane Normal State, the boundaries of the Service Flight Envelopes can be coincident with or lie outside the corresponding Operational Flight Envelopes, but in no case shall they fall inside those Operational boundaries. The boundaries of the Service Flight Envelopes shall be based on considerations discussed in 3.1.8.1, 3.1.8.2, 3.1.8.3 and 3.1.8.4.

TABLE I. Operational Flight Envelopes

FLIGHT PHASE CATEGORY	FLIGHT PHASE	AIRSPEED $V_{o_{min}}$ ($M_{o_{min}}$)	AIRSPEED $V_{o_{max}}$ ($M_{o_{max}}$)	ALTITUDE $h_{o_{min}}$	ALTITUDE $h_{o_{max}}$	LOAD FACTOR $n_{o_{min}}$	LOAD FACTOR $n_{o_{max}}$
A	AIR-TO-AIR COMBAT (CO)	$1.4\ V_S$	V_{MAT}	MSL	Combat Ceiling	-1.0	n_L
	GROUND ATTACK (GA)	$1.3\ V_S$	V_{MRT}	MSL	Medium	-1.0	n_L
	WEAPON DELIVERY/LAUNCH (WD)	V_{range}	V_{MAT}	MSL	Combat Ceiling	.5	*
	AERIAL RECOVERY (AR)	$1.2\ V_S$	V_{MRT}	MSL	Combat Ceiling	.5	n_L
	RECONNAISSANCE (RC)	$1.3\ V_S$	V_{MAT}	MSL	Combat Ceiling	*	*
	IN-FLIGHT REFUEL (RECEIVER) (RR)	$1.2\ V_S$	V_{MRT}	MSL	Combat Ceiling	.5	2.0
	TERRAIN FOLLOWING (TF)	V_{range}	V_{MAT}	MSL	10,000 ft.	.0	3.5
	ANTISUBMARINE SEARCH (AS)	$1.2\ V_S$	V_{MRT}	MSL	Medium	0	2.0
	CLOSE FORMATION FLYING (FF)	$1.4\ V_S$	V_{MAT}	MSL	Combat Ceiling	-1.0	n_L
B	CLIMB (CL)	$.85\ V_{R/C}$	$1.3\ V_{R/C}$	MSL	Cruising Ceiling	.5	2.0
	CRUISE (CR)	V_{range}	V_{MRT}	MSL	Cruising Ceiling	.5	2.0
	LOITER (LO)	$.85\ V_{end}$	$1.3\ V_{end}$	MSL	Cruising Ceiling	.5	2.0
	IN-FLIGHT REFUEL (TANKER) (RT)	$1.4\ V_S$	V_{MAT}	MSL	Cruising Ceiling	.5	2.0
	DESCENT (D)	$1.4\ V_S$	V_{MAT}	MSL	Cruising Ceiling	.5	2.0
	EMERGENCY DESCENT (ED)	$1.4\ V_S$	V_{max}	MSL	Cruising Ceiling	.5	2.0
	EMERGENCY DECELERATION (DE)	$1.4\ V_S$	V_{max}	MSL	Cruising Ceiling	.5	2.0
	AERIAL DELIVERY (AD)	$1.2\ V_S$	200 kt	MSL	10,000 ft	0	2.0
C	TAKEOFF (TO)	Minimum Normal Takeoff Speed	V_{max}	MSL	10,000 ft.	.5	2.0
	CATAPULT TAKEOFF (CT)	Minimum Catapult End Airspeed	$V_{o_{min}}$ +30 kt	MSL	—	.5	n_L
	APPROACH (PA)	Minimum Normal Approach Speed	V_{max}	MSL	10,000 ft.	.5	2.0
	WAVE-OFF/GO-AROUND (WO)	Minimum Normal Approach Speed	V_{max}	MSL	10,000 ft.	.5	2.0
	LANDING (L)	Minimum Normal Landing Speed	V_{max}	MSL	10,000 ft.	.5	2.0

*Appropriate to the operational mission.

3.1.8.1 Maximum service speed. The maximum service speed, V_{max} or M_{max}, for each altitude is the lowest of:

a. The maximum permissible speed

b. A speed which is a safe margin below the speed at which intolerable buffet or structural vibration is encountered

c. The maximum airspeed at MAT, for each altitude, for dives (at all angles) from V_{MAT} at all altitudes, from which recovery can be made at 2,000 feet above MSL or higher without penetrating a safe margin from loss of control, other dangerous behavior or intolerable buffet, and without exceeding structural limits.

3.1.8.2 Minimum service speed. The minimum service speed, V_{min} or M_{min}, for each altitude is the highest of:

a. 1.1 V_S

b. V_S + 10 knots equivalent airspeed

c. The speed below which full airplane-nose-up pitch control power and trim are insufficient to maintain straight, steady flight

d. The lowest speed at which level flight can be maintained with MRT and,

for Category C Flight Phases:

e. A speed limited by reduced visibility or an extreme pitch attitude that would result in the tail or aft fuselage contacting the ground.

3.1.8.3 Maximum service altitude. The maximum service altitude, h_{max}, for a given speed is the maximum altitude at which a rate of climb of 100 feet per minute can be maintained in unaccelerated flight with MAT.

3.1.8.4 Service load factors. Maximum and minimum service load factors, n(+) [n(-)], shall be established as a function of speed for several significant altitudes. The maximum [minimum] service load factor, when trimmed for 1g flight at a particular speed and altitude, is the lowest [highest] algebraically of:

a. The positive [negative] structural limit load factor

b. The steady load factor corresponding to the minimum allowable value of lift coefficient for stall warning (3.4.2.1.1.2)

c. The steady load factor at which the pitch control is in the full airplane-nose-up [nose-down] position

d. A safe margin below [above] the load factor at which intolerable buffet or structural vibration is encountered.

3.1.9 Permissible Flight Envelopes. The contractor shall define Permissible Flight Envelopes which encompass all regions in which operation of the airplane is both allowable and possible, consistent with 3.1.10.3.3. These Envelopes define boundaries in terms of speed, altitude and load factor.

3.1.10 Application of Levels. Levels of flying qualities as indicated in 1.5 are employed in this specification in realization of the possibility that the airplane may be required to operate under abnormal conditions. Such abnormalities that may occur as a result of either flight outside the Operational Flight Envelope, failure of airplane components, or both, are permitted to comply with a degraded Level of flying qualities as specified in 3.1.10.1 through 3.1.10.3.3 (see also 4.1.1).

3.1.10.1 Requirements for Airplane Normal States. The minimum required flying qualities for Airplane Normal States (3.1.6.1) are as specified in table II.

TABLE II. Levels for Airplane Normal States.

Within Operational Flight Envelope	Within Service Flight Envelope
Level 1	Level 2

3.1.10.2 Requirements for Airplane Failure States. When Airplane Failure States exist (3.1.6.2), a degradation in flying qualities is permitted only if the probability of encountering a lower Level than specified in 3.1.10.1 is sufficiently small. At intervals established by the procuring activity, the contractor shall determine, based on the most accurate available data, the probability of occurrence of each Airplane Failure State per flight and the effect of that Failure State on the flying qualities within the Operational and Service Flight Envelopes. These determinations shall be based on MIL-STD-756 except that:

a. All airplane components and systems are assumed to be operating for a time period, per flight, equal to the longest operational mission time to be considered by the contractor in designing the airplane, and

b. Each specific failure is assumed to be present at whichever point in the Flight Envelope being considered is most critical (in the flying qualities sense). From these Failure State probabilities and effects, the contractor shall determine the overall probability, per flight, that one or more flying qualities are degraded to Level 2 because of one or more failures. The contractor shall also determine the probability that one or more flying qualities are degraded to Level 3. These probabilities shall be less than the values specified in table III.

In no case shall a Failure State (except an approved Special Failure State) degrade any flying quality parameter outside the Level 3 limit.

TABLE III. Levels for Airplane Failure States.

Probability of Encountering	Within Operational Flight Envelope	Within Service Flight Envelope
Level 2 after failure	$< 10^{-2}$ per flight	
Level 3 after failure	$< 10^{-4}$ per flight	$< 10^{-2}$ per flight

3.1.10.2.1 Requirements for specific failures. The requirements on the effects of specific types of failures, e.g., propulsion or flight control system, shall be met on the basis that the specific type of failure has occurred, regardless of its probability of occurrence.

3.1.10.3 Exceptions

3.1.10.3.1 Ground operation and terminal Flight Phases. Some requirements pertaining to takeoff, landing and taxiing involve operation outside the Operational, Service and Permissible Flight Envelopes, as at V_S or on the ground. When requirements are stated at conditions such as these, the levels shall be applied as if the conditions were in the Operational Flight Envelope.

3.1.10.3.2 When Levels are not specified. Within the Operational and Service Flight Envelopes, all requirements that are not identified with specific Levels shall be met under all conditions of component and system failure except approved Airplane Special Failure States (3.1.6.2.1).

3.1.10.3.3 Flight outside the Service Flight Envelope. From all points in the Permissible Flight Envelopes, it shall be possible readily and safely to return to the Service Flight Envelope without exceptional pilot skill or technique, regardless of component or system failures. The requirements on flight at high angle of attack, dive characteristics, dive recovery devices and dangerous flight conditions shall also apply.

3.1.11 Interpretation of subjective requirements. In several instances throughout the specification subjective terms, such as objectionable flight characteristics, realistic time delay, normal pilot technique and excessive loss of altitude or buildup of speed, have been employed to permit latitude where absolute quantitative criteria might be unduly restrictive. Final determination of compliance with requirements so worded will be made by the procuring activity (1.5).

3.1.12 Interpretation of quantitative requirements. The numerical requirements of this specification generally are stated in terms of a linear mathematical description of the airplane. Certain factors, for example flight control system nonlinearities and higher-order characteristics or aerodynamic nonlinearities, can cause the aircraft response to differ significantly from that of the linear model. The contractor shall define equivalent classical systems which have responses most closely matching those of the actual aircraft. Then those numerical requirements of section 3 which are stated in terms of linear system parameters (such as frequency, damping ratio and modal phase angles) apply to the parameters of that equivalent system rather than to any particular modes of the actual higher-order system. The procuring activity shall be the judge of the adequacy of the response match between equivalent and actual aircraft.

3.2 Longitudinal flying qualities

3.2.1 Longitudinal stability with respect to speed

3.2.1.1 Longitudinal static stability. For Levels 1 and 2 there shall be no tendency for airspeed to diverge aperiodically when the airplane is disturbed from trim with the cockpit controls fixed and with them free. This requirement will be considered satisfied if the variations of pitch control force and pitch control position with airspeed are smooth and the local gradients stable, with:

a. Trimmer and throttle controls not moved from the trim settings by the crew, and

b. 1g acceleration normal to the flight path, and

c. Constant altitude

over a range about the trim speed of ±15 percent or ±50 knots equivalent airspeed, whichever is less (except where limited by the boundaries of the Service Flight Envelopes). Alternatively, this requirement will be considered satisfied if stability with respect to speed is provided through the flight control system, even though the resulting pitch control force and deflection gradients may be zero. For Level 3 the requirements may be relaxed, subject to approval by the procuring activity of the maximum instability to be allowed for the particular case. In no event shall its time to double amplitude be less than 6 seconds. In the presence of one or more other Level 3 flying qualities, no static longitudinal instability will be permitted unless the flight safety of that combination of characteristics has been demonstrated to the satisfaction of the procuring activity. Stable gradients mean that the pitch controller deflection and force increments required to maintain straight, steady flight at a different speed are in the same sense as those required to initiate the speed change; that is, airplane-nose-down control to fly at a faster speed, airplane-nose-up control to fly at a slower speed. The term gradient does not include that portion of the control force or control position versus airspeed curve within the breakout force range.

3.2.1.1.1 Relaxation in transonic flight. The requirements of 3.2.1.1 may be relaxed in the transonic speed range provided any divergent airplane motions or reversals in slope of pitch control force and position with speed are gradual and not objectionable to the pilot. In no case, however, shall the requirements of 3.2.1.1 be relaxed more than the following:

a. Levels 1 and 2 - For center-stick controllers, no local force gradient shall be more unstable than 3 pounds per 0.01 M nor shall the force change exceed 10 pounds in the unstable direction. The corresponding limits for wheel controllers are 5 pounds per 0.01 M and 15 pounds, respectively

b. Level 3 - For center-stick controllers, no local force gradient shall be more unstable than 6 pounds per 0.01 M nor shall the force ever exceed 20 pounds in the unstable direction. The corresponding limits for wheel controllers are 10 pounds per 0.01 M and 30 pounds, respectively.

This relaxation does not apply to Level 1 for any Flight Phase which requires prolonged transonic operation.

3.2.1.1.2 Pitch control force variations during rapid speed changes. When the airplane is accelerated and decelerated rapidly through the operational speed range and through the transonic speed range by the most critical combination of changes in power, actuation of deceleration devices, steep turns and pullups, the magnitude and rate of the associated trim change shall not be so great as to cause difficulty in maintaining the desired load factor by normal pilot techniques.

3.2.1.2 Phugoid stability. The long-period airspeed oscillations which occur when the airplane seeks a stabilized airspeed following a disturbance shall meet the following requirements:

a. Level 1 ----- ζ_p at least 0.04

b. Level 2 ----- ζ_p at least 0

c. Level 3 ----- T_2 at least 55 seconds

These requirements apply with the pitch control free and also with it fixed. They need not be met transonically in cases where 3.2.1.1.1 permits relaxation of the static stability requirement.

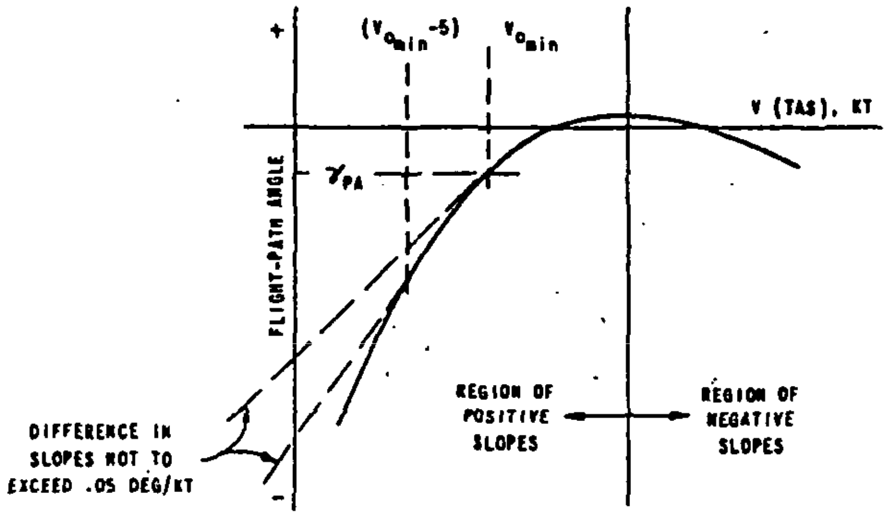
3.2.1.3 Flight-path stability. Flight-path stability is defined in terms of flight-path-angle change where the airspeed is changed by the use of pitch control only (throttle setting not changed by the crew). For the landing approach Flight Phase, the curve of flight-path angle versus true airspeed shall have a local slope at $V_{o_{min}}$ which is negative or less positive than:

a. Level 1 ----- 0.06 degrees/knot

b. Level 2 ----- 0.15 degrees/knot

c. Level 3 ----- 0.24 degrees/knot.

The thrust setting shall be that required for the normal approach glide path at $V_{o_{min}}$. The slope of the curve of flight-path angle versus airspeed at 5 knots slower than $V_{o_{min}}$ shall not be more than 0.05 degrees per knot more positive than the slope at $V_{o_{min}}$, as illustrated by:



3.2.2 Longitudinal maneuvering characteristics

3.2.2.1 Short-period response. The short-period response of angle of attack which occurs at approximately constant speed, and which may be produced by abrupt pitch control inputs, shall meet the requirements of 3.2.2.1.1 and 3.2.2.1.2. These requirements apply, with the cockpit control free and with it fixed, for responses of any magnitude that might be experienced in service use. If oscillations are nonlinear with amplitude, the requirements shall apply to each cycle of the oscillation. In addition to meeting the numerical requirements of 3.2.2.1.1 and 3.2.2.1.2, the contractor shall show that the airplane has suitable response characteristics in atmospheric disturbances (3.7 and 3.8).

3.2.2.1.1 Short-period frequency and acceleration sensitivity. The equivalent short-period undamped natural frequency, ω_{nSP}, shall be within the limits shown on figures 1, 2 and 3. If suitable means of directly controlling normal force are provided, the lower bounds on ω_{nSP} and n/α of figure 3 may be relaxed if approved by the procuring activity.

3.2.2.1.2 Short-period damping. The equivalent short-period damping ratio, ζ_{SP}, shall be within the limits of table IV.

TABLE IV. Short-period damping ratio limits.

Level	Category A and C Flight Phases		Category B Flight Phases	
	Minimum	Maximum	Minimum	Maximum
1	0.35	1.30	0.30	2.00
2	0.25	2.00	0.20	2.00
3	0.15*	-	0.15*	-

*May be reduced at altitudes above 20,000 feet if approved by the procuring activity.

3.2.2.1.3 Residual oscillations. Any sustained residual oscillations in calm air shall not interfere with the pilot's ability to perform the tasks required in service use of the airplane. For Levels 1 and 2, oscillations in normal acceleration at the pilot's station greater than ±0.05g will be considered excessive for any Flight Phase, as will pitch attitude oscillations greater than ±3 mils for Category A Flight Phases requiring precise control of attitude. These requirements shall apply with the pitch control fixed and with it free.

3.2.2.2 Control feel and stability in maneuvering flight at constant speed. In steady turning flight and in pullups at constant speed, there shall be no tendency for the airplane pitch attitude or angle of attack to diverge aperiodically with controls fixed or with controls free. For the above conditions, the incremental control force and control deflection required to maintain a change in normal load factor and pitch rate shall be in the same sense (aft-more positive, forward-more negative) as those required to initiate the change. These requirements apply for all local gradients throughout the range of service load factors defined in 3.1.8.4.

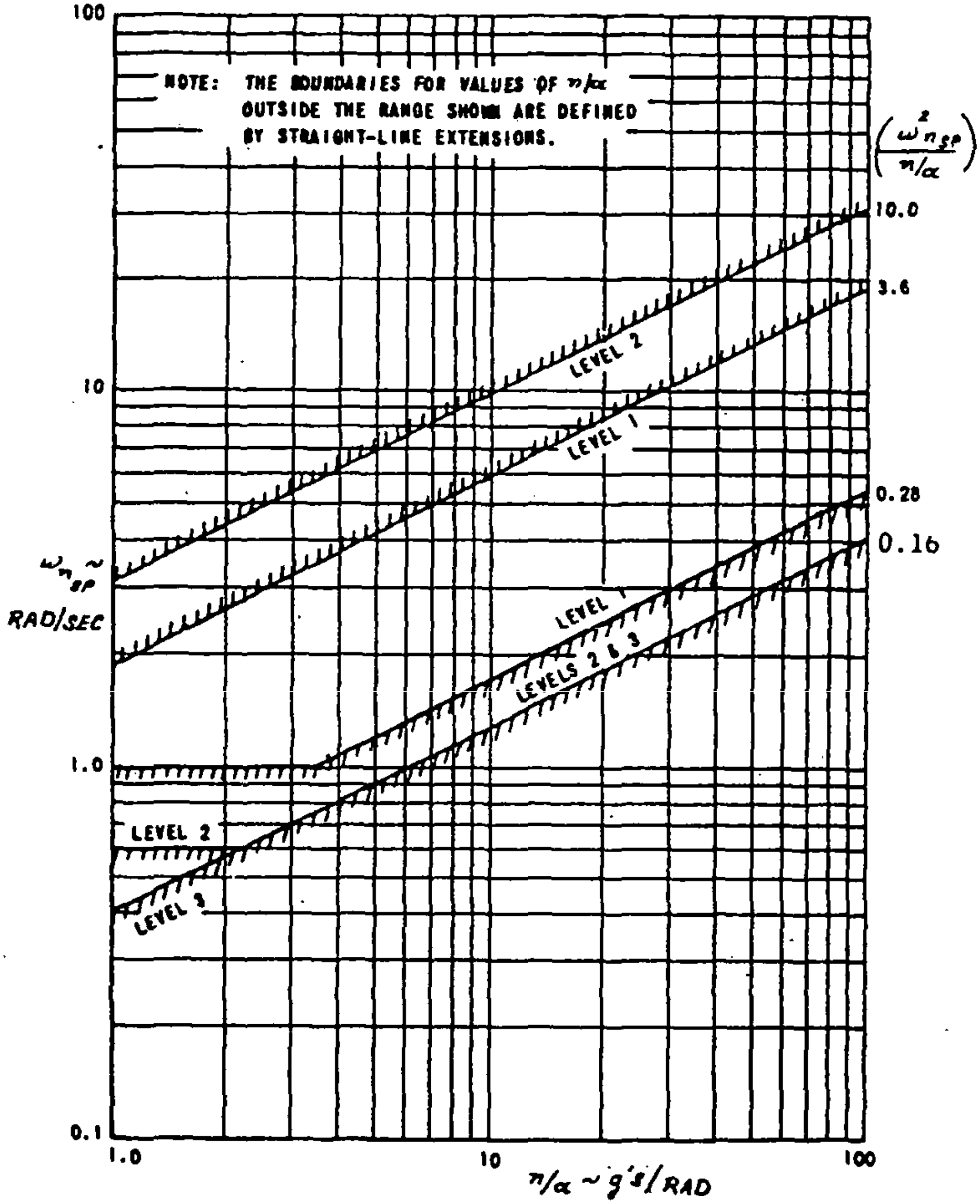


FIGURE 1. Short-period frequency requirements - Category A Flight Phases.

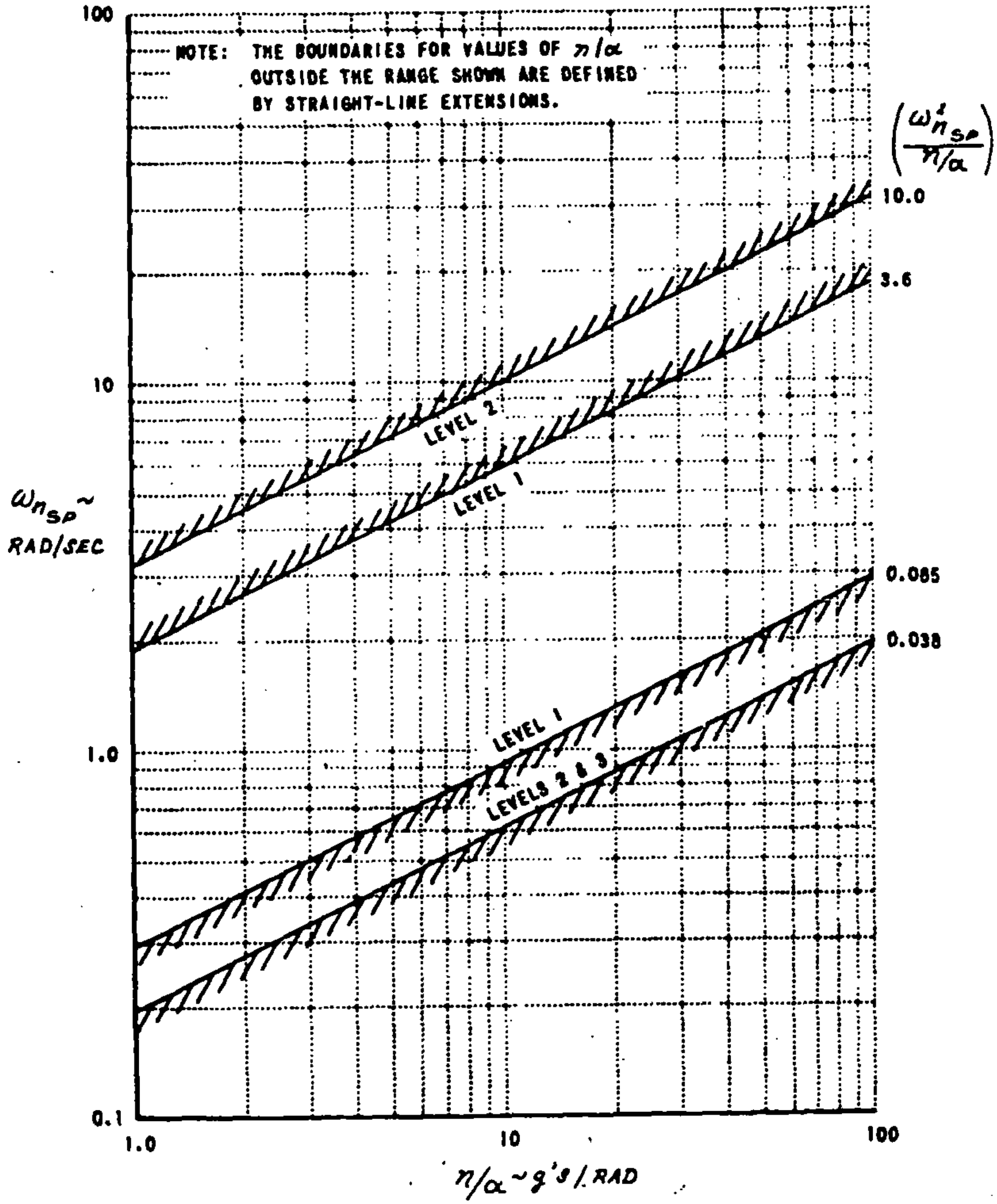


FIGURE 2. Short-period frequency requirements - Category B Flight Phases.

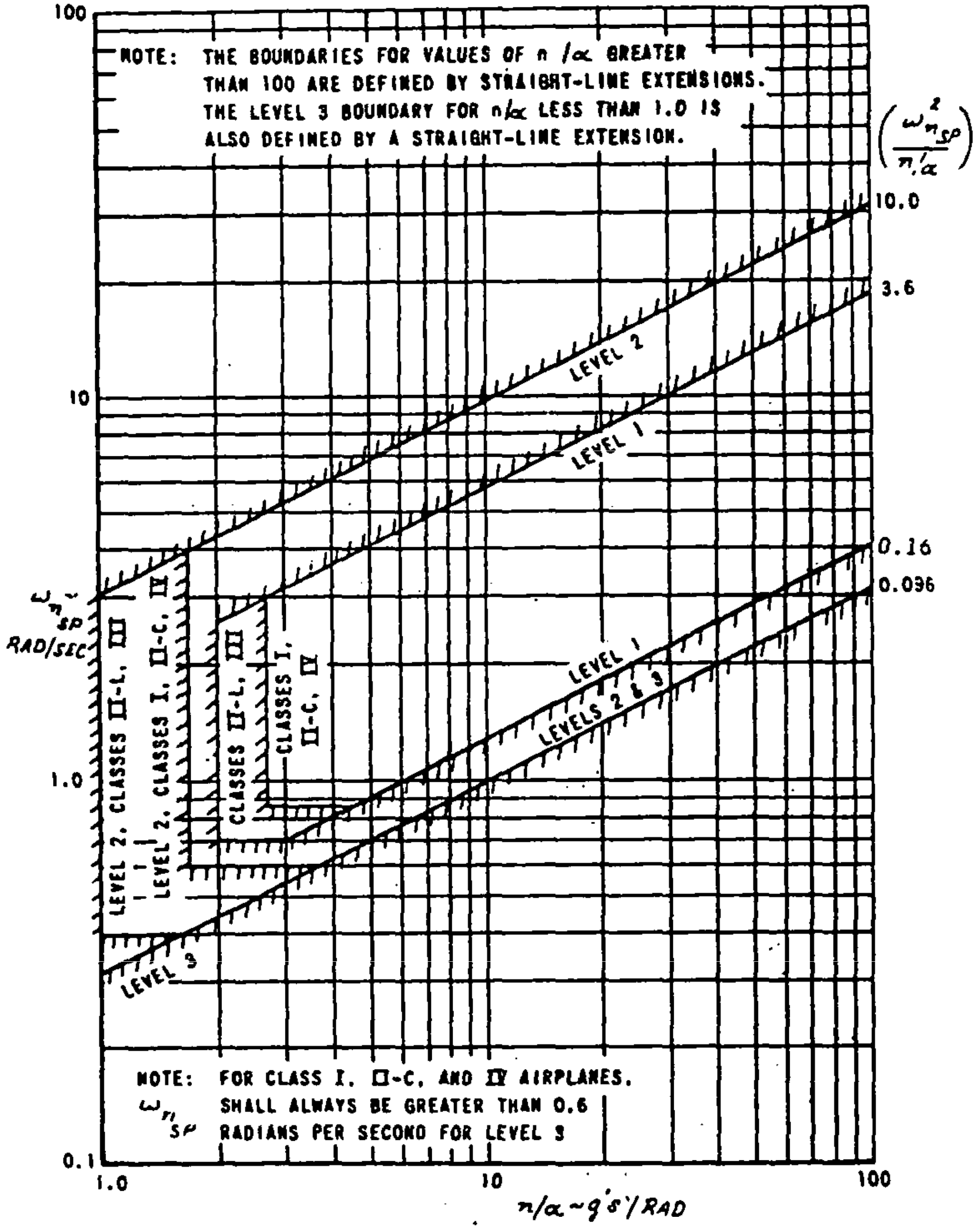


FIGURE 3. Short-period frequency requirements - Category C Flight Phases.

3.2.2.2.1 Control forces in maneuvering flight. At constant speed in steady turning flight, pullups and pushovers, the variation in pitch controller force with steady-state normal acceleration shall have no objectionable non-linearities within the following load factor ranges:

Class	Min.	Max.
I, II & III	.5	$.5[n_o(+) + 1]$ or 3
IV	0	whichever is less

Outside this range, a departure from linearity resulting in a local gradient which differs from the average gradient for the maneuver by more than 50 percent is considered excessive, except that larger increases in force gradient are permissible at load factors greater than 0.85 n_L. All local force gradients shall be within the limits of table V. In addition, F_s/n_z should be near the Level 1 upper boundaries of table V for combinations of high frequency and low damping. The term gradient does not include that portion of the force versus n_z curve within the breakout force.

Since the range of acceptable force gradients for side stick controllers varies with the control deflection gradient and the task to be performed, the contractor shall show that the control force gradients will produce suitable flying qualities.

3.2.2.2.2 Control motions in maneuvering flight. For all types of pitch controllers, the control motions in maneuvering flight shall not be so large or so small as to be objectionable. For Category A Flight Phases, the average gradient of pitch-control force per unit of pitch-control deflection at constant speed shall not be less than 5 pounds per inch for wheel and center-stick controllers or 2.0 pounds per degree for side-stick controllers for Levels 1 and 2.

3.2.2.3 Longitudinal pilot-induced oscillations. There shall be no tendency for pilot-induced oscillations, that is, sustained or uncontrollable oscillations resulting from the efforts of the pilot to control the airplane. The pitch attitude response dynamics of the airframe plus control system shall not change abruptly with the motion amplitudes of pitch, pitch rate or normal acceleration unless it can be shown that this will not result in a pilot-induced oscillation. The requirements in 3.2.2.3.1 and 3.2.2.3.2 shall be met for all expected airplane motion amplitudes and frequencies, starting at any service load factor.

3.2.2.3.1 Dynamic control forces in maneuvering flight. The frequency response of normal acceleration at the pilot to pitch control force shall be such that the inverse amplitude is greater than the following for all frequencies greater than 1.0 rad/sec. Units are pounds per g.

	Level 1	Level 2	Level 3
One-handed Controllers	$\frac{14}{n_L-1}$	$\frac{12}{n_L-1}$	$\frac{8}{n_L-1}$
Two-handed Controllers	$\frac{30}{n_L-1}$	$\frac{25}{n_L-1}$	$\frac{17}{n_L-1}$

TABLE V. Pitch maneuvering force gradient limits.

Center Stick Controllers

Level	Maximum Gradient, $(F_s/n)_{max}$, pounds per g	Minimum Gradient $(F_s/n)_{min}$, pounds per g
1	$\frac{240}{n/\alpha}$ but not more than 28.0 nor less than $\frac{56}{n_L-1}$ *	The higher of $\frac{21}{n_L-1}$ and 3.0
2	$\frac{360}{n/\alpha}$ but not more than 42.5 nor less than $\frac{85}{n_L-1}$	The higher of $\frac{18}{n_L-1}$ and 3.0
3	56.0	The higher of $\frac{12}{n_L-1}$ and 2.0

*For $n_L<3$, $(F_s/n)_{max}$ is 28.0 for Level 1, 42.5 for Level 2.

Wheel Controllers

Level	Maximum Gradient, $(F_s/n)_{max}$, pounds per g	Minimum Gradient, $(F_s/n)_{min}$, pounds per g
1	$\frac{500}{n/\alpha}$ but not more than 120.0 nor less than $\frac{120}{n_L-1}$	The higher of $\frac{35}{n_L-1}$ and 6.0
2	$\frac{775}{n/\alpha}$ but not more than 182.0 nor less than $\frac{182}{n_L-1}$	The higher of $\frac{30}{n_L-1}$ and 6.0
3	240.0	5.0

3.2.2.3.2 Control feel. The deflection of the pilot's control must not lead the control force throughout the frequency range of pilot control inputs. In addition, the peak pitch control forces developed during abrupt maneuvers shall not be objectionably light, and the buildup of control force during the maneuver entry shall lead the buildup of normal acceleration.

3.2.3 Longitudinal control

3.2.3.1 Longitudinal control in unaccelerated flight. In erect unaccelerated flight at all service altitudes, the attainment of all speeds between V_S and V_{max} shall not be limited by the effectiveness of the longitudinal control or controls.

3.2.3.2 Longitudinal control in maneuvering flight. Within the Operational Flight Envelope, it shall be possible to develop, by use of the pitch control alone, the following range of load factors:

Levels 1 and 2 ----- $n_o(-)$ to $n_o(+)$

Level 3 ----- $n = 0.5g$ to the lower of:

a) $n_o(+)$

b) $n = 2.0$ for $n_o(+) \leq 3g$
$0.5\,[n_o(+) + 1]$ for $n_o(+) > 3g$

This maneuvering capability is required at the 1g trim speed and, with trim and throttle settings not changed by the crew, over a range about the trim speed the lesser of ±15 percent or ±50 knots equivalent airspeed (except where limited by the boundaries of the Operational Flight Envelope). Within the Service and Permissible Flight Envelopes, the dive-recovery requirements of 3.2.3.5 and 3.2.3.6, respectively, shall be met.

3.2.3.3 Longitudinal control in takeoff. The effectiveness of the pitch control shall not restrict the takeoff performance of the airplane and shall be sufficient to prevent over-rotation to undesirable attitudes during takeoffs. Satisfactory takeoffs shall not be dependent upon use of the trimmer control during takeoff or on complicated control manipulation by the pilot. For nose-wheel airplanes it shall be possible to obtain, at $0.9\ V_{min}$, the pitch attitude which will result in takeoff at V_{min}. For tail-wheel airplanes, it shall be possible to maintain any pitch attitude up to that for a level thrust-line at $0.5\ V_S$ for Class I airplanes and at V_S for Class II, III, and IV airplanes. These requirements shall be met on hard-surfaced runways. In the event that an airplane has a mission requirement for operation from unprepared fields, these requirements shall be met on such fields.

3.2.3.3.1 Longitudinal control in catapult takeoff. On airplanes designed for catapult takeoff, the effectiveness of the pitch control shall be sufficient to prevent the airplane from pitching up or down to undesirable attitudes in catapult takeoffs at speeds ranging from the minimum safe launching speed to a launching speed 30 knots higher than the minimum. Satisfactory catapult takeoffs shall not depend upon complicated control manipulation by the pilot.

3.2.3.3.2 Longitudinal control force and travel in takeoff. With the trim setting optional but fixed, the pitch-control forces required during all types of takeoffs for which the airplane is designed, including short-field takeoffs and assisted takeoffs such as catapult or rocket-augmented, shall be within the following limits:

Nose-wheel and bicycle-gear airplanes

Classes I, IV-C -------- 20 pounds pull to 10 pounds push

Classes II-C, IV-L ----- 30 pounds pull to 10 pounds push

Classes II-L, III ------ 50 pounds pull to 20 pounds push

Tail-wheel airplanes

Classes I, II-C, IV ---- 20 pounds push to 10 pounds pull

Classes II-L, III ------ 35 pounds push to 15 pounds pull

The pitch-control travel during these takeoffs shall not exceed 75 percent of the total travel, stop-to-stop. Here the term takeoff includes the ground run, rotation and lift-off, the ensuing acceleration to V_{max} (TO), and the transient caused by assist cessation. Takeoff power shall be maintained until V_{max} (TO) is reached, with the landing gear and high-lift devices retracted in the normal manner at speeds from $V_{o_{min}}$(TO) to V_{max}(TO).

3.2.3.4 Longitudinal control in landing. The pitch control shall be sufficiently effective in the landing Flight Phase in close proximity to the ground, that in calm air:

a. The geometry-limited touchdown attitude can be maintained in level flight, or

b. The lower of V_S(L) or the guaranteed landing speed can be obtained.

This requirement shall be met with the airplane trimmed for the approach Flight Phase at the recommended approach speed. The requirements of 3.2.3.4 and 3.2.3.4.1 define Levels 1 and 2, and the requirements of 3.4.10 define Level 3.

3.2.3.4.1 Longitudinal control forces in landing. The pitch-control forces required to meet the requirements of 3.2.3.4 shall be pull forces and shall not exceed:

Classes I, II-C, IV ----- 35 pounds

Classes II-L, III ------- 50 pounds

3.2.3.5 Longitudinal control forces in dives - Service Flight Envelope. With the airplane trimmed for level flight at speeds throughout the Service Flight Envelope, the control forces in dives to all attainable speeds within the Service Flight Envelope shall not exceed 50 pounds push or 10 pounds pull for center-stick controllers, nor 75 pounds push or 15 pounds pull for wheel controllers. In similar dives, but with trim optional following the dive entry, it shall be possible with normal piloting techniques to maintain the forces within the limits of 10 pounds push or pull for center-stick controllers, and 20 pounds push or pull for wheel controllers. In event that operation of the trim system requires removal of one hand from a wheel control the force limits shall be as for a center-stick. The forces required for recovery from these dives shall be in accordance with the gradients specified in 3.2.2.2.1 although speed may vary during the pullout.

3.2.3.6 Longitudinal control forces in dives - Permissible Flight Envelope. With the airplane trimmed for level flight at V_{MAT} but with trim optional in the dive, it shall be possible to maintain the pitch control force within the limits of 50 pounds push or 35 pounds pull in dives to all attainable speeds within the Permissible Flight Envelope. The force required for recovery from these dives shall not exceed 120 pounds. Trim and deceleration devices, etc., may be used to assist in recovery if no unusual pilot technique is required.

3.2.3.7 Longitudinal control in sideslips. With the airplane trimmed for straight, level flight with zero sideslip, the pitch-control force required to maintain constant speed in steady sideslips with up to 50 pounds of pedal force in either direction shall not exceed the pitch-control force that would result in a 1g change in normal acceleration. In no case, however, shall the pitch-control force exceed:

Center-stick controllers ----- 10 pounds pull to 3 pounds push

Wheel controllers ------------ 15 pounds pull to 10 pounds push

If a variation of pitch-control force with sideslip does exist, it is preferred that increasing pull force accompany increasing sideslip, and that the magnitude and direction of the force change be similar for right and left sideslips. These requirements define Levels 1 and 2. For Level 3 there shall be no uncontrollable pitching motions associated with the sideslips discussed above.

3.3 Lateral-directional flying qualities

3.3.1 Lateral-directional mode characteristics

3.3.1.1 Lateral-directional oscillations (Dutch roll). The frequency, ω_{n_d}, and damping ratio, ζ_d, of the lateral-directional oscillations following a yaw disturbance input shall exceed the minimum values in table VI. The requirements shall be met in trimmed and in maneuvering flight with cockpit controls fixed and with them free, in oscillations of any magnitude that might be experienced in operational use. If the oscillation is nonlinear with amplitude, the requirement shall apply to each cycle of the oscillation. In calm air residual oscillations may be tolerated only if the amplitude is sufficiently small that the motions are not objectionable and do not impair mission performance. For Category A Flight Phases, angular deviations shall be less than ±3 mils.

TABLE VI. Minimum Dutch roll frequency and damping.

Level	Flight Phase Category	Class	Min ζ_d *	Min $\zeta_d\omega_{n_d}$ * rad/sec.	Min ω_{n_d} rad/sec.
1	A (CO and GA)	IV	0.4	-	1.0
1	A	I, IV	0.19	0.35	1.0
1	A	II, III	0.19	0.35	0.4**
1	B	All	0.08	0.15	0.4**
1	C	I, II-C, IV	0.08	0.15	1.0
1	C	II-L, III	0.08	0.10	0.4**
2	All	All	0.02	0.05	0.4**
3	All	All	0	-	0.4**

* The governing damping requirement is that yielding the larger value of ζ_d, except that a ζ_d of 0.7 is the maximum required for Class III.

** Class III airplanes may be excepted from the minimum ω_{n_d} requirement, subject to approval by the procuring activity, if the requirements of 3.3.2 through 3.3.2.4.1, 3.3.5 and 3.3.9.4 are met.

When $\omega_{n_d}^2|\phi/\beta|_d$ is greater than 20 (rad/sec)^2, the minimum $\zeta_d\omega_{n_d}$ shall be increased above the $\zeta_d\omega_{n_d}$ minimums listed above by:

Level 1 - $\Delta\zeta_d\omega_{n_d} = .014(\omega_{n_d}^2 |\phi/\beta|_d - 20)$

Level 2 - $\Delta\zeta_d\omega_{n_d} = .009(\omega_{n_d}^2 |\phi/\beta|_d - 20)$

Level 3 - $\Delta\zeta_d\omega_{n_d} = .005(\omega_{n_d}^2 |\phi/\beta|_d - 20)$

with ω_{n_d} in rad/sec.

3.3.1.2 Roll mode. The roll-mode time constant, τ_R, shall be no greater than the appropriate value in table VII.

TABLE VII. Maximum roll-mode time constant, seconds.

Flight Phase Category	Class	Level 1	Level 2	Level 3
A	I, IV	1.0	1.4	
	II, III	1.4	3.0	
B	All	1.4	3.0	10
C	I, II-C, IV	1.0	1.4	
	II-L, III	1.4	3.0	

3.3.1.3 Spiral stability. The combined effects of spiral stability, flight-control-system characteristics and rolling moment change with speed shall be such that following a disturbance in bank of up to 20 degrees, the time for the bank angle to double shall be greater than the values in table VIII. This requirement shall be met with the airplane trimmed for wings-level, zero-yaw-rate flight with the cockpit controls free.

TABLE VIII. Spiral stability - minimum time to double amplitude.

Flight Phase Category	Level 1	Level 2	Level 3
A & C	12 sec	8 sec	4 sec
B	20 sec	8 sec	4 sec

3.3.1.4 Coupled roll-spiral oscillation. For Flight Phases which involve more than gentle maneuvering, such as CO and GA, the airplane characteristics shall not exhibit a coupled roll-spiral mode in response to the pilot roll control commands. A coupled roll-spiral mode will be permitted for Category B and C Flight Phases provided the product of frequency and damping ratio exceeds the following requirements:

Level	$\zeta_{RS}\omega_{n_{RS}}$, rad/sec
1	0.5
2	0.3
3	0.15

3.3.2 Lateral-directional dynamic response characteristics. Lateral-directional dynamic response characteristics are stated in terms of response to atmospheric disturbances and in terms of allowable roll rate and bank oscillations, sideslip excursions, roll control forces and yaw control forces that occur during specified rolling and turning maneuvers both to the right and to the left. The requirements of 3.3.2.2, 3.3.2.3 and 3.3.2.4 apply for roll commands of all magnitudes up to the magnitude required to meet the roll performance requirements of 3.3.4 and 3.3.4.1.

3.3.2.1 Lateral-directional response to atmospheric disturbances. The combined effect of ω_{nd}, ζ_d, T_R, $|\phi/\beta|_d$, ψ_β, gust sensitivity, and flight-control-system nonlinearities on response and controllability characteristics in atmospheric disturbances shall be considered (see 3.8.3). In particular, the roll acceleration, rate and displacement responses to side gusts shall be investigated for airplanes with large rolling moment due to sideslip.

3.3.2.2 Roll rate oscillations. Following a yaw-control-free step roll control command, the roll rate at the first minimum following the first peak shall be of the same sign and not less than the following percentage of the roll rate at the first peak:

Level	Flight Phase Category	Percent
1	A & C	60
	B	25
2	A & C	25
	B	0

For all Levels, the change in bank angle shall always be in the direction of the roll control command. The roll command shall be held fixed until the bank angle has changed at least 90 degrees.

3.3.2.2.1 Additional roll rate requirement for small inputs. The value of the parameter P_{osc}/P_{av} following a yaw-control-free step roll command shall be within the limits shown on figure 4 for Levels 1 and 2. This requirement applies for step roll-control commands up to the magnitude which causes a 60-degree bank angle change in $1.7T_d$ seconds.

3.3.2.3 Bank angle oscillations. The value of the parameter ϕ_{OSC}/ϕ_{AV} following a yaw-control-free impulse roll control command shall be within the limits as shown on figure 5 for Levels 1 and 2. The impulse shall be as abrupt as practical within the strength limits of the pilot and the rate limits of the roll control system.

3.3.2.4 Sideslip excursions. Following a yaw-control-free step roll control command, the ratio of the sideslip increment, $\Delta\beta$ to the parameter k (6.2.6) shall be less than the values specified herein. The roll command shall be held fixed until the bank angle has changed at least 90 degrees.

Level	Flight Phase Category	Adverse Sideslip (Right roll command causes right sideslip	Proverse Sideslip (Right roll command causes left sideslip
1	A	6 degrees	2 degrees
	B & C	10 degrees	3 degrees
2	All	15 degrees	4 degrees

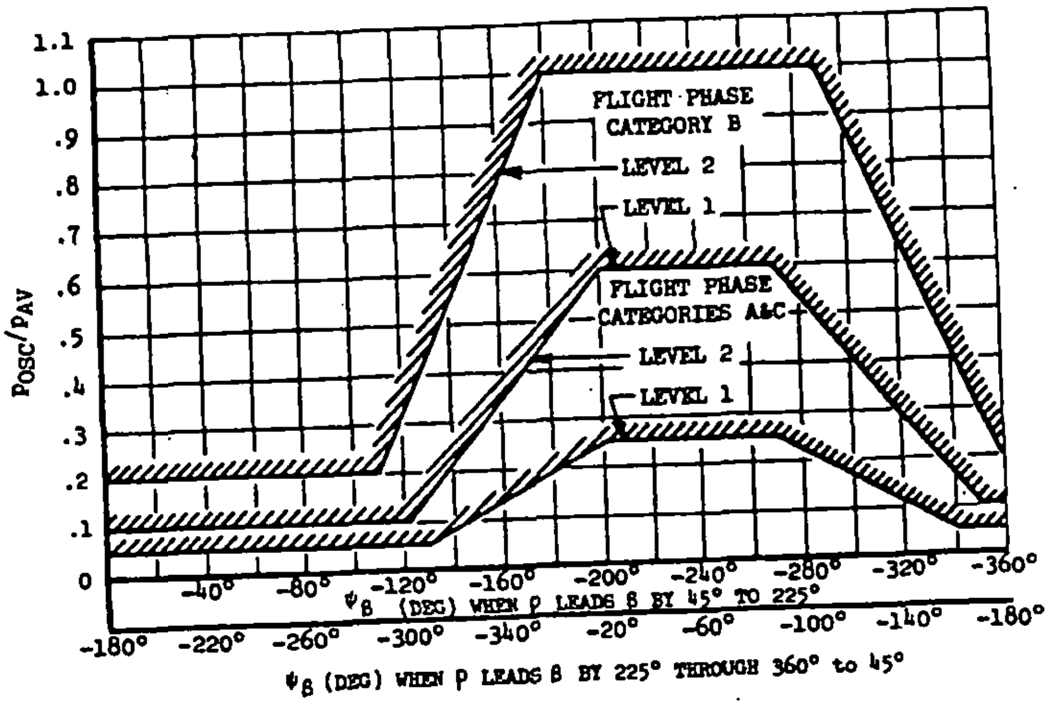


FIGURE 4. Roll rate oscillation limitations.

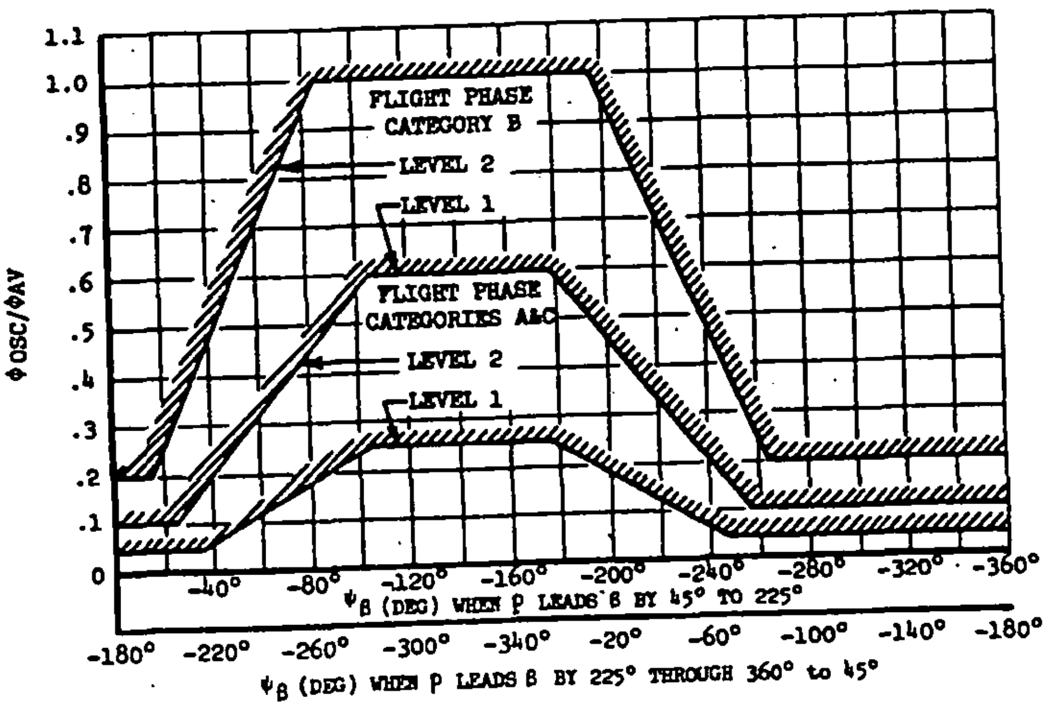


FIGURE 5. Bank angle oscillation limitations.

3.3.2.4.1 Additional sideslip requirement for small inputs. The amount of sideslip following a yaw-control-free step roll control command shall be within the limits as shown on figure 6 for Levels 1 and 2. This requirement shall apply for step roll control commands up to the magnitude which causes a 60-degree bank angle change within T_d or 2 seconds, whichever is longer.

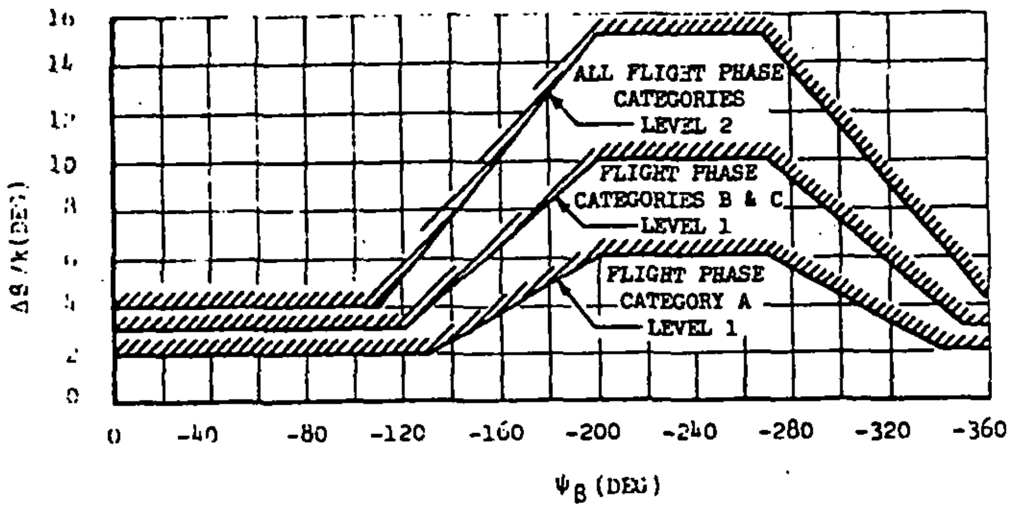


FIGURE 6. Sideslip excursion limitations.

3.3.2.5 Control of sideslip in rolls. In the rolling maneuvers described in 3.3.4, but with coordination allowed for all Classes, directional-control effectiveness shall be adequate to maintain zero sideslip with pedal force not greater than 50 pounds for Class IV airplanes in Flight Phase Category A, Level 1, and 100 pounds for all other combinations of Class, Flight Phase Category and Level.

3.3.2.6 Turn coordination. It shall be possible to maintain steady coordinated turns in either direction, using 60 degrees of bank for Class IV airplanes, 45 degrees of bank for Class I and II airplanes, and 30 degrees of bank for Class III airplanes, with a pedal force not exceeding 40 pounds. It shall be possible to perform steady turns at the same bank angles with yaw controls free, with a roll stick force not exceeding 5 pounds or a roll wheel force not exceeding 10 pounds. These requirements constitute Levels 1 and 2, with the airplane trimmed for wings-level straight flight.

3.3.3 Pilot-induced oscillations. There shall be no tendency for sustained or uncontrollable lateral-directional oscillations resulting from efforts of the pilot to control the airplane.

3.3.4 Roll control effectiveness. Roll performance in terms of a bank angle change in a given time, ϕ_t, is specified in table IXa for Class I and Class II airplanes, in 3.3.4.1 for Class IV airplanes, and in 3.3.4.2 for Class III airplanes. For rolls from banked flight, the initial condition shall be coordinated, that is, zero lateral acceleration. The requirements apply to roll commands to the right and to the left, initiated both from steady bank angles and from wings-level flight except as otherwise stated. Inputs shall be abrupt, with time measured from the initiation of control force application. The pitch control shall be fixed throughout the maneuver. Yaw control pedals shall remain free for Class IV airplanes for Level 1, and for all carrier-based airplanes in Category C Flight Phases for Levels 1 and 2; but otherwise, yaw control pedals may be used to reduce sideslip that retards roll rate (not to produce sideslip which augments roll rate) if such control inputs are simple, easily coordinated with roll control inputs and consistent with piloting techniques for the airplane class and mission. For Flight Phase TO, the time required to bank may be increased proportional to the ratio of the rolling moment of inertia at takeoff to the largest rolling moment of inertia at landing, for weights up to the maximum authorized landing weight.

TABLE IXa. Roll performance for Class I and II airplanes.

Time to Achieve The Following Bank Angle Change (Seconds)

Class	Level	Category A 60°	Category A 45°	Category B 60°	Category B 45°	Category C 30°	Category C 25°
I	1	1.3		1.7		1.3	
I	2	1.7		2.5		1.8	
I	3	2.6		3.4		2.6	
II-L	1		1.4		1.9	1.8	
II-L	2		1.9		2.8	2.5	
II-L	3		2.8		3.8	3.6	
II-C	1		1.4		1.9		1.0
II-C	2		1.9		2.8		1.5
II-C	3		2.8		3.8		2.0

3.3.4.1 Roll performance for Class IV airplanes. Roll performance in terms of ϕ_t for Class IV airplanes is specified in table IXb. Additional or alternate roll performance requirements are specified in 3.3.4.1.1 and 3.3.4.1.2; these requirements take precedence over table IXb. Roll performance for Class IV airplanes is specified over the following ranges of airspeeds:

Speed Range Symbol	Equivalent Airspeed Range For Level 1	Equivalent Airspeed Range For Levels 2 & 3
VL	$V_{o_{min}} \leq V < V_{min} + 20$ KTS	$V_{min} \leq V \leq V_{min} + 20$ KTS
L	$V_{min} + 20$ KTS(1) $\leq V < 1.4\ V_{min}$	$V_{min} + 20$ KTS $\leq V < 1.4\ V_{min}$
M	$1.4\ V_{o_{min}} \leq V < .7\ V_{max}$(2)	$1.4\ V_{min} \leq V < .7\ V_{max}$
H	$.7\ V_{max}$(2) $\leq V \leq V_{o_{max}}$	$.7\ V_{max} \leq V \leq V_{max}$

(1) or $V_{o_{min}}$ whichever is greater

(2) or $V_{o_{max}}$ whichever is less

TABLE IXb. Roll performance for Class IV airplanes.

Time to Achieve The Following Bank Angle Change (Seconds)

Level	Speed Range	Category A 30°	Category A 50°	Category A 90°	Category B 90°	Category C 30°
1	VL	1.1			2.0	1.1
	L	1.1			1.7	1.1
	M			1.3	1.7	1.1
	H		1.1		1.7	1.1
2	VL	1.6			2.8	1.3
	L	1.5			2.5	1.3
	M			1.7	2.5	1.3
	H		1.3		2.5	1.3
3	VL	2.6			3.7	2.0
	L	2.0			3.4	2.0
	M			2.6	3.4	2.0
	H		2.6		3.4	2.0

3.3.4.1.1 Roll performance in Flight Phase CO. Roll performance for Class IV airplanes in Flight Phase CO is specified in table IXc in terms of ϕ_t for 360° rolls initiated at 1g, and in table IXd for rolls initiated at load factors between $.8n_o(-)$ and $.8n_o$ (+).

3.3.4.1.2 Roll performance in Flight Phase GA. The roll performance requirements for Class IV airplanes in Flight Phase GA with large complements of external stores may be relaxed from those specified in table IXb, subject to approval by the procuring activity. For any external loading specified in the contract, however, the roll performance shall be not less than that in table IXe where the roll performance is specified in terms of ϕ_t for rolls initiated at load factors between $.8n_o(-)$ and $.8n_o(+)$. For any asymmetric loading specified in the contract, roll control power shall be sufficient to hold the wings level at the maximum load factors specified in 3.2.3.2 with adequate control margin (3.4.10).

3.3.4.1.3 Roll response. Stick-controlled Class IV airplanes in Category A Flight Phase shall have a roll response to roll control force not greater than 15 degrees in 1 second per pound for Level 1, and not greater than 25 degrees in 1 second per pound for Level 2. For Category C Flight Phases, the roll sensitivity shall be not greater than 7.5 degrees in 1 second per pound for Level 1, and not greater than 12.5 degrees in 1 second per pound for Level 2. In case of conflict between the requirements of 3.3.4.1.3 and 3.3.4.3, the requirements of 3.3.4.1.3 shall govern. The term sensitivity does not include breakout force.

TABLE IXc. Flight Phase CO roll performance in 360° rolls.

Time to Achieve The Following Bank Angle Change (Seconds).

Level	Speed Range	30°	90°	180°	360°
1	VL L M H	1.0	 1.4 1.0 1.4	 2.3 1.6 2.3	 4.1 2.8 4.1
2	VL L M H	1.6 1.3	 1.3 1.7	 2.0 2.6	 3.4 4.4
3	VL L M H	2.5 2.0	 1.7 2.1	3.0	

TABLE IXd. Flight Phase CO roll performance.

Time to Achieve The Following Bank Angle Change (Seconds).

Level	Speed Range	30°	50°	90°	180°
1	VL L M H	1.0	 1.1 1.0	1.1	2.2
2	VL L M H	1.6 1.3	 1.4	1.4	2.8
3	VL L M H	2.5 2.0	 1.7	1.7	3.4

TABLE IXe. Flight Phase GA roll performance.

Time to Achieve The Following Bank Angle Change (Seconds).

Level	Speed Range	30°	50°	90°	180°
1	VL	1.5			
	L		1.7		
	M			1.7	3.0
	H		1.5		
2	VL	2.8			
	L	2.2			
	M			2.4	4.2
	H		2.4		
3	VL	4.4			
	L	3.8			
	M			3.4	6.0
	H		3.4		

3.3.4.2 Roll performance for Class III airplanes. Roll performance in terms of ϕ_t for Class III airplanes is specified in table IXf over the following ranges of airspeeds:

Speed Range Symbol	Airspeed Range For Level 1	Airspeed Range For Levels 2 & 3
L	$V_{o_{min}} \leq V < 1.8\ V_{min}$	$V_{min} \leq V < 1.8\ V_{min}$
M	$1.8\ V_{min}$ (1) $\leq V < .7\ V_{max}$ (2)	$1.8\ V_{min} \leq V < .7\ V_{max}$
H	$.7\ V_{max}$ (2) $\leq V \leq V_{o_{max}}$	$.7\ V_{max} \leq V \leq V_{max}$

(1) Or $V_{o_{min}}$ whichever is greater (2) Or $V_{o_{max}}$ whichever is less

TABLE IXf. Class III roll performance.

Time to Achieve 30° Bank Angle Change (Seconds).

Level	Speed Range	Category A	Category B	Category C
1	L	1.8	2.3	2.5
	M	1.5	2.0	2.5
	H	2.0	2.3	2.5
2	L	2.4	3.9	4.0
	M	2.0	3.3	4.0
	H	2.5	3.9	4.0
3	All	3.0	5.0	6.0

3.3.4.3 Roll control forces. The stick or wheel force required to obtain the rolling performance specified in 3.3.4, 3.3.4.1 and 3.3.4.2 shall be neither greater than the maximum in table X nor less than the breakout force plus:

a. Level 1 ----- one-fourth the values in table X

b. Level 2 ----- one-eighth the values in table X

c. Level 3 ----- zero

TABLE X. Maximum roll control force.

Level	Class	Flight Phase Category	Maximum Stick Force (Pound)	Maximum Wheel Force (Pound)
1	I, II-C, IV	A, B	20	40
		C	20	20
	II-L, III	A, B	25	50
		C	25	25
2	I, II-C, IV	A, B	30	60
		C	20	20
	II-L, III	A, B	30	60
		C	30	30
3	All	All	35	70

3.3.4.4 Linearity of roll response. There shall be no objectionable nonlinearities in the variation of rolling response with roll control deflection or force. Sensitivity or sluggishness in response to small control deflections or force shall be avoided.

3.3.4.5 Wheel control throw. For airplanes with wheel controllers, the wheel throw necessary to meet the roll performance requirements specified in 3.3.4 and 3.3.4.2 shall not exceed 60 degrees in either direction. For completely mechanical systems, the requirement may be relaxed to 80 degrees.

3.3.5 Directional control characteristics. Directional stability and control characteristics shall enable the pilot to balance yawing moments and control yaw and sideslip. Sensitivity to yaw control pedal forces shall be sufficiently high that directional control and force requirements can be met and satisfactory coordination can be achieved without unduly high pedal forces, yet sufficiently low that occasional improperly coordinated control inputs will not seriously degrade the flying qualities.

3.3.5.1 Directional control with speed change. When initially trimmed directionally with symmetric power, the trim change of propeller-driven airplanes with speed shall be such that wings-level straight flight can be maintained over a speed range of ±30 percent of the trim speed or ±100 knots equivalent airspeed, whichever is less (except where limited by boundaries of the Service Flight Envelope) with yaw-control-pedal forces not greater than

100 pounds for Levels 1 and 2 and not greater than 180 pounds for Level 3, without retrimming. For other airplanes, yaw-control-pedal forces shall not exceed 40 pounds at the specified conditions for Level 1 and 2 or 180 pounds for Level 3.

3.3.5.1.1 Directional control with asymmetric loading. When initially trimmed directionally with each asymmetric loading specified in the contract at any speed in the Operational Flight Envelope, it shall be possible to maintain a straight flight path throughout the Operational Flight Envelope with yaw-control-pedal forces not greater than 100 pounds for Levels 1 and 2 and not greater than 180 pounds for Level 3, without retrimming.

3.3.5.2 Directional control in wave-off (go-around). For propeller-driven Class IV, and all propeller-driven carrier-based airplanes the response to thrust, configuration and airspeed change shall be such that the pilot can maintain straight flight during wave-off (go-around) initiated at speeds down to V_S (PA) with yaw-control-pedal forces not exceeding 100 pounds when trimmed at $V_{o_{min}}$ (PA). For other airplanes, yaw-control-pedal forces shall not exceed 40 pounds for the specified conditions. The preceding requirements apply for Levels 1 and 2. For all airplanes the Level 3 requirement is to maintain straight flight in these conditions with yaw-control-pedal forces not exceeding 180 pounds. For all Levels, bank angles up to 5 degrees are permitted.

3.3.6 Lateral-directional characteristics in steady sideslips. The requirements of 3.3.6.1 through 3.3.6.3.1 and 3.3.7.1 are expressed in terms of characteristics in yaw-control-induced steady, zero-yaw-rate sideslips with the airplane trimmed for wings-level straight flight. Requirements of 3.3.6.1 through 3.3.6.3 apply at sideslip angles up to those produced or limited by:

a. Full yaw-control-pedal deflection, or

b. 250 pounds of yaw-control-pedal force, or

c. Maximum roll control or surface deflection,

except that for single-propeller-driven airplanes during wave-off (go-around), yaw-control-pedal deflection in the direction opposite to that required for wings-level straight flight need not be considered beyond the deflection for a 10-degree change in sideslip from the wings-level straight flight condition.

3.3.6.1 Yawing moments in steady sideslips. For sideslips specified in 3.3.6, right yaw-control-pedal deflection and force shall produce left sideslips and left yaw-control-pedal deflection and force shall produce right sideslips. For Levels 1 and 2 the following requirements shall apply. The variation of sideslip angle with yaw-control-pedal deflection shall be essentially linear for sideslip angles between +15 degrees and -15 degrees. For larger sideslip angles, an increase in yaw-control-pedal deflection shall always be required for an increase in sideslip. The variation of sideslip angle with yaw-control-pedal force shall be essentially linear for sideslip angles between +10 degrees and -10 degrees. Although a lightening of pedal force is acceptable for sideslip angles outside this range, the pedal force shall never reduce to zero.

3.3.6.2 Side forces in steady sideslips. For the sideslips of 3.3.6, an increase in right bank angle shall accompany an increase in right sideslip, and an increase in left bank angle shall accompany an increase in left sideslip.

3.3.6.3 Rolling moments in steady sideslips. For the sideslips of 3.3.6, left roll-control deflection and force shall accompany left sideslips, and right roll-control deflection and force shall accompany right sideslips. For Levels 1 and 2, the variation of roll-control deflection and force with sideslip angle shall be essentially linear.

3.3.6.3.1 Exception for wave-off (go-around). The requirement of 3.3.6.3 may, if necessary, be excepted for wave-off (go-around) if task performance is not impaired and no more than 50 percent of roll control power available to the pilot, and no more than 10 pounds of roll-control force, are required in a direction opposite to that specified in 3.3.6.3.

3.3.6.3.2 Positive effective dihedral limit. For Levels 1 and 2, positive effective dihedral (right roll control for right sideslip and left roll control for left sideslip) shall never be so great that more than 75 percent of roll control power available to the pilot, and no more than 10 pounds of roll-stick force or 20 pounds of roll-wheel force, are required for sideslip angles which might be experienced in service employment.

3.3.7 Lateral-directional control in crosswinds. It shall be possible to take off and land with normal pilot skill and technique in 90-degree crosswinds, from either side, of velocities up to those specified in table XI. Roll-control force shall be within the limits specified in 3.3.4.2, and yaw-control-pedal forces shall not exceed 100 pounds for Level 1 or 180 pounds for Levels 2 and 3. This requirement can normally be met through compliance with 3.3.7.1 and 3.3.7.2.

TABLE XI. Crosswind velocity.

Level	Class	Crosswind
1 and 2	I	20 knots
	II, III, & IV	30 knots
	Water-based airplanes	20 knots
3	All	one-half the values for Levels 1 and 2

3.3.7.1 Final approach in crosswinds. For all airplanes except land-based airplanes equipped with crosswind landing gear, or otherwise constructed to land in a large crabbed attitude, yaw- and roll-control power shall be adequate to develop at least 10 degrees of sideslip (3.3.6) in the power approach with yaw control pedal forces not exceeding the values specified in 3.3.7. For Level 1, roll control shall not exceed either 10 pounds of force or 75 percent of control power available to the pilot. For Levels 2 and 3, roll-control force shall not exceed 20 pounds.

3.3.7.2 Takeoff run and landing rollout in crosswinds. Yaw and roll control power, in conjunction with other normal means of control, shall be adequate to maintain a straight path on the ground or other landing surface. This requirement applies in calm air and in crosswinds up to the values specified in table XI with cockpit control forces not exceeding the values specified in 3.3.7.

3.3.7.2.1 Cold- and wet-weather operation. The requirements of 3.3.7.2 apply on wet runways for all airplanes, and on snow-packed and icy runways for airplanes intended to operate under such conditions. If compliance is not demonstrated under these adverse runway conditions, directional control shall be maintained by use of aerodynamic controls alone at all airspeeds above 50 knots for Class IV airplanes and above 30 knots for all others. For very slippery runways, the requirement need not apply for crosswind components at which the force tending to blow the airplane off the runway exceeds the opposing tire-runway frictional force with the tires supporting all of the airplane's weight.

3.3.7.2.2 Carrier-based airplanes. All carrier-based airplanes shall be capable of maintaining a straight path on the ground without the use of wheel brakes, at airspeeds of 30 knots and above, during takeoffs and landings in a 90-degree crosswind of at least 10 percent $V_S(L)$. Cockpit control forces shall be as specified in 3.3.7.

3.3.7.3 Taxiing wind speed limits. It shall be possible to taxi at any angle to a 35-knot wind for Class I airplanes and to a 45-knot wind for Class II, III, and IV airplanes.

3.3.8 Lateral-directional control in dives. Yaw and roll control power shall be adequate to maintain wings level and sideslip zero, without retrimming, throughout the dives and pullouts of 3.2.3.5 and 3.2.3.6. In the Service Flight Envelope, roll control forces shall not exceed 20 pounds for propeller-driven airplanes or 10 pounds for other airplanes. Yaw-control-pedal forces shall not exceed 180 pounds for propeller-driven airplanes or 50 pounds for other airplanes.

3.3.9 Lateral-directional control with asymmetric thrust. Asymmetric loss of thrust may be caused by many factors including engine failure, inlet unstart, propeller failure or propeller-drive failure. Following sudden asymmetric loss of thrust from any factor, the airplane shall be safely controllable in the crosswinds of table XI from the unfavorable direction. The requirements of 3.3.9.1 through 3.3.9.4 apply for the appropriate Flight Phases when any single failure or malperformance of the propulsive system, including inlet or exhaust, causes loss of thrust on one or more engines or propellers, considering also the effect of the failure or malperformance on all subsystems powered or driven by the failed propulsive system.

3.3.9.1 Thrust loss during takeoff run. It shall be possible for the pilot to maintain control of an airplane on the takeoff surface following sudden loss of thrust from the most critical factor. Thereafter, it shall be possible to achieve and maintain a straight path on the takeoff surface without a deviation of more than 30 feet from the path originally intended, with yaw-control-pedal forces not exceeding 180 pounds. For the continued takeoff, the requirement shall be met when thrust is lost at speeds from the refusal speed (based on the shortest runway from which the airplane is designed to operate) to the maximum takeoff speed, with takeoff thrust maintained on the operative engine(s), using only controls not dependent upon friction against the takeoff surface or upon release of the pitch, roll, yaw or throttle controls. For the aborted takeoff, the requirement shall be met at all speeds below the maximum takeoff speed; however, additional controls such as nosewheel steering and differential braking may be used. Automatic devices which normally operate in the event of a thrust failure may be used in either case.

3.3.9.2 Thrust loss after takeoff. During takeoff it shall be possible without a change in selected configuration to achieve straight flight following sudden asymmetric loss of thrust from the most critical factor at speeds from V_{min} (TO) to V_{max} (TO), and thereafter to maintain straight flight throughout the climbout. The yaw-control-pedal force required to maintain straight flight with asymmetric thrust shall not exceed 180 pounds. Roll control shall not exceed either the force limits specified in 3.3.4.2 or 75 percent of available control power, with takeoff thrust maintained on the operative engine(s) and trim at normal setting for takeoff with symmetric thrust. Automatic devices which normally operate in the event of a thrust failure may be used, and the airplane may be banked up to 5 degrees away from the inoperative engine.

3.3.9.3 Transient effects. The airplane motions following sudden asymmetric loss of thrust shall be such that dangerous conditions can be avoided by pilot corrective action. A realistic time delay (3.4.8) of a least 1 second shall be incorporated.

3.3.9.4 Asymmetric thrust - yaw controls free. The static directional stability shall be such that at all speeds above 1.4 V_{min}, with asymmetric loss of thrust from the most critical factor while the other engine(s) develop normal rated thrust, the airplane with yaw control pedals free may be balanced directionally in steady straight flight. The trim settings shall be those required for wings-level straight flight prior to the failure. Roll-control forces shall not exceed the Level 2 upper limits specified in 3.3.4.2 for Levels 1 and 2 and shall not exceed the Level 3 upper limits for Level 3.

3.3.9.5 Two engines inoperative. At the one-engine-out speed for maximum range with any engine initially failed, it shall be possible upon failure of the most critical remaining engine to stop the transient motion and thereafter to maintain straight flight from that speed to the speed for maximum range with both engines failed. In addition, it shall be possible to effect a safe recovery at any service speed above $V_{o_{min}}$ (CL) following sudden simultaneous failure of the two critical failing engines.

3.4 Miscellaneous flying qualities

3.4.1 Dangerous flight conditions. Dangerous conditions may exist where the airplane should not be flown. When approaching these flight conditions, it shall be possible by clearly discernible means for the pilot to recognize the impending dangers and take preventive action. Final determination of the adequacy of all warning of impending dangerous flight conditions will be made by the procuring activity, considering functional effectiveness and reliability.

3.4.1.1 Warning and indication. Warning or indication of approach to a dangerous condition shall be clear and unambiguous. For example, a pilot must be able to distinguish readily among stall warning (which requires pitching down or increasing speed), Mach buffet (which may indicate a need to decrease speed), and normal airplane vibration (which indicates no need for pilot action).

3.4.1.2 Devices for indication, warning, prevention, recovery. It is intended that dangerous flight conditions be eliminated and the requirements of this specification met by appropriate aerodynamic design and mass distribution, rather than through incorporation of a special device or devices. Such devices may be used only if the procuring activity approves the need, the design criteria, possible Special Failure States (3.1.6.2.1) and the devices themselves. As a minimum, these devices shall perform their function whenever needed but shall not limit flight within the Operational Flight Envelope. Neither normal nor inadvertent operation of such devices shall create a hazard to the airplane. For Levels 1 and 2, nuisance operation shall not be possible. Functional failure of the devices shall be indicated to the pilot.

3.4.2 Flight at high angle of attack. The requirements of 3.4.2 through 3.4.2.2.2 concern stall warning, stalls, departure from controlled flight, post-stall gyrations, spins, recoveries and related characteristics. They apply at speeds and angles of attack which in general are outside the Service Flight Envelope. They are intended to assure safety and the absence of mission limitations due to high angle of attack characteristics.

3.4.2.1 Stalls. The stall is defined in terms of airspeed and angle of attack in 6.2.2 and 6.2.5 respectively. It usually is a phenomenon caused by airflow separation induced by high angle of attack, but it may instead be determined by some limit on usable angle of attack. The stall requirements apply for all Airplane Normal States in straight unaccelerated flight and in turns and pullups with attainable normal accelerations up to n_L. Specifically, the Airplane Normal States associated with the configurations, throttle settings and trim settings of 6.2.2 shall be investigated; also, the requirements apply to Airplane Failure States that affect stall characteristics.

3.4.2.1.1 Stall approach. The stall approach shall be accompanied by an easily perceptible warning consisting of shaking of the cockpit controls, buffeting or shaking of the airplane, or a combination of both. The onset of this warning shall occur within the ranges specified in 3.4.2.1.1.1 and 3.4.2.1.1.2 but not within the Operational Flight Envelope. The increase in buffeting intensity with further increase in angle of attack shall be sufficiently marked to be noted by the pilot. The warning shall continue until the angle of attack is reduced to a value less than that for warning onset. At all angles of attack up to the stall, the cockpit controls shall remain effective in their normal sense, and small control inputs shall not result in departure from controlled flight. Prior to the stall, uncommanded oscillations shall not be objectionable to the pilot.

3.4.2.1.1.1 Warning speed for stalls at 1g normal to the flight path. Warning onset for stalls at 1g normal to the flight path shall occur between the following limits when the stall is approached gradually:

Flight Phase	Minimum Speed for Onset	Maximum Speed for Onset
Approach	Higher of $1.05V_S$ or V_S + 5 knots	Higher of $1.10V_S$ or V_S + 10 knots
All Other	Higher of $1.05V_S$ or V_S + 5 knots	Higher of $1.15V_S$ or V_S + 15 knots

3.4.2.1.1.2 Warning range for accelerated stalls. Onset of stall warning shall occur outside the Operational Flight Envelope associated with the Airplane Normal State and within the following range or percentage of lift at stall at that airspeed, in that Airplane State, when the stall is approached gradually:

Flight Phase	Minimum Lift at Onset	Maximum Lift at Onset
Approach	82% C_L stall	90% C_L stall
All Other	75% C_L stall	90% C_L stall

3.4.2.1.2 Stall characteristics. In the unaccelerated stalls of 3.4.2.1, the airplane shall not exhibit rolling, yawing or downward pitching at the stall which cannot be controlled to stay within 20 degrees for Classes I, II and III, or 30 degrees for Class IV airplanes. It is desired that no pitchup tendencies occur in unaccelerated or accelerated stalls. In unaccelerated stalls, mild nose-up pitch may be acceptable if no pitch control force reversal occurs and if no dangerous, unrecoverable or objectionable flight conditions result. A mild nose-up tendency may be acceptable in accelerated stalls if the operational effectiveness of the airplane is not compromised and:

a. The airplane has adequate stall warning

b. Pitch control effectiveness is such that it is possible to stop the pitchup promptly and reduce the angle of attack, and

c. At no point during the stall, stall approach or recovery does any portion of the airplane exceed structural limit loads.

The requirements apply for all stalls, including stalls entered abruptly.

3.4.2.1.3 Stall prevention and recovery. It shall be possible to prevent the stall by moderate use of the pitch control alone at the onset of the stall warning. It shall be possible to recover from a stall by simple use of the pitch, roll and yaw controls with cockpit control forces not to exceed those of 3.4.4.1, and to regain level flight without excessive loss of altitude or buildup of speed. Throttles shall remain fixed until speed has begun to increase and an angle of attack below the stall has been regained unless compliance would result in exceeding engine operating limitations. In the straight-flight stalls of 3.4.2.1, with the airplane trimmed at an airspeed not greater than $1.4V_S$, pitch control power shall be sufficient to recover from any attainable angle of attack.

3.4.2.1.3.1 One-engine-out stalls. On multi-engine airplanes, it shall be possible to recover safely from stalls with the critical engine inoperative. This requirement applies with the remaining engines at up to:

Flight Phase	Thrust
TO	Takeoff
CL	Normal climb
PA	Normal approach
WO	Waveoff

3.4.2.2 Post-stall gyrations and spins. The post-stall gyration and spin requirements apply to all modes of motion that can be entered from upsets, decelerations, and extreme maneuvers appropriate to the Class and Flight Phase Category. Entries from inverted flight shall be included for Class I and IV airplanes. Entry angles of attack and sideslip up to maximum control capability and under dynamic flight conditions are to be included, except as limited by structural considerations. For all Classes and Flight Phase Categories, thrust settings up to and including MAT shall be included, with and without one critical engine inoperative at entry. The requirements hold for all Airplane Normal States and for all states of stability and control augmentation systems, except approved Special Failure States. Store release shall not be allowed during loss of control, spin or gyration, recovery, or subsequent dive pullout. Automatic disengagement of augmentation systems, however, is permissible if it is necessary and does not prevent meeting any other requirements; re-engagement shall be possible in flight following recovery.

3.4.2.2.1 Departure from controlled flight. All Classes of airplanes shall be extremely resistant to departure from controlled flight, post-stall gyrations and spins. The airplane shall exhibit no uncommanded motion which cannot be arrested promptly by simple application of pilot control. In addition, the procuring activity may designate that certain training airplanes shall be capable of a developed spin and consistent recovery.

3.4.2.2.2 Recovery from post-stall gyrations and spins. For airplanes which, according to MIL-A-8861 must be structurally designed for spinning, the following requirements apply. The proper recovery technique(s) must be readily ascertainable by the pilot, and simple and easy to apply under the motions encountered. Whatever the motions, safe consistent recovery and pullout shall be possible without exceeding the control forces of 3.4.4.1 and without exceeding structural limitations. A single technique shall provide prompt recovery from all post-stall gyrations and incipient spins, without requiring the pilot to determine the direction of motion and without tendency to develop a spin. The same technique used to recover from post-stall gyrations and incipient spins, or at least a compatible one, is also desired for spin recovery. For all modes of spin that can occur, these recoveries shall be attainable within the number of turns, measured from the initiation of recovery action, specified as follows:

Class	Flight Phase	Turns for Recovery
I	Category A, B	1-1/2
I	PA	1
Other Clasess	PA	1
Other Classes	A & B	2

Avoidance of a spin reversal or an adverse mode change shall not depend upon precise pilot control timing or deflection. It is desired that all airplanes be readily recoverable from all attainable attitudes and motions. The post-stall characteristics of those airplanes not required to comply with requirements of this paragraph shall be determined by analysis and model test.

3.4.3 Cross-axis coupling in roll maneuvers. For Class I and IV airplanes in yaw-control-free, pitch-control-fixed, maximum-performance rolls through 360 degrees, entered from straight flight or from turns, pushovers, or pullups ranging 0_g to 0.8 n_L, the resulting yaw or pitch motions and sideslip or angle of attack changes shall neither exceed structural limits nor cause other dangerous flight conditions such as uncontrollable motions or roll autorotation.

During combat-type maneuvers involving rolls through angles up to 360 degrees and rolls which are checked at a given bank angle, the yawing and pitching shall not be so severe as to impair the tactical effectiveness of the maneuver. These requirements define Level 1 and 2 operation. For Class II and III airplanes, these requirements apply in rolls through 120 degrees and rolls which are checked at a given bank angle.

3.4.4 Control harmony. The pitch- and roll-control force and displacement sensitivities and breakout forces shall be compatible so that intentional inputs to one control axis will not cause inadvertent inputs to the other.

3.4.4.1 Control force coordination. The cockpit control forces required to perform maneuvers which are normal for the airplane should have magnitudes which are related to the pilot's capability to produce such forces in combination. The following control force levels are considered to be limiting values compatible with the pilot's capability to apply simultaneous forces:

Type Control	Pitch	Roll	Yaw
Side-stick or Center-stick	50 pounds	25 pounds	
Wheel	75 pounds	40 pounds	
Pedal			175 pounds

3.4.5 Buffet. Within the boundaries of the Operational Flight Envelope, there shall be no objectionable buffet which might detract from the effectiveness of the airplane in executing its intended missions.

3.4.6 Release of stores. The intentional release of any stores shall not result in objectionable flight characteristics for Levels 1 and 2. However, the intentional release of stores shall never result in dangerous or intolerable flight characteristics. This requirement applies for all flight conditions and store loadings at which normal or emergency store release is permissible.

3.4.7 Effects of armament delivery and special equipment. Operation of moveable parts such as bomb bay doors, cargo doors, armament pods, refueling devices and rescue equipment, or firing of weapons, release of bombs, or delivery or pickup of cargo shall not cause buffet, trim changes, or other characteristics which impair the tactical effectiveness of the airplane under any pertinent flight condition. These requirements shall be met for Levels 1 and 2.

3.4.8 Transients following failures. The airplane motions following sudden airplane system or component failures shall be such that dangerous conditions can be avoided by pilot corrective action. A realistic time delay between the failure and initiation of pilot corrective action shall be incorporated when determining compliance. This time delay should include an interval between the occurrence of the failure and the occurrence of a cue such as acceleration, rate, displacement, or sound that will definitely indicate to the pilot that a failure has occurred, plus an additional interval which represents the time required for the pilot to diagnose the situation and initiate corrective action.

3.4.9 Failures. No single failure of any component or system shall result in dangerous or intolerable flying qualities; Special Failure States (3.1.6.2.1) are excepted. The crew member concerned shall be provided with immediate and easily interpreted indications whenever failures occur that require or limit any flight crew action or decision.

3.4.10 Control margin. Control authority, rate and hinge moment capability shall be sufficient to assure safety throughout the combined range of all attainable angles of attack (both positive and negative) and sideslip. This requirement applies to the prevention of loss of control and to recovery from any situation for all maneuvering, including pertinent effects of factors such as regions of control-surface-fixed instability, inertial coupling, fuel slosh, the influence of symmetric and asymmetric stores (3.1.4), stall/post-stall/spin characteristics (3.4.2 through 3.4.2.2.2), atmospheric disturbances (3.8) and Airplane Failure States (3.1.10.1 and 3.1.10.2; maneuvering flight appropriate to the Failure State is to be included). Consideration shall be taken of the degrees of effectiveness and certainty of operation of limiters, cg control malfunction or mismanagement, and transients from failures in the propulsion, flight control and other relevant systems.

3.4.11 Direct force controls. Use of devices for direct normal-force control and direct side-force control shall not produce objectionable changes in attitude for any amount of control up to the maximum available. This requirement shall be met for Levels 1 and 2.

3.5 Characteristics of the primary flight control system

3.5.1 General characteristics. As used in this specification, the term primary flight control system includes the pitch, roll and yaw controls, stability augmentation systems, and all mechanisms and devices that they operate. The requirements of this section are concerned with those aspects of the primary flight control system which are directly related to the flying qualities. These requirements are in addition to the requirements of the applicable control system design specification, e.g., MIL-F-9490 or MIL-C-18244.

3.5.2 Mechanical characteristics. Some of the important mechanical characteristics of control systems (including servo valves and actuators) are: friction and preload, lost motion, flexibility, mass imbalance and inertia, nonlinear gearing, and rate limiting. Requirements for some of these characteristics are contained in 3.5.2.1 through 3.5.2.4. Meeting these separate requirements, however, will not necessarily ensure that the overall system will be adequate; the mechanical characteristics must be compatible with the nonmechanical portions of the control system and with the airframe dynamic characteristics.

3.5.2.1 Control centering and breakout forces. Longitudinal, lateral and directional controls should exhibit positive centering in flight at any normal trim setting. Although absolute centering is not required, the combined effects of centering, breakout force, stability and force gradient shall not produce objectionable flight characteristics, such as poor precision-tracking ability, or permit large departures from trim conditions with controls free. Breakout forces, including friction, preload, etc., shall be within the limits of table XII. The values in table XII refer to the cockpit control force required to start movement of the control surface in flight for Levels 1 and 2; the upper limits are doubled for Level 3.

TABLE XII. Allowable breakout forces, pounds.

Control		Classes I, II-C, IV		Classes II-L, III	
		Min.	Max.	Min.	Max.
Pitch	Stick	1/2	3	1/2	5
	Wheel	1/2	4	1/2	7
Roll	Stick	1/2	2	1/2	4
	Wheel	1/2	3	1/2	6
Yaw	Pedal	1	7	1	14

Measurement of breakout forces on the ground will ordinarily suffice in lieu of actual flight measurement, provided that qualitative agreement between ground measurement and flight observation can be established.

3.5.2.2 Cockpit control free play. The free play in each cockpit control, that is, any motion of the cockpit control which does not move the control surface in flight, shall not result in objectionable flight characteristics, particularly for small-amplitude control inputs.

3.5.2.3 Rate of control displacement. The ability of the airplane to perform the operational maneuvers required of it shall not be limited in the atmospheric disturbances specified in 3.7 by control surface deflection rates (3.8.3.1, 3.8.3.2 and 3.4.10). For powered or boosted controls, the effect of engine speed and the duty cycle of both primary and secondary control together with the pilot control techniques shall be included when establishing compliance with this requirement.

3.5.2.4 Adjustable controls. When a cockpit control is adjustable for pilot physical dimensions or comfort, the control forces defined in 6.2 refer to the mean adjustment. A force referred to any other adjustment shall not differ by more than 10 percent from the force referred to the mean adjustment.

3.5.3 Dynamic characteristics. A linear or smoothly varying airplane response to cockpit-control deflection and to control force shall be provided for all amplitudes of control input. The response of the control surfaces in flight

TABLE XIII. Allowable control surface lags.

Allowable Lag, deg		
Level	Category A & C Flight Phases	Category B Flight Phases
1	15	30
2	30	45
3	60	60

Control	Upper Frequency, rad/sec
Pitch	the larger of $\omega_{n_{SP}}$ and 2.0
roll & yaw	the largest of ω_{n_d}, $1/\tau_R$ and 2.0

In addition, the response of the airplane motion shall not exhibit a time delay longer than the following for a pilot-initiated step control force input.

TABLE XIV. Allowable airplane response delay.

Level	Allowable Delay Sec
1	0.10
2	0.20
3	0.25

Further, the values of the equivalent time delay derived from equivalent system match of the aircraft response to cockpit controls shall not exceed the values of table XIV.

3.5.3.1 Damping. All control system oscillations shall be well damped, unless they are of such an amplitude, frequency and phasing that they do not result in objectionable oscillations of the cockpit controls or the airframe during abrupt maneuvers and during flight in atmospheric disturbances.

3.5.4 Augmentation systems. Operation of stability augmentation and control augmentation systems and devices shall not introduce any objectionable flight or ground handling characteristics.

3.5.5 Failures. The following events shall not cause dangerous or intolerable flying qualities:

a. Complete or partial loss of any function of the augmentation system following a single failure

b. Failure-induced transient motions and trim changes either immediately after failure or upon subsequent transfer to alternate control modes

c. Configuration changes required or recommended following failure.

3.5.5.1 Failure transients. With controls free, the airplane motions due to failures described in 3.5.5 shall not exceed the following limits for at least 2 seconds following the failure, as a function of the Level of flying qualities after the failure transient has subsided:

Levels 1 and 2 (after failure)	±.5g incremental normal or lateral acceleration at the pilot's station and ±10 degrees per second roll rate, except that neither stall angle of attack nor structural limits shall be exceeded. In addition for Category A, vertical or lateral excursions of 5 feet, ±2 degrees bank angle
Level 3 (after failure)	No dangerous attitude or structural limit is reached, and no dangerous alteration of the flight path results from which recovery is impossible.

3.5.5.2 Trim changes due to failures. The changes in control forces required to maintain attitude and sideslip for the failures described in 3.5.5 shall not exceed the following limits for at least 5 seconds following the failure:

Pitch ------------------------- 20 pounds
Roll -------------------------- 10 pounds
Yaw --------------------------- 50 pounds

3.5.6 Transfer to alternate control modes. The transient motions and trim changes resulting from the intentional engagement or disengagement of any portion of the primary flight control system by the pilot shall be such that dangerous flying qualities never result.

3.5.6.1 Transfer transients. With controls free, the transients resulting from the situations described in 3.5.6 shall not exceed the following limits for at least 2 seconds following the transfer:

Within the Operational Flight Envelope	±0.1g normal or lateral acceleration at the pilot's station and ±3 degrees per second roll
Within the Service Flight Envelope	±0.5g at the pilot's station, ±5 degrees per second roll, the lesser of ±5 degrees sideslip and the structural limits.

These requirements apply only for Airplane Normal States.

3.5.6.2 Trim changes. The changes in control forces required to maintain attitude and sideslip for the situations described in 3.5.6 shall not exceed the following limits for at least 5 seconds following the transfer:

Pitch ------------------------- 20 pounds
Roll -------------------------- 10 pounds
Yaw --------------------------- 50 pounds

These requirements apply only for Airplane Normal States

3.6 Characteristics of secondary control systems

3.6.1 Trim system. In straight flight, throughout the Operational Flight Envelope the trimming devices shall be capable of reducing all the cockpit control forces to zero for Levels 1 and 2. For Level 3 the untrimmed steady-state cockpit-control forces shall not exceed 10 pounds pitch, 5 pounds roll and 20 pounds pedal. The failures to be considered in applying the Level 2 and 3 requirements shall include trim sticking and runaway in either direction. It is permissible to meet the Level 2 and 3 requirements by providing the pilot with alternate trim mechanisms or override capability. Additional requirements on trim rate and authority are contained in MIL-F-9490 and MIL-F-18372.

3.6.1.1 Trim for asymmetric thrust. For all multi-engine airplanes, it shall be possible to trim the cockpit-control forces to zero in straight flight with up to two engines inoperative following asymmetric loss of thrust from the most critical factors (3.3.9). This requirement defines Level 1 in level-flight cruise at speeds from the maximum-range speed for the engine(s)-out configuration to the speed obtainable with normal rated thrust on the functioning engine(s). Systems completely dependent on the failed engines shall also be considered failed.

3.6.1.2 Rate of trim operation. Trim devices shall operate rapidly enough to enable the pilot to maintain low control forces under changing conditions normally encountered in service, yet not so rapidly as to cause oversensitivity or trim precision difficulties under any conditions. Specifically, it shall be possible to trim the pitch control forces to less than ±10 pounds for center-stick airplanes and ±20 pounds for wheel-control airplanes throughout
a. dives and ground attack maneuvers required in normal service operation and
b. level-flight accelerations at maximum augmented thrust from 250 knots or $V_{R/C}$, whichever is less, to V_{max} at any altitude when the airplane is trimmed for level flight prior to initiation of the maneuver. In the event that operation of the trim system requires removal of one hand from the wheel-control, Level 1 force limits shall be as for a center-stick.

3.6.1.3 Stalling of trim systems. Stalling of a trim system due to aerodynamic loads during maneuvers shall not result in an unsafe condition. Specifically, the longitudinal trim system shall be capable of operating during the dive recoveries of 3.2.3.6 at any attainable permissible n, at any possible position of the trimming device.

3.6.1.4 Trim system irreversibility. All trimming devices shall maintain a given setting indefinitely unless changed by the pilot, or by a special automatic interconnect (such as to the landing flaps), or by the operation of an augmentation device. If an automatic interconnect or augmentation device is used in conjunction with a trim device, provision shall be made to ensure the accurate return of the device to its initial trim position on removal of each interconnect or augmentation command.

3.6.2 Speed and flight-path control devices. The effectiveness and response times of the longitudinal controls shall be sufficient to provide adequate control of flight path and airspeed at any flight condition within the Operational Flight Envelope. This requirement may be met by use of devices such as throttles, thrust reversers, auxiliary drag devices and flaps.

3.6.3 Transients and trim changes. The transients and steady-state trim changes for normal operation of secondary control devices (such as throttle, thrust reversers, flaps, slats, speed brakes, deceleration devices, dive recovery devices, wing sweep and landing gear) shall not impose excessive control forces to maintain the desired heading, altitude, attitude, rate of climb, speed or load factor without use of the trimmer control. This requirement applies to all in-flight configuration changes and combinations of changes made under service conditions, including the effects of asymmetric operations such as unequal operation of landing gear, speed brakes, slats or flaps. In no case shall there be any objectionable buffeting or oscillation caused by such devices. More specific requirements on secondary control devices are contained in 3.6.3.1, 3.6.4 and 3.6.5 and in MIL-F-9490 and MIl-F-18372.

3.6.3.1 Pitch trim changes. The pitch trim changes caused by operation of secondary control devices shall not be so large that a peak pitch control force in excess of 10 pounds for center-stick controllers or 20 pounds for wheel controllers is required when such configuration changes are made in flight under conditions representative of operational procedure. Generally, the conditions listed in table XV will suffice for determination of compliance with this requirement. (For airplanes with variable-sweep wings, additional requirements will be imposed consistent with operational employment of the vehicle). With the airplanes trimmed for each specified initial condition, the peak force required to maintain the specified parameter constant following the specified configuration change shall not exceed the stated value for a time interval of at least 5 seconds following the completion of the pilot action initiating the configuration change. The magnitude and rate of trim change subsequent to this time period shall be such that the forces are easily trimmable by use of the normal trimming devices. These requirements define Level 1. For Levels 2 and 3, the allowable forces are increased by 50 percent.

3.6.4 Auxiliary dive recovery devices. Operation of any auxiliary device intended solely for dive recovery shall always produce a positive increment of normal acceleration, but the total normal load factor shall never exceed $0.8n_L$, controls free.

3.7 Atmospheric disturbances

3.7.1 Form of the disturbance models. Where feasible, the von Karman form shall be used for the continuous turbulence model, so that the flying qualities analyses will be consistent with the comparable structural analyses. When no comparable structural analysis is performed or when it is not feasible to use the von Karman form, use of the Dryden form will be permissible. In general, both the continuous turbulence model and the discrete gust model shall be used. The scales and intensities used in determining the gust magnitudes for the discrete gust model shall be the same as those in the Dryden turbulence model.

TABLE XV. Pitch trim change conditions.

	Flight Phase	Initial Trim Condition					Configuration Change	Parameter to be held constant
		Altitude	Speed	Landing Gear	High-lift Devices & Wing Flaps	Thrust		
1	Approach	$h_{o_{min}}$	Normal pattern entry speed	Up	Up	TLF	Gear down	Altitude and airspeed*
2				Up	Up	TLF	Gear down	Altitude
3				Down	Up	TLF	Extend high-lift devices and wing flaps	Altitude and airspeed*
4				Down	Up	TLF	Extend high-lift devices and wing flaps	Altitude
5				Down	Down	TLF	Idle thrust	Airspeed
6			$V_{o_{min}}$	Down	Down	TLF	Extend approach drag device	Airspeed
7				Down	Down	TLF	Takeoff thrust	Airspeed
8	Approach		$V_{o_{min}}$	Down	Down	TLF	Takeoff thrust plus normal clean-up for wave-off (go-around)	Airspeed
9	Takeoff			Down	Take-off	Take-off thrust	Gear up	Pitch attitude
10			Minimum flap-retract speed	Up	Take-off	Take-off thrust	Retract high-lift devices and wing flaps	Airspeed
11	Cruise and air-to-air combat	$h_{o_{min}}$ and $h_{o_{max}}$	Speed for level flight	Up	Up	MRT	Idle thrust	Pitch attitude
12				Up	Up	MRT	Actuate deceleration device	
13				Up	Up	MRT	Maximum augmented thrust	
14			Speed for best range	Up	Up	TLF	Actuate deceleration device	

*Throttle setting may be changed during the maneuver

Notes: Auxiliary drag devices are initially retracted, and all details of configuration not specifically mentioned are normal for the flight Phase.

- If power reduction is permitted in meeting the deceleration requirements established for the mission, actuation of the deceleration device in #12 and #14 shall be accompanied by the allowable power reduction.

3.7.1.1 Turbulence model (von Karman form). The von Karman form of the spectra for the turbulence velocities is:

$$\Phi_{u_g}(\Omega) = \sigma_u^2 \frac{2L_u}{\pi} \frac{1}{[1 + (1.339\ L_u\Omega)^2]^{5/6}}$$

$$\Phi_{v_g}(\Omega) = \sigma_v^2 \frac{L_v}{\pi} \frac{1 + \frac{8}{3}(1.339\ L_v\Omega)^2}{[1 + (1.339\ L_v\Omega)^2]^{11/6}}$$

$$\Phi_{w_g}(\Omega) = \sigma_w^2 \frac{L_w}{\pi} \frac{1 + \frac{8}{3}(1.339\ L_w\Omega)^2}{[1 + (1.339\ L_w\Omega)^2]^{11/6}}$$

3.7.1.2 Turbulence model (Dryden form). The Dryden form of the spectra for the turbulence velocities is:

$$\Phi_{u_g}(\Omega) = \sigma_u^2 \frac{2L_u}{\pi} \frac{1}{1 + (L_u\Omega)^2}$$

$$\Phi_{v_g}(\Omega) = \sigma_v^2 \frac{L_v}{\pi} \frac{1 + 3(L_v\Omega)^2}{[1 + (L_v\Omega)^2]^2}$$

$$\Phi_{w_g}(\Omega) = \sigma_w^2 \frac{L_w}{\pi} \frac{1 + 3(L_w\Omega)^2}{[1 + (L_w\Omega)^2]^2}$$

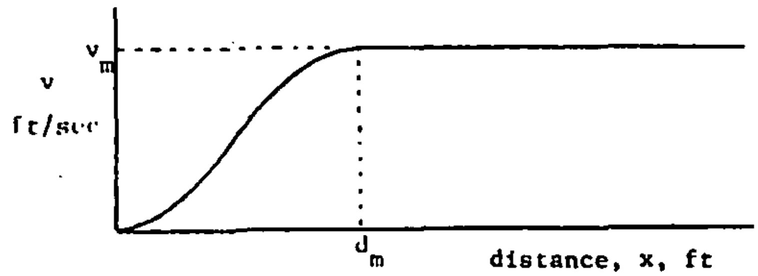
3.7.1.3 Discrete gust model. The discrete gust model may be used for any of the three gust-velocity components and, by derivation, any of the three angular components.

The discrete gust has the "1 - cosine" shape given by:

$$v = 0 \qquad , x < 0$$

$$v = \frac{v_m}{2}\left(1 - \cos\frac{\pi x}{d_m}\right) \qquad , 0 \leq x \leq d_m$$

$$v = v_m \qquad , x > d_m$$



The discrete gust above may be used singly or in multiples in order to assess airplane response to, or pilot control of, large disturbances. Step function or linear ramp gusts may also be used.

3.7.2 Medium/high-altitude model. The scales and intensities are based on the assumption that turbulence above 2,000 feet is isotropic. Then

$$\sigma_u = \sigma_v = \sigma_w$$

$$\text{and } L_u = L_v = L_w$$

3.7.2.1 Turbulence scale lengths. The scales to be used are

$L_u = L_v = L_w = 2{,}500$ feet using the von Karman form or

$L_u = L_v = L_w = 1{,}750$ feet using the Dryden form.

3.7.2.2 Turbulence intensities. Root-mean-square turbulence intensities are shown on figure 7 as functions of altitude and probability of exceedance. Simplified variations for application to the requirements of this specification are indicated.

3.7.2.3 Gust lengths. Several values of d_m shall be used, each chosen so that the gust is tuned to each of the natural frequencies of the airplane and its flight control system (higher-frequency structural modes may be excepted). For the Severe intensities modes with wavelengths less than the turbulence scale length may be excepted.

3.7.2.4 Gust magnitudes. The Light and Moderate gust magnitudes u_g, v_g, w_g shall be determined from figure 8 using values of d_x, d_y, d_z determined according to 3.7.2.3, and the appropriate RMS turbulence intensities from figure 7. Severe gust magnitudes shall be:

a. 66 ft/sec EAS at V_G, gust penetration speed

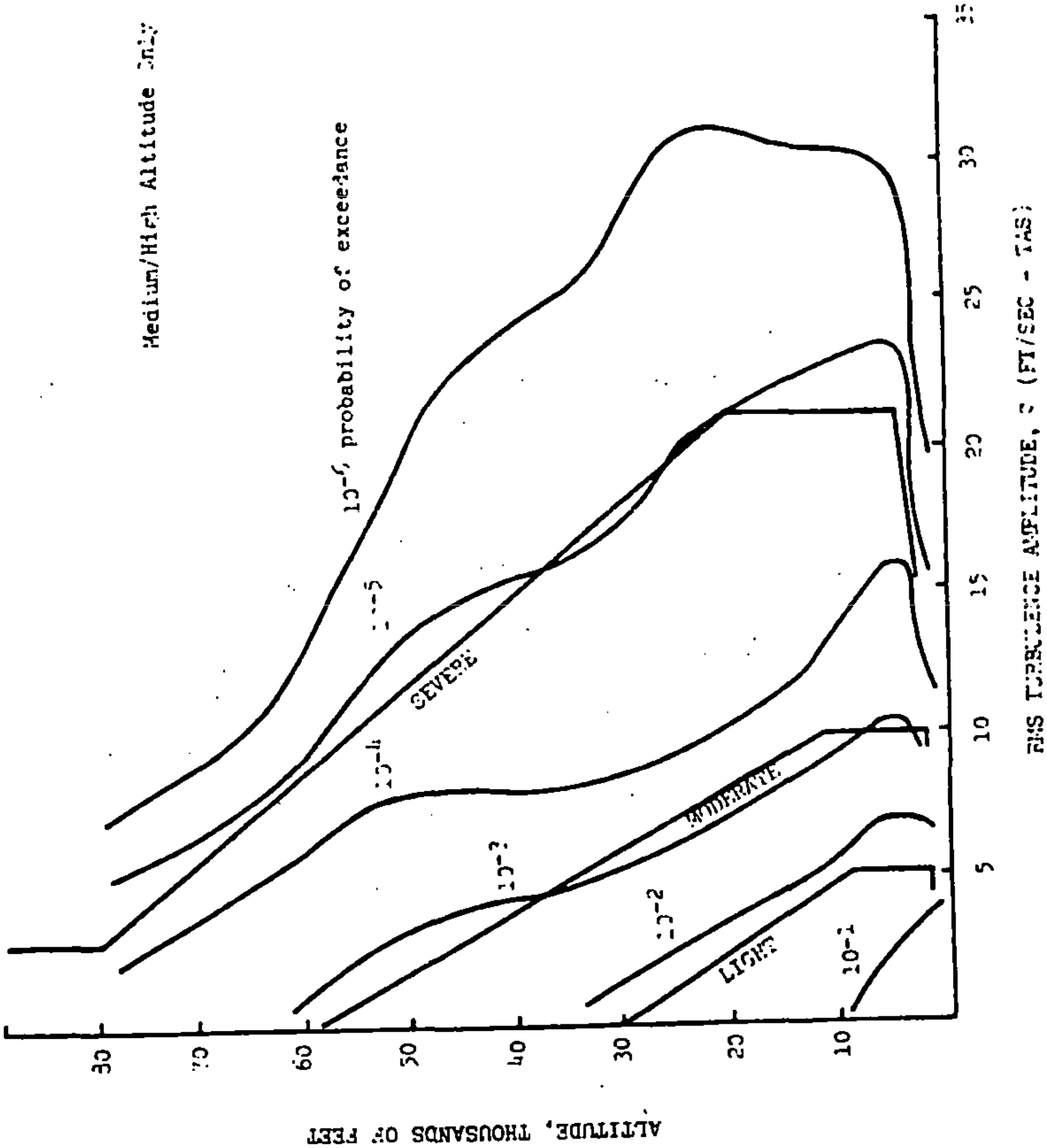


FIGURE 7. Turbulence exceedance probability.

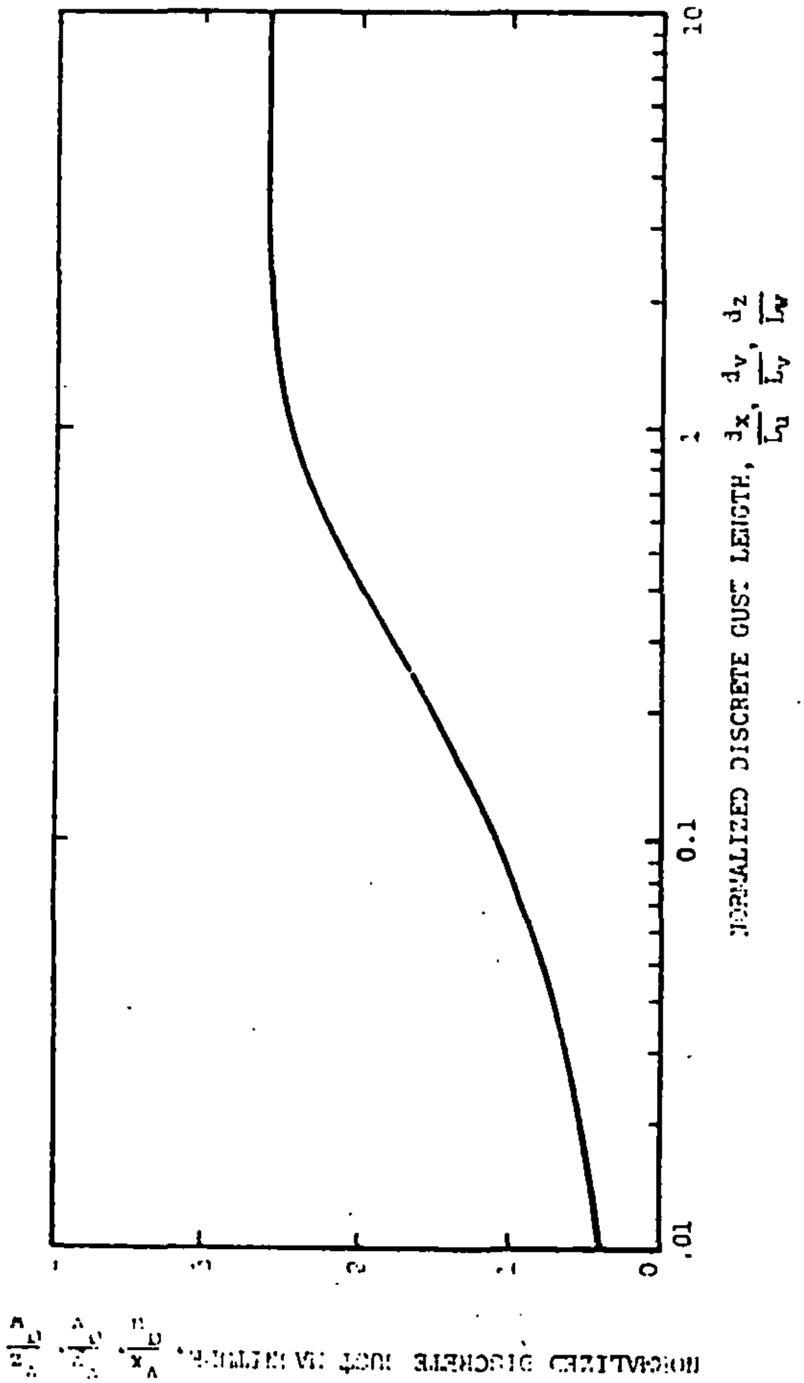


FIGURE 8. Magnitude of discrete gusts.

b. 50 ft/sec EAS at $V_{O_{max}}$

c. 25 ft/sec EAS at V_{max}

d. 50ft/sec EAS at speeds up to V_{max} (PA) with the landing gear and other devices which are open or extended in their maximum open or maximum extended positions

e. For altitudes above 20,000 feet the gust magnitudes may be reduced linearly from:

(1) 66 ft/sec EAS at 20,000 feet to 38 ft/sec EAS at 50,000 feet for the V_G condition

(2) 50 ft/sec EAS at 20,000 feet to 25 ft/sec EAS at 50,000 feet for the $V_{O_{max}}$ condition

(3) 25 ft/sec EAS at 20,000 feet to 12.5 ft/sec EAS at 50,000 feet for the V_{max} condition

f. For altitudes above 50,000 feet the equivalent gust velocity specified at 50,000 feet shall be multiplied by the factor $\sqrt{\rho/\rho_{50}}$, the square root of the ratio of air density at altitude to standard atmospheric density at 50,000 feet.

3.7.3 Low-altitude disturbance model. This section specifies the model of atmospheric disturbances to be used for all Category C operations. The effects of wind shear, turbulence and gusts may be analyzed separately. Some analysis and piloted simulation is required considering a complete environmental representation, demonstrating compliance with the requirements with the cumulative effects of wind shear, turbulence and gusts. A non-Gaussian turbulence representation together with a wind model may also be used to represent the patchy, intermittent nature of actual measured turbulence.

3.7.3.1 Wind speeds. The wind speed at 20 feet above the ground, u_{20}, is shown on figure 9 as a function of probability of occurrence. The values to be used for the different intensities of atmospheric disturbance are indicated.

3.7.3.2 Wind shear. The magnitude of the wind scalar shear is defined by the use of the following expression for the mean wind profile as a function of altitude:

$$u_w = u_{20} \frac{\ln (h/z_0)}{\ln (20/z_0)}$$

where z_0 = 0.15 feet for Category C Flight Phase

= 2.0 feet for other Flight Phases.

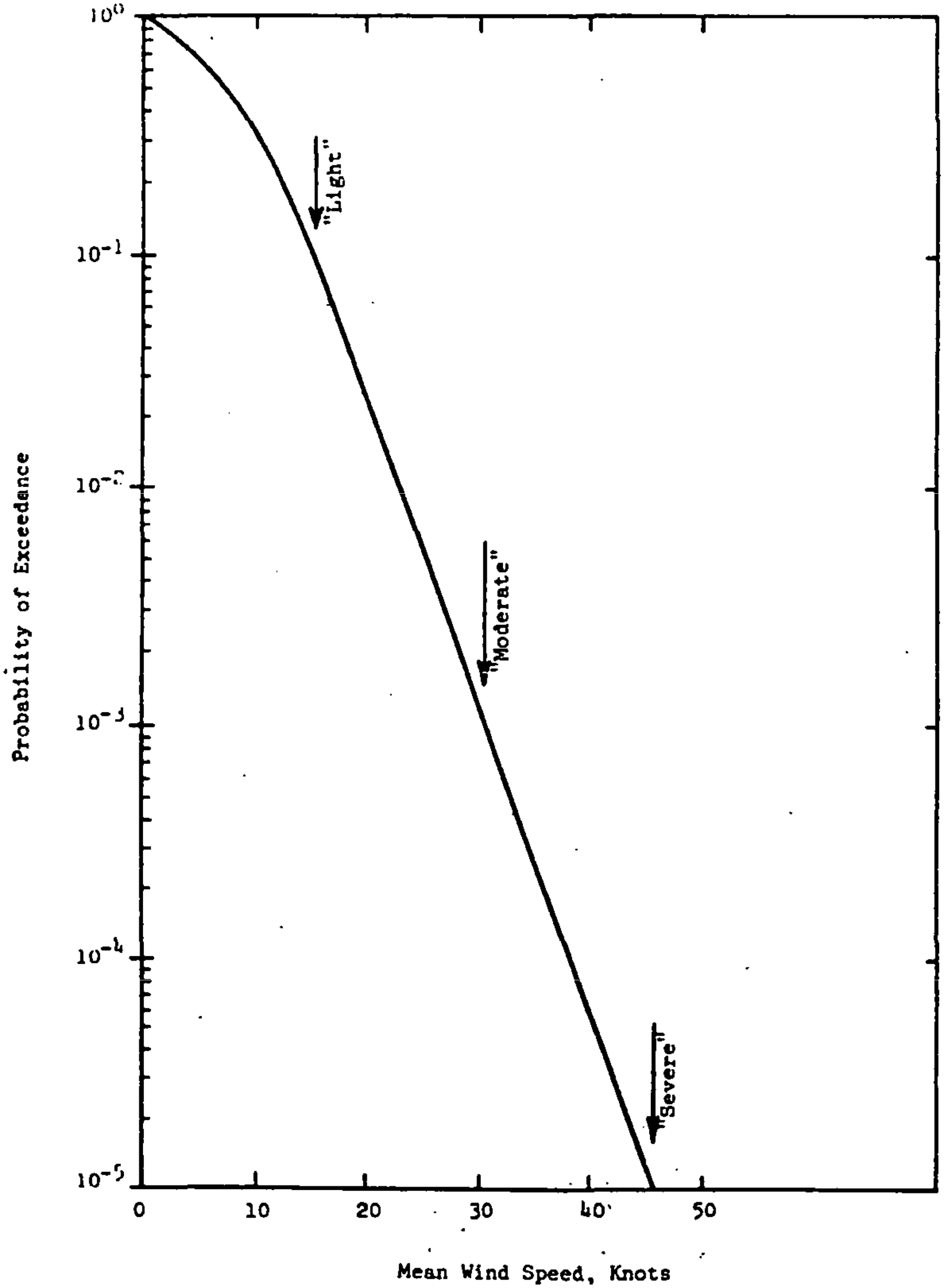


FIGURE 9. Probability of exceeding mean wind speed at 20 feet.

3.7.3.3 Vector shear. Different orientations of the mean wind relative to the runway for Category C, or relative to the aircraft flight path for other Flight Phases, shall be considered. In addition, changes in direction of the mean wind speed over a given height change shall be considered as follows:

Disturbance intensity	Change in mean wind heading degrees	Height of vector shear feet
LIGHT	0	----
MODERATE	90	600
SEVERE	90	300

A range of values for the initial wind orientation and the initial altitude for onset of the shear shall be considered. Relative to the runway, magnitudes of $u_{20} \sin \psi_w$ greater than the crosswind values in 3.3.7 or tailwind component at 20 feet greater than 10 knots need not be considered. At any altitude other than 20 feet these limits do not apply.

3.7.3.4 Turbulence. The turbulence models of 3.7.1.1 or 3.7.1.2 shall be used. The appropriate scale lengths are shown on figure 10 as functions of altitude. The turbulence intensities to be used are $\sigma_w = 0.1\ u_{20}$, and σ_u and σ_v given by figure 11 as functions of σ_w and altitude.

3.7.3.5 Gusts. Discrete gusts of the form specified in 3.7.2.3 shall be used, with both single and double ramps to be considered. Several values of d_m shall be used, each chosen so that the gust is tuned to each of the natural frequencies of the airplane and its flight control system. The gust magnitudes shall be determined from figure 8 using the appropriate values from figures 10 and 11. The two halves of a double gust do not have to be the same length or magnitude.

3.7.4 Carrier landing disturbance model. This section specifies the model of atmospheric disturbances to be used for carrier landing operations. This model shall be used in analysis and piloted simulation to determine aircraft control response and path control accuracy during carrier landing. This model supplements but does not replace the low-altitude model of 3.7.3.

The terminal approach carrier landing disturbance model shall be used during simulation of the last 1/2 mile of the carrier approach. The u velocity component is aligned with the wind over deck. Total disturbance velocities are computed by adding segments caused by random free-air turbulence, u_1, v_1, w_1; steady ship-wake disturbance, u_2, w_2; periodic ship-motion-induced turbulence, u_3, w_3; and random ship-wake disturbance, u_4, v_4, w_4. The total air disturbance conponents u_g, v_g, and w_g are then computed as:

$$u_g = u_1 + u_2 + u_3 + u_4$$

$$v_g = v_1 + v_4$$

$$w_g = w_1 + w_2 + w_3 + w_4$$

The input to all of the random disturbance filters shall be generated by filtering the wide-band, Gaussian output of zero-mean, unit-variance random-number generators.

3.7.4.1 Free-air turbulence components. The free-air turbulence components which are independent of aircraft relative position are represented by filtering the output of white-noise generators described in 3.7.4 to produce the following spectra:

$$\Phi_{u_1}(\Omega) = \frac{200}{1 + (100\ \Omega)^2} \qquad \text{per radian/foot}$$

$$\Phi_{v_1}(\Omega) = \frac{5900[1 + (400\ \Omega)^2]}{[1 + (1000\Omega)^2][1 + (\frac{400}{3}\Omega)^2]} \qquad \text{per radian/foot}$$

$$\Phi_{w_1}(\Omega) = \frac{71.6}{1 + (100\ \Omega)^2} \qquad \text{per radian/foot}$$

3.7.4.2 Steady component of carrier airwake. The steady components of the carrier airwake consist of a reduction in the steady wind and a predominant upwash aft of the ship which are functions of range. Figure 12 illustrates the steady wind functions $u_2/V_{w/d}$ and $w_2/V_{w/d}$ as functions of position aft of the ship center of pitch.

3.7.4.3 Periodic component of carrier airwake. The periodic component of the airwake varies with ship pitching frequency, pitch magnitude, wind over deck and aircraft range. These components are computed as follows:

$$u_3 = \theta_s V_{w/d}(2.22 + 0.0009X)C$$
$$w_3 = \theta_s V_{w/d}(4.98 + 0.0018X)C$$
$$C = \text{cosine}\left\{\omega_p\left[t\left(1 + \frac{V - V_{w/d}}{0.85V_{w/d}}\right) + \frac{X}{0.85V_{w/d}}\right] + P\right\}$$

where: ω_p = Ship pitch frequency, radians/second.

θ_s = Ship pitch amplitude, radians.

P = Random phase, radians.

The u component is set to zero for X < -2236 feet, and the w component is set to zero for X < -2536 feet.

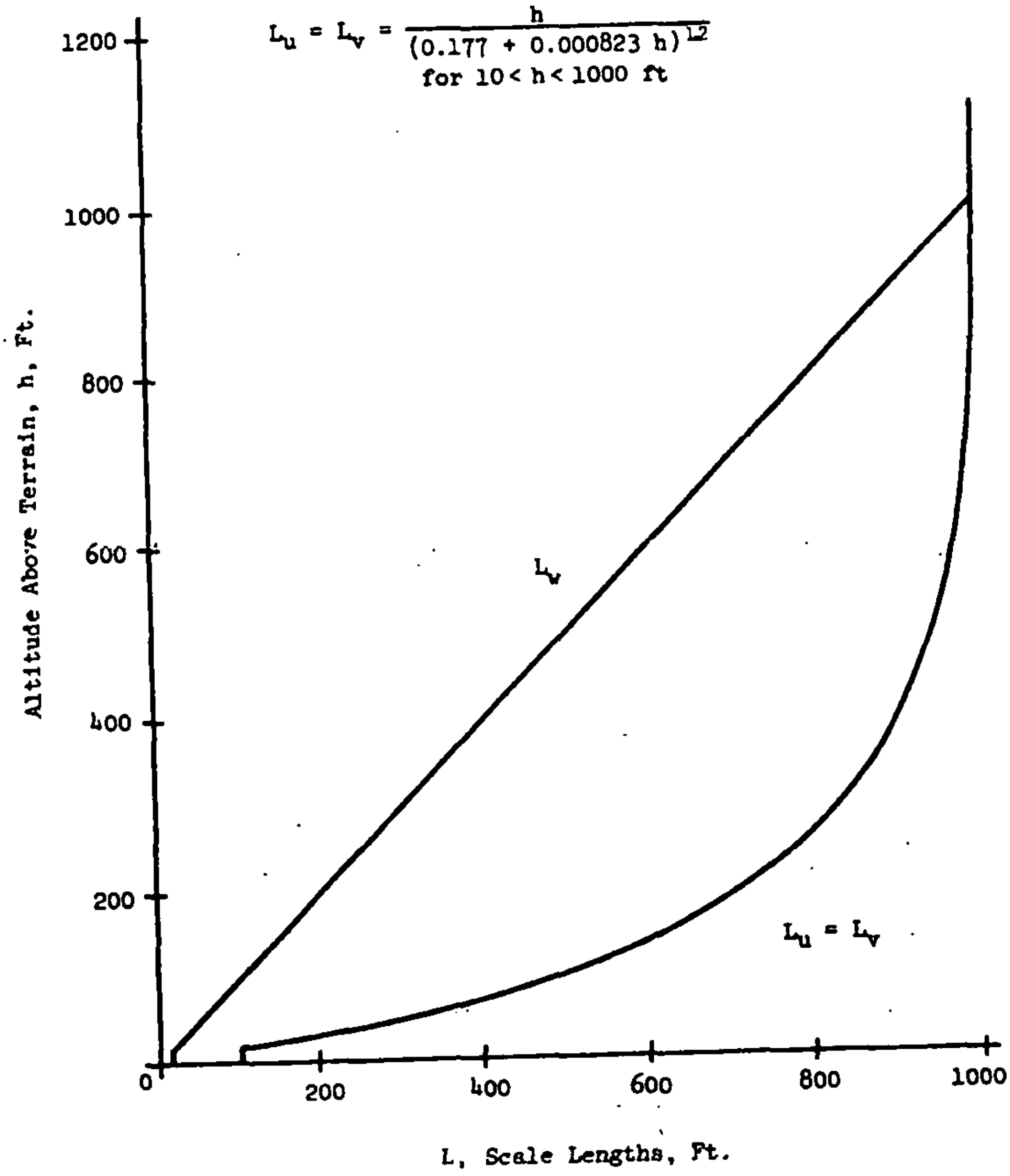


FIGURE 10. Low-altitude turbulence integral scales.

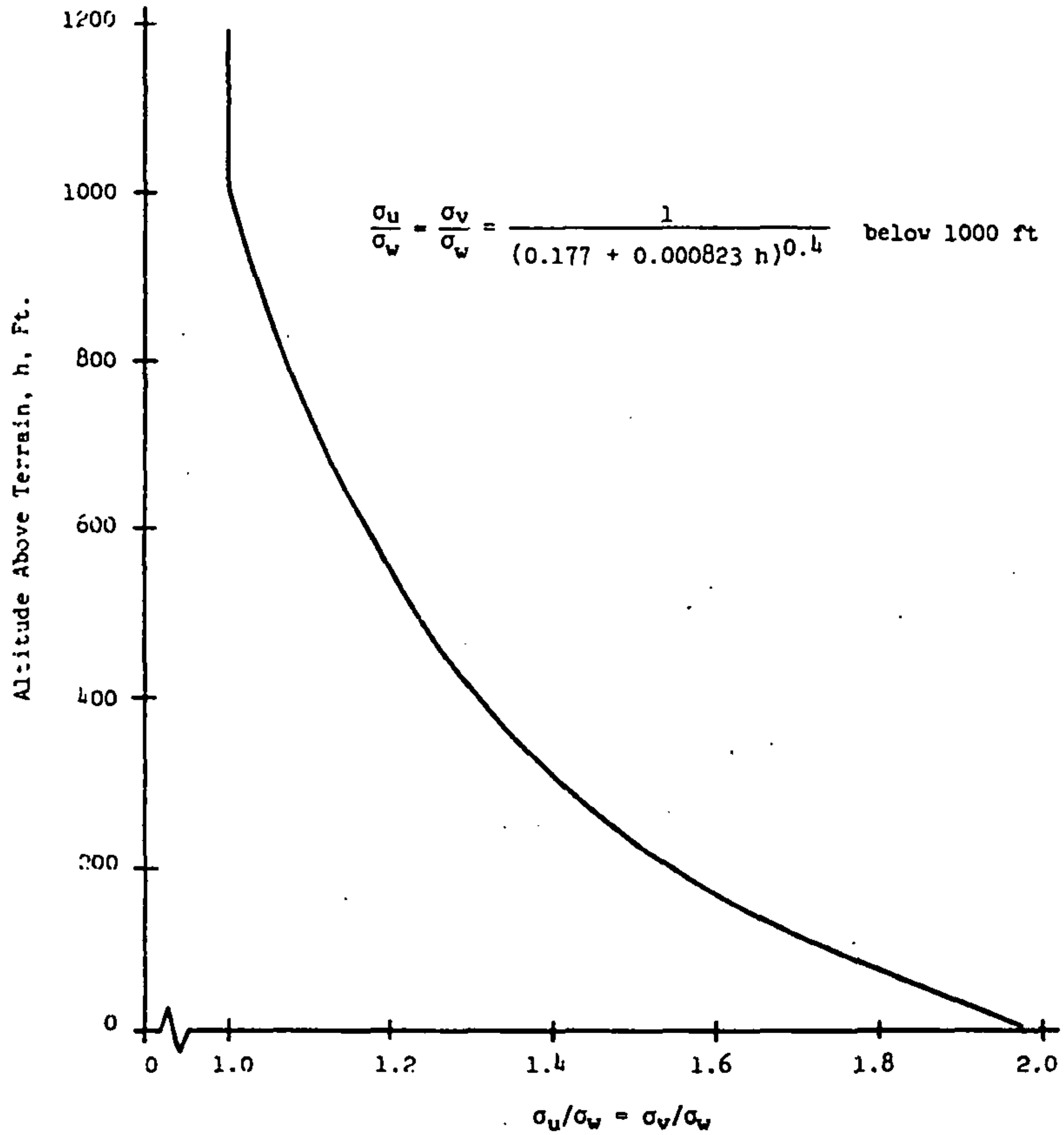


FIGURE 11. Horizontal turbulence RMS intensities.

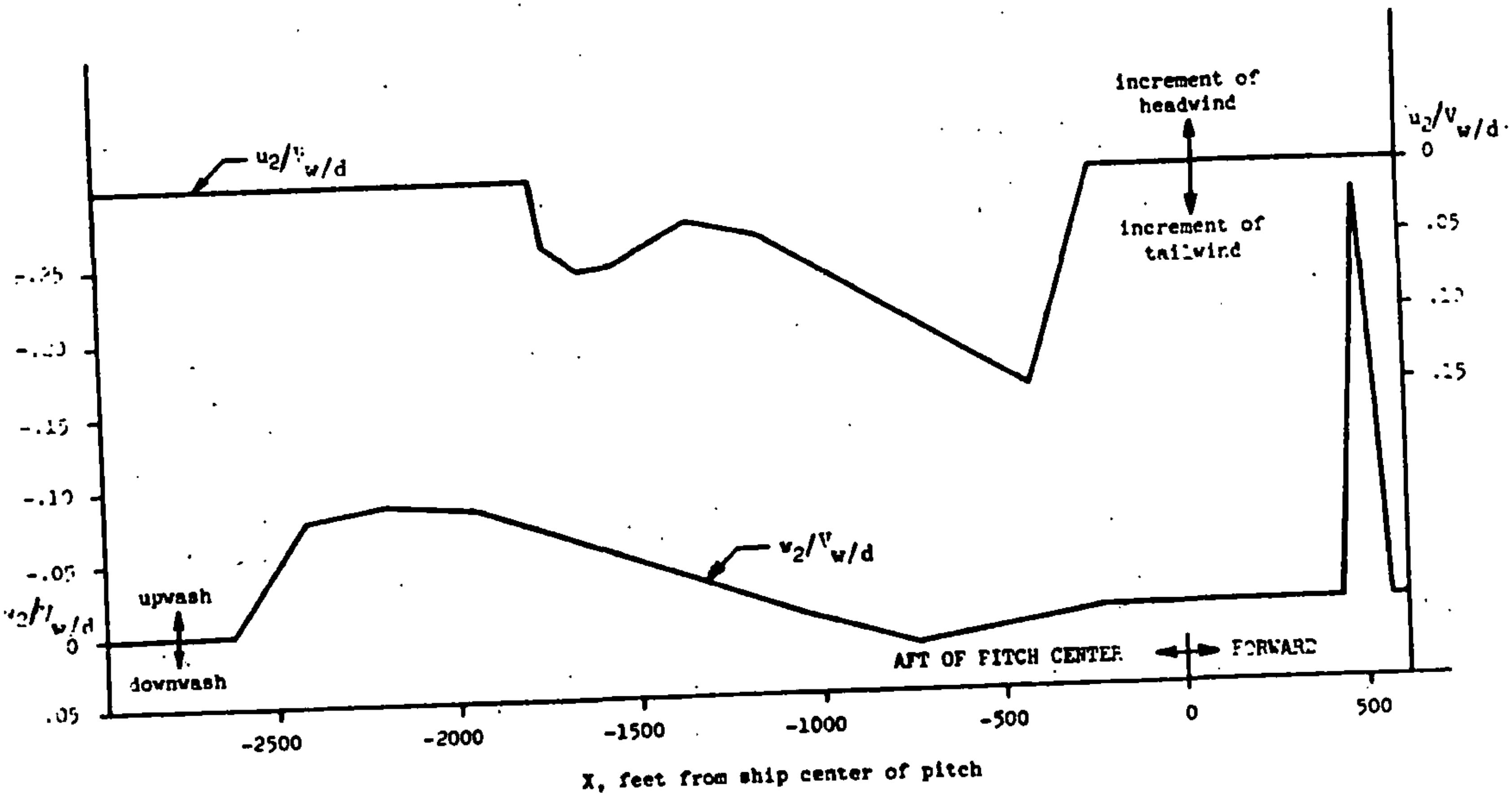


FIGURE 12. CVA ship burble steady wind ratios.

3.7.4.4 Random component of carrier air wake. The ship-related random velocity components are computed by filtering white noise (3.7.4) as follows:

$$u_4 = \frac{\sigma(X)\sqrt{2\tau(X)}\,(\text{Input})}{\tau(X)j\omega + 1}$$

$$w_4 = v_4 = \frac{0.035\, V_{w/d}\sqrt{6.66}\,(\text{Input})}{3.33j\omega + 1}$$

where: $\sigma(X)$ = RMS Amplitude-ft/sec. (Figure 13)

$\tau(X)$ = Time constant-sec. (Figure 13)

$$\text{Input} = \left[\begin{matrix}\text{Random number}\\ \text{output}\end{matrix}\right]\left[\frac{j\omega}{j\omega + 0.1}\right] \sin(10\,\pi\, t)$$

3.7.5 Application of the disturbance model in analyses. The gust and turbulence velocities shall be applied to the airplane equations of motion through the aerodynamic terms only, and the direct effect on the aerodynamic sensors shall be included when such sensors are part of the airplane augmentation system. When using the discrete gust model, all significant aspects of the penetration of the gust by the airplane shall be incorporated in the analyses. Application of the disturbance model depends on the range of frequencies of concern in the analyses of the airframe. When structural modes are significant, the exact distribution of turbulence velocities should be considered. For this purpose, it is acceptable to consider u_g and v_g as being one-dimensional functions only of x, but w_g shall be considered two-dimensional, a function of both x and y, for the evaluation of aerodynamic forces and moments.

When structural modes are not significant, airframe rigid-body responses may be evaluated by considering uniform gust or turbulence immersion along with linear gradients of the disturbance velocities. The uniform immersion is accounted for by u_g, v_g and w_g defined at the airplane center of gravity. The angular velocities due to turbulence are equivalent in effect to airplane angular velocities. Approximations for these angular velocities are defined (precisely at very low frequencies only) as follows:

$$-\dot{\alpha}_g = q_g = \frac{\partial w_g}{\partial x}, \quad p_g = -\frac{\partial w_g}{\partial y}, \quad r_g = -\frac{\partial v_g}{\partial x}$$

The spectra of the angular velocity disturbances due to turbulence are then given by:

$$\Phi_{p_g}(\Omega) = \frac{\sigma_w^2}{L_w}\,\frac{0.8\left(\frac{\pi L_w}{4b}\right)^{1/3}}{1 + \left(\frac{4b}{\pi}\Omega\right)^2}, \quad \Phi_{q_g}(\Omega) = \frac{\Omega^2}{1 + \left(\frac{4b}{\pi}\Omega\right)^2}\Phi_{w_g}(\Omega), \quad \Phi_{r_g}(\Omega) = \frac{\Omega^2}{1 + \left(\frac{3b}{\pi}\Omega\right)^2}\Phi_{v_g}(\Omega)$$

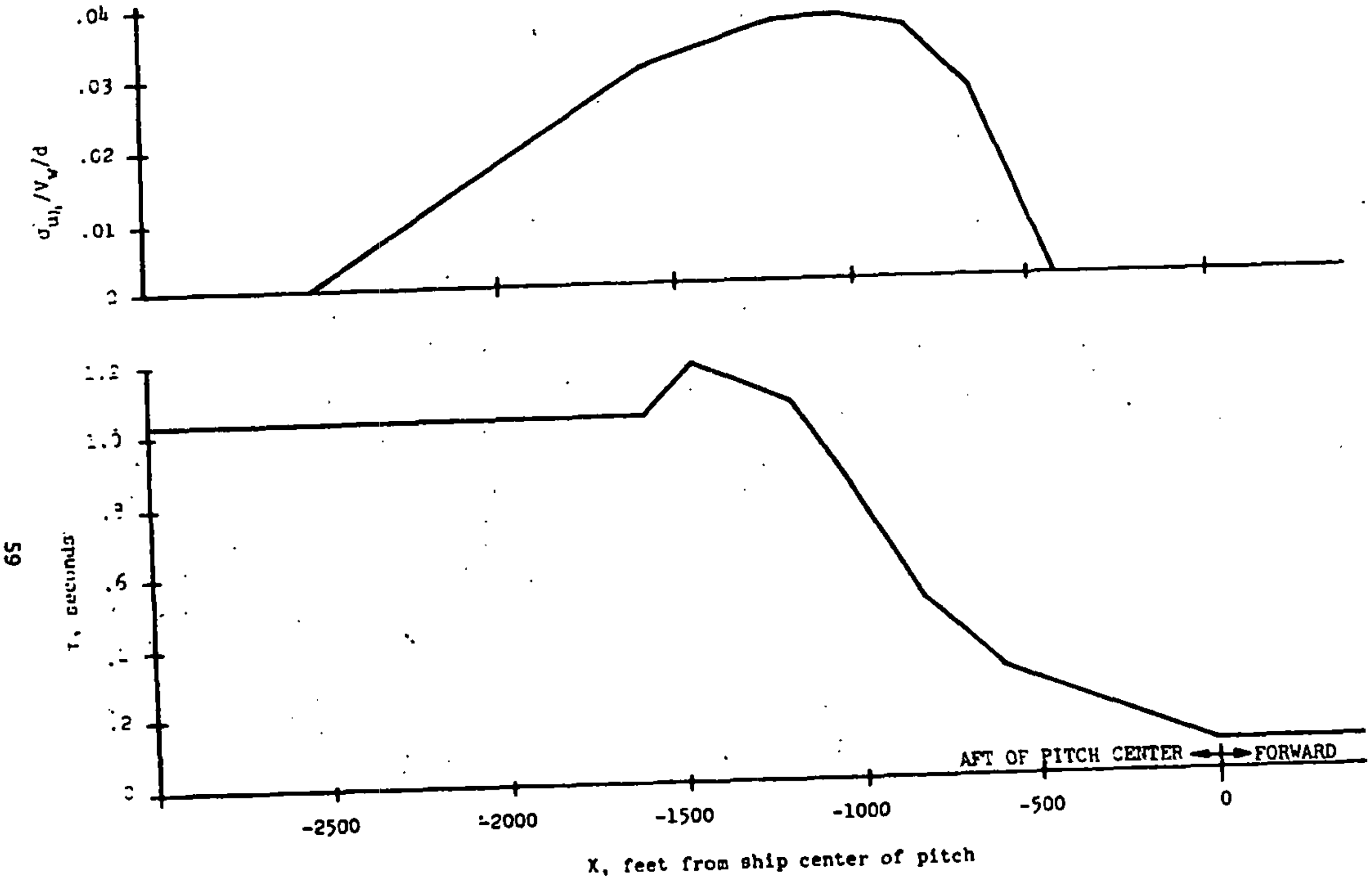


FIGURE 13. u-component burble time constant and variance.

where b = wing span. The turbulence components u_g, v_g, w_g and p_g shall be considered mutually independent (uncorrelated) in a statistical sense. However, q_g is correlated with w_g, and r_g is correlated with v_g. For the discrete gusts the linear gradient gives angular velocity perturbations of the form:

$$p_g = p_m \sin\left(\frac{\pi x}{d_m}\right) \qquad 0 \leq x \leq d_m$$

For the low-altitude model, the turbulence velocity components u_g, v_g and w_g are to be taken along axes with u_g aligned along the relative mean wind vector and w_g vertical.

3.8 Requirements for use of the disturbance models

Explicit consideration of the effects of disturbances on flying qualities, if required by the procuring activity, shall be in accordance with requirements in 3.8.2 through 3.8.3.2. In particular, 3.8.3.1 will replace 3.1.10.1 and 3.8.3.2 will replace 3.1.10.2.

3.8.1 Use of disturbance models. Paragraphs 3.7.1 through 3.7.4.4 specify models of wind shear, continuous random turbulence and discrete gusts that shall be used to assess:

a. The effects of certain environmental conditions on the flying qualities of the airplane.

b. The ability of a pilot to recover from upsets caused by environmental conditions.

c. Flight path control precision during manual and automatic carrier landing.

For the purpose of this specification the atmosphere shall be considered to consist of three regions: low altitude (ground level to approximately 2,000 feet AGL), medium/high altitude (above approximately 2,000 feet) and, for carrier landing only, terminal approach (0-300 feet altitude and 1/2 mile to touchdown). The low altitude model shall apply to Category C and any other Flight Phase (e.g. ground attack, terrain following) designated by the procuring activity. The medium/high-altitude model is intended to apply to those Flight Phases where proximity to the ground is not a factor, generally Categories A and B. In application it will be permissible to use conditions at an average altitude for the medium/high-altitude model only. The carrier landing disturbance model will apply to carrier-based aircraft only.

3.8.2 Qualitative degrees of suitability. In assessing the qualitative suitability of flying qualities three intensities of disturbances shall be considered. These intensities are Light, Moderate and Severe as defined in 3.7. The requirements for the effects of these disturbances are contained in 3.8.3.1 and 3.8.3.2 for the different Flight Envelopes and Airplane States.

The qualitative degrees of suitability of flying qualities are categorized as follows:

Satisfactory	Flying qualities clearly adequate for the mission Flight Phase
Acceptable	Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists
Controllable	Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate, or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed.
Recoverable	Flying qualities such that control can be maintained long enough to fly out of a disturbance. All Flight Phases can be terminated safely and a wave-off/go-around can be accomplished.

3.8.3 Effects of atmospheric disturbances. Levels of flying qualities as indicated in 1.5 are employed in this specification in realization of the possibility that the airplane may be required to operate under abnormal conditions. Such abnormalities may occur also as a result of extreme atmospheric disturbances, or some combination of conditions. For these factors a degradation of flying qualities is permitted as specified in 3.8.3.1 and 3.8.3.2 (see also 4.1.1).

3.8.3.1 Requirements for Airplane Normal States. In atmospheric disturbances the minimum required flying qualities for Airplane Normal States (3.1.6.1) are as specified in table XVI.

TABLE XVI. Levels for Airplane Normal States.

Atmospheric Disturbances	Within Operational Flight Envelope	Within Service Flight Envelope
LIGHT TO CALM	Quantitative requirements Level 1; qualitative requirements Satisfactory	Quantitative requirements Level 2; qualitative requirements Acceptable
MODERATE TO LIGHT	Quantitative requirements Level 1; qualitative requirements Acceptable or better	Quantitative requirements Level 2; qualitative requirements Controllable or better
SEVERE TO MODERATE	Qualitative requirements Controllable or better	Qualitative requirements Recoverable or better

3.8.3.2 Requirements for Airplane Failure States. When Airplane Failure States exist (3.1.6.2), a degradation in flying qualities is permitted only if the probability of encountering a lower Level than specified in 3.8.3.1 is sufficiently small. At intervals established by the procuring activity, the contractor shall determine, based on the most accurate available data, the probability of occurrence of each Airplane Failure State per flight and the effect of that Failure State on the flying qualities within the Operational and Service Flight Envelopes. These determinations shall be based on MIL-STD-756 except that:

a. All airplane components and systems are assumed to be operating for a time period, per flight, equal to the longest operational mission time to be considered by the contractor in designing the airplane, and

b. Each specific failure is assumed to be present at whichever point in the Flight Envelope being considered is most critical (in the flying qualities sense).

From these Failure State probabilities and effects, the contractor shall determine the overall probability, per flight, that one or more flying qualities are degraded to Level 2 because of one or more failures. The contractor shall also determine the probability that one or more flying qualities are degraded to Level 3. Table XVII specifies the requirements as functions of the probability of encountering the degradation in flying qualities.

TABLE XVII. Levels for Airplane Failure States.

Atmospheric Disturbances	Failure State I*	Failure State II**
LIGHT TO CALM	Quantitative requirements Level 2 and qualitative requirements Acceptable or better	Quantitative requirements Level 3 and qualitative requirements Controllable or better
MODERATE TO LIGHT	Quantitative requirements Level 2 and qualitative requirements Controllable or better	Quantitative requirements Level 3 and qualitative requirements Recoverable or better
SEVERE TO MODERATE	Qualitative requirements Recoverable or better	

* For flight in the Operational Flight Envelope:
Probability of encountering degraded levels of flying qualities due to failure(s) $< 10^{-2}$/flight

** For flight in the Operational Flight Envelope:
Probability of encountering degraded levels of flying qualities due to failure(s) $< 10^{-4}$/flight, and for flight in the Service Flight Envelope:
Probability of encountering degraded levels of flying qualities due to failure(s) $< 10^{-2}$/flight

4. QUALITY ASSURANCE

4.1 Compliance demonstration. Compliance with all requirements of section 3 shall be demonstrated through analysis. In addition, compliance with many of the requirements will be demonstrated by simulation, flight test, or both. The methods for demonstrating compliance shall be established by agreement between the procuring activity and the contractor. Representative flight conditions, configurations, external store complements, loadings, etc., shall be determined for detailed investigations in order to restrict the number of design and test conditions. The selected design points must be sufficient to allow accurate extrapolation to the other conditions at which the requirements apply.

Table XVIII specifies general guidelines but the peculiarities of the specific airplane design may require additional or alternate test conditions. The required failure analyses shall be thorough, excepting only approved Special Failure States (3.1.6.2.1).

4.1.1 Analytical compliance

4.1.1.1 Effects of Failure States. To determine theoretical compliance with the requirements of 3.1.10.2, the following steps must be performed:

a. Identify those Airplane Failure States which have a significant effect on flying qualities (3.1.6.2)

b. Define the longest flight duration to be encountered during operational missions (3.1.1)

c. Determine the probability of encountering various Airplane Failure States per flight, based on the above flight duration (3.1.10.2)

d. Determine the degree of flying qualities degradation associated with each Airplane Failure State in terms of Levels as defined in the specific requirements

e. Determine the most critical Airplane Failure States (assuming the failures are present at whichever point in the Flight Envelope being considered is most critical in a flying qualities sense), and compute the total probability of encountering Level 2 flying qualities in the Operational Flight Envelope due to equipment failures. Likewise, compute the probability of encountering Level 3 qualities in the Operational Flight Envelope, etc.

f. Compare the computed values above with the requirements specified in 3.1.10.2 and 3.1.10.3. An example which illustrates an approximate estimate of the probabilities of encounter follows: if the failures are all statistically independent, determine the sum of the probabilities of encountering all Airplane Failure States which degrade flying qualities to Level 2 in the Operational Envelope. This sum must be less than 10^{-2} per flight.

If the requirements are not met, the designer must consider alternate courses such as:

a. Improve the airplane flying qualities associated with the more probable Failure States, or

b. Reduce the probability of encountering the more probable Failure States through equipment redesign, redundancy, etc.

Regardless of the probability of encountering any given Airplane Failure States (with the exception of Special Failure States) the flying qualities shall not degrade below Level 3.

4.1.1.2 Effects of atmospheric disturbances. Paragraph 4.1.1.1 indicates a procedure for satisfying the requirements on the degrading effects of Airplane Failure States, without consideration of disturbances. Atmospheric disturbances also may cause a degradation in pilot opinion as specified in 3.8.2. In application, numerical values of control force and deflection, and of steady-state and dynamic response parameters (for example $n_{o_{max}}$, F_s/n and θ_t) are to be considered as mean values in the presence of atmospheric disturbances. These frequently are equivalent to the values in calm air. Numerical values of frequency-response parameters and of control authority are effective values for the airplane in each particular intensity of atmospheric disturbance. The qualitative requirements of 3.8.3.1 and 3.8.3.2 should then be assessed for both Airplane Normal States and critical Failure States identified in 4.1.1.1.

4.1.1.3 Computational assumptions. Assumptions a and b of 3.1.10.2 are somewhat conservative, but they simplify the required computations in 3.1.10.2 and provide a set of workable ground rules for theoretical predictions. The reasons for these assumptions are:

a. "... components and systems are ... operating for a time period per flight equal to the longest operational mission time ...". Since most component failure data are in terms of failures per flight hour, even though continuous operation may not be typical (e.g. yaw damper ON during supersonic flight only), failure probabilities must be predicted on a per flight basis using a "typical" total flight time. The "longest operational mission time" as "typical" is a natural result. If acceptance cycles-to-failure reliability data are available (MIL-STD-756), these data may be used for prediction purposes based on maximum cycles per operational mission, subject to procuring activity approval. In any event, compliance with the requirements of 3.1.10.2, as determined in accordance with Section 4, is based on the probability of encounter per flight.

b. "... failure is assumed to be present at whichever point ... is most critical ...". This assumption is in keeping with the requirements of 3.1.6.2 regarding Flight Phases subsequent to the actual failure in question. In cases that are unrealistic from the operational standpoint, the specific Airplane Failure States might fall in the Airplane Special Failure State classification (3.1.6.2.1).

4.1.2 Simulation. The danger, extent or difficulty of flight testing may dictate simulation rather than flight test to evaluate some conditions and events, such as the influence of Severe disturbances, events close to the ground (except 3.2.3.4 shall be demonstrated in flight), combined Failure States and disturbances, etc. In addition, by agreement with the procuring activity, piloted simulation shall be performed before first flight of a new airplane design in order to demonstrate the suitability of the handling qualities, and also to demonstrate compliance with qualitative requirements in atmospheric disturbances and in the critical conditions identified in 4.1.1.1. Where simulation is the ultimate method of demonstrating compliance for a requirement, the simulation model shall be validated with flight test data and approved by the procuring activity.

4.1.3 Flight test demonstration. The required flight tests will be defined by operational, technical and safety considerations as decided jointly by the procuring activity, the test agency and the contractor using results from 4.1.1 and 4.1.2. It is not expected that flight test demonstration of the requirements in Moderate and Severe disturbances will be done unless required by the airplane mission. Some flights can be expected to encounter actual disturbances; then the qualitative requirements would apply if the disturbance intensity could be categorized.

4.2 Airplane States. The parameters defining Aircraft States shall be tabulated. Table XIX illustrates an acceptable format.

4.2.1 Weights and moments of inertia. Terms specified in table XVIII such as "heaviest weight" and "greatest moment of inertia" mean the heaviest and greatest consistent with 3.1.2 and 3.1.3. When a critical center-of-gravity position is identified, the airplane weight and associated moments of inertia shall correspond to the most adverse service loading in which that critical center-of-gravity position is obtained.

4.2.2 Center-of-gravity positions. Terms specified in table XVIII such as "most forward c.g." and most aft c.g." mean the most forward or aft consistent with 3.1.2. When a critical weight or moment of inertia is identified, the center-of-gravity position shall correspond to the most adverse service loading in which that critical weight or moment of inertia is obtained.

4.2.3 Thrust settings. Thrust settings shall be as listed in table XIX.

4.3 Design and test conditions

4.3.1 Altitudes. For terminal Flight Phases, it will normally suffice to examine the selected Airplane States at only one altitude below 10,000 feet (low altitude). For nonterminal Flight Phases, it will normally suffice to examine the selected Airplane States at one altitude below 10,000 feet or at the lowest operational altitude (low altitude), the maximum operational altitude ($h_{o_{max}}$), and one intermediate altitude. When the maximum operational altitude is above 40,000 feet or when stability or control characteristics vary rapidly with altitude, more intermediate altitudes than specified in table XVIII shall be investigated. When the Service Flight Envelope extends far above or below the Operational Flight Envelope, the service-altitude extremes must be considered.

4.3.2 Special conditions. In addition to the flight conditions previously indicated, the speed-altitude combinations that result in the following shall all be investigated, where applicable:

a. Maximum normal acceleration response per degree of controller deflection

b. Maximum normal acceleration response per pound of control force

c. Highest dynamic pressure and highest Mach number.

TABLE XVIII. Design and test condition guidelines.

REQUMT. NO.	TITLE	CRITICAL LOADING (4.2.1, 4.2.2)	LOAD FACTOR	ALTITUDE (4.3.1)	SPEED	FLIGHT PHASE
SECTION 3.2	LONGITUDINAL FLYING QUALITIES					
3.2.1.1	Longitudinal static stability	Most aft c.g.	1.0	$h_{o_{min}}$, medium, $h_{o_{max}}$	V_{min} to V_{max} & transonic	CO,CR,LO,RR,TF,RT,PA,L,WO,TO,CT
3.2.1.1.1	Relaxation in transonic flight					
3.2.1.1.2	Elevator control force variations during rapid speed changes	—	As required		$V_{o_{min}}$ to $V_{o_{max}}$ & transonic	CO,GA,DL
3.2.1.2	Phugoid stability	Most forward c.g.†	1.0		V_{min} to V_{max}	CR,LO,PA,RT
3.2.1.3	Flight path stability				$V_{o_{min}}$, $V_{o_{min}}$ - 5 kt	PA
3.2.2.1.1	Short period frequency and acceleration sensitivity	Most forward c.g.† and most aft c.g.††			V_{min} to V_{max}	*,CR,RT,PA,L,CT
3.2.2.1.2	Short-period damping	Most forward c.g.			V_{min} to V_{max}	*,CR,RT,PA,L,CT
3.2.2.1.3	Residual oscillations				$V_{o_{min}}$ to $V_{o_{max}}$	*,PA
3.2.2.2	Control feel and stability in maneuvering flight	Most aft c.g.	n(-) to n(+)		V_{min} to V_{max}	*,RT,CR,PA,L,CT
3.2.2.2.1	Control forces in maneuvering flight	Most forward c.g.† and most aft c.g.††	n_o(-) to n(+)			
3.2.2.2.2	Control motions in maneuvering flight	Most forward c.g.†	n_o(-) to n(+)			
3.2.2.3	Longitudinal pilot induced oscillations	—	Min. permissible to max. permissible			*,RT,CR,PA,L,CT
3.2.2.3.1 3.2.2.3.2	Dynamic control forces in maneuvering flight Control feel	Most forward c.g.† Most aft c.g.††	1.0			—
3.2.3.1	Longitudinal control in unaccelerated flight	Most forward c.g.	1.0			—
3.2.3.2	Longitudinal control in maneuvering flight	Most forward c.g.†	As required		$V_{o_{min}}$ to $V_{o_{max}}$	CO,GA,RR,TF,CR,PA
3.2.3.3	Longitudinal control in takeoff	Most forward c.g. for nose-wheel airplanes, most aft c.g. for tail-wheel airplanes	1.0	low	As required	TO
3.2.3.3.1	Longitudinal control in catapult takeoff	Most forward c.g. and most aft c.g.	As required		Min. safe launch speed to min. +30	CT
3.2.3.3.2	Longitudinal control force and travel in takeoff	Most forward c.g. and most aft c.g.	As required		0 to V_{max} (TO)	TO,CT
3.2.3.4	Longitudinal control in landing	Most forward c.g.	1.0		V_S (L) or geometric limit	L
3.2.3.4.1	Longitudinal control forces in landing	Most forward c.g.	1.0			L
3.2.3.5	Longitudinal control forces in dives - Service Flight Envelope	Most forward c.g.† and most aft c.g.††	As required	2000 ft above MSL to h_{max}	V_{min} to V_{max}	D,ED,CO,CR
3.2.3.6	Longitudinal control forces in dives - Permissible Flight Envelope		As required	As required	V_{MAT} to max permissible	D,ED,CO,CR
3.2.3.7	Longitudinal control in sideslips	—	1.0	$h_{o_{min}}$, medium, $h_{o_{max}}$	V_{min} to V_{max}	CO,CR,PA,L

† Combined with heaviest weight

†† Combined with lightest weight

TABLE XVIII. Design and test condition guidelines. (Continued)

REQ'MT. NO.	TITLE	CRITICAL LOADING (4.2.1, 4.2.2)	LOAD FACTOR	ALTITUDE (4.3.1)	SPEED	FLIGHT PHASE
SECTION 3.3	LATERAL-DIRECTIONAL FLYING QUALITIES					
3.3.1.1	Lateral-directional oscillations (Dutch roll)	Greatest yawing moment of inertia	1.0 and $n_o(+)$	$h_{o_{min}}$, medium,	V_{min} to V_{max}	*,CR,RI,PA,L
3.3.1.2	Roll mode	Greatest rolling moment of inertia	1.0 and $n_o(+)$	$h_{o_{max}}$	V_{min} to V_{max}	*,CR,PA,L
3.3.1.3	Spiral stability	---	1.0	↓	V_{min} to V_{max}	*,CL,CR,LO,RT, TO,PA,L
3.3.1.4	Coupled roll-spiral oscillation	---	1.0 and $n_o(+)$	↓	↓	*,CR,PA,L
3.3.2.1	Lateral-directional response to atmospheric disturbances	---	1.0	↓	↓	---
3.3.2.2	Roll rate oscillations	---	1.0 and $n_o(+)$	↓	↓	*,CR,PA,L
3.3.2.2.1	Additional roll rate requirement for small inputs	---	↓	↓	↓	↓
3.3.2.3	Bank angle oscillations	---	↓	↓	↓	↓
3.3.2.4	Sideslip excursions	Greatest yawing and rolling moment of inertia	1.0	↓	↓	↓
3.3.2.4.1	Additional sideslip requirement for small inputs	↓	1.0	↓	↓	↓
3.3.2.5	Control of sideslip in rolls	Greatest rolling moment of inertia	As required	↓	↓	CO,GA,AR,TF, CR,PA,L
3.3.2.6	Turn coordination	---	↓	↓	$V_{o_{min}}$	CO,CR,LO,PA
3.3.3	Pilot-induced oscillations	---	Min. permissible to max. permissible	MSL to h_{max}	V_{min} to V_{max}	---
3.3.4	Roll control effectiveness	Greatest rolling moment of inertia	As required (not above 0.8 n_L)	$h_{o_{min}}$, medium, $h_{o_{max}}$	↓	CO,GA,AR,TF, CR,PA,L
3.3.4.1	Roll performance for Class IV airplanes	↓	↓		↓	
3.3.4.1.1	Roll performance in Flight Phase CO	↓	↓	$h_{o_{min}}$	↓	CO
3.3.4.1.2	Roll performance in Flight Phase GA	↓	↓	↓	↓	GA
3.3.4.1.3	Roll response	Smallest rolling moment of inertia	↓	$h_{o_{min}}$, medium	↓	---
3.3.4.2	Roll performance for Class III airplanes	Greatest and smallest rolling moment of inertia	↓	$h_{o_{max}}$	↓	CO,GA,AR,TF, CR,PA,L
		↓	↓	↓	↓	--
3.3.4.3	Roll control forces	Greatest rolling moment of inertia	↓	↓	↓	CO,GA,AR,TF, CR,PA,L
3.3.4.4	Linearity of roll response	↓	↓	↓	↓	CO,GA,AR,TF, CR,PA,L
3.3.4.5	Wheel control throw				↓	
3.3.5	Directional control characteristics	---	n(-) to n(+)	$h_{o_{min}}$, medium,	↓	*,CR,PA,L
3.3.5.1	Directional control with speed change	---	1.0	$h_{o_{max}}$	↓	CO,GA,CR,TO, PA,L
3.3.5.1.1	Directional control with asymmetric loading	---	1.0	↓	$V_{o_{min}}$ to $V_{o_{max}}$	---
3.3.5.2	Directional control in wave-off (go around)	Lightest weight	1.0	low	V_{min} (PA) or guaranteed landing speed	WO
3.3.6, 3.3.6.1, 3.3.6.2, 3.3.6.3, 3.3.6.3.1, 3.3.6.3.2	Lateral-directional characteristics in steady sideslips	↓	1.0	$h_{o_{min}}$, medium, $h_{o_{max}}$	V_{min} to V_{max}	CO,CR,PA,L

TABLE XVIII. Design and test condition guidelines. (Continued)

REQ'MT. NO.	TITLE	CRITICAL LOADING (4.2.1, 4.2.2)	LOAD FACTOR	ALTITUDE (4.3.1)	SPEED	FLIGHT PHASE
3.3.7	Lateral-directional control in cross winds	—	1.0	low	As required	TO,L
3.3.7.1	Final approach in cross winds	—	1.0	↓	V_{min} to V_{max}	PA
3.3.7.2 (3.3.7.2.1 3.3.7.2.2)	Takeoff run and landing rollout in crosswinds	—	As required	↓	As required	TO,L
3.3.7.3	Taxiing wind speed limits	—	As required	↓	All taxiing speeds	TAXI
3.3.8	Lateral-directional control in dives	—	As required	2000 ft above MSL to h_{max}	V_{MAT} to V_{max}	D,ED
3.3.9.1	Thrust loss during takeoff run	Lightest weight	1.0	$h_{o_{min}}$	0 to max takeoff speed	TO
3.3.9.2	Thrust loss after takeoff	↓	1.0	↓	Down to V_{min}(TO)	TO,CT
3.3.9.3	Transient effects	Lightest weight	1.0	All	V_{min} to V_{max}	CO,GA,TF,CR, CL,TO,CT
3.3.9.4	Asymmetric thrust - rudder pedals free	↓	1.0	$h_{o_{min}}$, medium, $h_{o_{max}}$	1.4 V_{min}	CR
3.3.9.5	Two engines inoperative	↓	1.0	↓	V_{range} (1 & 2 engines out)	—
SECTION 3.4	MISCELLANEOUS FLYING QUALITIES					
3.4.2	Flight at high angle of attack	See MIL-C-83691 or MIL-D-8708, whichever is applicable for flight demonstration. More severe conditions generally will be investigated by analysis and model testing.				
3.4.2.1 (3.4.2.1.1 through 3.4.2.1.3.1)	Stalls					
3.4.2.2 (3.4.2.2.1, 3.4.2.2.2)	Post-stall gyrations and spins					
3.4.3	Cross-axis coupling in roll maneuvers	—	0 to 0.8 n_L	$h_{o_{min}}$, medium, $h_{o_{max}}$	$V_{o_{min}}$ to $V_{o_{max}}$	CO,GA,AR,TF
3.4.4 (3.4.4.1)	Control harmony	—	$n_o(-)$ to $n_o(+)$	↓	↓	—
3.4.5	Buffet	—	↓	↓	↓	*
3.4.6	Release of stores	—	↓	↓	↓	CO,GA,WD,AD
3.4.7	Effects of armament delivery and special equipment	—	↓	↓	↓	*,RT
3.4.8	Transients following failures	—	all	↓	all	—
3.4.10	Control margin	—	↓	↓	↓	—
3.4.11	Direct force control	—	1.0 ± maximum DLC authority	$h_{o_{min}}$, medium, $h_{o_{max}}$	$V_{o_{min}}$ to $V_{o_{max}}$	—

TABLE XVIII. Design and test condition guidelines. (Continued)

REQ'MT. NO	TITLE	CRITICAL LOADING (4.2.1, 4.2.2)	LOAD FACTOR	ALTITUDE (4.3.1)	SPEED	FLIGHT PHASE
SECTION 3.5	CHARACTERISTICS OF THE PRIMARY FLIGHT CONTROL SYSTEM					
3.5.2 (3.5.2.1, 3.5.2.2, 3.5.2.3)	Mechanical characteristics	—	$n_o(-)$ to $n_o(+)$	$h_{o_{min}}$ and $h_{o_{max}}$	V_{min} to V_{max}	—
3.5.3 (3.5.3.1, 3.5.3.2)	Dynamic characteristics	most forward c.g. & lowest values of rolling and yawing moments of inertia	1.0			—
3.5.5 (3.5.5.1, 3.5.5.2)	Failures	—	all			—
3.5.6 (3.5.6.1, 3.5.6.2)	Transfer to alternate control modes	—	1.0	$h_{o_{min}}$, medium, $h_{o_{max}}$		—
SECTION 3.6	CHARACTERISTICS OF SECONDARY CONTROL SYSTEMS					
3.6.1	Trim system	most forward c.g. and most aft c.g.	1.0	$h_{o_{min}}$, medium, $h_{o_{max}}$	V_{min} to V_{max}	—
3.6.1.1	Trim for asymmetric thrust	most forward c.g. and most aft c.g.	1.0	$h_{o_{min}}$ and max. attainable	V_{range} to V_{MRT} (with 1 & 2 engines out)	CR
3.6.1.2	Rate of trim operation	—	1.0	As required	As required	CO,GA,D,FO
3.6.1.3	Stalling of trim system	most forward c.g. combined with heaviest weight	As required	As required	Start of dive recov. to V_{max}	D,ED,CO,CR
3.6.1.4	Trim system irreversibility	—	1.0	MSL to h_{max}	V_{min} to V_{max}	—
3.6.2	Speed and flight-path control devices	—	1.0 to $n_o(+)$	$h_{o_{min}}$, medium, $h_{o_{max}}$	$V_{o_{min}}$ to $V_{o_{max}}$	*,RT,FD,BM,PA,WD,CA
3.6.3	Transients and trim changes	—	$n_o(-)$ to $n_o(+)$	$h_{o_{min}}$, medium, $h_{o_{max}}$	$V_{o_{min}}$ to $V_{o_{max}}$	—
3.6.3.1	Pitch trim changes	—	As required	As required	As required	CO,CR,PA,TO,CT
3.6.4	Auxiliary dive recovery devices	most aft c.g. combined with lightest weight	As required	MSL to h_{max}	$V_{o_{min}}$ to V_{max}	D,ED
SECTION 3.7	ATMOSPHERIC DISTURBANCES	—	1.0	MSL to h_{max}	V_{min} to V_{max}	—
SECTION 3.8	REQUIREMENTS FOR USE OF THE DISTURBANCE MODELS	—	All	MSL to h_{max}	V_{min} to V_{max}	—

NOTES:

(1) a dash (-) indicates no general guidance can be provided.

(2) The phrase "as required" means the flight conditions are specified in the requirement or are determined by the nature of the test maneuver.

(3) An asterisk (*) means all applicable Category A Flight Phases.

Flight Phase		Weight	C.G.	External Stores	Thrust	Thrust Vector Angle	High Lift Devices	Wing Sweep	Wing Incidence	Landing Gear	Speed Brakes	Bomb bay or Cargo Doors	Stability Augmentation	Other
Takeoff	TO													
Climb	CL													
Cruise	CR													
Loiter	LO													
Descent	D													
Emergency Descent	ED													
Emergency Deceleration	DE													
Approach	PA													
Wave-off/ Go-Around	WO													
Landing	L													
Air-to-air Combat	CO													
Ground Attack	GA													
Weapon Delivery/ Launch	WD													
Aerial Delivery	AD													
Aerial Recovery	AR													
Reconnaissance	RC													
Refuel Receiver	RR													
Refuel Tanker	RT													
Terrain Following	TF													
Antisubmarine Search	AS													
Close Formation Flying	FF													
Catapult Takeoff	CT													

TABLE XIX. Airplane Normal States.

4.4 Tests at specialized facilities. Certain tests, by their nature, can be conducted only at specialized facilities which are not accessible to either the procuring activity or the contractor except at the option of a third organization. In such cases, when an agreement of test suport at the specialized facility is obtained by the procuring activity, an analysis of results obtained in the tests is a necessary part of the analytical compliance demonstration.

5. PREPARATION FOR DELIVERY

5.1 Section 5 is not applicable to this specification.

6. NOTES

6.1 Intended use. This specification contains the flying qualities requirements for piloted airplanes and forms one of the bases for determination by the procuring activity of airplane acceptability. The specification consists of design requirements in terms of criteria for use in stability and control calculations, analysis of wind tunnel test results, simulator evaluations, flight testing, etc. The requirements should be met as far as possible by providing an inherently good basic airframe. Cost, performance, reliability, maintenance, etc. tradeoffs are necessary in determining the proper balance between basic airframe characteristics and augmented dynamic response characteristics. The contractor should advise the procuring activity of any significant design penalties which may result from meeting any particular requirement.

6.2 Definitions. Terms and symbols used throughout this specification are defined as follows:

6.2.1 General.

S	- wing area
s	- Laplace operator
q	- dynamic pressure
MSL	- mean sea level
T_2	- time to double amplitude; $T_2 = -.693/\zeta\omega_n$ for oscillations, $T_2 = .693\tau$ for first-order divergences
Airplane Normal States	- the nomenclature and format of table XIX shall be used in defining the Airplane Normal States (3.1.6.1)

Service ceiling - altitude at a given airspeed at which the rate of climb is 100 ft/min at stated weight and engine thrust

Combat ceiling - altitude at a given airspeed at which rate of climb is 500 ft/min at stated weight and engine thrust

Cruising ceiling - altitude at a given airpseed at which rate of climb is 300 ft/min at NRT at stated weight

h_{max} - maximum service altitude (defined in 3.1.8.3)

$h_{o_{max}}$ - maximum operational altitude (3.1.7)

$h_{o_{min}}$ - minimum operational altitude (3.1.7)

c.g. - airplane center of gravity

6.2.2 Speeds

Equivalent airspeed, EAS - true airspeed multiplied by $\sqrt{\sigma}$, where σ is the ratio of free-stream density at the given altitude to standard sea-level air density

Calibrated airspeed - airspeed-indicator reading corrected for position and instrument error but not for compressibility

Refusal speed - the maximum speed to which the airplane can accelerate and then stop in the available runway length

M - Mach number

V - airspeed along the flight path (where appropriate, V may be replaced by M in this specification),

V_S - stall speed (equivalent airspeed), at 1g normal to the flight path, defined as the highest of:

a. speed for steady straight flight at $C_{L_{max}}$, the first local maximum of the curve of lift coefficient (L/qS) vs. angle of attack which occurs as C_L is increased from zero

b. speed at which uncommanded pitching, rolling or yawing occurs (3.4.2.1.2)

c. speed at which intolerable buffet or structural vibration is encountered

Conditions for determining V_S.

The airplane shall be initially trimmed at approximately 1.2 V_S with the following settings, after which the trim and throttle settings shall be held constant:

Flight Phase	Thrust Settings*	Trim Setting
Climb (CL)	Normal climb	For straight flight
Descent (D)	Normal descent	For straight flight
Emergency descent (ED)	Idle	For straight flight
Emergency deceleration (DE)	Idle	For straight flight
Takeoff (TO)	Takeoff	Recommended takeoff setting
Approach (PA)	Normal approach	For normal approach
Wave-off/go-around (WO)	Takeoff	For normal approach
Landing (L)	Idle	For normal approach
All other	TLF at 1.2 V_S	For straight flight

* Either on all engines or on remaining engines with critical engine inoperative, whichever yields the higher value of V_S.

In flight test, it is necessary to reduce speed very slowly (typically 1/2 knot per second or less) to minimize dynamic lift effects. The load factor will generally not be exactly 1g when stall occurs; when this is the case, V_S is defined as follows:

$$V_S = \frac{V}{\sqrt{n_f}}$$

where V and n_f are the measured values at stall, n_f being the load factor normal to the flight path.

$V_S(X)$, $V_{min}(X)$, $V_{max}(X)$ - short-hand notation for the speeds V_S, V_{min}, V_{max} for a given configuration, weight, center-of-gravity position, and external store combination associated with Flight Phase X. For example, the designation $V_{max}(TO)$ is used in 3.2.3.3.2 to emphasize that the speed intended (for the weight, center of gravity), and external store combination under consideration) is V_{max} for the configuration associated with the takeoff Flight Phase. This is necessary to avoid confusion, since the configuration and Flight Phase change from takeoff to climb during the maneuver.

V_{trim} - trim speed

V_{end} - speed for maximum endurance

$V_{L/D}$ - speed for maximum lift-to-drag ratio

$V_{R/C}$ - speed for maximum rate of climb

V_{range} - speed for maximum range in zero wind conditions

V_{NRT} - high speed, level flight, normal rated thrust

V_{MRT} - high speed, level flight, military rated thrust

V_{MAT} - high speed, level flight, maximum augmented thrust

V_{max} - maximum service speed (defined in 3.1.8.1)

V_{min} - minimum service speed (defined in 3.1.8.2)

$V_{o_{max}}$ - maximum operational speed (3.1.7)

$V_{o_{min}}$ - minimum operational speed (3.1.7)

V_G - gust penetration speed

6.2.3 Thrust and power

Thrust and power - for propeller-driven airplanes, the word "thrust" shall be replaced by the word "power" throughout the specification

TLF - thrust for level flight

NRT - normal rated thrust, which is the maximum thrust at which the engine can be operated continuously

MRT - military rated thrust, which is the maximum thrust at which the engine can be operated for a specified period

MAT - maximum augmented thrust: maximum thrust, augmented by all means available for the Flight Phase

Takeoff thrust - maximum thrust available for takeoff

6.2.4 Control parameters

Pitch, roll, yaw controls - the stick or wheel and pedals manipulated by the pilot to produce pitching, rolling and yawing moments respectively; the cockpit controls

Pitch control force, F_S - component of applied force, exerted by the pilot on the cockpit control, in or parallel to the plane of symmetry, acting at the center of the stick grip or wheel in a direction perpendicular to a line between the center of the stick grip and the stick or control column pivot

Roll control force - for a stick control, the component of control force exerted by the pilot in a plane perpendicular to the plane of symmetry, acting at the center of the stick grip in a direction perpendicular to a line between the center of the stick grip and the stick pivot. For a wheel control, the total moment applied by the pilot about the wheel axis in the plane of the wheel, divided by the average radius from the wheel pivot to the pilot's grip

Yaw-control pedal force - difference of push-force components of forces exerted by the pilot on the yaw-control pedals, lying in planes parallel to the plane of symmetry, measured perpendicular to the pedals at the normal point of application of the pilot's instep on the respective yaw-control pedals

Direct normal force control - a device producing direct normal force for the primary purpose of controlling the flight path of the airplane. Direct normal force control is the descriptive title given to the concept of directly modulating the normal force on an airplane by changing its lifting capabilities at a constant angle of attack and constant airspeed or by controlling the normal force component of such items as jet exhausts, propellers, and fans

Control power - effectiveness of control surfaces in applying forces or moments to an airplane. For example, 50 percent of available roll control power is 50 percent of the maximum rolling moment that is available to the pilot with allowable roll control force

6.2.5 Longitudinal parameters

ζ_{SP} - damping ratio of the short-period oscillation

ω_{nSP} - undamped natural frequency of the short-period oscillation

ζ_p - damping ratio of the phugoid oscillation

ω_{n_p} - undamped natural frequency of the phugoid oscillation

n - normal acceleration or normal load factor, measured at the c.g.

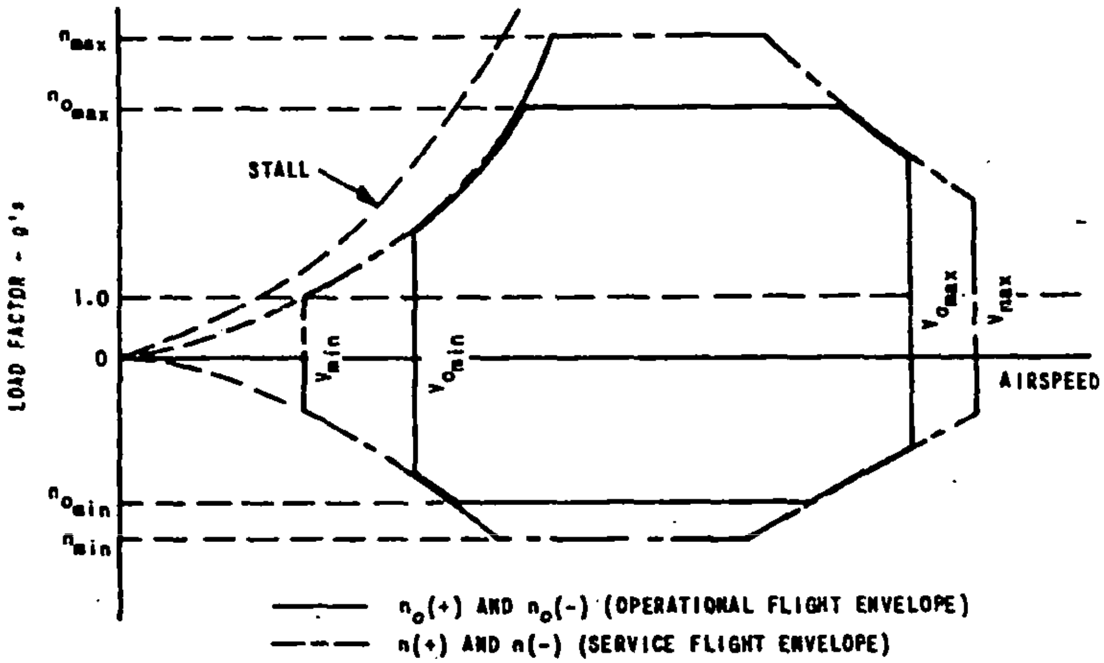
n_L - symmetrical flight limit load factor for a given Airplane Normal State, based on structural considerations

n_{max}, n_{min} - maximum and minimum service load factors

$n(+)$, $n(-)$ - for a given altitude, the upper and lower boundaries of n in the V-n diagrams depicting the Service Flight Envelope

$n_{o_{max}}$, $n_{o_{min}}$ - maximum and minimum operational load factors

$n_o(+)$, $n_o(-)$ - for given altitude, the upper and lower boundaries of n in the V-n diagrams depicting the Operational Flight Envelope



α - angle of attack; the angle in the plane of symmetry between the fuselage reference line and the tangent to the flight path at the airplane center of gravity

α_s - the stall angle of attack at constant speed for the configuration, weight, center of gravity position and external-store combination associated with a given Airplane Normal State; defined as the lowest of the following:

a. Angle of attack for the highest steady load factor, normal to the flight path, that can be attained at a given speed or Mach number

b. Angle of attack, for a given speed or Mach number, at which uncommanded pitching, rolling or yawing occurs (3.4.2.1.2)

c. Angle of attack, for a given speed or Mach number, at which intolerable buffeting is encountered.

$C_{L_{stall}}$ - lift coefficient at α_S defined above.

n/α - the steady-state normal acceleration change per unit change in angle of attack for an incremental pitch control deflection at constant speed (airspeed and Mach number)

F_S/n - gradient of steady-state pitch control force versus n at constant speed (3.2.2.2.1)

γ - climb angle, positive for climbing flight

$\gamma = \sin^{-1}$ (vertical speed/true airspeed)

θ - pitch attitude, the angle between the x-axis and the horizontal

L - aerodynamic lift plus thrust component normal to the flight path

6.2.6 Lateral-directional parameters

δ_{AS} - displacement of the roll control stick or wheel along its path

τ_R - first-order roll mode time constant, positive for stable mode

τ_S - first-order roll mode time constant, positive for stable mode

λ_R - $(-1/\tau_R)$

λ_S - $(-1/\tau_S)$

ω_ϕ - undamped natural frequency of numerator quadratic of ϕ/δ_{AS} transfer function

ζ_ϕ - damping ratio of numerator quadratic of ϕ/δ_{AS} transfer function

ω_{n_d} - undamped natural frequency of the Dutch roll oscillation

ζ_d - damping ratio of the Dutch roll oscillation

T_d - damped period of the Dutch roll, $T_d = \dfrac{2\pi}{\omega_{n_d}\sqrt{1-\zeta_d^2}}$

$\omega_{n_{RS}}$ - undamped natural frequency of a coupled roll-spiral oscillation

ζ_{RS} - damping ratio of a coupled roll-spiral oscillation

ϕ - bank angle measured in the y-z plane, between the y-axis and the horizontal (6.2.1)

ϕ_t - bank angle change in time t, in response to control deflection of the form given in 3.3.4

p - roll rate about the x-axis (6.2.1)

$\frac{p_{osc}}{p_{av}}$ - a measure of the ratio of the oscillatory component of roll rate to the average component of roll rate following a yaw-control-free step roll control command:

$$\zeta_d \leq 0.2: \quad \frac{p_{osc}}{p_{av}} = \frac{p_1 + p_3 - 2p_2}{p_1 + p_3 + 2p_2}$$

$$\zeta_d > 0.2: \quad \frac{p_{osc}}{p_{av}} = \frac{p_1 - p_2}{p_1 + p_2}$$

where p_1, p_2, and p_3 are roll rates at the first, second and third peaks, respectively. (Figures 14 and 15).

$\frac{\phi_{osc}}{\phi_{av}}$ - a measure of the ratio of the oscillatory component of bank angle to the average component of bank angle following a pedals-free impulse aileron control command:

$$\zeta_d \leq 0.2: \quad \frac{\phi_{osc}}{\phi_{av}} = \frac{\phi_1 + \phi_3 - 2\phi_2}{\phi_1 + \phi_3 + 2\phi_2}$$

$$\zeta_d > 0.2: \quad \frac{\phi_{osc}}{\phi_{av}} = \frac{\phi_1 - \phi_2}{\phi_1 + \phi_2}$$

where ϕ_1, ϕ_2, ϕ_3 are bank angles at the first, second and third peaks, respectively.

β - sideslip angle at the center of gravity, angle between undisturbed flow and plane of symmetry. Positive, or right sideslip corresponds to incident flow approaching from the right side of the plane of symmetry

$\Delta\beta$ - maximum change in sideslip occurring within 2 seconds or one half-period of the Dutch roll, whichever is greater, for a step roll-control command (figures 14 and 15)

k - ratio of "command roll performance" to "applicable roll performance requirement" of 3.3.4 or 3.3.4.1, where:

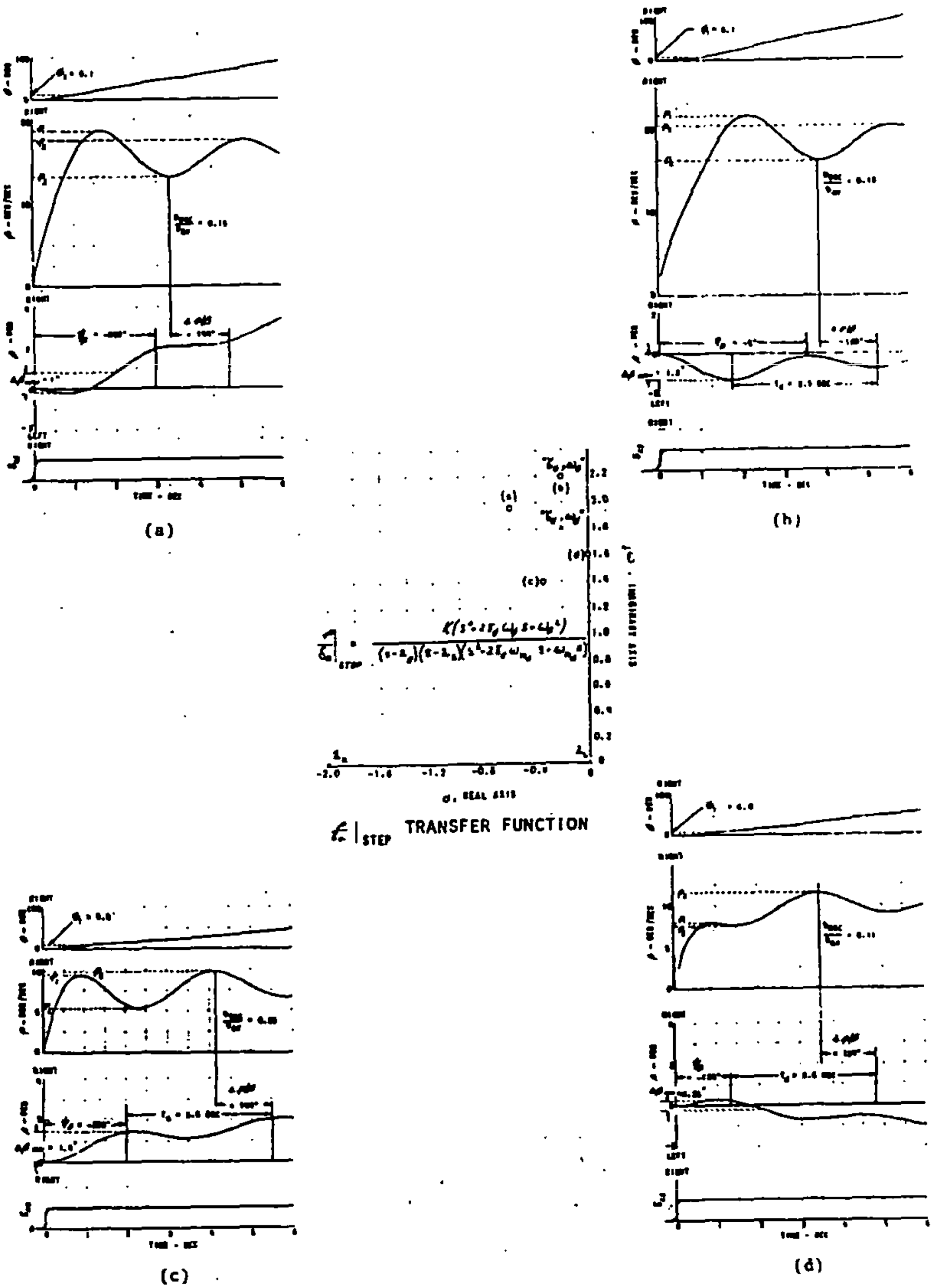


FIGURE 14. Roll-sideslip coupling parameters-right rolls.

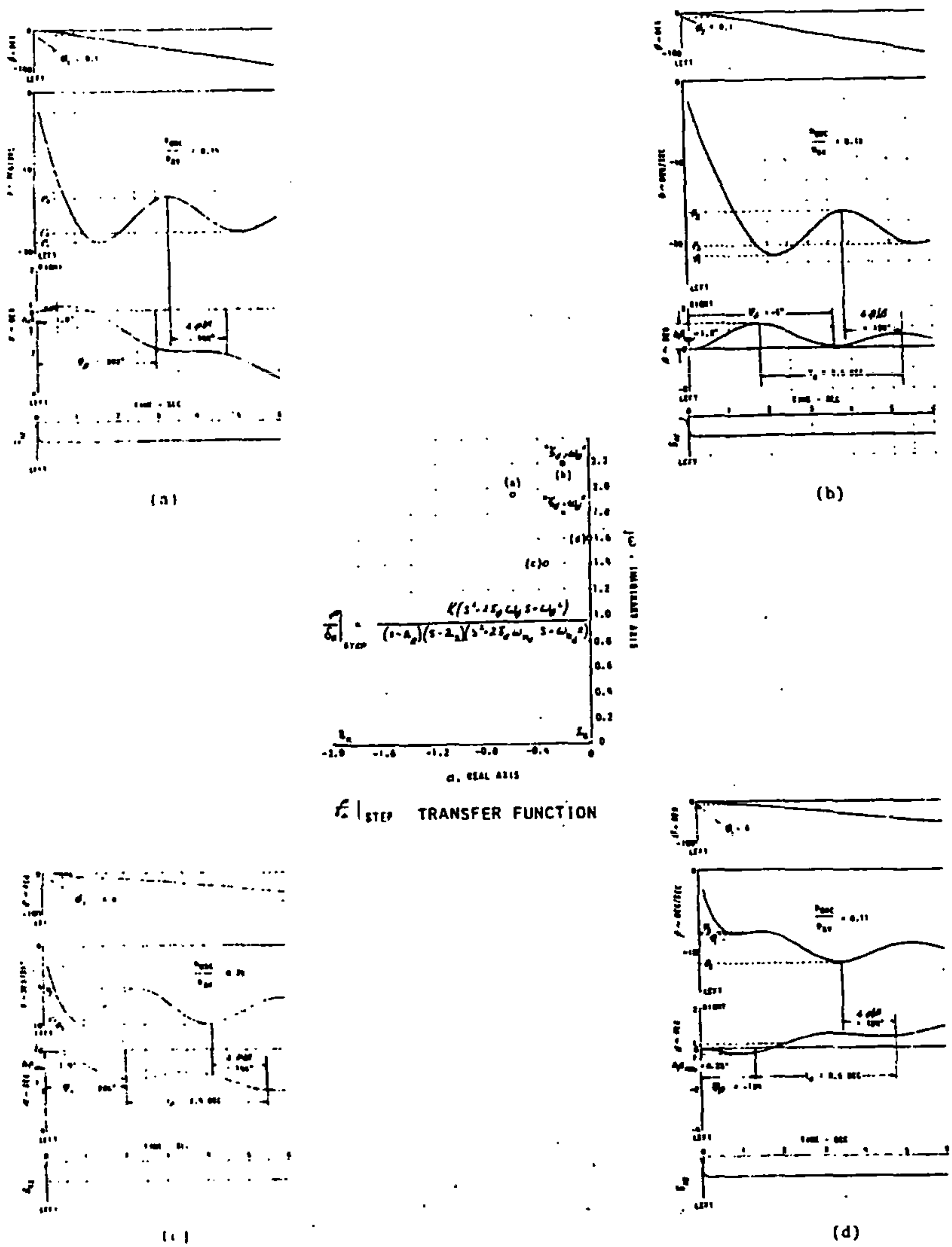


FIGURE 15. Roll-sideslip coupling parameters-left rolls.

a. "Applicable roll performance requirement", (ϕ_t) requirement, is determined from 3.3.4 and 3.3.4.1 for the Class, Flight Phase Category and Level under consideration

b. "Commanded roll performance", (ϕ_t) command, is the bank angle attained in the stated time for a given step roll command with yaw control pedals employed as specified in 3.3.4 and 3.3.4.1

$$k = \frac{(\phi_t)_{command}}{(\phi_t)_{requirement}}$$

t_{n_β} - time for the Dutch roll oscillation in the sideslip response to reach the n^{th} local maximum for a right step or pulse roll-control command, or the n^{th} local minimum for a left command. In the event a step control input cannot be accomplished, the control shall be moved as abruptly as practical and, for purposes of this definition, time shall be measured from the instant the cockpit control deflection passes through half the amplitude of the commanded value. For pulse inputs, time shall be measured from a point halfway through the duration of the pulse

ψ_β - phase angle expressed as a lag for a cosine representation of the Dutch roll oscillation in sideslip, where

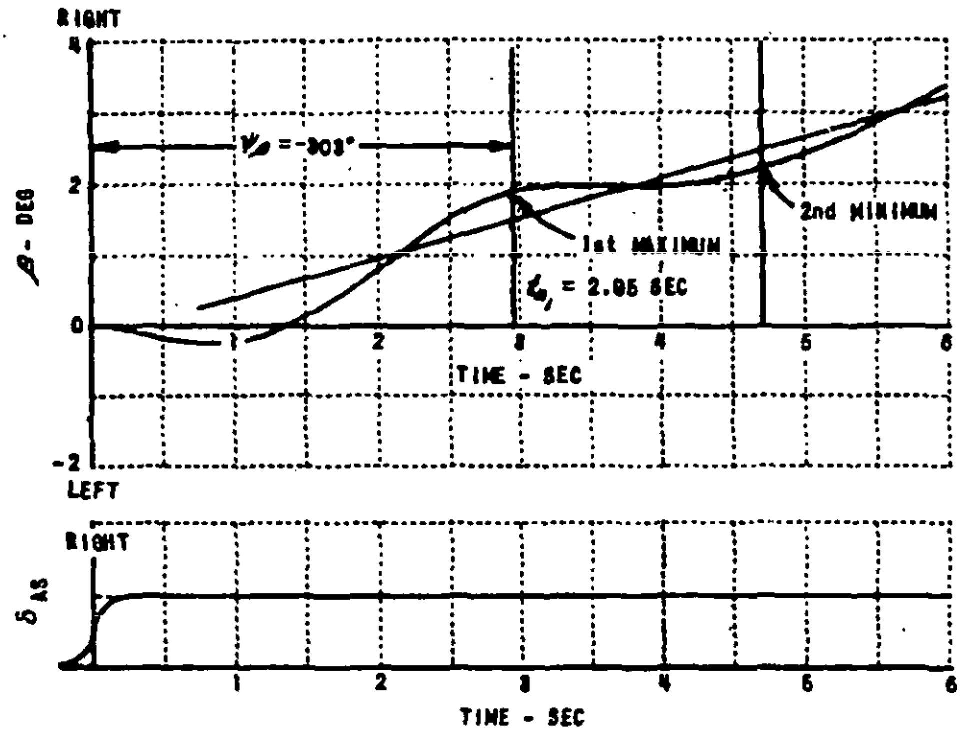
$$\psi_\beta = -\frac{360}{T_d} t_{n_\beta} + (n - 1)360 \qquad \text{(degrees)}$$

with n as in t_n above

$\psi_{p/\beta}$ - phase angle between roll rate and sideslip in the free Dutch roll oscillation. Angle is positive when p leads β by an angle between 0 and 180°

$|\phi/\beta|_d$ - at any instant, the ratio of amplitudes of the bank-angle and sideslip-angle envelopes in the Dutch roll mode

Examples showing measurement of roll-sideslip coupling parameters are shown on figure 14 for right rolls and figure 15 for left rolls. Since several oscillations of the Dutch roll are required to measure these parameters, and since for proper identification large roll rates and bank angle changes must generally be avoided, step roll control inputs should be small. It should be noted that since ψ_β is the phase angle of the Dutch roll component of sideslip, care must be taken to select a peak far enough downstream that the position of the peak is not influenced by the roll mode. In practice, peaks occurring one or two roll mode time constants after the aileron input will be relatively undistorted. Care must also be taken when there is ramping of the sideslip trace, since ramping will displace the position of a peak of the trace from the corresponding peak of the Dutch roll component. In practice, the peaks of the Dutch roll component of sideslip are located by first drawing a line through the ramping portion of the sideslip trace and then noting the times at which the vertical distance between the line and the sideslip trace is the greatest. (see following sketch for Case (a) of figures 14 and 15.)



Since the first local maximum of the Dutch roll <u>component</u> of the sideslip response occurs at t = 2.95 seconds,

$$\psi_\beta = \frac{-360}{T_d} t_{n_\beta} + (n - 1)360 = \frac{-360}{3.5}(2.95) = -303 \text{ degrees}$$

Level 1 flying qualities of a Class IV airplane in the approach are under examination; so the roll performance requirement from table IX upon which the parameter "k" in the sideslip excursion requirement (figure 6) is based, is ϕ_t = 30 degrees in 1 second with rudder pedals free (as in the rolls of 3.3.2.4). From the definitions, "k" for this condition is,

$$k = \frac{(\phi_1)_{command}}{(\phi_1)_{requirement}}$$

Therefore from figures 14 and 15:

Case (a), k = 9.1/30 = 0.30

Case (b), k = 8.1/30 = 0.27

Case (c), k = 6.8/30 = 0.23

Case (d), k = 6.0/30 = 0.20

6.2.7 Atmospheric disturbances parameters

j	- $\sqrt{-1}$
Ω	- spatial (reduced) frequency (radians per foot)
ω	- temporal frequency (radians per second), where $\omega = \Omega V$
t	- time (seconds)
u_g	- disturbance velocity along the x-axis, positive forward (feet per second)
v_g	- disturbance velocity along the y-axis, positive to pilot's right (feet per second)
w_g	- disturbance velocity along the z-axis, positive down (feet per second)
	Note: Random u_g, v_g, w_g have Gaussian (normal) distributions
$V_{w/d}$	- magnitude of wind over the aircraft carrier deck (feet per second)
σ, RMS	- root-mean-square disturbance intensity, where $\sigma^2 = \int_0^\infty \Phi(\Omega)d\Omega = \int_0^\infty \Phi(\omega)d\omega$
σ_u	- root-mean-square intensity of u_g
σ_v	- root-mean-square intensity of v_g
σ_w	- root-mean-square intensity of w_g
L_u	- scale for u_g (feet)
L_v	- scale for v_g (feet)
L_w	- scale for w_g (feet)
$\Phi_{u_g}(\Omega)$	- spectrum for u_g, where $\Phi_{u_g}(\Omega) = V\Phi_{u_g}(\omega)$
$\Phi_{v_g}(\Omega)$	- spectrum for v_g, where $\Phi_{v_g}(\Omega) = V\Phi_{v_g}(\omega)$
$\Phi_{w_g}(\Omega)$	- spectrum for w_g, where $\Phi_{w_g}(\Omega) = V\Phi_{w_g}(\omega)$
v_m	- generalized discrete gust intensity, positive along the positive axes, m = x, y, z (feet per second)
d_m	- generalized discrete gust length (always positive) m = x, y, z (feet)
u_{20}	- wind speed at 20 feet above the ground

x - distance from airplane to ship center of pitch, negative aft of ship (feet)

ψ_w - mean wind direction relative to runway (3.7.3.3)

6.2.8 Terms used in high angle of attack requirements

Post-stall - The flight regime involving angles of attack greater than nominal stall angles of attack. The airplane characteristics in the post-stall regime may consist of three more or less distinct consecutive types of airplane motion following departure from controlled flight: post-stall gyration, incipient spin, and developed spin.

Post-stall gyration (PSG) - Uncontrolled motions about one or more airplane axis following departure from controlled flight. While this type of airplane motion involves angles of attack higher than stall angle, lower angles may be encountered intermittently in the course of the motion.

Spin - That part of the post-stall airplane motion which is characterized by a sustained yaw rotation. The spin may be erect or inverted, flat (high angle of attack) or steep (low but still stalled angle of attack) and the rotary motions may have oscillations in pitch, roll and yaw superimposed on them. The incipient spin is the initial, transient phase of the motion during which it is not possible to identify the spin mode, usually followed by the developed spin, the phase during which it is possible to identify the spin mode.

6.3 Interpretation of F_s/n limits of table V. Because the limits on F_s/n are a function of both n_L and n/α, table V is rather complex. To illustrate its use, the limits are presented on figure 16 for an airplane having a center-stick controller and $n_L = 7.0$.

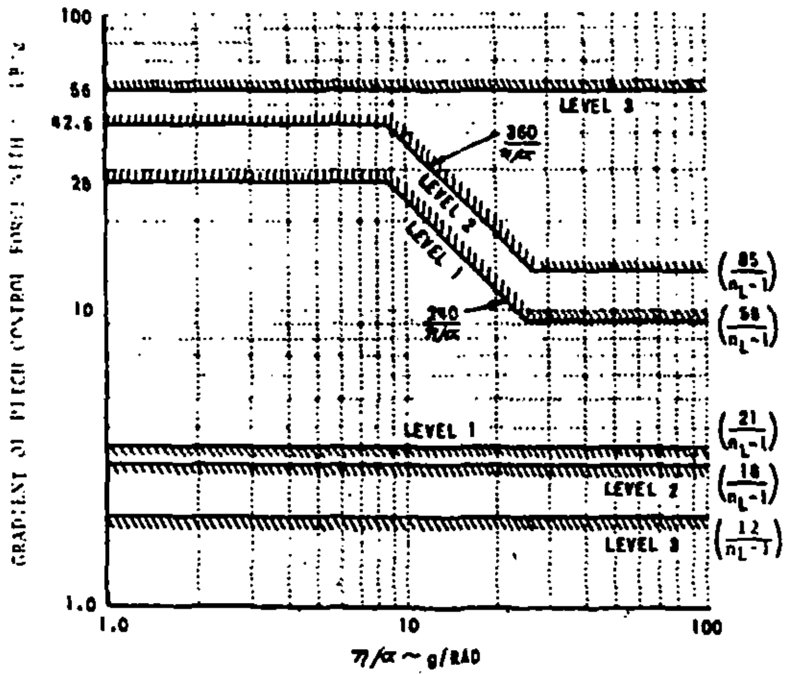


FIGURE 16. Example of pitch maneuvering force gradient limits: Center-stick controller, $n_L = 7.0$

6.4 Gain scheduling. Changes of mechanical gearings and stability augmentation gains in the primary flight control system are sometimes accomplished by scheduling the changes as a function of the settings of secondary control devices, such as flaps or wing sweep. This practice is generally acceptable, but gearings and gains normally should not be scheduled as a function of trim control settings since pilots do not always keep airplanes in trim.

6.5 Engine considerations. Secondary effects of engine operation may have an important bearing on flying qualities and should not be overlooked in design. These considerations are: the influence of engine gyroscopic moments on airframe dynamic motions; the effects of engine operation (including flameout and intentional shutdown) on characteristics of flight at high angle of attack (3.4.2); and the reduction at low rpm of engine-derived power for operating the flight control system.

6.6 Effects of aeroelasticity, control equipment and structural dynamics. Since aeroelasticity, control equipment and structural dynamics may exert an important influence on the airplane flying qualities, such effects should not be overlooked in calculations or analyses directed toward investigation of compliance with the requirements of this specification.

6.7 Application of Levels. Part of the intent of 3.1.10 is to ensure that the probability of encountering significantly degraded flying qualities because of component or subsystem failures is small. For example, the probability of encountering very degraded flying qualities (Level 3) must be less than specified values per flight.

6.7.1 Level definitions. To determine the degradation in flying qualities parameters for a given Airplane Failure State the following definitions are provided:

a. Level 1 is better than or equal to the Level 1 boundary, or number, specified in Section 3

b. Level 2 is worse than Level 1, but no worse than the Level 2 boundary, or number

c. Level 3 is worse than Level 2, but no worse than the Level 3 boundary, or number.

When a given boundary, or number, is identified as Level 1 and Level 2, this means that flying qualities outside the boundary conditions shown, or worse than the number given, are at best Level 3 flying qualities. Also, since Level 1 and Level 2 requirements are the same, flying qualities must be within this common boundary, or number, in both the Operational and Service Flight Envelopes for Airplane Normal States (3.1.10.1). Airplane Failure States that do not degrade flying qualities beyond this common boundary are not considered in meeting the requirements of 3.1.10.2. Airplane Failure States that represent degradations to Level 3 must, however, be included in the computation of the probability of encountering Level 3 degradations in both the Operational and Service Flight Envelopes. Again degradation beyond the Level 3 boundary is not permitted regardless of component failures.

6.8 Related documents. The documents listed below, while they do not form a part of this specification, are so closely related to it that their contents should be taken into account in any application of this specification.

SPECIFICATIONS

MILITARY

MIL-C-5011	Charts; Standard Aircraft Characteristics and Performance, Piloted Aircraft
MIL-M-7700	Manual, Flight
MIL-A-8860	Airplane Strength and Rigidity - General Specification for
MIL-A-8871	Airplane Strength and Rigidity Flight and Ground Operations Test
MIL-G-38478	General Requirements for Angle-of-Attack-Based Systems

STANDARD

MILITARY

MIL-STD-882	Systems Safety Program for Systems and Associated Subsystems and Equipment: Requirement for

PUBLICATIONS

AFSC Design Handbooks

DH 1-0 General
DH 2-0 Aeronautical Systems

AFFDL Technical Report

TR 69-72	Background Information and User Guide for MIL-F-8785B, Military Specification - Flying Qualities of Piloted Airplanes, August 1969

6.9 Marginal indicia. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:
Army - AV
Navy - AS
Air Force - 11

Preparing Activity:
Air Force - 11

Project 15GP-0030

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