INDEX

MILITARY SPECIFICATION

FLYING QUALITIES OF PILOTED AIRPLANES

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

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 <u>Land- or carrier-based designation</u>. 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 <u>Flight Phase Categories</u>. 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:

<u>Nonterminal Flight Phases</u>:

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 acceptabi9lity 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:

SPECIFICATION

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.

3.1.7 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, 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 CAT.	FLIGHT PHASE	AIRSPEED		ALTITUDE		LOAD FAC.	
		$V_{O_{MIN}}$ ($M_{O_{MIN}}$)	$V_{O_{MAX}}$ ($M_{O_{MAX}}$)	$h_{O_{MIN}}$	$h_{O_{MAX}}$	$n_{O_{MIN}}$	$n_{O_{MAX}}$
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	0.5	*
	AERIAL RECOVERY (AR)	1.2 V_S	V_{MRT}	MSL	Combat Ceiling	0.5	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	0.5	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)	0.85 $V_{R/C}$	1.3 $V_{R/C}$	MSL	Cruising Ceiling	0.5	2.0
	CRUISE (CR)	V_{range}	V_{NRT}	MSL	Cruising Ceiling	0.5	2.0
	LOITER (LO)	0.85 V_{end}	1.3 V_{end}	MSL	Cruising Ceiling	0.5	2.0
	IN-FLIGHT REFUEL (TANKER) (RT)	1.4 V_S	V_{MAT}	MSL	Cruising Ceiling	0.5	2.0
	DESCENT (D)	1.4 V_S	V_{MAT}	MSL	Cruising Ceiling	0.5	2.0
	EMERGENCY DESCENT (ED)	1.4 V_S	V_{Max}	MSL	Cruising Ceiling	0.5	2.0
	EMERGENCY DECELERATION (DE)	1.4 V_S	V_{Max}	MSL	Cruising Ceiling	0.5	2.0
	AERIAL DELIVERY (AD)	1.2 V_S	200 kt	MSL	10,000 ft	0	2.0
C	TAKEOFF (TO)	Min. Normal Takeoff Speed	V_{Max}	MSL	10,000 ft	0.5	2.0
	CATAPULT TAKEOFF (CT)	Min. Catapult End Speed	$V_{o_{min}}$ + 30 kt	MSL	-	0.5	n_L
	APPROACH (PA)	Min. Normal Approach Spd.	V_{Max}	MSL	10,000 ft	0.5	2.0
	WAVE-OFF (WO)	Min. Normal Approach Spd.	V_{Max}	MSL	10,000 ft	0.5	2.0
	LANDING (L)	Min. Normal Landing Speed	V_{Max}	MSL	10,000 ft	0.5	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 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 distubed 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 stabilty with respect to speed is provided through the flight control system, even though the resulting pitch control force and deflections 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 postion 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 teh 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 tha 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, repsectively.

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

3.2.1.1.2 Pitch control force variations duing 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 poser, actuation of deceleration devices, stepp 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 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.

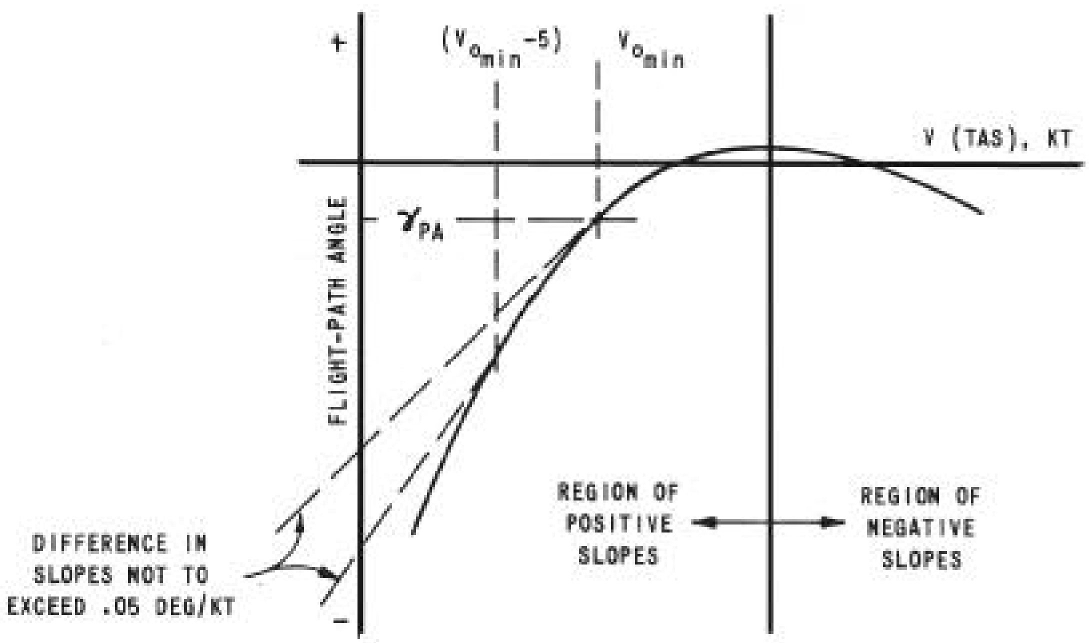
3.2.1.3 Flight-path stability. Flight-path stability is defined in terms of flight-path-angle change where the airspeed is changed by the use of pitch control only (throttle setting not changed by the crew). For the landing approach Flight Phase, the curve of flight-path angle versus true airspeed shall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

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

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

c. Level 3 ----- 0.25 degreees/knot

The thrust setting shall be that required for the normal approach glide path at V_{omin}. The slope of the curve of flight-path angle versus airspeed at 5 knots slower than V_{omin} shall not be more than 0.05 degrees per knot more positive than the slope at V_{omin}, 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 sevice 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 forces 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.

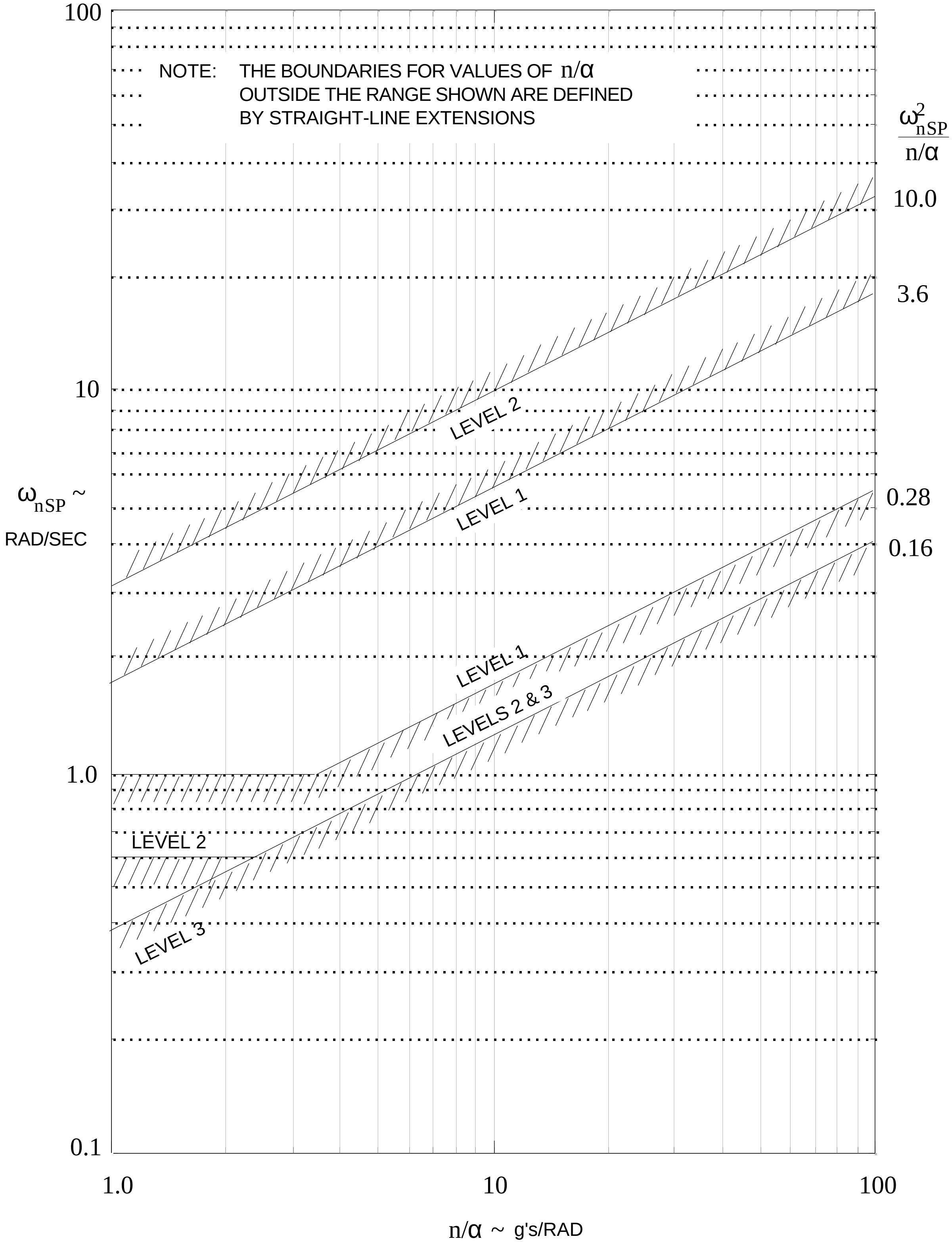


FIGURE 1. Short-period frequency requirements - Category A Flight Phases.

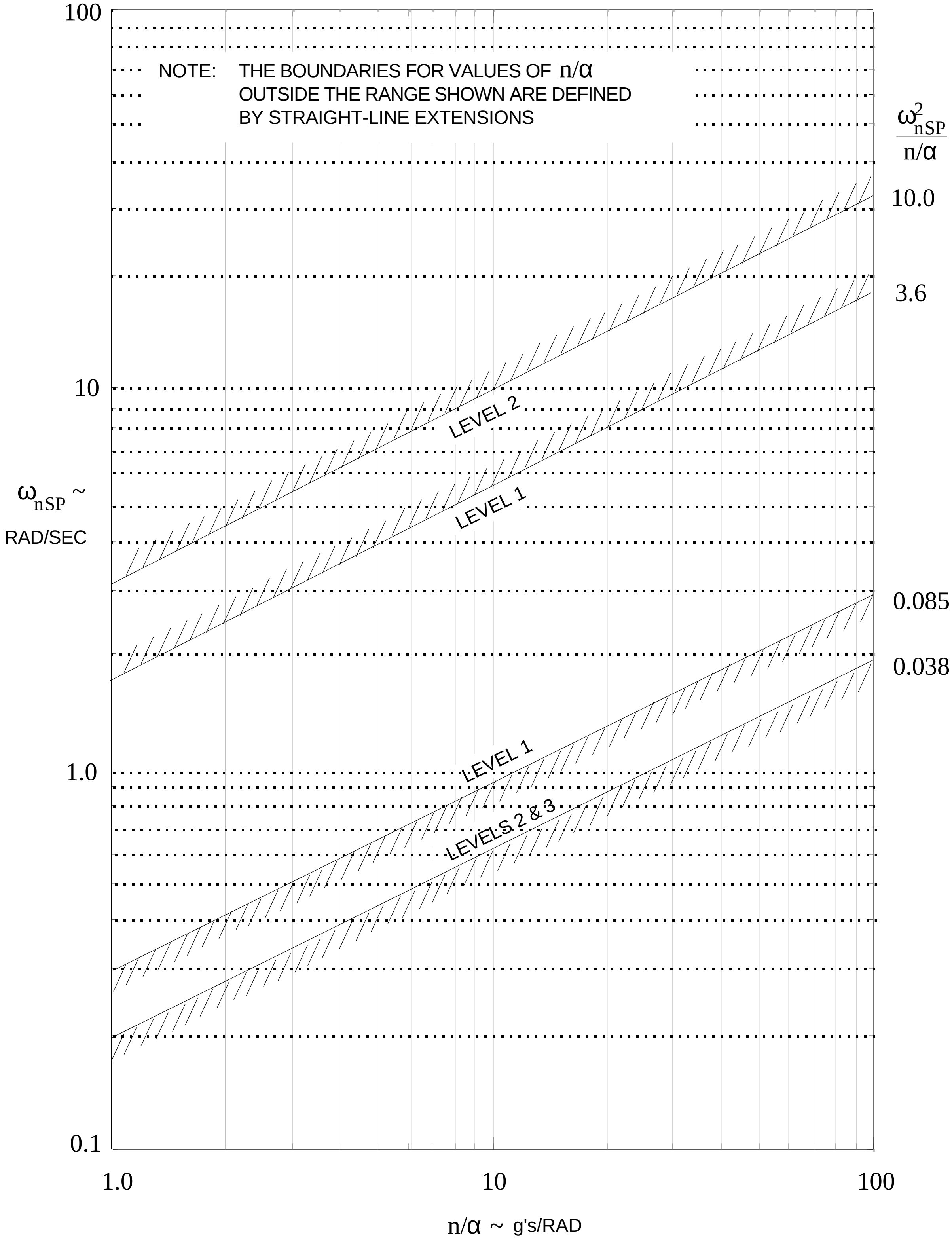


FIGURE 2. Short-period frequency requirements - Category B Flight Phases.

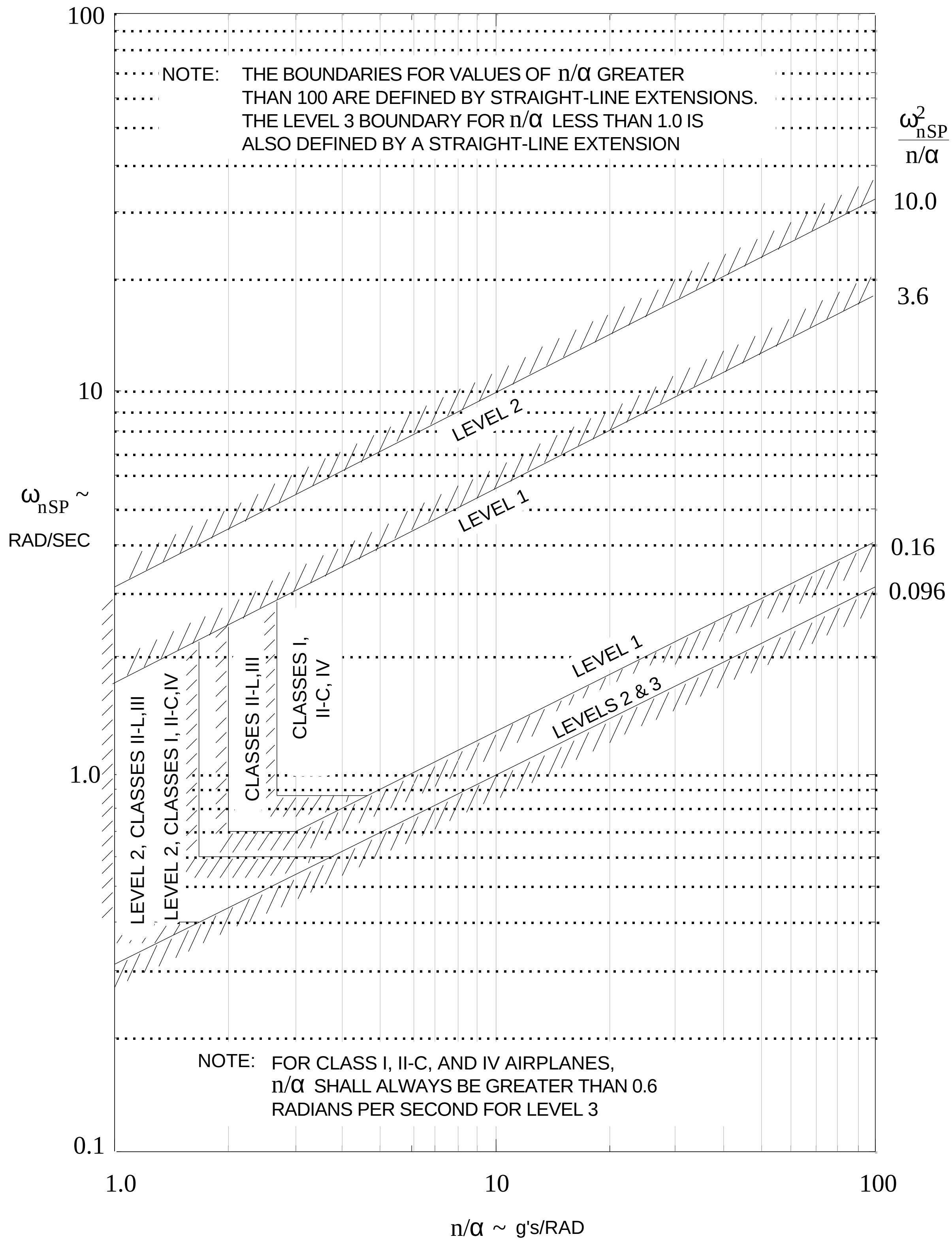


FIGURE 3. Short-period frequency requirements - Category C Flight Phases.

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 nonlinearities 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 additions, 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 28.0 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 $\frac{18}{n_L - 1}$ and 3.0
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 $n_o(+) \le 3g$
$0.5\,[n_o(+) + 1]$ for $n_o(+) \le 3g$

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 the 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 pull to 10 pounds push

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

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_{omin} (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 VMAT 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 require.

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

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

** Class III airplanes may be excepted from the minimum ω_{nd} 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 $\omega_{nd}^2 \left|\varphi/\beta\right|_d$ is greater than 20 (rad/sec)^2, the minimum $\zeta_d\omega_{nd}$ shall be increased above the $\zeta_d\omega_{nd}$ minimums listed above by:

Level 1 - $\Delta\zeta_d\omega_{nd} = .014\left(\omega_{nd}^2 \left|\varphi/\beta\right|_d - 20\right)$

Level 2 - $\Delta\zeta_d\omega_{nd} = .009\left(\omega_{nd}^2 \left|\varphi/\beta\right|_d - 20\right)$

Level 3 - $\Delta\zeta_d\omega_{nd} = .004\left(\omega_{nd}^2 \left|\varphi/\beta\right|_d - 20\right)$

with ω_{nd} 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	2	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_{n_d}, ζ_d, $|\varphi/\beta|_d$, p/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.

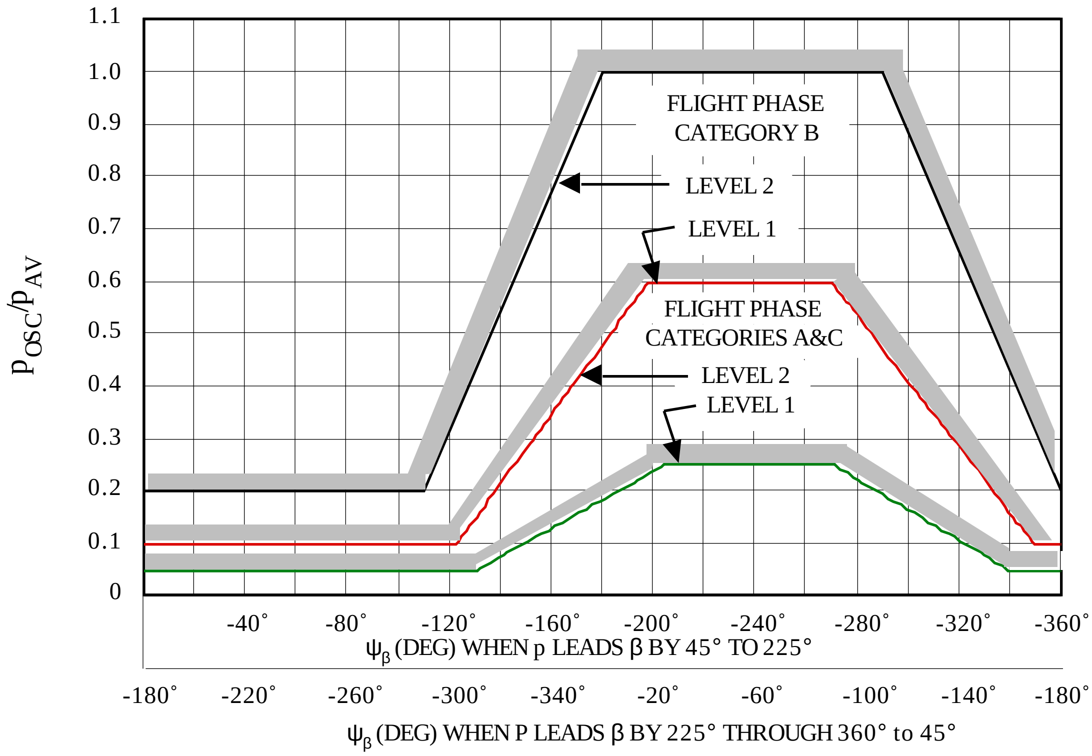
3.3.2.2 Roll rate oscillations. Following a yaw-control-free step roll control command, the roll rate at the first minimum following the first peak shall be of the same sign and not less than the following percentage of the roll rate at the first peak:

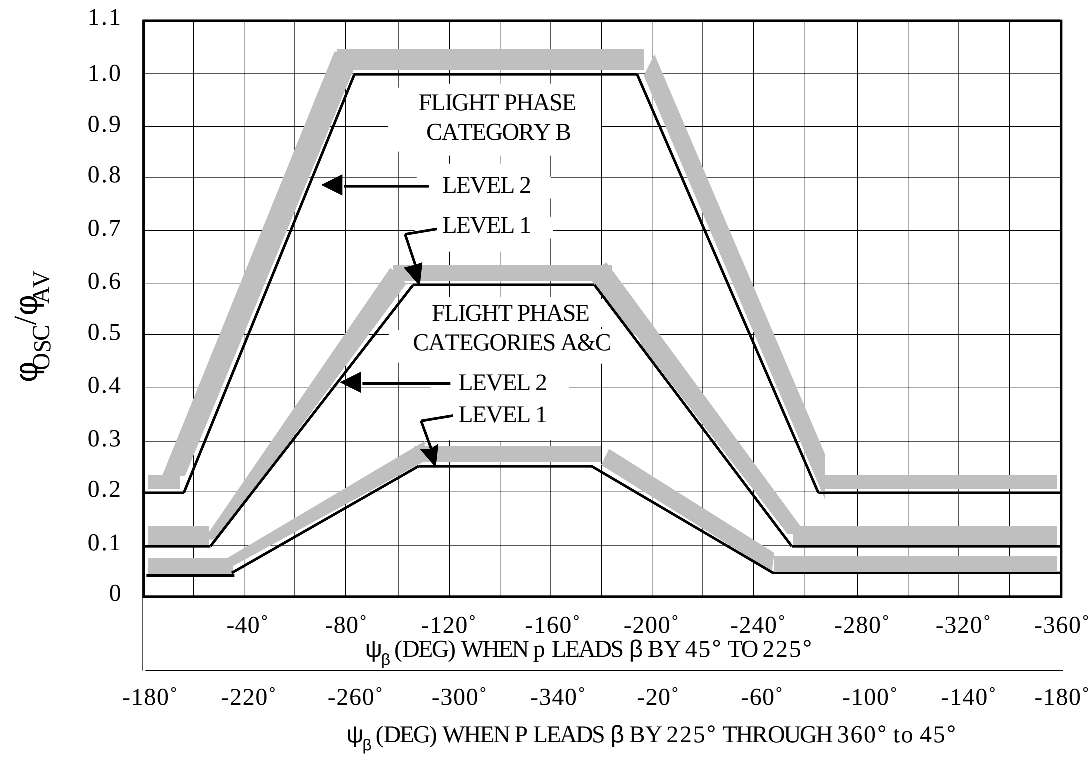
Level	Flight Phase Category	Percent
1	A & C	60
	B	25
2	A & C	25
	B	0

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 requirements 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 1.7 T_d seconds.

3.3.2.3 Bank angle oscillations. The value of the parameter $\varphi_{osc}/\varphi_{av}$ 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.


1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
p_{OSC}/p_{AV}
FLIGHT PHASE
CATEGORY B
LEVEL 2
LEVEL 1
FLIGHT PHASE
CATEGORIES A&C
LEVEL 2
LEVEL 1
-40° -80° -120° -160° -200° -240° -280° -320° -360°
ψ_β (DEG) WHEN p LEADS β BY 45° TO 225°
-180° -220° -260° -300° -340° -20° -60° -100° -140° -180°
ψ_β (DEG) WHEN P LEADS β BY 225° THROUGH 360° to 45°


1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$\varphi_{OSC}/\varphi_{AV}$
FLIGHT PHASE
CATEGORY B
LEVEL 2
LEVEL 1
FLIGHT PHASE
CATEGORIES A&C
LEVEL 2
LEVEL 1
-40° -80° -120° -160° -200° -240° -280° -320° -360°
ψ_β (DEG) WHEN p LEADS β BY 45° TO 225°
-180° -220° -260° -300° -340° -20° -60° -100° -140° -180°
ψ_β (DEG) WHEN P LEADS β BY 225° THROUGH 360° to 45°

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

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.

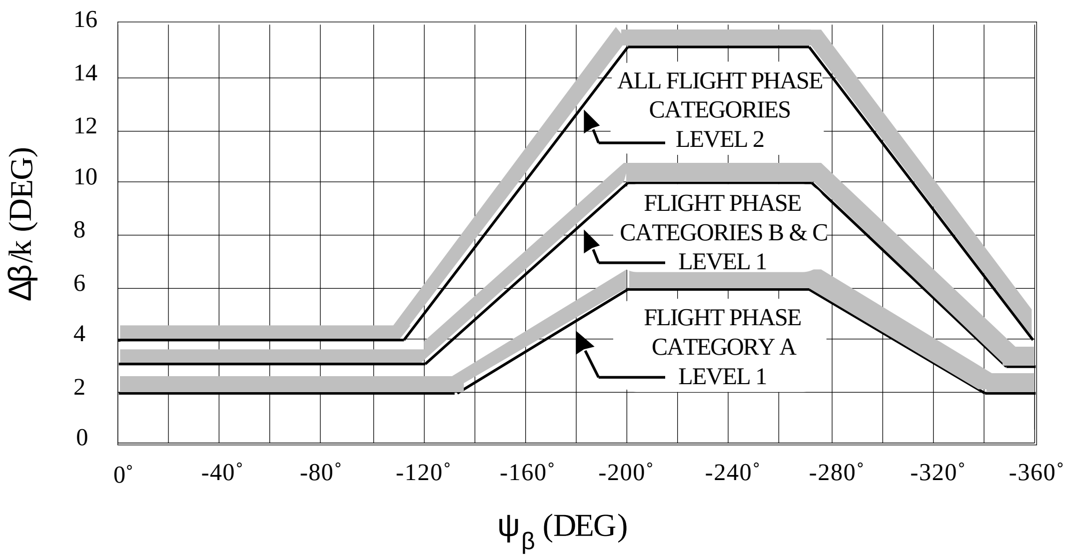


FIGURE 6. Sideslip excursion limitations.

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)

		Category A		Category B		Category C	
Class	Level	60°	45°	60°	45°	30°	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	$V_{o_{min}} \leq V \leq V_{min} + 20$ 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	1.0			
	L		1.4	2.3	4.1
	M		1.0	1.6	2.8
	H		1.4	2.3	4.1
2	VL	1.6			
	L	1.3			
	M		1.3	2.0	3.4
	H		1.7	2.6	4.4
3	VL	2.5			
	L	2.0			
	M		1.7	3.0	
	H		2.1		

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	1.0			
	L		1.1		
	M			1.1	2.2
	H		1.0		
2	VL	1.6			
	L	1.3			
	M			1.4	2.8
	H		1.4		
3	VL	2.5			
	L	2.0			
	M			1.7	3.4
	H		1.7		

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	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 C	20 20	40 20
	II-L, III	A, B C	25 25	50 25
2	I, II-C, IV	A, B C	30 20	60 20
	II-L, III	A, B C	30 30	60 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 me 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 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 forces 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, and 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 angles 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	I	20 knots
and		
2	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 pull outs 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 there after 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 at 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 save recovery at any service speed above $V_{o_{min}}$ (CL) following sudden simultaneous failure of the two critical failing engines.