SAE
AEROSPACE RECOMMENDED PRACTICE

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DESIGN OBJECTIVES FOR FLYING QUALITIES OF CIVIL TRANSPORT AIRCRAFT

1. PURPOSE AND SCOPE - This recommended practice sets forth the design objectives for flying qualities applicable to civil transport type aircraft operating in the subsonic, transonic and supersonic speed range. These objectives are not necessarily applicable to rotor type or VTOL aircraft.

Background - Prior to writing this practice the committee investigated several documents describing flying qualities of piloted aircraft, deciding that the military specification MIL-F-8785 (ASG) came closest to expressing the type material and format desired by the committee. As a result, this specification was used as a model. However, the content was modified, updated and pointed towards desirable modern transport flying qualities.

2. OBJECTIVES

2.1 General

2.1.1 Airplane Loading - Unless otherwise stated, the following objectives shall apply to all aircraft weights and CG locations within the approved limits.

2.1.2 Altitudes - Unless otherwise stated, the requirements for the following regimes of flight shall apply at the altitudes listed.

a.	Take-off	Airport altitudes from sea level to 13,000 ft pressure altitude, including ground effects for takeoff and landing.
b.	Approach	
c.	Landing	
d.	Climb	Sea level to maximum approved altitude.
e.	Descent	
f.	Cruise	1500 ft PA to maximum approved altitude.

2.1.3 Temperature - Unless otherwise stated, these objectives shall apply to all temperatures within the approved operational envelope for the appropriate flight regime.

2.1.4 Operational Flight Envelopes - Operational flight envelopes, in terms of normal acceleration versus speed shall be established for each of the flight conditions specified in Paragraphs 2.1.1, 2.1.2, 2.1.3. Within these envelopes there shall be no buffet, trim or stability changes, or other irregularities which might detract from the effectiveness of the airplane in completing its transport function.

2.1.5 Deceleration Devices - The airplane shall incorporate deceleration means capable of providing:

a. Adequate slow down from cruising speed to holding speed at all altitudes.

b. Rapid descent from cruise altitudes to sea level at V_B and ATC controlled area speeds.

c. Adequate ability to maintain approach and glide path angles for all possible landing configurations.

These deceleration means in any selectable position shall have no objectionable buffet, trim change or other adverse effect on flight controllability or flight characteristics associated with their operation. It shall not be required to exceed V_B in normal cruise speeds in order to execute rapid descent.

2.1.6 Configurations - For the purpose of this document, the basic airplane configurations shall be as described below. Items not specified, such as oil cooler flaps, cowl flaps, etc., shall be considered in their normal setting for the specified configuration. In the case of variable sweep or variable geometry aircraft, the manufacturer will define the wing sweep position(s) or geometry and deceleration devices associated with each configuration defined below.

a. Take-off - Gear down, flaps and high lift devices at take-off position, take-off thrust and/or augmentation, if provided.

b. Climb - Thrust, flaps, gear, and speed, as specified for each climb configuration.

c. Cruise - Thrust for level flight at all specified operating speeds within the operating envelope.

d. Descent - Thrust, flaps, gear, and speed, as specified for each descent configuration.

e. Maneuvering Approach - Thrust for level flight at recommended approach speed, gear up, flaps, and high lift devices at approach setting.

f. Landing Approach - Thrust for approach descent at recommended landing approach speed, gear down, flaps, and high lift devices at landing setting.

g. Go Around - Gear down, flaps, and high lift devices in landing position, thrust set at maximum authorized. Speed - landing approach speed.

2.1.7 Aeroelastic Effects - Since it can be expected that aeroelastic effects will play an important role in supersonic transport design, it should be clear that all requirements for flying qualities are applicable to the elastic airframe.

2.2 Mechanical Control Systems - Characteristics

2.2.1 Control Friction and Breakout Force - Longitudinal, lateral and directional controls shall exhibit positive centering in flight at any normal trim setting. Although absolute centering is not required, the degree of centering shall be such that the combined effects of centering, breakout force, stability and force gradient do not produce objectionable flight characteristics or permit large departures from trim conditions with controls free. Control system friction in all airplanes shall be as low as possible, and breakout forces, including friction, feel preload, etc., shall not exceed the values given in Table I. These values refer to the pilot control force required to start movement of the control surface and apply in flight at all attainable conditions of trimmed airspeed, altitude, temperature and control deflection.

Table I
Allowable Breakout Forces - Wheel or Stick Controls
(Including Friction)

Control	Minimum (lbs)	Maximum (lbs)
Aileron	1/2	3
Elevator	1/2	4
Rudder	1	10

2.2.1.1 Adjustable Controls - When the cockpit control is adjustable for pilot physical dimensions or comfort and varies pilots' mechanical advantage, the control force as defined shall refer to the mean adjustment. The force referred to any other adjustment shall not differ by more than 10% from the force referred to the mean adjustment.

2.2.2 For Abnormal Operation - Upon failure of a power-operated or power-boosted control system, the allowable maximum breakout forces specified in Table I may be doubled.

2.2.3 Rate of Control Displacement - The ability of the airplane to perform the maneuvers expected of it shall not be limited by the rates of control surface deflection or auxiliary control operation, nor shall the rates of operation of either primary controls or auxiliary devices result in objectionable flight characteristics.

2.2.4 Cockpit Control Free Play - The free play in each cockpit control, i.e., the motion of the cockpit control, from the trim position, which does not move the control surface in flight, shall be insignificant in normal or alternate configurations.

2.2.5 Artificial Stability Systems - Normal operation of artificial stability systems for improvement of any characteristic shall not introduce any objectional flight or ground handling characteristics. Failure of any system shall not result in a dangerous or intolerable flight condition. Adequate redundancy must be provided to assure acceptable handling qualities.

2.2.6 Control Sensitivity - Careful attention must be given to the design of control forces and displacements on all axes, versus the airplane response rates and accelerations throughout the operational flight envelopes and in all airplane configurations listed in paragraph 2.1.6. This is mandatory so that the longitudinal, directional and lateral control characteristics are compatible with the requirement for precision flight path control.

2.2.7 Control Force Coordination - The peak 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. As a tentative guide on this subject, it is desired that the relative magnitudes of control forces in coordinated maneuvers should be approximately in the ratio of 1:2:3 for aileron, elevator, and rudder force, respectively.

2.3 Longitudinal Stability and Control

2.3.1 Static Longitudinal Stability - The variation of elevator stick force with speed in the aft critical loading, shall be a smooth curve with a stable gradient throughout the speed ranges and configurations specified in Table II, except that this speed need not exceed $\pm$50 knots or $\pm$15% from the trim speed, whichever is less. At the extremes of this speed range the force level should be approximately 20 lb . Outside this speed range a neutral gradient of force versus speed is desirable. The airspeed shall return to within $\pm$5% of the trim speed when the elevator control is slowly released after changing speed $\pm$10% from the trim speed.

Table II

Longitudinal Static Stability Conditions

Configuration	Speed Range - CAS	Trim Speeds - CAS*
Climb	$.85\ V_{RC}$ to $1.15\ V_{RC}$	V_{RC}
Cruise	$.85V_{TRIM}$ to V_{FC}	VMax. range - V_{mo} and one other
Descent	V_{s1} to V_{FC}	$1.4\ V_{s1}$ - 15000 ft PA holding pattern speed, and normal descent speed.
Maneuvering Approach	V_{so} to approach flap structural limit speed.	Recommended approach speed
Landing Approach	V_{so} to landing flap structural limit speed.	Recommended landing approach speed.

*Trim speeds shall be so selected as to examine the most critical areas of the operating envelope.

2.3.2 Short Period Characteristics - The dynamic response of airplane pitch attitude and normal acceleration to the pilot's use of elevator control in performing the mission of the airplane that is appropriate to the flight condition and airplane configuration shall be such as to produce precise flight path control. The airplane response shall be neither too sluggish nor too abrupt, nor shall there be any tendency for an objectionable oscillation resulting from efforts of the pilot to control the flight path or during controls-free operation in the presence of external disturbances, such as turbulence. Eventually it is the intent to furnish quantitative data to define these objectives (see Appendix I).

2.3.2.1 The motion of the pilot's longitudinal control, when the control is suddenly deflected and released, shall be essentially deadbeat.

2.3.3 Long Period Oscillations - There shall be no objectionable flight characteristics, such as poor instrument approach qualities, attributable to poor phugoid damping. If the damped period of a longitudinal oscillation is less than 3 times the short period oscillation, the oscillation shall be at least neutrally damped, and under no circumstances shall the time to double-amplitude be less than 55 sec.

2.3.4 Control Effectiveness in Accelerated Flight - In the forward critical loading, when trimmed at any permissible speed and altitude in the configurations listed in Table II, it shall be possible to develop at the trim speed, by use of the elevator control alone, the limit load factor, the lift coefficient corresponding to V_{s1} or a load factor consistent with the operational flight envelope.

2.3.5 Control Forces in Steady Accelerated Flight - Increases in pull forces shall be required to produce an increase in normal acceleration throughout the range of permissible accelerations, in steady turning flight and pull-outs. The variation of force with normal acceleration at all points beyond the breakout force shall be approximately linear, except that an increase in slope is permissable above .85 limit load factor as might be introduced by an acceleration restrictor. The average force gradient shall be within the limits shown in Table III for climb, dive and approach configurations throughout the operational flight envelope up to .85 limit load factor.

2.3.5.1 The local value of the force gradient at all permissible speeds and accelerations shall never be less than 5 lb per g.

Table III
Elevator Control Force Gradient Limits
lb/g

Minimum	Maximum
25	50

2.3.5.2 The requirements of paragraph 2.3.5 apply to negative as well as positive acceleration.

2.3.6 Sudden Pull-Up Control Forces - The ratio of the maximum elevator control force to maximum change (peak) in normal acceleration in which the elevator cockpit control is rapidly deflected and returned to its initial position shall never be less than the ratio of force to acceleration change obtained in steady acceleration under the same conditions, in sudden pull-ups from trimmed straight flight.

2.3.7 Elevator Effectiveness in Take-Off - Elevator effectiveness shall not restrict the airplane take-off performance. It shall be possible on a hard surface runway with longitudinal trim set for no less than V_2 + 15 knots to take-off at .95 V_{LOF}. This objective shall be met on nosewheel airplanes at the most forward CG loading. The loadings considered for this purpose shall include all full and partial loads which might normally be employed during training as well as operational take-offs.

2.3.8 Take-Off Control Forces - The elevator control forces required throughout the take-off described in 2.3.7 and during the ensuing acceleration to a speed of V_2 + 30 knots, in the take-off configuration shall be within the following limits: 25 lbs pull below trim speed to 15 lbs push above the trim speed. These objectives apply to thrust augmented take-offs and the cessation of such augmentation. In no case shall a push force be required below the (V_2 + 15 knot) trim speed, under any CG condition.

2.3.9 Elevator Effectiveness in Landing Approach - The elevator effectiveness, with the aircraft loaded at the most forward CG and trimmed for the landing approach, shall be such that C_L max or geometry limited attitude can be obtained in close proximity to the ground.

2.3.10 Landing Control Force - The objective of paragraph 2.3.9 shall not require a longitudinal control pull greater than 40 lbs.

2.3.11 Control Forces in Descents

2.3.11.1 With the airplane trimmed and throttles set for level flight at maximum cruising speed, a dive to any higher speed within V_D/M_D shall require a push force. This push force shall not be such that instantaneous release of the control column would induce more than limit load factor on the airplane.

2.3.11.2 With the airplane trimmed for V_{mo}/M_{mo} it shall be possible at any attainable higher speed within V_D/M_D, and using elevator control alone, to pull 2.0 g load factor without exceeding 100 lbs pull force.

2.3.11.3 The longitudinal trim system shall be capable of being operated at the normal rate while holding the pull force required to perform the maneuver described in 2.3.11.2.

2.3.12 Longitudinal Trim Changes - The longitudinal trim changes caused by changes in power, flap setting, gear operation, deceleration devices, wing sweep, variable geometry, etc. shall not be so large that peak longitudinal control forces in excess of 15 lb are required when such configuration changes are made in flight under conditions representative of operational procedure. Generally, the conditions listed in Table IV will suffice for determination of compliance with this objective. With the airplane trimmed for each specified initial condition, the peak force required to maintain the specified constant parameter following the specified configuration change shall not exceed 15 lb push or pull. This objective shall apply to a time interval of at least 5 sec following the completion of the pilot action initiating the configuration change, or the time for configuration change, whichever is longer. 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.

2.3.13 Longitudinal Trim Change Caused by Sideslip - With the airplane trimmed for straight flight in each of the configurations and at the trim speeds specified in Table II, the longitudinal control force required to maintain constant speed in sideslips (generated from any reasonable flight condition or malfunction), shall not exceed numerically the lowest force which in the same configuration would produce a normal acceleration change of 0.2 g in the accelerated maneuvers of paragraph 2.3.5. In no event, however, shall the force exceed a 10-lb pull or 5-lb push. The sideslips considered need not exceed angles greater than 10 deg, or the structural limit in either direction from wings-level trimmed flight.

2.4 Lateral-Directional Stability Control

2.4.1 Damping of the Lateral-Directional Oscillations - In the configurations and over the corresponding speed ranges specified in Table II, the damping of the lateral-directional oscillations, with controls fixed and with controls free, when excited by rudder pulses, shall be such that the damping parameter $K/T_{1/2}$ has a value not less than that require by line A of Figure 1. Residual undamped oscillations are objectionable and must be eliminated. This criterion shall apply throughout the entire operational envelope.

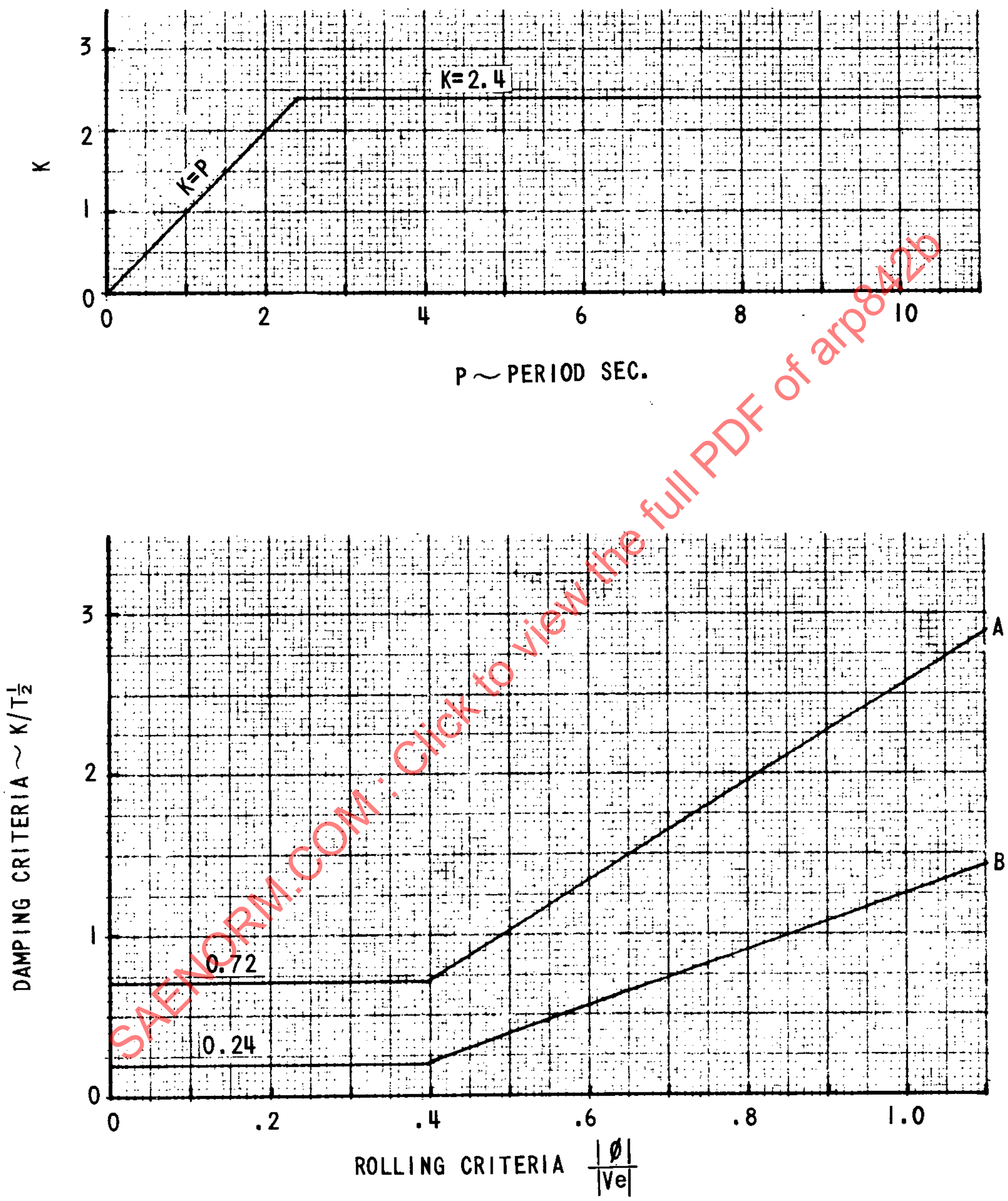
2.4.1.1 If artificial stabilization is employed, the damping parameter $K/T_{1/2}$ with any single failure in the artificial stabilization system shall be at least 0.24 in all configurations. In the approach configurations, this parameter shall, moreover, have a value at least as high as that required by line B of Figure 1.

Note: Also see Appendix I, Figure 2.

Table IV

Longitudinal Trim Change Conditions

INITIAL TRIM CONDITION						CONFIGURATION CHANGE	PARAMETER TO BE HELD
Condition No.	Altitude	Speed	Gear	Flaps	Thrust		
1	1500 ft PA	1.4 V_{s1}	Up	Up	For level flight	Gear Down	Altitude
2	1500 ft PA	1.4 V_{s1}	Down	Up	For level flight	Flaps Down	Altitude
3	1500 ft PA	1.4 V_{so}	Down	Down	For level flight	Idle Thrust	Speed
4	1500 ft PA	1.15 V_{so}	Down	Down	For level flight	Take-Off Thrust	Altitude
5	1500 ft PA	1.3 V_{s1}	Down	Take-off	For level flight	Gear Up	Altitude
6	1500 ft PA	1.5 V_{s1}	Up	Take-off	For level flight	Flaps Up	Altitude
7	.1 Max Approved	Climb	Up	Up	Maximum Continuous	Idle Thrust	Altitude
8	Most Critical	Max Cruise not to Exceed M_{mo}	Up	Up	Maximum Cruise	Idle Thrust	Altitude
9	All Altitudes	All Speeds	Up	Up	For level flight	Deceleration Device	Altitude
10	1500 ft PA	1.5 V_{so}	Down	Down	Approach	Deceleration Device	Flight Path
11	.5 Max Approved	Level Flight	Up	Up	Maximum Continuous	Augmented Thrust	Altitude
12	1500 ft PA	Landing Approach	Down	Down	Thrust For 3°Glide Slope	Go Around Thrust	Speed
13	As Scheduled	As Scheduled	Up	Up	As Scheduled	Variable Geometry	Flight Profile


3
2
1
0
K
K=2.4
K=P
0
2
4
6
8
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P ~ PERIOD SEC.
3
2
1
0
DAMPING CRITERIA ~ K/T½
A
B
0.72
0.24
0
.2
.4
.6
.8
1.0
ROLLING CRITERIA |Ø|/|Ve|

FIGURE 1

2.4.2 Spiral Stability - Neutral spiral stability is desired; however, if the spiral motion is divergent, the rate of divergence shall not be so great that, following a small disturbance in bank with controls fixed, the bank angle is doubled in less than 20 sec in the approach and cruise configurations, or 10 sec in any of the other flight conditions.

2.4.3 Static Lateral-Directional Stability Conditions - In the configurations and over the corresponding speed ranges specified in Table II, static directional stability, dihedral effect and variation of side force are expressed below in terms of steady sideslip characteristics. These characteristics shall be for flight in straight path (zero turn rate) sideslips up to the maximum sideslip angles produced by maximum available rudder deflection, with the aircraft trimmed for straight and level flight, at the lightest operational weight or structural limit.

2.4.4 Static Directional Stability (Rudder Position) - The airplane shall possess rudder-fixed directional stability such that, in the sideslip specified in paragraph 2.4.3., right rudder pedal deflection from the wings-level position is required in left sideslips, and left rudder pedal deflection is required in right sideslips. For angles of sideslip between ± 15 deg or structural limits from the wings-level condition, the variation of sideslip angle with rudder pedal deflection shall be essentially linear. Throughout the remainder of the range of required pedal deflections, an increase in pedal deflection shall always be required for an increase in sideslip.

2.4.5 Static Directional Stability (Rudder Force) - The airplane shall possess rudder-free stability such that, in the sideslips specified in paragraph 2.4.3, right rudder force is required in left sideslip and left rudder force is required in right sideslip. For angles of sideslip between ± 15 deg from the wings-level, straight-flight condition, the variation of sideslip angle with rudder force shall be essentially linear. At greater angles of sideslip, a lightening of the rudder force by 20% is acceptable; however, for dynamic sideslip conditions throughout the design envelope of rudder deflection and sideslip, the rudder force shall never reduce to zero or overbalance.

2.4.6 Dihedral Effect (Aileron Position) - The airplane need not exhibit positive control-fixed dihedral effect as indicated by the variation of aileron cockpit control deflection with sideslip in the maneuvers specified in paragraph 2.4.3, but shall never be negative.

2.4.6.1 The positive effective dihedral shall never be so great that more than 75% of full aileron cockpit control deflection is required in any of sideslips specified.

2.4.7 Dihedral Effect (Aileron Force) - The airplane need not exhibit positive control-free dihedral effect as indicated by the variation of aileron control force with sideslip in the maneuvers specified in paragraph 2.4.3, but shall never be negative.

2.4.8 Side Force Sideslips - The side force characteristics shall be such that in the sideslips specified in paragraph 2.4.3 an increase in right bank angle accompanies an increase in right sideslip, and an increase in left bank angle accompanies an increase in left sideslip.

2.4.9 Yaw Due to Roll Control - The resulting roll rate caused by lateral control displacement, with rudder free, shall not induce significant amounts of sideslip and/or associated variation in roll rate, throughout the operational flight envelopes.

2.4.10 Asymmetric Power (Rudder Free) - In all normal flight conditions at speeds above V_2 + 10 knots, including turns up to 30 deg bank angle, the airplane motions following a sudden propulsion system malfunction, or failure, shall be such that hazardous flight conditions or objectional accelerations on the occupants can be avoided by normal pilot corrective action with rudder pedals free.

Further, with the airplane trimmed for straight, wings-level flight and symmetrical thrust, it shall be possible, with rudder pedals free, to restore the wings to a straight level attitude following the sudden malfunction.

2.4.11 Directional Control (Symmetric Power) - Directional control shall be sufficiently effective to maintain wings-level straight flight in the configurations and speed ranges specified in Table II with rudder control forces not greater than 15 lb when the airplane is trimmed directionally at the trim speeds specified in Table II.

2.4.11.1 Directional control shall be sufficient to permit development of at least 10 deg of steady sideslip in landing configuration at 1.3 V_{so} with rudder control forces not greater than 75 lb.

2.4.12 Static Directional Control (Asymmetric Power) - Multiengine aircraft in the take-off configuration with the most critical engine inoperative, loaded to the lightest practicable take-off loading, CG in most critical condition, with take-off thrust on the remaining engine shall be capable of maintaining straight flight with a bank angle no greater than 5 deg at all speeds above V_{mca}. The rudder pedal force required, with the aircraft trimmed for symmetric power take-off to maintain straight flight with the most critical engine inoperative, shall not exceed 75 lb.

Directional control on the ground shall be such that following an abrupt failure of the critical engine the lateral deviation shall be negligible at speeds above V_{mcg}. In flight at speeds in excess of V_{mca}, the heading change resulting from a sudden critical engine failure shall not be greater than 10 deg.

2.4.13 Directional Control During Take-Off and Landing - The rudder control, in conjunction with other normal means of control, shall be adequate to maintain straight paths on the ground during normal take-offs and landings. Directional control shall be sufficiently effective to conduct take-off and landings in 90-deg crosswind of at least 30% V_{so} or 40 knots, whichever is less. It shall be permissible to utilize a combination of crab angle and sideslip in conducting these demonstrations. This criterion shall be met with not more than a 75-lb pedal force.

2.4.14 Directional Control Forces - The rudder pedal forces that provide maximum available rudder deflection, throughout the speed range, shall not exceed 75 lb.

2.4.14.1 Nose Steering Wheel Force - This section will be added in a subsequent revision to this document.

2.4.14.2 Wheel Brake Pedal Force - Wheel brake pedal force for maximum brake pressure shall not exceed 60 lb per pedal. The pedal force to obtain initial braking (minimum brake pressure) shall be approximately 10 lb.

2.4.15 Lateral Control - Lateral control shall be adequate for compliance with the rolling performance specified in 2.4.15.1. In those requirements involving measurement of time, the time shall be measured from the instant of initiation of pilot control force. The rudder pedals are to be free in obtaining the required rolling performance.

2.4.15.1 The rolling acceleration shall be such that in the normal loading condition, which produces the most critical rolling moment of inertia (light weight, heavy outboard concentration of spanwise weight), it is possible to attain a rate of roll of at least 15 deg/sec within no more than 1.5 sec after initiation of pilot control force, with peak forces not greater than 20 lb. (See Appendix I, Figure 3.)

2.4.15.2 A lateral control force of 20 lb, tangentially applied at the control wheel or to a control stick, shall produce a roll rate of at least 25 deg/sec.

2.4.15.3 The wheel throw necessary to meet the lateral control requirements shall not exceed 75 deg in each direction for all airplanes with wheel-type controls.

For stick-type controls the lateral displacement of the hand grip shall not exceed ± 7 inches.

2.4.15.4 Lateral control shall be sufficiently effective to balance the airplane laterally under the conditions specified in paragraphs 2.4.10, 2.4.11, 2.4.11.1, 2.4.12 and 2.4.13, with aileron control forces not exceeding those specified in paragraph 2.4.15.2.

2.4.15.5 When trimmed laterally at the maximum approved ceiling in climb configuration, lateral control shall be adequate to maintain the wings level throughout the speed range with aileron control forces not exceeding 10 lb for wheel or stick controls.

2.4.15.6 Lateral control in the correct direction is required at all permissible speeds.

2.5 General Control and Trimmability Objectives

2.5.1 Control for Taxiing - It shall be possible to perform all normal taxiing operations without undue pilot effort or inconvenience.

2.5.1.1 Nose Wheel Centering - On nose wheel type airplanes with power steering, nose wheel should caster returning smoothly to a centered position if the steering control is released. With loss of steering power, the nose wheel should caster to center such that the airplane will maintain direction when there is no turning moment applied. Under this condition it shall be possible to turn the nose wheel by application of asymmetric turning moments.

2.5.2 Control Surface Oscillations - All control surfaces, and surfaces such as flaps, slats and speed brakes, shall be free of any tendency toward significant sustained oscillations at all speeds up to V_D/M_D.

2.5.3 Pilot Induced Oscillations There shall be no tendency for a sustained or uncontrollable oscillation about or along any axis resulting from efforts of the pilot to maintain steady flight. Phase lag between the cockpit control deflection and/or force and control surface deflection shall be kept to a minimum for a reasonably large amplitude motions and should not increase unduly at very small control amplitudes.

2.5.4 Primary Flight Control Trimmability - The trimming devices shall be capable of reducing the elevator, rudder and aileron control forces to zero, at all speeds between the minimum trim speeds specified in Table V and the upper limits of the speed ranges specified in Table II.

Table V

Conditions For Trimming To Zero Control Forces

Condition	Configuration	Minimum Trim Speed
1	Climb - at forward and aft CG limits	1.2 V_{s1} or minimum flight speed
2	Landing - at forward and aft CG limits	1.2V_{so}
3	Approach - at forward and aft CG limits	1.3 V_{s1}
4	Climb - the most critical engine inoperative - wings level	1.4 V_{s1}
5	Climb - two most critical engines on one side inoperative - wings level	Speed for best climb gradient
6	Cruise - two most critical engines on one side inoperative - wings level	Speed for maximum range

2.5.4.1 Longitudinal Trim - The pilot shall not be required to give undue attention to the longitudinal trim of an aircraft.

2.5.4.1.1 Total trim actuation time to restore pilot control forces to zero shall not exceed 2 sec for the following flight phases.

Flight Phases

a. V_2 speed to enroute climb speed.
b. Enroute climb speed to subsonic climb Mach.
c. Subsonic climb Mach to maximum climb Mach.
d. Maximum climb Mach to M_{mo}.
e. Holding speed to enroute climb speed.
f. Holding Mach to M_{mo}.

2.5.4.1.2 The trim rate shall be such as not to cause the pilot to overcontrol due to its actuation. (See also paragraph 3.3.)

2.5.4.2 Directional Trim - There shall be no significant directional trim changes during operation in the normal flight profile. This objective arises from undue pilot effort experienced on some aircraft, due to frequent retrim of the rudder as the airplane changes speed.

2.5.5 Trim Controls - All trimming devices shall maintain a given setting indefinitely unless changed by the pilot, by a special automatic interconnect, such as to the landing flaps, or by the operation of an artificial stability device. Operation of the automatic trim devices shall be unmistakably discernible to the pilots.

2.5.6 Trim System Failure - Failure of a power-actuated trim system (including sticking or runaway in either direction) shall not result in an unsafe flight condition. Following such failure, it shall be possible to cruise for extended periods and to make a safe landing. Override provisions or alternate trim mechanisms shall be available to the pilot. This objective shall apply to both aerodynamic and artificial trim devices.

2.6 Stall

2.6.1 Required Flight Conditions - Except where otherwise stated, the criteria for stall characteristics and for stall warning shall apply for all configurations and for all CG's within the approved limits, in straight unaccelerated flight in turning flight with bank angles up to 45 deg and at thrust settings between idle and the maximum thrust normally required for the flight regime under consideration.

2.6.2 Definition of Stalling Speed - The stalling speed, V_s, is the minimum speed in flight at which the airplane can develop a lift (i.e. aerodynamic force perpendicular to the flight path) equal to the weight of the airplane, with idle thrust and with CG on the forward limit for the configuration. In establishing the stalling speed, the airplane shall be trimmed at not less than 1.2 V_s; the approach to the stall shall be at a rate not exceeding 1 knot/sec and shall be with wings level.

NOTE: In the event considerations other than maximum available lift determine the minimum usable flying speed in any configuration (e.g. ability to maintain straight flight to perform flight path and speed control, or lateral/directional characteristics), speed increments or suitable percentages of this minimum flying speed shall be used in place of the percentages of the stall speed specified in this document. (Adequate warning of approach to such minimum speeds shall be provided.)

2.6.3 Stall-Warning Objectives - The approach to the stall should, in all cases, be accompanied by an unmistakable natural aerodynamic buffeting and also by an unmistakable artificial shaking of the control column at approximately 1.07 times the stall speed, but not less than 10 knots CAS above the stall.

In case natural aerodynamic warning is not present or is marginal for identification under such conditions as turbulent air, it may be necessary to duplicate the artificial stick shaker system. The requirement for redundancy is somewhat dependent on the individual airplanes handling characteristics at speeds below the desired warining speed and also on the stalling and stall recovery characteristics.

Consideration shall be given to the need for anticipatory inputs to the stick shaker warning system to prevent overshooting critical angles of attack.

2.6.4 Criteria for Acceptable Stalling Characteristics - Although it is desired that no nose-up pitch occurs at the stall, a mild nose-up pitch may be accepted, provided that no dangerous or seriously objectionable flight conditions result. It shall be possible to recover from a complete stall by normal use of controls without excessive control forces, loss of altitude or buildup of speed. In a complete unaccelerated stall it shall be possible to prevent the airplane from rolling in excess of 20 deg wing-down following the stall.

In unaccelerated stalls with the airplane trimmed for not greater than 1.4 V_s and an approach rate of 1 knot/sec, it shall be possible by use of elevator control alone to recover from any angle of attack attainable with full up elevator control.

2.7 Objectives for Power and Boost Flight Control Systems

2.7.1 Normal Control System Operation - The control system shall satisfy the applicable mechanical design requirements as well as the objectives of this document. The system shall be capable of providing rapid repeated control movements as might be required in very rough air operation.

2.7.2 Power or Boost Failures

2.7.2.1 Single Most Critical Failure - Airplanes employing power or boost control shall have provisions so that following the most critical failure in the flight control system, the planned flight may be completed without significant degradation of flying qualities.

2.7.2.2 Second Most Critical Failure- Following a second critical failure in the flight control system, the flying qualities shall satisfy the objectives listed in paragraph 2.7.2.3.

Following the second most critical flight control system failure, it shall be possible to complete the flight, after takeoff, to a suitable airport from the V_2 transition to enroute climb to cruise to a safe landing with the most critical engine inoperative at the most critical phase of flight.

2.7.2.3 Trim Change and Controllability Following Critical System Failures - The trim changes associated with single and dual (not simultaneous) failures in the flight control systems, whether actual or simulated, shall not result in objectionable flight conditions. To satisfy these objectives, the following shall apply within the normal operating envelope. With the longitudinal control system out of trim not more than 5 lb and rudder and aileron in trim prior to failure, the airplane shall not pitch, roll or yaw after failure more than the following:

(1) Pitch - $\pm$ 0.2 g incremental load factor.
(2) Roll - 5 deg per second (after 5 sec).
(3) Yaw - that amount which can be overpowered by 20 lb rudder force.

In the out of trim conditions outlined in paragraphs 2.3.11.1 and 2.3.11.2, trim changes occurring at failure shall not impose loads which exceed the structural limits of the airplane.

Following failure, the controllability objectives of paragraphs 2.3.11.1 and 2.3.11.2 shall also be met.

2.7.3 Longitudinal Control - At V_{mo} - M_{mo}, it shall be possible, following the failures specified in 2.7.2.1 and 2.7.2.2, to obtain at least 1.5 g or 0.6 limit load factor, whichever is less, unless limited by buffet. Elevator control force in this maneuver, with the airplane trimmed for 1 g flight, shall not exceed 60 lb. This requirement shall be met with the most critical CG loading.

2.7.3.1 With the failures described in 2.7.2.1 and 2.7.2.2 and the elevator control force trimmed to within 5 lb at 1.3 V_{so} in approach configuration, it shall be possible to execute a safe landing with elevator control forces not exceeding 60 lb wheel force when loaded at the most forward CG location.

2.7.4 Lateral Control - With the two most critical failures, it shall be possible to obtain 50% of the pertinent objectives of 2.4.15.1 and 2.4.15.2, with aileron control forces not exceeding 40 lb.

2.7.5 Directional Control - With the two most critical failures, it shall be possible to perform the landing of paragraph 2.7.4.1 in a crosswind of 50% of the value specified in paragraph 2.4.13, with rudder control forces not exceeding 120 lb.

2.7.6 Ability to Trim - With the most critical failure, it shall be possible to trim the elevator, aileron and rudder control forces to zero at all level-flight speeds consistent with the critical engine inoperative.

3. DEFINITIONS

3.1 The terms and symbols used throughout this specification are defined below:

CAS	-	Calibrated air speed (air speed indicator reading corrected for position and instrument error).
V_e	-	Equivalent Airspeed - True airspeed multiplied by square root of the relative density.
V_s	-	Stalling speed or minimum usable flying speed in general (see paragraph 2.6.2).
V_{s1}	-	Stalling speed or minimum usable flying speed obtained in a specified configuration.
V_{so}	-	Stalling speed or minimum usable flying speed with wing flaps in the landing position.
V_2	-	Take-off safety speed.
V_{RC}	-	Recommended climb speed with climb thrust.
V_{TRIM}	-	A speed chosen whereby the aircraft is trimmed to fly straight and level hands off.
V_{LOF}	-	Speed at which the aircraft actually lifts off the ground and first becomes airborne.
V_B	-	Design speed for maximum gust intensity.
V_D	-	Maximum design or demonstrated speed.
V_{mca}	-	Minimum control speed in the air with the critical engine inoperative.
V_{mcg}	-	Minimum control speed on the ground with the critical engine inoperative.

V_{FC}/M_{FC}	-	Maximum speed for stability characteristics (normally speed midway between V_{mo}/M_{mo} and V_D/M_D).
V_{mo}	-	Maximum operating speed.
M_D	-	Design or demonstrated Mach number, associated with V_D.
M_{mo}	-	Maximum operating Mach No.
K	-	Constant depending upon the period of the lateral-directional oscillation - See Figure 1.
$K/T_{1/2}$	-	Equals $1/C_{1/2}$ for periods less than 2.4 seconds.
$C_{1/2}$	-	Number of cycles for the lateral oscillations to damp to half amplitude.
$T_{1/2}$	-	Time to damp to 1/2 amplitude.
ϕ	-	Bank angle, degrees.
β	-	Sideslip angle, degrees.
$\frac{\lvert\phi\rvert}{\lvert\beta\rvert}$	-	Ratio of amplitudes of bank and sideslip angles in oscillatory mode.
$\frac{\lvert\phi\rvert}{\lvert V_e\rvert}$	-	Rolling parameter, degrees/feet per second.

$$\frac{|\phi|}{|V_e|} = \frac{57.3}{V_e} \quad \frac{|\phi|}{|\beta|}$$

Where V_e is equivalent airspeed in feet per second.

P	-	Period in seconds.
Deadbeat	-	To come to rest without oscillation or overshoot.

3.2 Interpretation of Qualitative Objectives - In several instances throughout the document, qualitative terms, such as "objectionable flight characteristics", "unacceptable flight conditions", "unusual pilot technique", etc., have been employed as a means of permitting latitude where absolute quantitative criteria might be unduly restrictive.

3.3 Rates of Operation of Auxiliary Aerodynamic Devices - Although it has not been considered feasible to include in this document quantitative criteria for rates of operation of trim tabs, trimmable stabilizers, artificial feel trimmers, etc., or for rates of extension and retraction of flaps, speed brakes, etc., the influence of such rates on the flying qualities may be appreciable and is treated qualitatively in paragraph 2.2.3. In general, trim devices should be operable rapidly enough to enable the pilot to maintain trim under changing conditions as normally encountered in functional employment of the airplane, and yet must not be so rapid in operation as to induce oversensitivity of trim precision difficulties under any flight condition. Flaps and other high-lift devices should operate at a rate sufficient to permit transition into the high lift configuration without undue delay, and yet must not operate so rapidly as to cause sudden or erratic trim or lift changes. This limitation on rate of operation applies also to speed brakes which, nevertheless, must function at a rate sufficient to meet the operational needs.