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SUGGESTED REQUIREMENTS FOR V/STOL FLYING QUALITIES

By
Major Paul R. Curry
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Applied Aeronautical Engineering Group

June 1965

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

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SUMMARY

This Research Technical Memorandum presents suggestions for a specification on flying and handling qualities requirements for subsonic V/STOL aircraft. In addition to including the ideas of many others, the authors have incorporated two basic suggestions: (1) the use of a pilot rating system (since the ultimate measures of handling qualities are determined by the pilot) and (2) the use of servo-analysis techniques and terms to define quantitative requirements. There are no statistical or quantitative data available to verify the stated requirements in some cases; however, the requirements are based on many different V/STOL research aircraft funded by the U. S. Army and flown by U. S. Army pilots.

FOREWORD

There are too many contributors in the preparation of material relating to handling qualities requirements for subsonic V/STOL aircraft for any one person or group to take credit for all of the results, and it would be too difficult to locate the originator of each idea. Therefore, the authors acknowledge that a very large percentage of the contents of this Research Technical Memorandum is not original. Material has been extracted from the efforts of many individuals, Government agencies, commercial establishments, and from the results of various free-world panels, such as the NATO Working Group sponsored by the AGARD Flight Mechanics Panel.

This memorandum represents the thoughts of the authors but does not necessarily represent the official position of the Department of the Army.

All constructive comments, suggestions, and recommendations are solicited; they should be forwarded to

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BACKGROUND

A requirement exists for a specification for flying and handling qualities of V/STOL aircraft to be used in any future procurement of operational V/STOL aircraft. The present method of utilizing Military Specifications H-8501A and F-8785, plus numerous revisions and additional information to bridge the gap between these two specifications, leaves much to be desired. This research memorandum contains suggestions for a specification on V/STOL handling qualities requirements.

The authors have tried to relate quantitative requirements to human pilot capabilities; the ultimate measure of success or failure of the designer to produce an acceptable aircraft should be dependent on an unbiased evaluation by qualified customer test pilot(s). To provide a consistent basis for evaluation, it is believed that ultimately standard tests and/or tasks should be included for each requirement or flight regime. Since many requirements are based on the response of the aircraft to prescribed inputs (that is, the open-loop characteristics of the aircraft-control system and the closed-loop characteristics of the pilot-aircraft control system combination), it also appears reasonable to state requirements in terms associated with dynamic systems, such as servo-analysis terminology. An attempt has been made to relate requirements to the basic capability of a human, and servo-analysis terminology has been utilized. However, time has not permitted the development and subsequent inclusion herein of tests and/or tasks for evaluation purposes. The proposed requirements are only preliminary in nature.

SUGGESTED FLYING QUALITIES REQUIREMENTS FOR VTOL, V/STOL, AND STOL AIRCRAFT

1. INTRODUCTION

1.1 Scope - The flying and ground handling qualities of all VTOL, V/STOL, and STOL aircraft proposed or contracted for shall be in accordance with the requirements contained herein, unless specific deviations are authorized by the procuring activity.

1.2 Format - ***Recommended for specifications:*** Requirements shall be shown in bold-faced type. Indented paragraphs forming a part of the requirements as explanatory statements, discussions, and demonstration tests shall be in plain type.

1.3 Philosophy - The handling qualities of an aircraft ultimately are determined by how the aircraft feels to the pilot, and by how apprehensive he may be about structural, control, or other possible failures. How the aircraft feels to the pilot depends on many factors (such as friction, control forces, apparent damping, control power, and sensitivity), all of which must be properly related to produce results that assure a satisfactory, or better, pilot opinion. The methods used herein relate most of the factors into criteria tailored to the basic capability of the human. Stated requirements are for normal operation, including instrument flight conditions, and should assure a pilot opinion rating of better than 3.5 (see paragraph 2.6).

Where applicable, requirements are stated to define deterioration acceptable upon a single failure in a power control system, stability augmentation system, artificial feel system, trim system, or in any other flight control component. It is assumed that designers will assure that a failure in one mode (longitudinal, lateral, height, or directional) will not affect the other modes at the same time. Such deterioration should correspond to a pilot opinion rating not in excess of 5.5.

2. DEFINITIONS

2.1 Terms and Symbols*

Aft Critical Loading - Normal service loading which results in a combination of weight and center-of-gravity position producing minimum stability (ordinarily, the lightest gross weight at which the most aft center-of-gravity position can be obtained in a given configuration at a normal service loading).

β - Sideslip angle, degrees.

Control Moment Available - Total moment available by use of cockpit controls (not including trim devices) between control stops, at any given flight condition.

Calm Air - Wind up to 3 knots.
C - Speed of sound.
cg - Aircraft center of gravity.

Control-Fixed - A condition where the pilot's cockpit control is restrained by the pilot. Longitudinal control-fixed, directional control-fixed, and lateral control-fixed refer to the condition of the individual cockpit control (position stability).

Control-Free - A condition where the cockpit control is unrestrained by the pilot. Longitudinal control-free, directional control-free, and lateral control-free refer to the condition of the individual cockpit control (force stability).

Control Surfaces - An external surface or device which is positioned by a cockpit control and which produces aerodynamic or jet-reaction-type forces in such a manner as to control the attitude of the aircraft.

Cruise - Flight regime from V_{con} to V_M or M_M.

Directional Control Force - Difference between push-force components (that is between the forces exerted by the pilot on the directional control pedals) lying in planes parallel to the plane of symmetry, and measured along lines connecting the foremost point of the seat (at mid-adjustment) and the normal points of application of the pilot's instep on the respective rudder pedals.

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*All airspeeds are V_{cal} unless otherwise stated.

Forward Critical Loading - Normal service loading which results in a combination of weight and cg position producing the heaviest gross weight at which the most forward cg position can be obtained in a given configuration at a normal service loading.

f_d - Damped frequency (cycles per second).

g - Gravitational constant, 32.2 feet per second per second.

Hover - Flight regime where the aircraft is supported by vertical thrust producer(s); includes forward, rearward, and sideward flight at airspeeds corresponding to wind conditions specified by the procuring activity.

IGE - In ground effect.

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

Longitudinal Control Force - Component of applied force exerted by the pilot on the cockpit control, in or parallel to the plane of symmetry, acting at the center of the stick grip (or wheel) in a direction perpendicular to a line between the center of the stick (or wheel) and the stick (or control column pivot).

M - Mach number, $\frac{V_T}{C}$.

n - Normal load factor, in g units, normal to the body axis.

n_L - Limit load factor for a given loading, based on structural considerations (normally at design gross weight).

OGE - Out of ground effect.

Power and Thrust - For reaction-type engines, the word "power" shall be replaced by the word "thrust" throughout these requirements.

S - Wing area, square feet.

Sideslip Angle - Angle between the undisturbed flow and the plane of symmetry of the airplane, measured in a plane parallel to the relative wind and perpendicular to the plane of symmetry. Plus, or right sideslip, corresponds to incident flow approaching from the right side of the plane of symmetry.

Transition - Flight regime between maximum airspeed for hover flight and airspeed for V_{con}.

$\frac{T}{W}$ - Ratio of total vertical thrust, in pounds, to total weight of the aircraft, in pounds (usually design gross weight).

V_{cal} - Indicated airspeed corrected for instrument and statis source position error.

V_{con} - 1.1 times the minimum speed, inclean or cruise configuration, where the entire aircraft weight is sustained by the lift system configuration for cruising flight, or as specifically defined by the procuring activity.

V_D/M_D - Maximum permissible airspeed or Mach number, as defined by the maximum permissible speed envelope of paragraph 3.2.2.

V_e - Equivalent airspeed, V_{cal} corrected for adiabatic compressibility effects.

v_e - Equivalent side velocity ($V_e \sin \beta$).

V_H/M_H - Highest airspeed or Mach obtained in level flight with maximum augmented power.

V_M/M_M - Maximum operational airspeed or Mach, as defined by the maximum operational airspeed envelope of paragraph 3.2.1.

$V_{\frac{M}{R}}$ - Airspeed for maximum range.

$V_{\frac{M}{e}}$ - Airspeed for maximum endurance.

V_M - Limit structural speed.

$V_{\frac{R}{C}}$ - Airspeed for maximum rate of climb.

V_S - Minimum speed attainable in flight not determined by control power. (See paragraph 3.7.6, where the subscripts L, PA, G, TR, etc., refer to the aircraft configurations described in paragraph 2.3.)

V_T - True airspeed, $\frac{Ve}{\sqrt{\sigma}}$.

β - Sideslip angle, degrees.

$\Delta\alpha$ - Incremental change in angle of attack, degrees.

σ - Ratio of density at altitude to density at sea level, ambient.

ϕ - Bank angle, degrees.

ψ - Yaw angle, degrees.

$\frac{|\phi|}{|v_e|}$ - Ratio of magnitude of bank angle to equivalent side velocity, degrees per feet per second.

2.2 Types of Aircraft

CTOL - An aircraft which utilizes conventional techniques for takeoff and landing.

STOL - An aircraft which, under calm wind conditions, can take off and land over a 50-foot obstacle in not more than the distance specified by the procuring activity (usually, between 200 and 2,000 feet, depending on size, configuration, mission, and so forth).

VTOL - An aircraft which, under calm wind conditions and zero ground roll, can take off and land over a 50-foot obstacle in a distance not to exceed twice the maximum plan view dimension of the aircraft.

V/STOL - A VTOL aircraft that has an increased capability (greater payload and/or operation at higher altitude and/or temperature conditions) when field conditions permit rolling takeoffs and landings.

2.3 Aircraft Configurations

CR - Cruise (or clean): Gear up; flaps or other high-lift devices, doors, closures, and other elements in a position for minimum drag for the speed and/or flight regime being considered.

D - Dive: Same as CR, except speed reduction devices (gear, flaps, brake) extended.

G - Glide: Same as CR.

HO - Hover: Gear down; thrust vectors, lift units, or other items in normal position for hover flight.

L - Landing: Gear down, flaps or other high-lift devices at landing setting.

PA - Power approach: Gear down; flaps or other high-lift devices, canopy, and approach brake in normal position for an approach in the flight regime specified.

ST - STOL: Gear down; flaps or other high-lift devices at STOL position and/or vertical thrust producers in configuration for STOL operation.

TR - Transition: Gear retracted; other doors, closures, rotating elements [(wing(s), propulsion unit(s)] in position required to allow all, or such part as may be necessary, of the vertical thrust to be utilized to support the aircraft.

2.4 <u>Power (or Thrust) and/or Propulsion System Conditions</u> - Power conditions defined below apply to all propulsive units required for the configuration and flight regime being considered or specified. (For instance, a direct-lift VTOL in hover would include the basic engine(s) and lift engine(s) when the basic engine thrust is utilized in the hover flight regime.)

ARP - Maximum augmented power rating at which the propulsive unit(s) can be operated for a specified period, including jato, afterburners, water injection, and similar means of increasing power for limited periods.

MRP - Military rated power: Maximum power (not including augmentation) at which the propulsion unit(s) can be operated for a specified period.

NRP - Normal rated power: Maximum power at which the propulsion unit(s) can be operated continuously. (Limitations imposed by installation, such as a specified time limit because of aircraft structure overheat, shall not be considered as limiting the ability of a propulsion unit to operate continuously.)

PLF - Power for level flight: Power required for constant altitude unaccelerated flight in the configuration and flight regime specified.

PRD( ) - Power for a specified rate of descent in the configuration and flight regime specified. Specific rates of descent in feet per minute shall be designated by appropriate subscripts such as $PRD_{(500)}$, which is power required of propulsion unit(s) to establish a constant rate of descent of 500 feet per minute.

FIP - Flight idle power: Minimum power at which the propulsion unit(s) will continue to operate in the configuration and flight regime specified.

2.5 Flight Regimes - The following flight regimes are defined for use as subscripts to other parameters, such as power condition, configuration, and speed:

sto - STOL takeoff.

sl - STOL landing.

cto - CTOL takeoff.

cl - CTOL landing.

hto - Hovering takeoff.

hl - Hovering landing.

2.6 Pilot Opinion Rating System - Where a qualitative opinion rating is specified, it shall correspond to the rating system shown in Table I.

3. REQUIREMENTS

3.1 General - The requirements of section 3 shall apply in the following instances:

a. At all normal service loadings.

b. At any available thrust usable in each configuration, to include any form of thrust augmentation.

c. At all operational altitudes.

d. At all applicable temperatures.

e. At all speeds or Mach numbers at which the aircraft may be operated with each configuration and loading.

TABLE I
PILOT OPINION RATING SYSTEM

Adjective	Description	Rating
Excellent	Includes optimum	1
Very Good	No unpleasant characteristics; some nuisance-type deficiencies where no impairment to normal operation occurs	2
Good	Some unpleasant characteristics in regimes where no impairment to normal operation occurs	3
Fair	Some unpleasant characteristics that cause perceptible fatigue; precision tasks possible after additional training	4
Poor	Controllable but fatiguing; precision tasks possible but difficult even after extensive training	5
Poor to Bad	Controllable for only short periods without excessive fatigue; precision tasks questionable even after extensive training	6
Bad	Total pilot attention required just to operate aircraft; precision tasks impossible	7
Dangerous	Almost uncontrollable; accident probable	8
Catastrophic	No control; accident certain; escape questionable	9

3.1.1 Pilot Rating - In addition to the quantitative requirements contained in subsequent paragraphs of section 3, the aircraft shall achieve overall qualitative ratings for each flight regime (hover, transition, STOL, and cruise) for each specified mission as follows:

a. Normal Operation: 3.5 or better unless specifically stated otherwise by the procuring activity; however, a rating of 5.5 shall not be exceeded.

b. Single-Failure Operation: 5.5 or better unless specifically stated otherwise by the procuring activity; however, a rating of 6.5 shall not be exceeded.

3.1.2 Compliance

3.1.2.1 Quantitative Requirements - Determination of compliance shall be demonstrated by appropriate ground/flight tests and/or as described in subsections of section 3. Determination of compliance shall be consistent with aircraft mission statements as defined for each aircraft procurement.

3.1.2.2 Qualitative Requirements - Qualified pilot(s) designated by the procuring activity shall rate the aircraft (against stated mission(s)) during and at the end of contractor's flight tests to determine if the specified qualitative ratings have been and will be attained.

3.1.3 Loadings - Normal service loadings shall include all combinations of gross weight and center-of-gravity locations that could ordinarily be encountered in normal service operations. Demonstration shall include at least the following:

a. Hover: Normal, forward, and aft cg limits at design vertical takeoff gross weight.

b. STOL: Normal, forward, and aft cg limits at the design STOL gross weight.

c. CTOL: Normal, forward, and aft cg limits at design CTOL gross weight.

3.1.4 Altitude and Temperature - Unless otherwise stated, the following shall be investigated:

a. Hover: at specified design condition, or at sea-level standard day if not specified.

b. STOL: At specified design condition, or at sea-level standard day if not specified.

c. Cruise and/or CTOL: At specified design condition plus the following:

(1) Low Altitude: Sea level.

(2) High Altitude: Not less than 80 percent of the service ceiling.

(3) Medium altitude: Approximately 50 percent of high altitude or 40,000 feet, whichever is lower. Use only when service ceiling is 40,000 feet or higher.

The high and medium altitude conditions may be excluded in consideration of configurations L, WO, PA, TO, H, TR, and STOL.

3.1.5 Weight and Inertia - The weight and corresponding moment of inertia for use in determining compliance with requirements stated herein shall be those that are critical with respect to the requirement. At any other weight and inertia, the requirements should therefore be exceeded.

3.1 6 Wind Conditions - Unless otherwise specified by the procuring activity, VTOL aircraft shall be capable of operating in a steady wind of up to 20 knots from any direction (relative to aircraft).

3.2 Flight Envelopes

3.2.1 Operational Flight - Airspeed and/or Mach number (normal accelerations) shall be specified by the procuring activity or established by agreement between the procuring activity and the contractor. Both positive and negative normal accelerations are to be included. These envelopes shall serve to define the boundaries within which the airplane is expected to be operational and within which these requirements therefore apply. Within these boundaries, there shall be no objectionable buffet, trim or stability changes, or other irregularities which might detract from the effectiveness of the airplane in executing its intended mission. The operational flight envelopes shall have cutoff points representing the highest Mach number and/or airspeeds at which the airplane is to be considered operational. These maximums shall be based on considerations of pull-out recovery (reaching level flight at 2,000 feet above sea level), as well as on attainable speeds. In the requirements of this specification, a curve of such cutoff speeds plotted against altitude is referred to as the maximum speed envelope. If necessary for adequate definition of this envelope, maximum speed points for various intermediate altitudes shall be included.

3.2.2 Maximum Speed - A V_D (or M_D) altitude envelope shall be established in addition to the envelopes specified in paragraph 3.2.1. This maximum permissible speed envelope shall be derived from consideration of dives entered at V_H. Unless limited by structural considerations, this envelope shall define, at each altitude the maximum speed from which a recovery can be made that will result in level flight at an altitude of not less than 2,000 feet above sea level without encountering intolerable buffet, loss of control, uncontrollable trim changes, or other dangerous airplane behavior during the entire dive or pullout. When this maximum permissible speed is established, the pullout shall be initiated with the airplane trimmed initially in level flight at V_H; but with trim optional in the dive, it shall be possible to maintain the longitudinal control forces within the limits of 50-pound push or 35-pound pull in dives to any attainable speed within the maximum permissible speed envelope. The forces required for recovery from these dives shall not exceed 120 pounds. Trim, deceleration devices, or other control devices may be used to assist in recovery, provided that no unusual pilot technique is required.

3.3 External Stores - In preparation of the flight envelopes discussed in paragraph 3.2, external stores that are not normally droppable in flight or that are intended to be carried during the primary mission shall be considered as integral elements of the aircraft configuration. When such stores contain expendable loads, the requirements shall, unless otherwise stated, apply throughout the range of store loadings. For other significant installations of stores, revisions to the flight envelopes and deviations from the flying qualities requirements, including pilot opinion rating, shall be established by agreement between the procuring activity and the contractor in accordance with the mission requirements of the airplane with such stores installed. In establishing these requirements, consideration of reasonable single malfunctions (such as failure of release mechanism or failure of fuel feed), as well as normal initial asymmetric store installations, shall be included.

3.3.1 Normal Release of Stores - Normal release of any external stores shall be demonstrated for the particular stores installed and type of mission under the following conditions:

a. Separation: Positive separation shall occur without excessive g-jump, oscillation about any of the airplane axes, trim change, or buffet at separation. The type of aircraft and mission requirements shall be considered when excessive g-jump is evaluated. Aircraft that have design load factors of up to 4g shall have a limit of 25-percent jump, and aircraft with design load factors greater than 4g shall have a jump limit not to exceed 40 percent. Aircraft that have g-jump shall release stores from unaccelerated flight only.

b. Speed: The release of stores shall be demonstrated at the applicable maximum speed for either the stores or the airplane, whichever is lower.

c. Altitude: The stores shall be dropped from an altitude, or altitudes, applicable to the stores to be released and to the mission. Where applicable, stores should be dropped at high and low altitudes.

d. Types of stores: The stores may be inert (or dummy) so long as aerodynamic, cg, and weight similarities exist between the inert stores and actual stores.

e. Tests: Tests should be conducted at the most adverse cg and gross weight.

3.3.2 Emergency Release of Stores - Any release of external stores other than normal shall be considered an emergency release. Emergency releases shall be demonstrated under the following conditions:

a. Separation: Positive separation shall occur with a g-jump that does not approach design structural limit or cause trim disturbances that are dangerous, as determined by the procuring agency.

b. Speed: Emergency releases, or jettisons, shall be demonstrated from hover and critical points up to 1.2 V_S, and from 1.2 V_S in the takeoff configuration to V_H in the cruise configuration. In the case of external fuel tanks, both full and empty, releases shall be demonstrated as described above.

c. Altitude: To obtain maximum Mach rumber, emergency releases shall be demonstrated at low altitude in the takeoff configuration and at 2,000 feet below service ceiling in the cruise configuration.

d. Expendables: Certain stores may be salvoed as an emergency measure. If stores are salvoed or fired, such action should not produce severe trim change, engine surge or stall, or excessive g-jump, as determined by the procuring agency.

3.4 Armament Provisions - Additional stability and control requirements, as necessary, shall be provided by the procuring agency to ensure characteristics acceptable for the mission of the aircraft being procured. In general, expending and/or operating the armament items shall not produce changes, such as trim, acceleration, attitude, or speed, that prevent effective utilization of the armament item. In all aircraft where the primary mission is weapons system oriented, the requirements contained in this document shall be applicable with the specific armament items installed and shall be demonstrated with these items installed and by the appropriate actual or simulated operations and conditions (as determined by the procuring agency) that follow:

a. **Types:** Shall be all-inclusive.

b. Altitude: Shall be as specified by procuring agency for each type of armament.

c. Speeds: Shall be as specified by procuring agency for each type; however, the minimum speed conditions to be demonstrated shall include takeoff, landing (VTOL, STOL, and CTOL, as applicable), cruise, and maximum speed for release or operation.

d. Blast and Vibration: Shall not be objectionable to or uncomfortable for the crew, as determined by procuring agency; specific limits to be established by procuring agency whenever possible.

e. Engine Operations: Shall not be affected adversely under any condition by armament, as evidenced by such abnormal effects as compressor stall, flameout, overtemperature, or ingestion due to operation of armament items.

3.5 Speed Reduction Devices - Unless specifically exempted by the procuring activity, all aircraft shall be capable of deceleration, dive speed limitation, constant speed, and glide path control, to any degree desired by the pilot, within limits that shall be stated in the contract or otherwise agreed to by the procuring activity.

3.5.1 Definition - Any device or system used to reduce the speed of the aircraft.

3.5.2 Demonstration - The speed reduction device shall be demonstrated as follows:

a. Airspeed: At speeds up to the limit allowable.

b. Altitude: At pressure altitudes that cover the operating envelope of the airplane.

c. Power: Demonstrations shall be conducted from maximum continuous power, both by simultaneously chopping power and by operating the speed reduction device, and without reducing power and operating the speed reduction device.

d. Acceleration: Operation of the speed reduction device shall be demonstrated from lg flight and from design limit load factor.

e. Tests: Tests should be conducted at the most adverse cg and gross weight. When the speed reduction device is operated, either to produce or remove a decelerating force, the aircraft shall not pitch, have objectionable trim changes, buffet, or have other objectionable characteristics. If the speed reducing device has components on either side of the plane of symmetry, it shall be shown that failure of one to operate does not result in yaw or roll rates that approach structural limits.

3.6 Control System - The characteristics of the control system, as felt by the pilot, shall not result in objectionable handling qualities at any speed or in any configuration covered by these requirements. In particular, the effects of centering, breakout force, feel, preload, friction, and free play, shall not result in objectionable flight characteristics or permit large departures from trim conditions with controls free. There shall be no undesirable variations in the control force gradients of the longitudinal, lateral, or directional controls.

Where two separate types of moment producers (such as rotor and tail rotor plus flaps, ailerons, elevators, and rudders) are operated by the cockpit controls, such controls shall be integrated into a single primary control system and shall exhibit no discontinuities in the aerial vehicle response to acceleration or speed within the flight envelope. In the case of any single failure in powered or boosted systems, in artificial trim devices, or in stability augmentation systems, it is important that the characteristics of the control system, as felt by the pilot, shall not result in unacceptable flying qualities in the configurations and flight conditions appropriate to normal operation.

3.6.1 Cockpit Controls

3.6.1.1 Longitudinal - Lateral - Stick-type controls shall be used for VTOL aircraft unless specifically exempted by the procuring activity. When wheel-type controls are authorized, the wheel throw necessary to meet the lateral control requirements shall be readily obtainable with one hand and shall not exceed 60 degrees in each direction. In aircraft with a second flight-crew member, whose primary function is nonpiloting (such as a gunner-copilot), the use of nonconventional methods for control is permitted upon approval of the procuring activity.

3.6.1.2 Directional - Conventional rudder pedals shall be used at the primary pilot station(s). In aircraft with a second flight-crew member, whose primary function is nonpiloting (such as a gunner-copilot), the use of nonconventional methods for control is permitted upon approval of the procuring activity.

3.6.1.3 Height Control - A specific lever configuration is not specified; however, the configuration approved by the procuring activity shall conform to the appropriate requirements contained herein. Where a lever is installed whose motion is in the vertical plane (that is, up and down), an upward motion or rotation shall produce an increase in vertical thrust or lift; and where the lever motion is in a horizontal plane (that is, fore and aft) a forward motion shall produce an increase in vertical thrust or lift.

3.6.1.4 Thrust Vector Control - In those aircraft configurations where the thrust vector must be varied relative to the longitudinal axis to transition between hovering flight and conventional flight, it is considered to be a longitudinal trim device, and, as such, shall be incorporated on the longitudinal-lateral control lever. In those aircraft where aircraft attitude change is the primary method utilized to transition between hovering and conventional flight and where step switching of the thrust vector from vertical to horizontal or on-off control of lift-type engines is required, such controls or switches shall be mounted on or within easy reach of the height or throttle control lever(s). Any selected setting of the thrust vector control elements shall be maintained indefinitely without attention from the pilot. It shall be possible for the pilot to select the angular setting for hovering without reference to an indicator.

The acceleration and deceleration usable during a transition shall not be limited by the rate at which the thrust vector can be rotated.

In addition, performance and repeatability of the takeoff maneuver shall not be limited by this rate, nor by the accuracy by which a chosen angle setting can be selected without reference to an indicator.

A single failure of the thrust vector control system shall not cause the thrust vector to rotate to a position, or at a rate, such that the aircraft cannot maintain height or make a safe landing.

After a failure in a power system, it shall still be possible to actuate the systems necessary for transition.

3.6.1.5 Trim - The trim system shall be of a type that is continuously adjustable throughout its range. Other systems such as "press-to-release" or "press-to-trim" shall not be used without specific approval of the procuring activity. All trim devices shall maintain indefinitely the setting selected by the pilot, unless actuated by an automatic system. The device shall be capable of easy and comfortable operation by the pilot at all times and at all points of the flight envelope. Following any trim system failure, the permanent out-of-trim forces shall not exceed 16 pounds longitudinally, 8 pounds laterally, and 40 pounds directionally at any speed up to V_{con}; and 30 pounds, 15 pounds, and 80 pounds, respectively, at any speed above V_{con}.

3.6.1.6 Mode Selector - Where a switch or selector lever is required to transition from hovering mode to conventional mode, and vice versa, such switch or lever shall be located in such a position that it can be operated by the pilot comfortably and easily at all times; no more than 3 inches shall separate his normal hand position from such device.

3.6.2 Mechanical Characteristics

3.6.2.1 Cockpit Control Travel - Control travel shall be in accordance with the "Desired Travel" column in Table II unless otherwise authorized by the procuring activity. In no case will maximums be exceeded.

TABLE II
CONTROL TRAVEL

Control	Type	Desired Travel (in.)	Maximum Travel (in.)
Longitudinal	Stick	± 4	± 6 1/2
Lateral	Stick	± 3	± 6 1/2
Directional	Pedal	± 3	± 3 1/3
Height	Lever Throttle	To be determined	To be determined

3.6.2.2 Free Play - The free play in each cockpit control (that is, the motion of the cockpit control from the trim position that does not move the control surface or produce any response of the aircraft in flight) shall not exceed ± 1 percent of total travel or cause objectionable handling characteristics. Following a failure in a power control, stability augmentation system, et cetera, the free play shall not exceed ± 3 percent of total travel.

3.6.2.3 Rate of Control Displacement - The ability of the pilot to perform maneuvers with the aircraft shall not be limited by the rates of movement of control moment producers, such as surface; nor shall the rates of operation of either primary controls or auxiliary devices result in objectionable flight characteristics.

3.6.2.4 Power Controls - The combined mechanical characteristics of the control system linkage (such as free play and friction) and of any associated hydraulic, pneumatic, or electric components of the power system (such as servo valve friction, output force to friction force, and gain) shall meet the requirements for control systems defined herein. In addition, no objectionable characteristics, such as difficulty in trim and pilot-induced oscillations, shall be introduced.

3.6.3 Simultaneous Uses - The specified minimum control response about any axis is the value which is desired, no matter how any other control may be used; however, as a minimum, the specified total longitudinal control and one-half the specified total lateral and directional control shall always be available simultaneously.

3.6.4 Coupling - For boosted or power-operated controls, there shall be no apparent control coupling between any controls. For unboosted controls, the maximum coupling that is tolerable is shown in Table III.

TABLE III
MAXIMUM COUPLING FOR UNBOOSTED CONTROLS

Control Input	Percent of Applied Control Force for Other Axes Forces Tolerated (Maximum)	
Longitudinal	20 - Lateral	75 - Directional
Lateral	40 - Longitudinal	100 - Directional
Directional	80 - Longitudinal	6 - Lateral

3.6.5 Power Controls

3.6.5.1 General - In the 100-percent power control system, the pilot furnishes none of the effort required to move the control surface; he merely supplies the signal to the power unit, which is generally electrically or hydraulically operated. This means that no control forces are fed back to the pilot with respect to the control movement; therefore, the feel, or force, must be induced artificially. In the boost power control system, the pilot is aided in his effort to move the control surface by some source of power. These systems may be combined with each other or combined with direct mechanical control systems to form two or more completely independent or alternate systems on the aircraft. These systems must be capable of providing rapid repeated control movements, such as would be required in very rough air operation.

3.6.5.2 Power or Boost Control Failure - Because of the instabilities and high required hinge moments of the V/STOL aircraft, all aircraft employing power or boost control systems must be provided with suitable means for control following complete loss of a power or boost control system. For control following such failure, either dual identical systems or an alternate system is mandatory and a third system of limited capacity is desirable as a reserve. Engine failure or electrical system failure, or both, shall not result or attribute to a failure in the primary power-operated control system; nor should a failure in the power-operated control system result in a failure of the trim system.

3.6.5.3 Transfer to Alternate Control System - The trim change associated with transfer to the alternate control system, when such transfer is either caused by power control failure or performed intentionally in accordance with routine procedure, shall not produce a dangerous flight condition. If dual independent control systems are used, a transfer in trimmed flight should cause no perceptible trim change. If the alternate system is not an independent power system, the out-of-trim condition resulting from an abrupt power-operated control system failure shall be such that with controls free for at least 3 seconds, the resulting rates of roll, pitch, and yaw shall not exceed 10 degrees per second, and the change in normal acceleration shall not exceed $\pm$ 0.5g. It shall also be possible to continue flight with zero sideslip with forces to operate the controls not to exceed those specified in paragraph 3.6.8.5.

With the power-operated control system off, it shall be possible to trim steady longitudinal, lateral, and directional control forces to zero under all conditions and speeds; and the height control (throttle, collective-pitch, or lift-stick control) shall not creep, whether or not the conventional flight controls are moved.

For aircraft having two or more completely independent power-operated control systems, the failure of one of the complete systems during the period of transfer from one system to another shall be such that with the controls free for at least 3 seconds, the resulting rates of roll, pitch, and yaw shall not exceed 10 degrees per second, and the change in normal acceleration shall not exceed $\pm$ 0.5g. With the remaining system, or systems, it shall be possible to trim steady longitudinal, lateral, and directional control forces to zero under all conditions and speeds. The rates of control motion attainable shall be such that safe operation is in no way compromised and shall in no case be less than 50 percent of the normal rates. In such operations, including the approach and landing, it shall be possible without retrimming to make a normal landing approach and landing without the control forces exceeding those specified in paragraph 3.6.8.5.

3.6.6 Artificial Feel Systems - Handling qualities, as associated with artificial feel, have not been given a precise quantitative measure, since they are intimately associated with the complex dynamic properties of the human pilot; however, approximate required characteristics can be assigned. The effects of centering, breakout forces, preload, friction, free play, and miscellaneous mechanical control effects should not result in objectionable flight characteristics or permit large departures from trim condition with controls free. Specific requirements of breakout forces, including preload and friction, can be found in pragraph 3.6.8.1.

3.6.7 Automatic Stabilization Systems - Automatic stabilization and control or stability augmentation systems, or both, if provided to meet some or all of the ground and flying qualities covered elsewhere in these requirements, shall meet the separate requirements stated within this section. Likewise, in satisfying the requirements of this section, the requirements of all other sections shall not be negated.

3.6.7.1 Equipment Failure - Following a failure or disengagement of the stability augmentation or atuomatic stabilization and control systems, or both, it is important that the characteristics of the basic control system, as felt by the pilot, should not result in unacceptable handling qualities in the configurations and flight conditions appropriate to emergency operation. Emergency operation pertains to that flight operation necessitated by such failure or disengagement in which the pilot conducts limited flight in order to execute an approach and touchdown or autorotative landing (or wave-off and missed-approach procedure) within normal restricted operating space or under instrument flight conditions. This flight operation should be possible for a pilot with a reasonable degree of skill and effort.

3.6.7.2 Control Margin - In cases where automatic stabilization and control or stability augmentation systems, or both, are utilized to meet the flying qualities requirements, a given amount of control moment margin, or excess, is required. Specifically, for pitch, roll, and yaw control, the augmentation system in combination with pilot-controlled inputs shall not utilize more than 50 percent of the available control moment for recovery from any maneuver within the flight conditions assigned by these specifications.

3.6.7.3 Switching Transients - For aircraft utilizing independent dual automatic stabilization and control or dual stability agumentation equipment (or a completely independent combination of both), there shall be no objectionable switching transients, upon the failure of one complete system or part of a system, upon switching or transferring from one system to another or upon engaging or disengaging the systems. Specifically, the rates of yaw, roll, and pitch shall not exceed 10 degrees per second, and the change in normal acceleration shall not exceed $\pm$ 1/2g.

3.6.8 Cockpit Control Forces - All forces covered in paragraph 3.6.8 and section 3.7 shall be within the limits established and shall be measured at the pilot's control (at the point of normal contact) in flight, or in conditions resembling those in flight as closely as possible. The forces apply to all aircraft, regardless of size, for conditions indicated unless specifically stated otherwise.

3.6.8.1 Breakout Forces - Breakout forces shall include all the pilot applied force (such as friction, feel, and preload) required to start movement of the control surface (or other device capable of producing moments on the aircraft) and shall apply in flight at all attainable conditions of trimmed airspeed, altitude, temperature, and control deflections. The allowable breakout forces are tabulated in Table IV. The forces shall be those measured in flight, or in conditions resembling those in flight, as close as possible.

TABLE IV
BREAKOUT FORCES

Control	Normal Operation (lb)	After Failure of Power Control (lb)
Longitudinal	0.5 to 2.5	Less than 5
Lateral	0.5 to 2.0	Less than 4
Directional	1.0 to 10.0	Less than 15
Height*		
Lever	1.0 to 3.0	Less than 5
Throttle	1.0 to 3.0	Less than 3

*Adjustable friction is desirable; however, above forces shall be achieved when any adjustable friction device or friction damper is off.

3.6.8.2 Centering - Longitudinal, lateral, and directional controls shall exhibit positive centering in flight at any normal trim setting.

3.6.8.3 Control Force Coordination (Harmony) - Control forces from trim in coordinated maneuvers should be in the ratio of 2:5:1 for longitudinal, directional, and lateral forces, respectively, for stick and rudder pedal-controlled aircraft, throughout the speed range of the aircraft. However, the ratio for longitudinal and lateral shall not be less than 1:1 nor more than 4:1; directional to lateral shall not be less than 4:1 nor more than 8:1.

The control forces required to perform maneuvers that are normal for the aircraft should have magnitudes that are related to the pilot's capability to produce such forces. Control forces in hover should be lighter than those at high Mach numbers; however, coordination (harmony) between controls should remain approximately constant with changes in speed.

3.6.8.4 Linearity - Beyond the breakout region, the slope of the curve of control force versus displacement shall be positive at all times. The slope for the first 10 percent of travel from trim shall be greater than, or equal to, the slope for the remaining control travel; however, the change in slope shall not exceed 50 percent.

3.6.8.5 Limit Forces - The maneuvering forces (except control force transients) or steady force required to change from any trim and power condition to any other trim and power condition without retrimming shall not exceed the values stated in Table V.

TABLE V
CONTROL FORCE (POUNDS)

	Normal			After Failure*		
Control	Hover	Transition or STOL	Cruise	Hover	Transition or STOL	Cruise
Longitudinal	10	30	40**	20	40	50**
Lateral	7	15	20	15	20	25
Directional	30	75	100	40	100	125

*Failure of any power, control, critical engine, or stability augmentation system.

**Maneuver limit force shall be 60 pounds at $.8n_L$.

3.6.8.6 Trimmability - It shall be possible for the pilot to reduce all control forces to zero under any steady flight condition within the allowable speed envelope of the aircraft. The trimmability of the aircraft shall be demonstrated in steady flight under the configurations, powers, and speed ranges of interest of Table VI. Trimmability shall be demonstrated about all axes at the most critical allowable cg. Other conditions for demonstration of trimmability may be specified by the procuring activity. Those aircraft with on-off conversion sequences (for example, instantaneous engine diversion) need not demonstrate manual trimmability in the conversion if conversion trim automation is provided.

TABLE VI
FLIGHT DEMONSTRATION CONDITIONS

Condition	Configuration	Power	Trim Speed*	Speed Range of Interest
1	HO	a. PLF (IGE and OGE)	0	Zero to designated wind speed, any direction
		b. ARP or MRP and NRP, as applicable	0	Zero to forward designated wind speed
2	ST	a. ARP or MRP, as applicable	Critical and 1.15 $V_{S_{sto}}$	$V_{S_{sto}}$ to V_{sto} limit
		b. PLF	Critical and 1.15 $V_{S_{sto}}$	$V_{S_{sto}}$ to V_{sto} limit
		c. FIP	Critical and 1.15 $V_{S_{sl}}$	$V_{S_{sl}}$ to V_{sl} limit
		d. $PRP_{(500)}$	Critical and 1.15 $V_{S_{sl}}$	$V_{S_{sl}}$ to V_{sl} limit
3	TR	a. ARP, MRP and NRP, as applicable	Critical	Forward designated wind speed to V_{con}
		b. PLF	Critical	Forward designated wind speed to V_{con}
4	CR	PLF	1.15 $V_{S_{cto}}$ or V_{con} (whichever is lower) and V_{NRP}, $V_{\frac{M}{e}}$, $V_{\frac{R}{c}}$	$V_{S_{cto}}$ to V_M or M_M
5	PA	a. PLF	1.15 $V_{S_{cto}}$	$V_{S_{cto}}$ to V_{cto} limit
		b. PRD (500)	1.15 $V_{S_{cto}}$	$V_{S_{cto}}$ to V_{cto} limit
		c. MRP or ARP, as applicable	1.15 $V_{S_{cto}}$	$V_{S_{cto}}$ to V_{cto} limit
6	G	FIP	V for best L/D	V_{S_G} to V_H
7	D	FIP	1 or more representative speeds	All speeds normally attained in configuration D dives
8	L	a. PLF	1.15 $V_{S_{cl}}$	$V_{S_{cl}}$ to V_{cl} limit
		b. FIP	1.15 $V_{S_{cl}}$	$V_{S_{cl}}$ to V_{cl} limit
		c. ARP or MRP as applicable	1.15 $V_{S_{cl}}$	$V_{S_{cl}}$ to V_{cl} limit

*Sufficient trim speeds shall be selected, in addition to those listed, to define the characteristics of the aircraft throughout its allowable operating envelope.

3.6.8.6.1 Trim With Asymmetric Power - The aircraft shall be trimmable about all axes at a speed of 1.4 V_S during climbing flight under the following conditions:

a. Critical engine inoperative and a minimum drag condition.

b. Remaining engine(s) operating at maximum continuous power.

c. Gear and flaps retracted.

d. Maximum of 5 degrees of bank allowable to maintain heading and zero rudder force.

3.6.8.7 Adjustable Controls - When a cockpit control is adjustable for pilot physical dimensions or comfort, the control force as defined in paragraph 3.6.8 shall refer to the mean adjustment; a force referred to any other adjustment shall not differ by more than 10 percent from the force referred to the mean adjustment.

3.7 Stability and Control - It is a prime objective of VTOL, V/STOL, and STOL aircraft that the aircraft be capable of operating from restricted spaces. It is therefore mandatory that the average pilot be able to make accurate takeoffs, approaches, and landings consistently in terms of speed and flight-path holding.

3.7.1 General - In addition to static and dynamic stability and trim characteristics, there are many characteristics associated with the initial transient and maneuvering response of an aircraft to an abrupt control input that contribute significantly to pilot opinion when properly related to the force-feel characteristics producing the response. The important response parameters are listed below, and the interrelationship of the force-feel characteristics are stated in the following sections.

T_1 - Time to reach the specified threshhold value in proper direction, seconds.

τ - Time to reach 63 percent of steady-state value initially or time to reach 63 percent of initial peak for oscillatory modes initially with a period longer than 3 seconds, seconds (subscripts L, R, and Y refer to longitudinal, lateral, and directional, respectively).

O_p - Magnitude of peak overshoot, percent of steady state or magnitude of second peak to first peak, percent of first peak.

T_2 - Time to reverse response for a pulse input to specified value in opposite direction, seconds.

ζ - Damping ratio, ratio of actual damping to critical damping (exponential attentuation envelope for oscillatory modes).

3.7.2 Flight Demonstration Conditions - Compliance with requirements of section 3.7 shall be demonstrated at the appropriate flight demonstration conditions defined in Table VI. All conditions shall be those for the most critical loading.

3.7.3 Longitudinal

3.7.3.1 Static Stability - The aircraft shall possess positive cockpit control position and cockpit control force stability with respect to speed for all steady-flight conditions in which the aircraft is to be operated, including the conditions listed in paragraph 3.7.2. When it is clear that the aircraft is not required to operate continuously in any one or more conditions, the procuring activity may allow a mild degree of instability; or following a failure in the longitudinal stability augmentation system, a mild degree of instability may be tolerated. However, the magnitude shall never exceed 0.5 inch for cockpit control position or 1.0 pound for cockpit control force in the unstable direction.

3.7.3.2 Dynamic Stability - For all permissible forward speeds and loadings and for both straight and turning flight, longitudinal oscillation with controls fixed, following a single disturbance in smooth air, shall exhibit damping characteristics as close as possible to the curve labeled "Target" in Figure 1 but in no case less than in the "Normal Minimum Acceptable" limits curve. Small amplitude residual oscillations shall not exceed 0.5 degree per second pitching velocity or 0.05g, whichever is less.

After a failure in a stability augmentation system, the aircraft shall exhibit damping characteristics no less than in the "Single Failure Limit" curve of Figure 1.

3.7.3.3 Forces - The longitudinal control force versus deflection shall not be less than 1 pound per inch for any flight condition. (No maximum is established, since the response capability of the aircraft will determine the maximum force allowable.) At the most critical loading for any constant speed, power setting, and configuration, an increase in pull force and a rearward displacement of the cockpit control shall produce an increase in normal acceleration and/or an increase in nose-up pitching velocity for all longitudinal maneuvers within the design flight envelope.

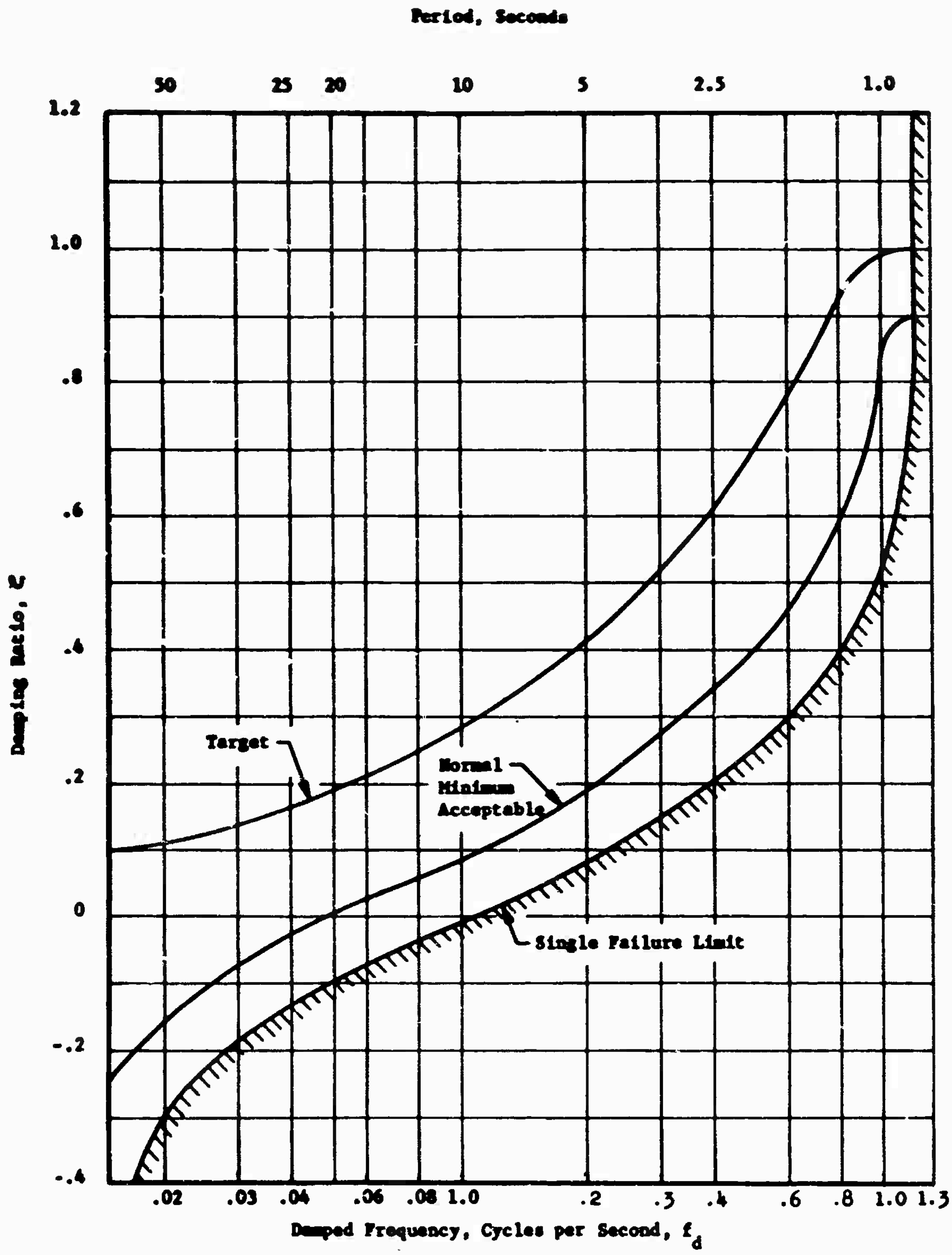

Figure 1. Damping Characteristics Versus Frequency.

The maneuvering control force per g shall be between $\frac{35}{n_L-1}$ and $\frac{60}{n_L-1}$ with a target of $\frac{50}{n_L-1}$ for all aircraft (n_L is used here as design positive limit load factor). The slope of the curve of control force per g shall be essentially linear throughout the maneuvering envelope; however, the slope may be as much as 50 percent greater than (in no case less than) between $0.8n_L$ and n_L (positive and negative n_L).

3.7.3.3.1 Control Force Transients - The time history of longitudinal control force, following any rate of application form trimmed straight flight, shall not fall to less than 50 percent of, or exceed by more than 100 percent, the steady-state force required to produce the steady-state response; and it shall always lead the pitching velocity and/or normal acceleration response.

3.7.3.3.2 Force/Effectiveness - Longitudinal control force should be tailored to provide 1.5 degrees per second per pound of force above breakout throughout the speed range of the aircraft. However, the angular rate shall not be less than 1.0 degree per second per pound nor more than 2.0 degrees per second per pound. The minimum acceptable pitching velocity response from hover to V_{con} is ± 15.0 degrees per second for full control displacement from trim; the target is ± 20.0 degrees per second; no maximum is specified.

3.7.3.4 Transient/Maneuver Characteristics

3.7.3.4.1 Input - The response characteristics shall be those determined from abrupt cockpit control displacement(s) (that is, step, pulse) from trimmed steady flight, as illustrated in Figure 2 at (a) and (b).

3.7.3.4.2 Response Characteristics - After abrupt control input(s) (as illustrated in Figure 2 at (a) and (b)) of various magnitudes sufficient to cover up to 80-percent design flight envelope limits (the minimum shall be that required to produce 5.0 degrees per second or Δ_n of 1.0g, whichever occurs last), the aircraft shall meet the following conditions:

a. $T_1 < 0.4$ second to reach 0.5 degree-per-second pitching or .01g (target, 0.1 second).

b. T_L - Between 0.1 and 1.0 second (target, 0.3 second).

c. $O_p = 30$ percent except that with input for $0.8n_L$, the normal acceleration overshoot shall not exceed n_L.

d. T_2 - Same requirement as T_1.

e. Meet where possible the damping characteristics shown on the "Target" curve of Figure 1. However, the damping for normal flight shall never be less than that indicated by the "Normal Acceptable Limits" curve of Figure 1.

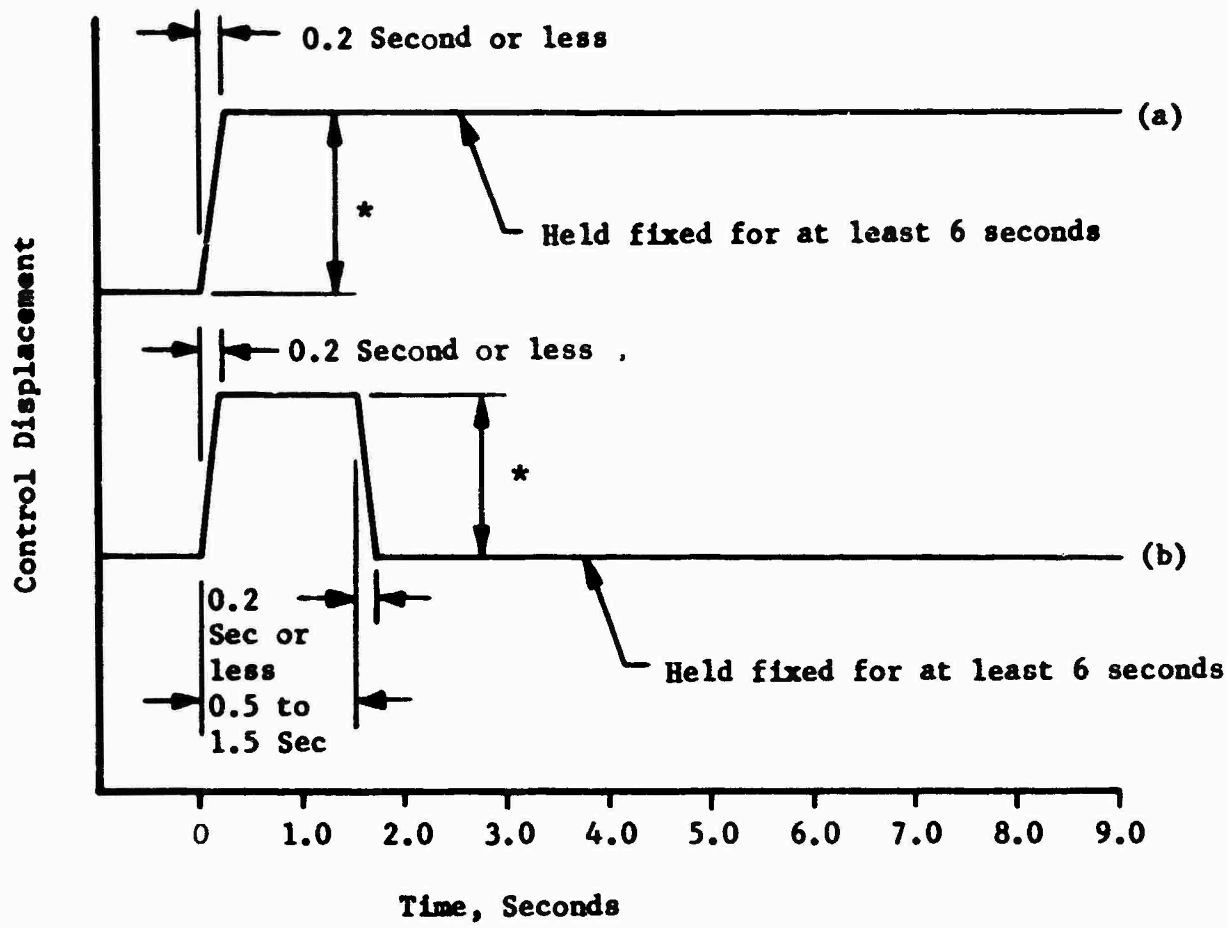

Figure 2. Control Displacement.

3.7.3.5 Longitudinal Control Effectiveness in Maneuvering Flight - At the most critical loading, when trimmed at any permissible speed and altitude appropriate to a given configuration and engine power, it shall be possible to develop at the trim speed, by the use of the longitudinal control alone, the limiting attitude or incidence consistent with the operational flight envelope. The initial conditions for demonstration of this recommendation shall be those of Table VI. This requirement shall also be met following a failure in a stability augmentation or power control system.

3.7.3.6 Longitudinal Control Effectiveness in Takeoff - Longitudinal control effectiveness shall not restrict the takeoff performance of the aircraft for STOL operation. Specifically, control effectiveness shall be adequate to achieve takeoff attitude at no greater than 0.9 times the lift-off speed necessary for demonstrating takeoff performance or this lift-off speed less 10 knots, whichever is the lower speed. This shall also apply after a failure in a power control or stability augmentation system.

For VTOL operation, it shall be possible to make vertical takeoffs in winds up to the designated wind condition. In addition, it shall be possible, in conjunction with other controls as necessary, to prevent fore or aft translation during run-up for takeoff, and there should be no objectionable longitudinal (or lateral) attitude changes during starting and run-up to maximum power. For all types of operation, it shall be possible to check for proper control functioning during run-up at less than takeoff power.

These requirements shall be met with the critical aircraft loading and should be applicable for all surfaces from which the aircraft may be operated.

3.7.3.7 Longitudinal Control Forces in Takeoff - With trim optional but constant, the longitudinal control forces required both for takeoff and during the ensuing acceleration to the takeoff safety speed shall not exceed the following limitations: a 10-pound pull or a 5-pound push for normal operation and a 20-pound pull or a 10-pound push after a failure in a stability augmentation or power control system has occurred.

3.7.3.8 Longitudinal Control Effectiveness in Landing - At the most critical loading, with the aircraft trimmed at V_{PA} the longitudinal control shall be sufficiently effective to permit landing from both shallow and steep approach angles. For VTOL operation, it shall be possible, in conjunction with the use of other controls as necessary, to make vertical landings from any operationally necessary height in winds of up to the maximum designated wind condition.

These requirements shall also apply following a failure in a power control or a stability augmentation system.

3.7.3.9 Longitudinal Control Forces in Landing - For STOL operation, it shall be possible to meet the landing requirements of paragraph 3.7.3.8 with forces not exceeding a 10-pound pull or a 5-pound push, except that momentary control forces of up to a 10-pound pull and a 10-pound push are acceptable.

Following a failure in a power control or a stability augmentation system, the above control forces shall not exceed the 10-pound pull or 10-pound push if they are to be held for more than a short time, but momentary control forces of up to a 40-pound pull and a 20-pound push will be acceptable.

3.7.3.10 Longitudinal Control Forces and Control Margins in Sideslips - With the aircraft trimmed for straight flight in the appropriate flight conditions specified in Table VI, the longitudinal control force in normal operation shall not exceed the 10-pound pull of the 5-pound push in sideslips up to those specified in paragraph 3.7.4.2. After a failure in a power control system, the limiting forces shall not exceed a 20-pound pull or a 10-pound push.

3.7.3.11 Longitudinal Change-of-Trim Limits - The change in stick force needed to trim, following any operationally necessary or normal configuration and/or power change, should be as small as possible and, in any case, shall not exceed the 10-pound pull or the 5-pound push when the aircraft is trimmed in the initial condition. After a failure in a power control system, the above forces shall not exceed a 20-pound pull or a 10-pound push.

3.7.4 Lateral-Directional

3.7.4.1 Flight Demonstration Conditions - Compliance with requirements of section 3.7 shall be demonstrated as the appropriate flight demonstration conditions defined in Table VI. All conditions shall be those for the most critical loading.

3.7.4.2 Sideslip Conditions for Static Lateral-Directional Stability - Requirements for static directional stability, dihedral effect, and side-force variation apply in straight (zero turn rate) sideslips up to the side-slip angles produced by full directional control with the stability augmentation system operative with a 125-pound directional control force, or with full lateral control, whichever is reached first. The requirements apply over the entire speed range.

3.7.4.3 Static Lateral-Directional Stability - The aircraft shall demonstrate control position and control force stability; that is, increasing left directional control motion, force, and bank angle shall be required to produce an increasing right sideslip, and vice versa. For angles of sideslip between +15 degrees and -15 degrees, the variation of sideslip angle with lateral and directional control motion and force shall be essentially linear (no more than 50-percent change in slope). Throughout the remainder of the required sideslip range, an increase in directional control motion and force shall be required to produce an increase in sideslip, and there shall be no tendency toward directional control lock or overbalance. No more than a 10-pound lateral force or 50 percent of available lateral rolling moment from trimmed, laterally level, straight flight shall be required to maintain heading in the sideslips specified.

3.7.4.3.1 Instability - When it is clear that the aircraft is not required to operate continuously in any one or more conditions, or when there has been a single failure in a lateral-directional stability augmentation system, the procuring activity may allow a mild degree of instability. However, the magnitude shall never exceed 0.5 inch for cockpit control position or 1.0 pound for lateral control force and/or 5.0 pounds for directional control force.

3.7.4.4 Lateral-Directional Dynamic Stability - Lateral-directional oscillations with controls fixed or free following a single disturbance in smooth air shall exhibit damping characteristics as a function of the damped natural frequency corresponding to the curves of Figure 3. Every effort shall be made to have the damping lie on or to the right of the "Target" boundary curve regardless of the $\frac{|\phi|}{|V_e|}$ ratio. However, the minimum acceptable value shall lie on or to the right of the boundary corresponding to the appropriate $\frac{|\phi|}{|V_e|}$ value. These requirements shall be demonstrated by abruptly releasing the controls from the sideslips specified in paragraph 3.7.4.3.

For armed aircraft in the firing or bombing configuration and at all flight conditions where firing or bombing may be performed, the minimum damping acceptable shall lie on or to the right of the "Target" curve. The magnitude of any residual oscillations should not cause tracking deviations outside a 2-mil-radius circle about the point of aim; however, deviations outside a 5-mil-radius circle are not acceptable.

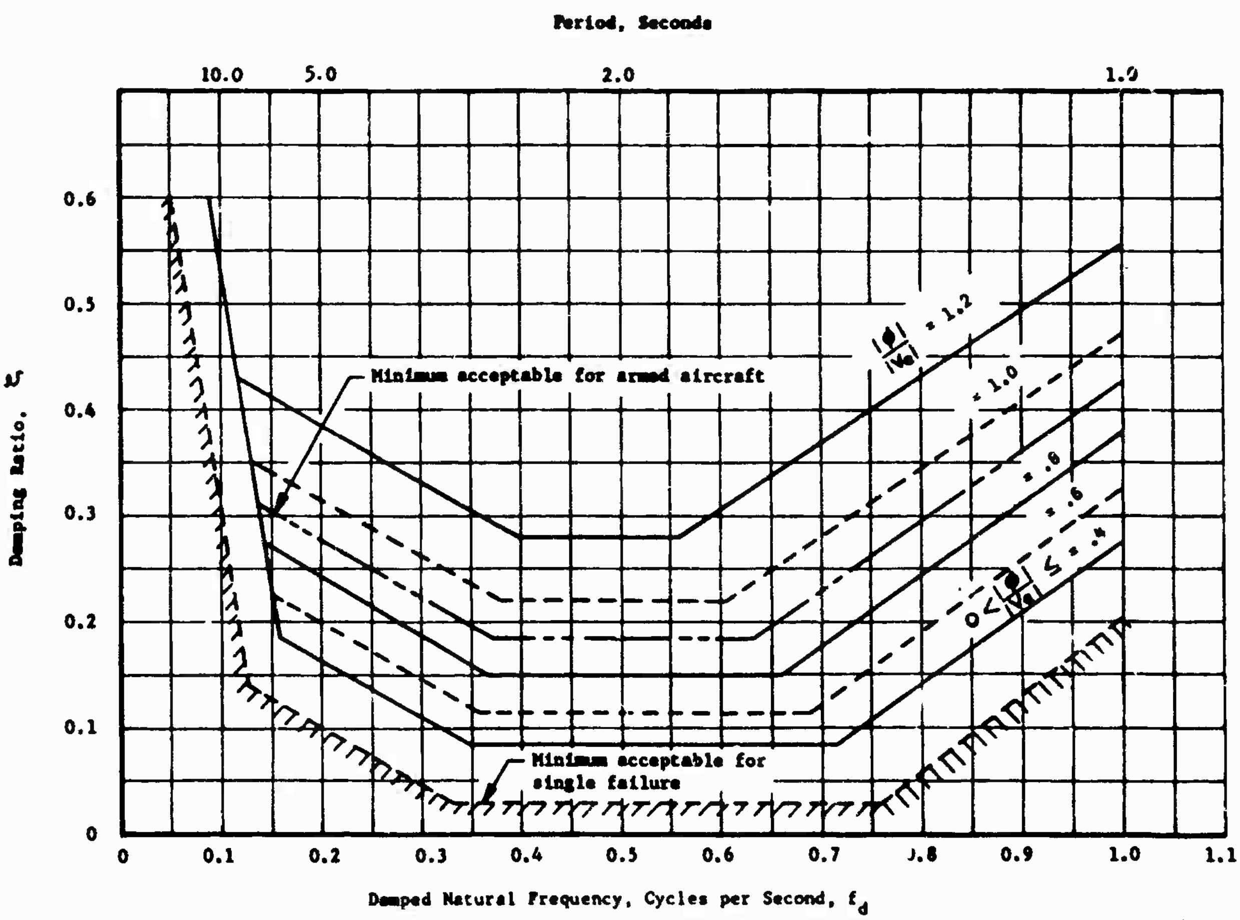

Figure 3. Lateral-Directional Requirements.

Upon a single failure in an automatic stabilization device, the minimum shall be on or to the right of the curve labeled "Single Failure Limit". (For demonstration purposes, the single failure shall occur just prior to release of controls.)

3.7.4.5 Spiral Stability - Positive spiral stability is not required; however, it is desired provided no Dutch roll tendencies exist. If spiral instability exists, the bank angle shall not double in less than 20 seconds when controls are released in a steady 10-degree banked turn from trimmed laterally level flight.

3.7.4.6 Adverse Yaw - At V_{PA}, the angle of sideslip developed during an abrupt rudder-pedal fixed roll from a trimmed, level, steady 30-degree banked turn to a bank angle of 30 degrees in the opposite direction, without checking, should not exceed 15 degrees. The lateral control deflection applied and held fixed during the roll should be at least that required for compliance with the lateral control performance tests. For smaller lateral control deflections, the acceptable angle of sideslip will be proportionally smaller.

Also, the sideslip, developed in a slow maneuver started from a laterally level condition and generated by a step displacement of the lateral control of such magnitude that a bank angle of 30 degrees is developed in not less than 6 seconds, should not exceed 15 degrees.

For both types of maneuver, the rolling velocity should always be in the correct direction; that is, it should not reverse due to the combination of dihedral effect and the sideslip developed. For aircraft which exhibit proverse (favorable) yaw, the values of sideslip in the proverse direction obtained during these roll maneuvers should not be so large as to cause objectionable flight characteristics.

In the rolling maneuvers specified above, the directional control should be adequate to maintain sideslip at the initial trim value.

In the case of a failure in a stability augmentation system, the sideslip developed in the roll maneuvers specified above should be permitted to reach 20 degrees. Compliance with these requirements shall be demonstrated in configuration CO at V_H, CR at 1.4 $V_{S_{CR}}$, and PA at 1.4 V_{SL}.

3.7.4.7 Forces

a. Lateral: The lateral control force versus deflection shall not be less than 1.0 pound per inch for any flight condition.

b. Directional: The directional control force versus deflection shall not be less than 6.0 pounds per inch.

3.7.4.7.1 Control Force Transients - The time history of lateral and directional control forces, following any rate of application in each direction from trimmed straight flight, shall always lead the angular velocity and/or bank angle and sideslip response respectively and shall not exceed the steady-state force by more than 100 percent.

3.7.4.8 Force/Effectiveness

a. Lateral: The lateral control force should provide a response of 5.0 degrees per seond per pound. However, it shall not be greater than 7.5 degrees per second per pound or less than 3.0 degrees per second per pound for any flight condition up to 1.5 V_{con} (or V_M, whichever is less) and shall not exceed 10.0 degrees per second per pound from 1.5 V_{con} to 0.8 V_H/M_H. Target and minimum acceptable rolling performance are shown in Figure 4.

b. Directional: Directional control force should provide a response of 3.0 degrees per second per pound. However, it shall not be greater than 5.0 degrees per second per pound nor less than 2.0 degrees per second per pound for any flight conditions up to V_{con}. Target and minimum acceptable yawing performance are shown in Figure 5.

3.7.4.9 Transient and/or Maneuver Characteristics

3.7.4.9.1 Demonstration Conditions - The response characteristics apply throughout the flight envelope of the aircraft. Compliance will be demonstrated at the conditions listed in Table VI and shall be determined from various magnitudes of abrupt cockpit control displacement(s), as illustrated in Figure 2 at (a) and (b). Ordinarily, 25, 50, 75, and 100 percent of control deflection in each direction should be investigated, except where structural limits or safety of flight considerations limit maximum deflections (such as in hover). However, the minimum shall correspond to at least the magnitude required to attain a bank angle of 15 degrees in 1 second for lateral deflections and a yaw angle of 10 degrees in 1 second or a sideslip angle of 5 degrees for directional deflections.

3.7.4.9.2 Requirements - Where target requirements are stated, every effort shall be made to meet or exceed them; however, the aircraft shall meet the following acceptable values:

ALTITUDE RANGE	SPEED RANGE	ϕ in 1 Sec	
		ACCEPTABLE	TARGET
S.L. to 6000'	Hover to V_{con}	15 - 50	30
S.L. to High	V_{con} to M_H (or M=.9 where M_H> .9)	50 - 90	90
Lowest alt. at which highest value of M_M may be attained	M_M	40 - 50	50

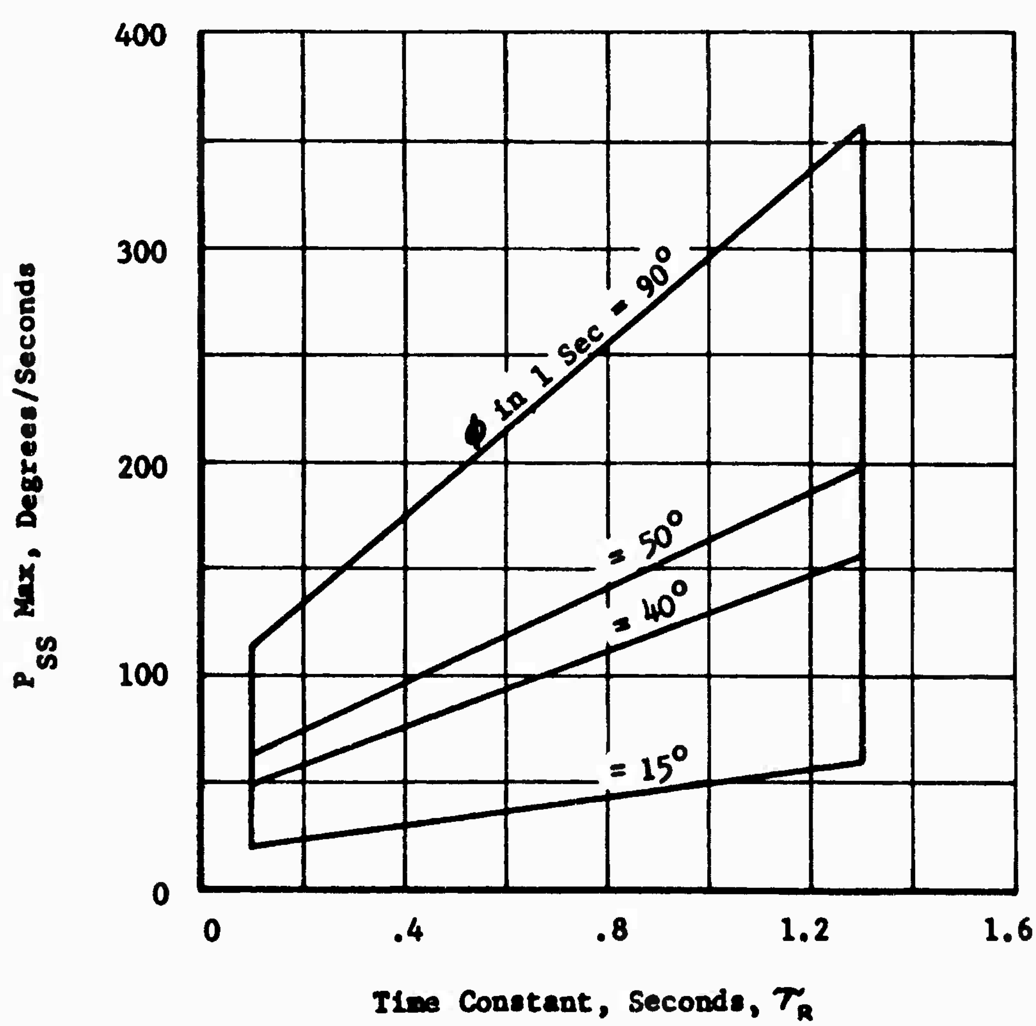

Figure 4. Roll Performance Requirements.

ALTITUDE RANGE	SPEED RANGE	ψ in 1 Sec	
		ACCEPTABLE	TARGET
S.L. (Std.) to 6000' 95°F	Up to V_{con}	10 - 40	20 *

* Minimum acceptable for aircraft where hover requirements are 10% or more of the total mission time and minimum acceptable for configuration requiring large corrections for torque (such as helicopters with antitorque tail rotors) unless automatic torque compensation of at least 75% is provided separately.

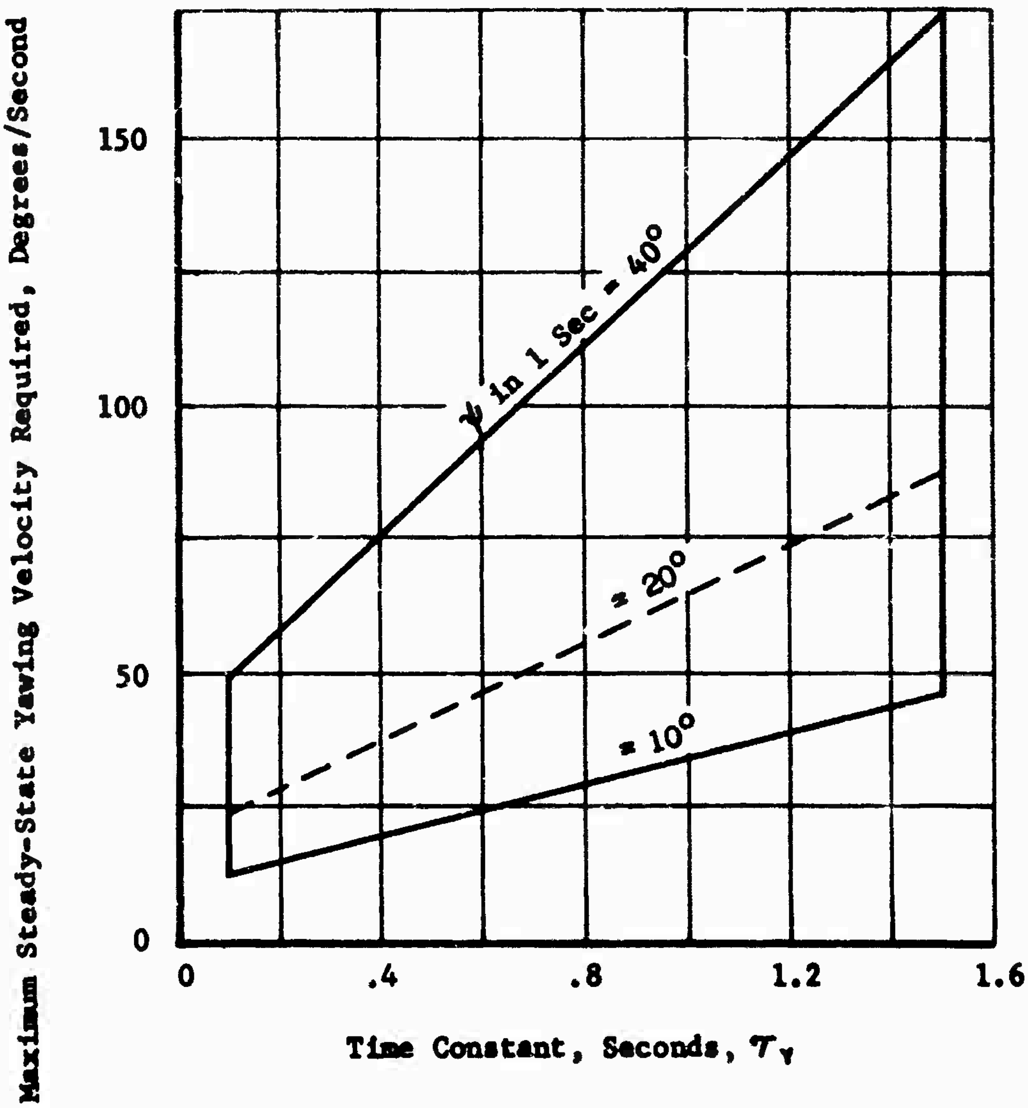

Figure 5. Yaw Performance Requirements.

a. Lateral

(1) $T_1 <$ 0.3 second to reach 0.5 degree-per-second rolling velocity (target, 0.1 second).

(2) τ - Between 0.1 and 1.3 seconds (target, 0.25 second).

(3) O_p = 30 percent (target, 5 percent).

(4) T_2 - Same requirement as T_1.

(5) ζ - As required by Figure 3.

b. Directional

(1) $T_1 <$ 0.3 second to reach 1.0 degree per second, or β = 0.5 degree, whichever comes first.

(2) T_R - Between 0.1 and 1.5 seconds (target, 0.5 second).

(3) O_p = 30 percent.

(4) T_2 - Same requirement as T_1.

(5) ζ - As required by Figure 3.

3.7.4.10 <u>Directional Control Effectiveness in Normal Flight</u> - The directional control shall be sufficiently effective to maintain laterally level straight flight in the configurations and speed range specified for longitudinal stability, with a margin of at least 50 percent of the nominal directional control moment remaining. Following a failure in a stability augmentation or power control system, this margin should be at least 50 percent.

3.7.4.11 <u>Directional Control Effectiveness During Takeoff, Landing, and Taxi</u> - The directional control, in conjunction with other normal means of control, shall be adequate to maintain the desired paths during taxi, takeoffs, and landings in the designated wind conditions. Specifically, for STOL operation a margin of at least 20 percent of the nominal directional control moment shall remain during crosswind takeoffs and landings.

It shall be possible to make a 360-degree taxiing turn in either direction within a circle whose radius equals the major dimension of the aircraft and in winds up to the designated wind conditions.

Except for the taxi cases, the above recommendations shall also apply following a failure in a power control system or stability augmentation system.

3.7.4.12 Lateral Control in Normal Flight - Lateral control shall be sufficiently effective, in combination with other normal means of control, to balance the aircraft laterally during all flight and ground-handling operations and specifically when demonstrating directional control effectiveness.

A margin of 50 percent of the roll control power needed to satisfy the recommendations of paragraph 3.7.4.3 shall remain at the most adverse of the above conditions. Under all these conditions, the out-of-trim lateral control force shall not exceed 10 pounds, with trim fixed at the initial laterally level straight flight condition. For all designated asymmetric loadings, the same margins shall apply, though not necessarily in combination with other laterally asymmetric conditions.

These requirements should also apply following a failure in a stability augmentation or power control system, except that the lateral control force shall be less than 20 pounds for stick or wheel.

3.7.4.13 Roll-Pitch-Yaw Coupling - In rudder and elevator cockpit-control-fixed rolls through 360 degrees at all altitudes and permissible speeds, entered from straight flight, turns, pushovers, or pull-ups ranging from zero g to $\frac{2}{3}n_L$, the resulting yaw motion, sideslip angle, and normal acceleration shall neither exceed structural limits nor cause other dangerous flight conditions, such as uncontrollable oscillations. During combat-type maneuvers involving similar rolls through angles of up to 180 degrees, the extent of the pitching and yawing shall not be so severe as to impair seriously the tactical effectiveness of the maneuver.

3.7.5 Height

3.7.5.1 Characteristics in Ground Interference Region - For all terrain clearances up to the disappearance of ground effect, the effects of downwash ground interference should not result in unsatisfactory characteristics while hovering in any designated wind condition. In addition, there should be no feedback of unsteady aerodynamic forces on control surfaces to the cockpit controls, nor should there be additional undesirable response from this source.

Following a failure in a power control system or stability augmentation system, downwash ground interference during the final landing should not result in objectionable flight characteristics.

3.7.5.2 <u>Height Control</u> - Without the need for exceptional skill on the part of the pilot, it should be possible to maintain satisfactory control of vertical speed within $\pm$ 1 foot per second by the use of the height control, while hovering in still air at all design hovering altitudes and ground clearances, both in and out of ground effect, with less than $\pm$ 1/2-inch movement or $\pm$ 5.0 degrees of rotation of height control lever.

Following a failure in a power control or stability augmentation system, it should be possible for the pilot to control the vertical speed of the aircraft with sufficient accuracy to make a safe vertical landing. To demonstrate compliance with this recommendation, it should be possible for a pilot with no exceptional skill to control vertical speed within $\pm$ 2 feet per second while hovering in still air within the ground effect region.

3.7.5.3 <u>Hovering Precision</u> - Without undue pilot skill or effort, it should be possible to hover continuously, in the designated wind condition at any height up to the disappearance of ground effect, while any chosen point on the aircraft remains within a circle of a 3-foot radius, without acquiring a velocity in excess of 2 feet per second in any horizontal direction.

After a failure in a power control or stability augmentation system, it should be possible for a pilot of average skill to maintain the same precision during a typical vertical landing.

3.7.5.4 <u>Vertical Thrust Margins</u> - To provide sufficient control of rate of ascent and descent during vertical takeoffs and landings, the vertical thrust available out of ground effect should be at least 1.05 times the aircraft weight for takeoff and 1.15 times the aircraft weight for landing under the most adverse specified altitude-temperature conditions. It should be assumed that 50 percent of the available control power is being used simultaneously about all three axes. In addition, during takeoff, application of full control about any one axis with 50-percent application about the remaining axes should not reduce the vertical thrust to less than the weight.

The pilot should be able to obtain full control power about all three axes simultaneously, although the thrust margin in this condition is not specified.

3.7.5.5 <u>Vertical Thrust Response</u> - During the final stages of a vertical landing, the vertical thrust response should be such that, after a step input of the height control, the lift increase is 63 percent of the demanded increase in no more than 0.3 second (target, 0.1 second). For demonstration purposes, the demanded increase should be 10 percent of the landing weight at any power setting between hovering and a 1000-foot-per-minute rate of descent, under the most adverse conditions for the power unit. The ratio of actual damping to critical damping of the vertical (normal acceleration) response shall not be less than 0.3. It shall also be possible to hold the demanded increase for at least 2.0 seconds.

3.7.6 Stall Characteristics

3.7.6.1 Required Flight Conditions - The requirements for stall characteristics shall apply at all permissible cg locations, for configurations G, CR, L, TR, and PA in symmetrical, unaccelerated flight and with normal acceleration up to the limits of the operational envelope of paragraph 3.2.1. Unless otherwise specified by the procuring activity, all stall requirements apply for normal symmetric external store installations throughout the entire range of store loadings, as well as for the clean aircraft. Aircraft that have two or more engines shall demonstrate stall characteristics with the most critical engine inoperative and in its normal inoperative condition. Stalls will be of such a nature as to preclude inadvertent spin entry.

3.7.6.2 Stall Speed Defined - The stall speed (V_S) is defined as the minimum speed, not determined by longitudinal control power, attainable in flight. Stall is normally associated with airflow breakdown immediately after attaining the maximum overall trimmed lift coefficient of the aircraft.

3.7.6.3 Method of Investigation - For unaccelerated stalls, speed reduction will be 1 knot per second, and this rate of reduction shall be in effect at least 10 knots before stall is attained. For accelerated stalls, the stall is attained from a 30-degree bank, coordinated turn by application of the aft control to produce increasing normal acceleration until stall is reached. Speed reduction rate is optional for accelerated stalls.

3.7.6.4 Limited Longitudinal Control - Some airplanes, because of limited longitudinal control power, will be unable to demonstrate true aerodynamic stall. Such airplanes will be required to determine minimum speeds at various combinations of cg and gross weight as determined by the procuring activity.

3.7.6.5 Minimum Speed - In the event that considerations other than wing maximum lift or available longitudinal control determine the minimum usable flying speed in any configuration, a minimum usable speed shall be demonstrated. This minimum speed shall be agreed upon by the manufacturer and the procuring activity.

3.7.6.6 Stall-Warning Requirements - A clear and distinctive stall warning shall precede the stalling of the airplane, with the aircraft in any configuration, in both straight and turning flight. The stall warning shall occur between 1.05 and 1.15 times V_S in configurations G, L, and CR and between 1.05 and 1.10 times V_S in configuration PA. Acceptable stall warning shall consist of shaking of the pilot's controls, buffeting or shaking of the airplane, or both. If natural stall warning is not acceptable, artificial means may be substituted, provided that the device is acceptable to the procuring activity. Aircraft that do not have true stall capabilities but have a minimum usable speed (such as those aircraft mentioned in paragraph 3.7.6.4) shall not require stall warning, provided no dangerous flight characteristics occur at the applicable minimum speed.

3.7.6.7 Requirements for Acceptable Stall Characteristics - It is desired that no nose-up pitch occur at stall; however, a mild nose-up pitch may be acceptable if it does not result in any dangerous characteristics. It shall be possible to control the aircraft about all axes by normal use of the controls down to stall. The stall shall be unacceptable if, at the stall, the aircraft exhibits uncontrollable rolling, yawing, or downward pitch in excess of 25 degrees or if there is any reversal of controls. It shall be possible to prevent stall by normal use of the controls at the onset of stall warning. In the event of a complete stall, it shall be possible to recover (by normal use of the controls with reasonable control forces) without excessive loss of altitude or buildup of speed.

3.7.7 Power Plant Failure

3.7.7.1 Single-Engine Aircraft - To ensure that the pilot has time to escape following engine failure of a single-engine V/STOL aircraft or that he can accomplish an immediate emergency landing in a near-wings and fuselage-level attitude, the attitude changes in roll and pitch should not exceed 20 degrees in the first 3 seconds following the failure, the controls being free during this period.

3.7.7.2 Multiengine Aircraft - Following failure of the critical engine of a multiengine aircraft, it is desirable that recovery be possible at all speeds up to V_{con}. However, the minimum acceptable conditions shall be those in an emergency landing in a near-wings and fuselage-level attitude that does not subject any occupant (pilot or passenger) to more than the following forces: vertical, 25g; longitudinal and lateral, 25g for 0.20 second and 45g for 0.10 second, as measured in the pelvic region of a suitable anthropomorhpic dummy having a weight and mass distribution of that of the heaviest occupant expected. It is permissible to meet the above requirements through emergency power, undercarriage design, structural deformation, an adequate seat/support restraint system, or a combination of the above. These requirements are based on several factors: (1) it does not appear realistic, in view of the excellent reliability of turbine power plants, to require the additional power to maintain an air-borne recovery in all cases; (2) failure of one engine of a two-engine air-craft should allow emergency landings within these limits with crew and passenger seats designed for the purpose; (3) loss of one engine in an aircraft with four or more power plants will, in all likelihood, be able to recover under most conditions but, if not, should still be able to make a landing at near-design maximum sink rates.

3.7.7.3 Asymmetric Power - Asymmetric power shall apply to multiengine aircraft, except where otherwise stated, under the following conditions:

a. Critical engine inoperative and in minimum drag condition.

b. Remaining engines at maximum continuous power.

3.7.7.3.1 Directional Control - It shall be possible to execute heading changes in either direction without inducing dangerous characteristics. Heading changes of 15 degrees shall be demonstrated except that heading change at which the rudder pedal force is greater than 125 pounds need not be exceeded. The demonstration speed shall be 1.4 V_S under the following conditions:

a. Power for level flight at 1.4 V_S but not greater than maximum continuous.

b. Most unfavorable cg.

c. Gear up.

d. Flaps in approach position.

3.7.7.3.2 Lateral Control - It shall be possible to execute 20-degree banked turns with and against the inoperative engine. Demonstration speed shall be 1.4 V_S under the following conditions:

a. Most unfavorable cg.

b. Gear retracted and extended.

c. Wing flaps in the most favorable climb position.

d. Maximum to gross weight.

3.7.7.3.3 Minimum Control Speed - In the cruise or CTOL configurations, minimum control speed shall not be limited by unsatisfactory lateral-directional control with most critical asymmetric power conditions (see paragraphs 3.7.7.3.1 and 3.7.7.3.2). Minimum control speed may be determined by conventional stall or by achievement of maximum trimmed lift as limited by longitudinal control power.

3.7.7.3.4 Touchdown Control - From hover to 1.4 V_S, it shall be possible to perform controlled level attitude touchdown following critical engine failure from any altitude. From altitudes and speeds outside the "deadman" zone, it shall be possible to execute controlled, level attitude landings within the structural limits of the aircraft.

3.7.8 Transition Characteristics

3.7.8.1 Acceleration and Deceleration - With the aircraft trimmed in hovering flight, it shall be possible to accelerate rapidly and safely to V_{con} at approximately constant altitude. From trimmed steady level unaccelerated flight at V_{con}, it shall be possible to decelerate rapidly and safely, at approximately constant altitude, to stop and hover. The time taken for these maneuvers shall be that designated by the mission requirements of the procuring activity.

It shall be possible to execute these maneuvers without restriction due to longitudinal control power, longitudinal trim, stalling or buffeting, or to engine thrust or response characteristics. There should be no need for the pilot to operate any but the primary flying controls plus power setting and tilt of the thrust vector. These recommendations apply both in and out of ground effect.

Following a failure in a stability augmentation system or in any power operated system, it should be possible to execute the transition maneuver without restriction and to make an approach and landing under instrument flight conditions. The whole maneuver should not be prohibitively long and should, in particular, be compatible with the available landing aids.

3.7.8.2 Flexibility of Operation - To demonstrate flexibility of operation, it shall be possible to stop and reverse the transition quickly and safely in either direction at any speed up to V_{con} and either to take a wave-off or to make a landing.

The requirement for flexibility of operation also applies following a failure in a power control or stability augmentation system.

3.7.8.3 Tolerance in Conversion Programming - It shall be possible to change from hovering to conventional flight, and vice versa, within a specified range of fuselage attitudes, safely and easily, without the need for precise programming of engine power, wing or lift engine tilt, et cetera, in terms of speed or time, such as to require excessive skill and attention from the pilot.

This requirement also applies following a failure in a power control or stability augmentation system.

3.7.8.4 Ascent and Descent - For every speed below V_{con}, there shall be a configuration in which the aircraft is flyable continuously from military power to a 1000-foot-per-minute rate of descent, without the configuration's changing or without retrimming by the pilot, and without encountering undesirable effects due to stalling or buffeting, including feedback of unsteady forces on the controls.

These requirements also apply following a failure in a power control or stability augmentation system.

3.7.8.5 Control Margin - To allow for disturbances and for maneuvering, the margin of longitudinal control power remaining at any stage in the transition, including the maneuvers defined by the recommendations of paragraph 3.8.4, shall not be less than 20 percent of the nominal pitch control moment.

The same margin should be available following a failure in a power control or stability augmentation system.

3.7.8.6 Trim Change - The trim change throughout the transition should be small and gradual, and, without retrimming, the forces should not exceed a 10-pound pull or a 5-pound push. Trim changes during the maneuvers defined by the recommendations of paragraph 3.8.4 should be as small as possible and, in any case, should not exceed a 10-pound pull or a 5-pound push.

Following a failure in a power control system, these trim changes shall not exceed a 20-pound pull or a 10-pound push.

3.7.8.7 Rate of Stick Movement - During transition, with the maximum available rate of change of forward speed, the rate of stick movement to maintain trim should not exceed 1/2 inch per second and shall not exceed 1 inch per second.

This requirement should still be met following a failure in a power control or stability augmentation system.

3.7.8.8 Speed Stability - To reduce the effect of horizontal gusts and to allow a reasonably wide band of usable speeds at a given configuration, the change in stick position with change in speed should not exceed 0.1 inch per knot.

If 0.1-inch longitudinal control displacement per knot is achieved by interconnection of the stability augmentation and power control systems, then a failure of either system should not result in a change in control displacement with change in speed greater than 0.25 inch per knot.

3.7.9 Spin Characteristics - At any possible flight condition appropriate to the type of operation, there should be no tendency for the aircraft to spin following the attainment of stalled conditions on the lifting surfaces, either during normal operation or following any single failure.

3.7.10 Vibration Characteristics - In general, throughout the design flight envelope, the aircraft shall be free of objectionable shake, vibration, or roughness. Specifically, the following vibration requirements shall be met:

a. Vibration accelerations at all controls in any direction shall not exceed 0.4g for frequencies up to 32 cycles per second nor a double amplitude of 0.008 inch for frequencies above 32 cycles per second. This requirement shall apply to all steady speeds within the helicopter design flight envelope as well as in slow and rapid transitions from one speed to another and during transitions from one steady acceleration to another.

b. Vibration accelerations at the pilot, crew, passenger, and litter stations at all steady speeds between 30 knots rearward and V_{cruise} shall not exceed 0.15g for frequencies up to 32 cycles per second nor a double amplitude of 0.003 inch for frequencies greater than 32 cycles per second. From V_{cruise} to V_{limit}, the maximum vibratory acceleration shall not exceed 0.2g up to 36 cycles per second nor a double amplitude of 0.003 inch for frequencies greater than 36 cycles per second. At all frequencies above 50 cycles per second, a constant velocity vibration of 0.039 feet per second shall not be exceeded.

c. Vibration characteristics at the pilot, crew, passenger, and litter stations shall not exceed 0.15g for frequencies up to 44 cycles per second nor a double amplitude of 0.003 inch at frequencies greater than 44 cycles per second during slow and rapid linear acceleration or deceleration from any speed to any other speed within the design flight envelope.

3.7.11 Autorotation - All rotor craft with an autorotative capability requirement shall be capable of power-off landings at touchdown speeds of no greater than 25 knots, with 15 knots or less as the desired touchdown speed.

The aircraft shall be capable of entry into autorotation (power off) at all speeds to V_{con}. A delay of 1 second following power failure prior to pilot corrective action is mandatory, and a delay of 2 seconds is desired. During the delay, no dangerous flight conditions (such as low main rotor rpm, lack of control, and transient aircraft attitudes) shall be encountered. With controls fixed for 2 seconds following sudden complete loss of power, roll, pitch, or yaw attitude changes shall not exceed 10 degrees. In rotorcraft requiring antitorque rotors, yaw attitude changes of 20 degrees are allowable below 50 knots following failure or reduction from climb power with pedals fixed.

While in autorotation at any speed, the longitudinal, lateral, and directional static and dynamic stability shall be essentially unchanged from those in powered flight with similar auxiliary equipment operating, such as control boost and autostabilization.

Engine failure or electrical system failure shall not result in primary power operated control system failure.

3.7.12 Tail Rotor Failure - Following complete loss of the antitorque tail rotor and tail rotor gearbox, the aircraft shall not pitch uncontrollably. Sufficient longitudinal control shall be available to allow safe flight with the weight of the tail rotor and gearbox removed.

The aircraft shall have sufficient directional stability with the tail rotor off, to fly at a speed for the minimum power required at maximum gross weight, with zero tail rotor thrust, at a sideslip angle of no greater than 20 degrees.

The aircraft shall be capable of making a power-off landing at a speed that is no greater than 35 knots, and preferably less, without turnover, on a level sod surface, with zero tail rotor thrust.