NASA TECHNICAL NOTE

NASA TN D-4170

NASA TN D-4170

GPO PRICE $ ______

CFSTI PRICE(S) $ 3.00

Hard copy (HC) ______

Microfiche (MF) .65

ff 653 July 65

FACILITY FORM 602

N67-37674 (ACCESSION NUMBER)

(THRU)

17 (PAGES)

1 (CODE)

(NASA CR OR TMX OR AD NUMBER)

02 (CATEGORY)

INVESTIGATION OF PITCH MANEUVER SPEED MARGINS FOR A SUPERSONIC TRANSPORT CONFIGURATION WITH A VARIABLE-SWEEP WING

by Richard H. Sawyer, Milton D. McLaughlin, and Norman S. Silsby

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • OCTOBER 1967

NASA TN D-4170

INVESTIGATION OF PITCH MANEUVER SPEED MARGINS FOR A SUPERSONIC TRANSPORT CONFIGURATION WITH A VARIABLE-SWEEP WING

By Richard H. Sawyer, Milton D. McLaughlin,
and Norman S. Silsby

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – CFSTI price $3.00

INVESTIGATION OF PITCH MANEUVER SPEED MARGINS FOR A SUPERSONIC TRANSPORT CONFIGURATION WITH A VARIABLE-SWEEP WING

By Richard H. Sawyer, Milton D. McLaughlin,
and Norman S. Silsby
Langley Research Center

SUMMARY

An investigation has been made of the speed and altitude excursions for 0.5g pushover and $7\frac{1}{2}^{\circ}$ upset-in-pitch maneuvers for a generalized supersonic transport (SST) configuration with a variable-sweep wing in order to provide information pertinent to the establishing of speed-margin requirements for the SST. A piloted fixed-base aircraft simulator was used in the investigation. Tests were made for level, climbing, high-speed descent, and emergency-descent flight conditions. The results show that at subsonic speeds, a 10-second 0.5g pushover maneuver would provide about the same speed margin between maximum operating speed and design dive speed as a $7\frac{1}{2}^{\circ}$ 20-second upset maneuver with the wings swept to either the 42° or 72° positions. Over the supersonic speed range below conditions at which the aircraft is Mach-limited, the speed margins for each of the 10-, 15-, and 20-second 0.5g pushover maneuvers were approximately constant, in contrast to the speed margin for the $7\frac{1}{2}^{\circ}$ upset maneuver which increased greatly with increase in speed. Over this speed region, the speed margin found for the 10-second 0.5g pushover maneuver generally exceeded the speed margin for the "miscellaneous causes" requirement. Over the Mach-limited flight region, the speed margin for the "miscellaneous causes" requirement exceeded the speed margins found for each of the 10-, 15-, and 20-second 0.5g pushover and the $7\frac{1}{2}^{\circ}$ 20-second upset maneuvers.

INTRODUCTION

In recent revisions to the Tentative Airworthiness Standards for the supersonic transport (SST) (ref. 1), it is proposed that the upset maneuver criterion for determining the speed margin between the maximum operating speed and the design dive speed for the supersonic speed region be a 0.5g pushover maneuver rather than the $7\frac{1}{2}^{\circ}$ 20-second upset maneuver currently specified for both subsonic and supersonic speeds. It is proposed that the 0.5g pushover maneuver be flown for the number of seconds shown to be adequate for subsonic operations; this proposal implies that the maneuver time chosen for the 0.5g pushover should provide a speed margin at subsonic speeds equivalent to the speed margin provided by the $7\frac{1}{2}^{\circ}$ upset maneuver.

The proposed change from the $7\frac{1}{2}^{\circ}$ upset maneuver to the 0.5g pushover maneuver for supersonic speeds is based on indications that the $7\frac{1}{2}^{\circ}$ upset maneuver may be inappropriate for use at supersonic speeds. Results of simulator tests (ref. 2 and unpublished North American Aviation tests made for the FAA) appear to support this view.

In order to provide information pertinent to the proposed revisions to the speed-margin requirements for the SST, simulator tests have been made to determine the speed and altitude excursions at both subsonic and supersonic speeds in $7\frac{1}{2}^{\circ}$ 20-second upset maneuvers and in 10-, 15-, and 20-second 0.5g pushover maneuvers. Level flight, climbing, high-speed-descent, and emergency-descent flight conditions were examined. A generalized SST configuration with a variable-sweep wing was used in the study. The tests were conducted with a fixed-base SST simulator. Results of these studies are presented and compared with the speed-margin requirement for miscellaneous causes such as atmospheric variations, instrument errors, and airframe production variations.

SYMBOLS

D	drag, pounds (newtons)
g	acceleration due to gravity, 32.2 ft/sec^2 $\left(9.81 \text{ m/sec}^2\right)$
h	altitude, feet (meters)
L	lift, pounds (newtons)
M	Mach number
T	thrust, pounds (newtons)
V_D	design dive speed, knots
V_{MO}	maximum operating limit speed, knots
V_i	indicated airspeed, knots
W	weight, pounds (newtons)
λ	wing-sweep angle, deg
γ	nominal flight-path angle, deg

Subscript:

TO	take-off conditions

SUPERSONIC TRANSPORT SIMULATION

The supersonic transport (SST) was simulated by use of a fixed-base aircraft flight compartment linked to an analog computer facility. The flight compartment was representative of current jet transport types with stations for captain, first officer, and flight engineer. (See fig. 1.) Airplane control was effected through conventional control column, rudder pedals, throttles, and trimming arrangements. The flight instruments were vertical-scale, tape-type instruments used in supersonic fighter aircraft (fig. 2). The normal acceleration was displayed on a digital-counter readout. The flight instruments included a modern flight-director system.

The analog computer was programed with six-degree-of-freedom motion equations and the physical, aerodynamic, and control characteristics of a generalized SST configuration with a variable-sweep wing. (See table I.) A more complete description of the equipment may be found in reference 3.

TABLE I.- SUPERSONIC TRANSPORT CHARACTERISTICS

Performance:			
Mach number	0.7	1.0	2.7
L/D	15.0	8.1	7.7
T/W (maximum dry)	0.22	0.18	0.11
T/W (maximum afterburner thrust)	0.30	0.26	0.22
Short-period dynamics:			
Mach number	0.7	1.0	2.7
Longitudinal short period (no damping augmentation), sec	6.0	5.0	6.2
Cycles to damp to one-half amplitude (damping augmentation)	Critically damped	Critically damped	0.1

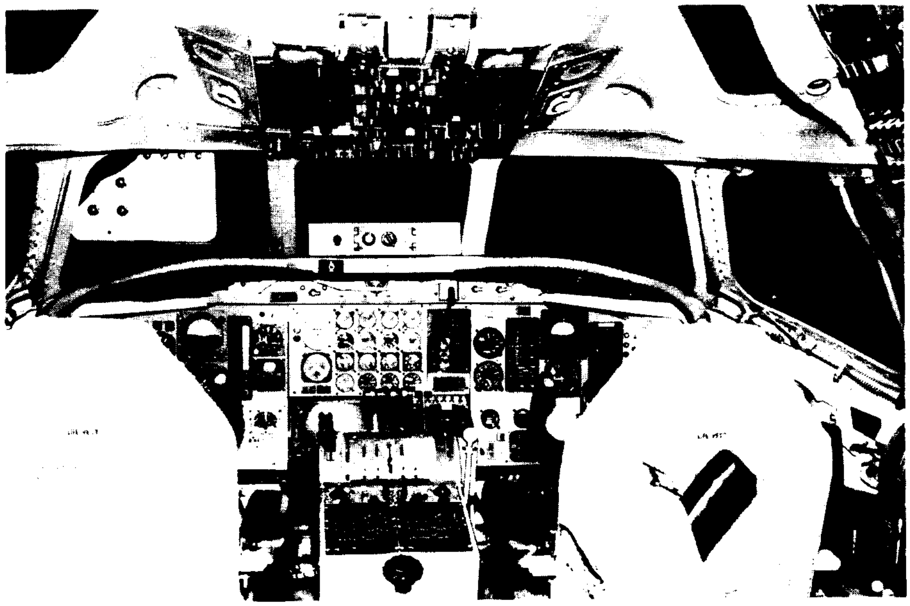


Figure 1.- Interior view of the fixed-base supersonic transport simulator cockpit. L-67-2802

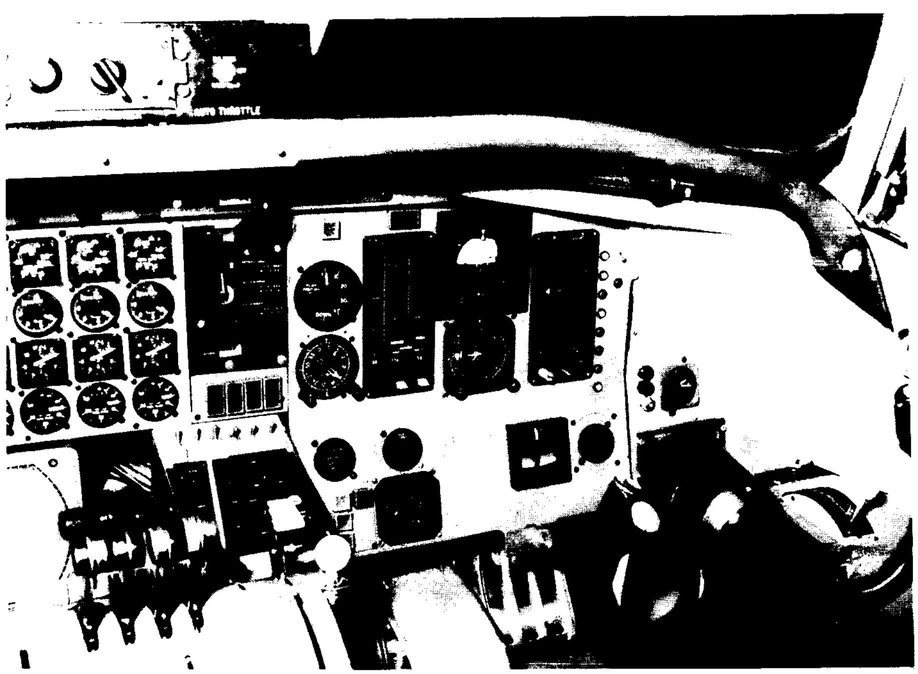


Figure 2.- View of the flight instruments used. L-67-2804

TENTATIVE SPEED-MARGIN REQUIREMENTS FOR THE SUPERSONIC TRANSPORT

The revised tentative standards (ref. 1) for maximum operating speeds established for Federal Aviation Agency type certification of supersonic transports require that a margin be provided to allow for inadvertent overspeeds resulting from either (1) a specified upset maneuver in pitch or (2) miscellaneous causes such as atmospheric variations, instrument errors, and airframe production variations, whichever is the greater, without exceeding the design dive speed. The currently specified upset maneuver is a $7\frac{1}{2}^{\circ}$ 20-second upset in flight path. As noted in reference 1, under consideration is a proposed revision which would establish the upset maneuver for supersonic speeds to be a 0.5g pushover flown for the number of seconds shown to be adequate for current subsonic aircraft and for SST configurations while flying subsonic. This proposal thus implies that the maneuver time chosen for the 0.5g pushover should provide a speed margin at subsonic speeds equivalent to the speed margin provided by the $7\frac{1}{2}^{\circ}$ upset maneuver. The procedures used in executing the upset and pushover maneuvers are described in the section "Test Procedure." The minimum overspeed margin specified for miscellaneous causes is 0.05M for subsonic speeds up to $M = 0.95$, and 0.20M for $M = 1.5$ and above, with a straight-line variation of the minimum overspeed margin between $M = 0.95$ and 1.5.

TEST PROCEDURE

The SST simulator was operated under manual control for all tests, guidance being supplied entirely by the aircraft flight and navigation instruments. The upset and pushover maneuver tests were performed by a research engineer having piloting experience.

Time histories of altitude, Mach number, indicated airspeed, vertical speed, control surface positions, angular attitudes and velocities, normal acceleration, thrust, drag, and throttle position were recorded for each test.

The upset and pushover maneuvers were initiated at flight conditions corresponding to points along the maximum-operating-speed—altitude $\left(V_{MO}\text{-}h\right)$ profiles between altitudes of 10 000 and 70 000 feet (3.0 and 21.3 km). At subsonic speeds, the maneuvers were initiated from maximum operating speed conditions corresponding to wing-sweep angles of 42° and 72°. Supersonic speed tests were made only for the 72° wing-sweep condition. The tests were made for level flight, climbing, high-speed-descent, and emergency-descent flight conditions. For the level flight and climbing flight conditions, the aircraft weight was adjusted to the climb weight at the specific altitude. Aircraft weight for the high-speed descent approximated end-of-mission letdown weight. Emergency descent weight conditions corresponded to an emergency descent initiated immediately after establishing initial cruise. Thrust settings and spoiler, forebody, and gear positions corresponded to normal operating procedures. The test conditions are summarized in table II.

TABLE II.- TEST CONDITIONS

Flight condition	λ, deg	h, ft	h, km	V_i, knots	M	γ, deg	W/W_{TO}	Thrust setting	Spoiler position	Forebody position	Gear position
Subsonic operations											
Level flight	42	10×10^3	3.05	358	0.64	0	0.974	Trimmed	Retracted	Down	Up
Level flight	42	20	6.07	368	.78	0	.966	Trimmed	Retracted	Down	Up
Level flight	42	30	9.14	348	.90	0	.955	Trimmed	Retracted	Up	Up
Climb	42	10	3.05	358	.64	7.6	.974	Maximum dry	Retracted	Down	Up
Climb	42	20	6.07	368	.78	4.7	.966	Maximum dry	Retracted	Down	Up
Climb	42	30	9.14	348	.90	2.6	.955	Maximum dry	Retracted	Up	Up
High-speed descent	42	10	3.05	358	.64	-8.9	.728	Idle	Extended	Down	Up
High-speed descent	42	20	6.07	368	.78	-6.9	.728	Idle	Extended	Down	Up
High-speed descent	42	30	9.14	348	.90	-6.5	.728	Idle	Extended	Up	Up
Level flight	72	15	4.57	387	.76	0	.972	Trimmed	Retracted	Down	Up
Level flight	72	20	6.07	392	.84	0	.966	Trimmed	Retracted	Down	Up
Level flight	72	25	7.62	410	.95	0	.959	Trimmed	Retracted	Up	Up
Climb	72	15	4.57	387	.76	6.3	.972	Maximum dry	Retracted	Down	Up
Climb	72	20	6.07	392	.84	4.6	.966	Maximum dry	Retracted	Down	Up
Climb	72	25	7.62	410	.95	3.2	.959	Maximum afterburner	Retracted	Up	Up
Emergency descent	72	15	4.57	387	.76	-8.4	.853	Idle	Extended	Down	Down
Emergency descent	72	20	6.07	392	.84	-7.7	.853	Idle	Extended	Down	Down
Emergency descent	72	25	7.62	410	.95	-6.4	.853	Idle	Extended	Up	Up
Supersonic operations											
Level flight	72	30	9.14	458	1.15	0	0.956	Trimmed	Retracted	Up	Up
Level flight	72	40	12.19	544	1.66	0	.928	Trimmed	Retracted	Up	Up
Level flight	72	60	18.29	574	2.70	0	.858	Trimmed	Retracted	Up	Up
Level flight	72	70	21.34	466	2.70	0	.846	Trimmed	Retracted	Up	Up
Climb	72	30	9.14	458	1.15	2.0	.956	Maximum afterburner	Retracted	Up	Up
Climb	72	40	12.19	544	1.66	.7	.928	Maximum afterburner	Retracted	Up	Up
Climb	72	60	18.29	574	2.70	.7	.858	Maximum afterburner	Retracted	Up	Up
High-speed descent	72	30	9.14	458	1.15	-5.1	.728	Idle	Extended	Up	Up
High-speed descent	72	40	12.19	544	1.66	-3.9	.728	Idle	Extended	Up	Up
High-speed descent	72	60	18.29	574	2.70	-.7	.728	Idle	Extended	Up	Up
High-speed descent	72	70	21.34	466	2.70	-1.8	.728	Idle	Extended	Up	Up
Emergency descent	72	30	9.14	458	1.15	-7.6	.853	Idle	Extended	Up	Up
Emergency descent	72	40	12.19	544	1.66	-5.1	.853	Idle	Extended	Up	Up
Emergency descent	72	60	18.29	574	2.70	-2.0	.853	Idle	Extended	Up	Up
Emergency descent	72	65	19.81	515	2.70	-3.6	.853	Idle	Extended	Up	Up

$7\frac{1}{2}^{\circ}$ 20-Second Upset Maneuver

The upset maneuver was initiated at an indicated airspeed corresponding to V_{MO} at selected altitudes in stabilized flight, except that the flight-path angle was set $7\frac{1}{2}^{\circ}$ below the nominal flight-path angle. The maneuver consisted of flight for 20 seconds at the reduced flight-path angle, and pull-up at a normal acceleration of 1.5g to a level or climbing flight condition. The initial throttle setting was unchanged until pull-up was initiated; power was then reduced to the idle setting.

0.5g Pushover Maneuver

The 0.5g pushover maneuvers were initiated from stabilized flight at the same altitude—maximum-operating-speed conditions as those for the $7\frac{1}{2}^{\circ}$ upset maneuvers. The pushover maneuver consisted of a control-column-forward movement until a normal acceleration of 0.5g was reached. The 0.5g condition was held for 10 seconds for the subsonic speed tests and for either 10, 15, or 20 seconds for the supersonic speed tests; a recovery at a normal acceleration of 1.5g was then made to a level or climbing flight condition. The initial throttle setting was unchanged until pull-up was initiated; power was then reduced to the idle setting.

RESULTS AND DISCUSSION

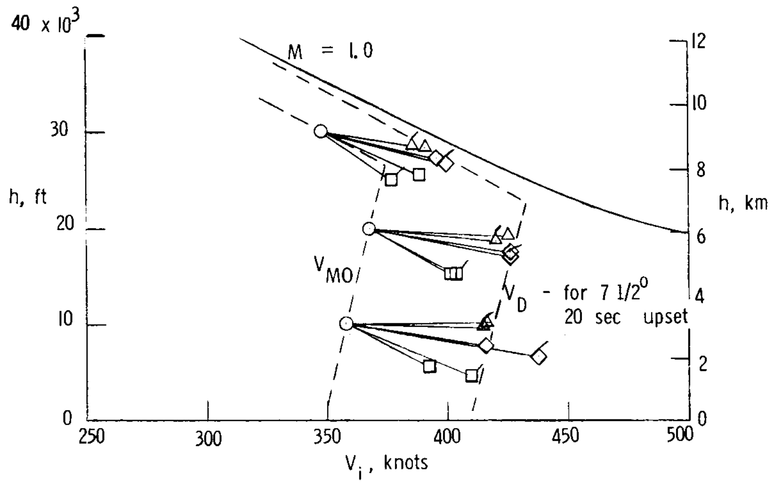
The piloted simulator was used in these studies as a matter of convenience; earlier studies (ref. 2) have shown that simple point-mass calculations gave about the same altitude and airspeed excursions as piloted-simulator tests.

Subsonic Flight Condition

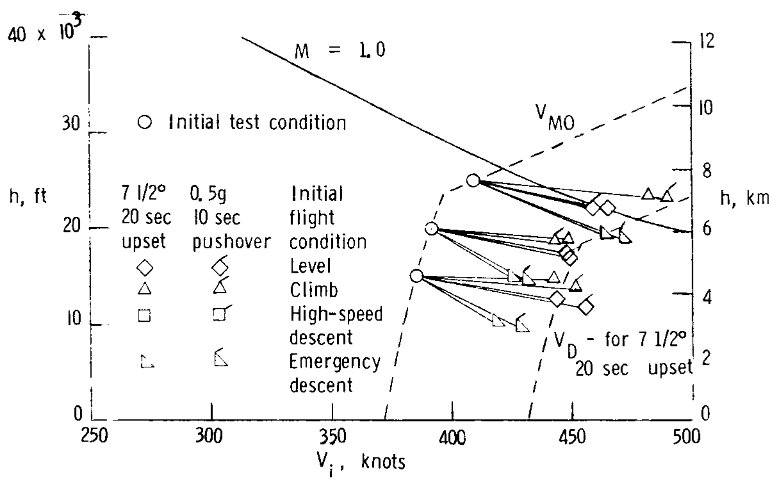
Speed and altitude excursions for the $7\frac{1}{2}^{\circ}$ 20-second maneuvers and 0.5g 10-second pushovers at subsonic speeds are presented in figure 3. Results are shown for wing sweep angles λ of 42° and 72°. Maximum operating speed V_{MO} curves and the test conditions from which the maneuvers were initiated are given for each sweep angle. For $\lambda = 42^{\circ}$, the V_{MO} curve reflects an aircraft operating speed limit of $M = 0.9$ above about 27,000 feet. The design dive speed V_D curves shown were established by the maximum speed excursions in the $7\frac{1}{2}^{\circ}$ 20-second upset maneuvers.

Inspection of the results in figure 3 indicates that with the exception of the high-speed descent flight condition, all the flight conditions tested contributed in establishing the V_D envelopes. Although for this configuration the high-speed descent condition gave smaller speed excursions than the other flight conditions, it would appear that, in general, all flight conditions should be examined in determining the speed margin between V_{MO} and V_D. In the remainder of the discussion, those flight conditions which determine the V_D boundary are referred to as the critical flight conditions.

Examination of the 0.5g 10-second pushover maneuver results indicate that, for the critical flight conditions, the speed excursions are generally either of the same magnitude or greater than the speed margin provided by the upset maneuver for both wing-sweep conditions. Thus, it appears that for the SST configuration tested a 0.5g 10-second pushover maneuver can be considered as providing a speed margin equivalent to the $7\frac{1}{2}^{\circ}$ 20-second upset maneuver speed margin at subsonic speeds.



(a) $\lambda = 42^{0}$.



(b) $\lambda = 72^{0}$.

Figure 3.- Airspeed and altitude excursions at subsonic speeds for upset and pushover maneuvers from level, climbing, high-speed descent, and emergency-descent flight conditions on the V_{MO} boundary.

Supersonic Flight Condition

Results at supersonic speeds of 10-second 0.5g pushover maneuvers are given in figure 4. For additional information, results of 15- and 20-second 0.5g pushovers are given in figures 5 and 6 and results of $7\frac{1}{2}^{\circ}$ 20-second upset maneuvers in figure 7. Design dive speed V_D curves established by the maximum speed excursions are given for each case.

Pushover maneuvers.- The results for the pushover maneuvers given in figures 4, 5, and 6 show that at supersonic speeds, all the flight conditions tested with the exception of the high-speed descent condition contributed in establishing the V_D envelopes. This result is the same as noted at subsonic speeds; as discussed before, it appears that, in general, all flight conditions should be examined in determining the V_D envelope. At speeds below the speed at which the aircraft is Mach-limited (M = 2.7), the speed margins established by the pushover maneuvers are seen to be approximately constant. Over the flight region where the aircraft is Mach-limited, the speed margin is much smaller and appears to be independent of the maneuver time.

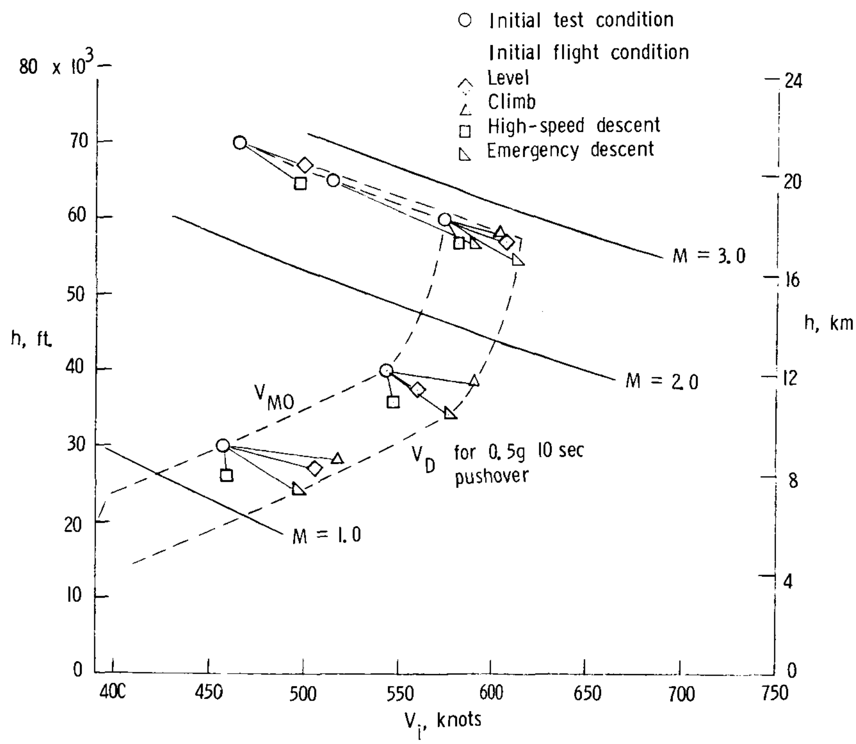


Figure 4.- Airspeed and altitude excursions at supersonic speeds for 0.5g 10-second pushover maneuver from level, climbing, high-speed descent, and emergency-descent flight conditions on the V_{MO} boundary.

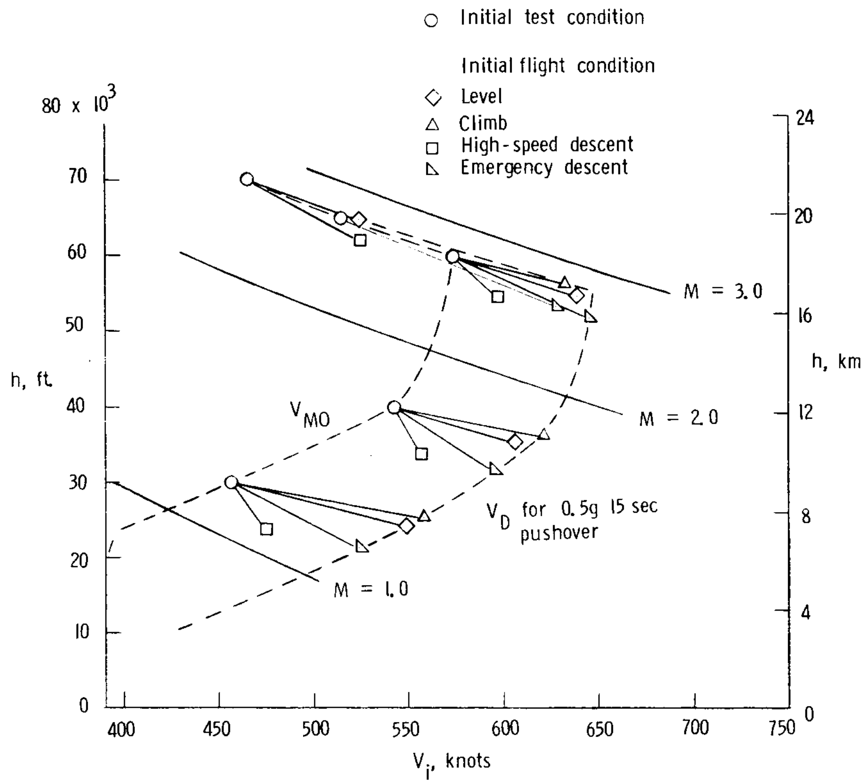


Figure 5.- Airspeed and altitude excursions at supersonic speeds for 0.5g 15-second pushover maneuver from level, climbing, high-speed descent, and emergency-descent flight conditions on the V_{MO} boundary.

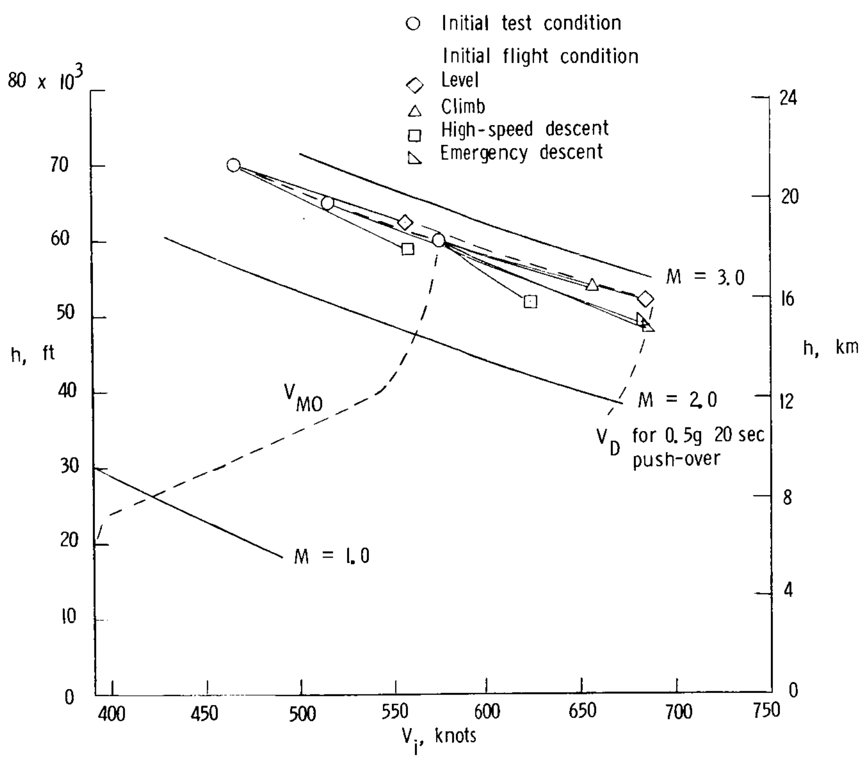


Figure 6.- Airspeed and altitude excursions at supersonic speeds for 0.5g 20-second pushover maneuvers from level, climbing, high-speed descent, and emergency-descent flight conditions on the V_{MO} boundary.

Upset maneuver.- The speed margin for the $7\frac{1}{2}^{\circ}$ upset maneuver at supersonic speeds (fig. 7) is solely determined by the emergency descent condition; however, speed margins for the climb and level-flight conditions are only slightly less. The speed margin is seen to increase greatly with speed up to Mach-limited flight speeds. Similar to the results for pushover maneuvers, the speed margin is small over the Mach-limited flight regime.

Comparison of pushover and upset maneuvers.- The speed-margin requirements for 0.5g pushovers and $7\frac{1}{2}^{\circ}$ 20-second upsets are compared in figure 8. The speed-margin requirements for the upset maneuver are seen to increase from being about equivalent to a 10-second pushover at $M = 1.0$ to greater than a 20-second pushover at higher speeds. Examination of the relative speed margins for the 10-, 15-, and 20-second pushovers indicates that the increase in speed margin with maneuver time is greater than a linear rate. Careful selection by the designer of the time for the equivalent pushover maneuver at subsonic speeds will be necessary in order to avoid establishing an excessive speed margin at supersonic speeds.

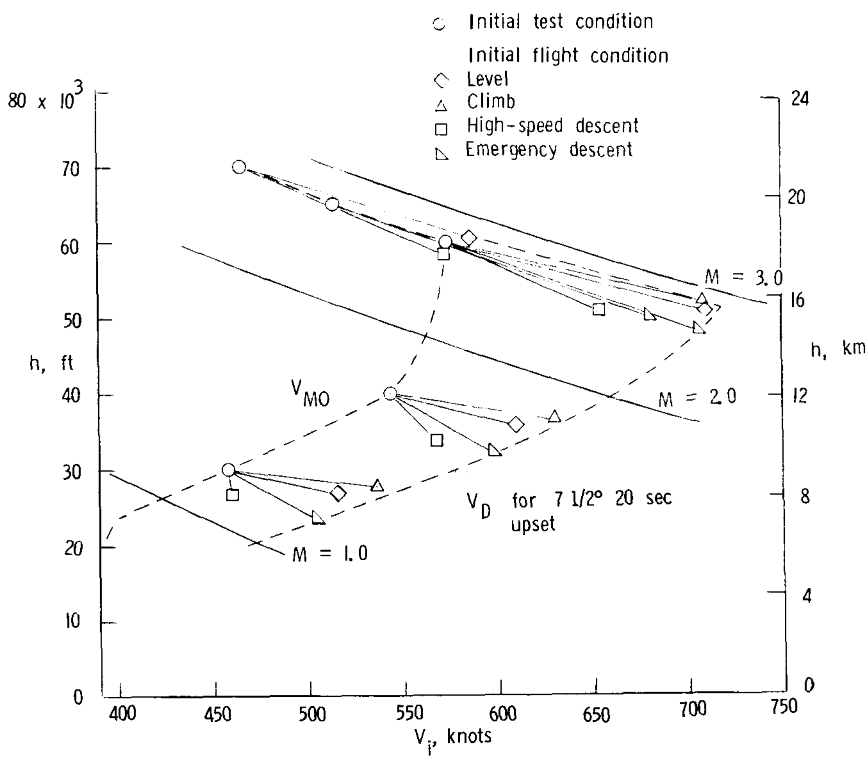


Figure 7.- Airspeed and altitude excursions at supersonic speeds for $7\frac{1}{2}^{\circ}$ 20-second upset maneuvers from level, climbing, high-speed descent, and emergency-descent flight conditions on the V_{MO} boundary.

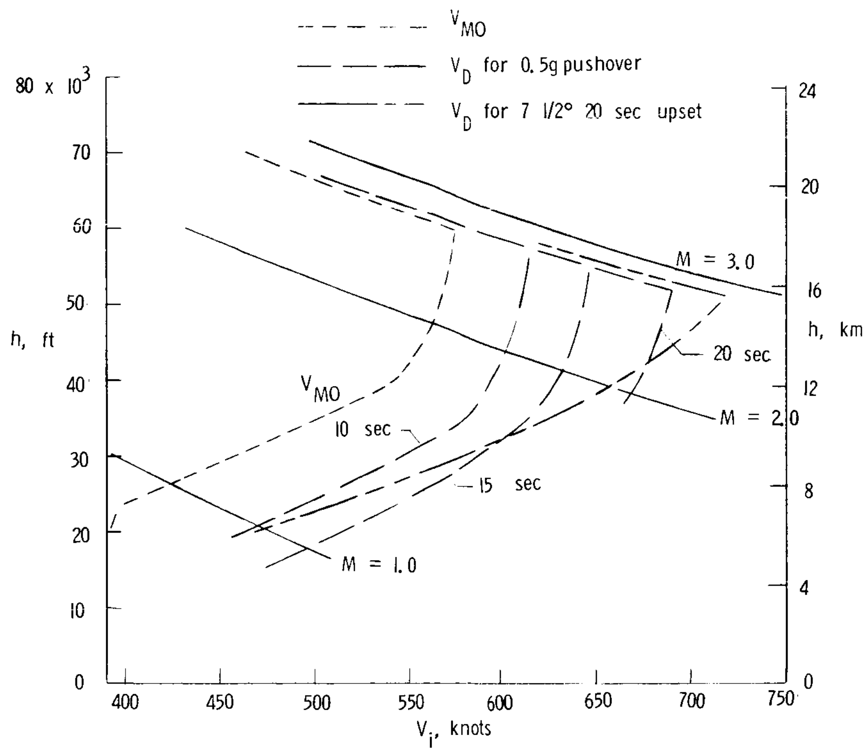


Figure 8.- Comparison of speed-margin requirements for 0.5g pushover and $7\frac{1}{2}^{\circ}$ 20-second upset maneuvers.

Comparison of maneuvers with other speed-margin requirements.- Speed-margin requirements for $7\frac{1}{2}^{\circ}$ 20-second upsets, and 0.5g 10-second pushovers are compared with the "miscellaneous causes" requirements (see section "Tentative Speed-Margin Requirements for the Supersonic Transport") in figure 9. For comparative purposes, an alternative method of speed-margin determination allowed in the Federal Aviation regulations for subsonic aircraft in lieu of providing the margins required by the upset maneuver and "miscellaneous causes" provisions is also shown. The optional method, which provides that $V_D = 1.25V_{MO}$, has not been included in the revised tentative standards for the SST. (See ref. 1.) The optional method calculation has been shown here to indicate the large penalties which would result from the use of such a simplified method, particularly at the higher supersonic speeds.

Comparison of the 0.5g 10-second pushover and "miscellaneous causes" speed margins show that below Mach-limited flight conditions, the "miscellaneous causes" speed margin is smaller, with the exception of the region between 37 000 and 50 000 feet (11.3 and 15.2 km). For Mach-limited flight conditions, the "miscellaneous causes" speed margin is larger than either the 10-second pushover or $7\frac{1}{2}^{\circ}$ upset maneuver margins.

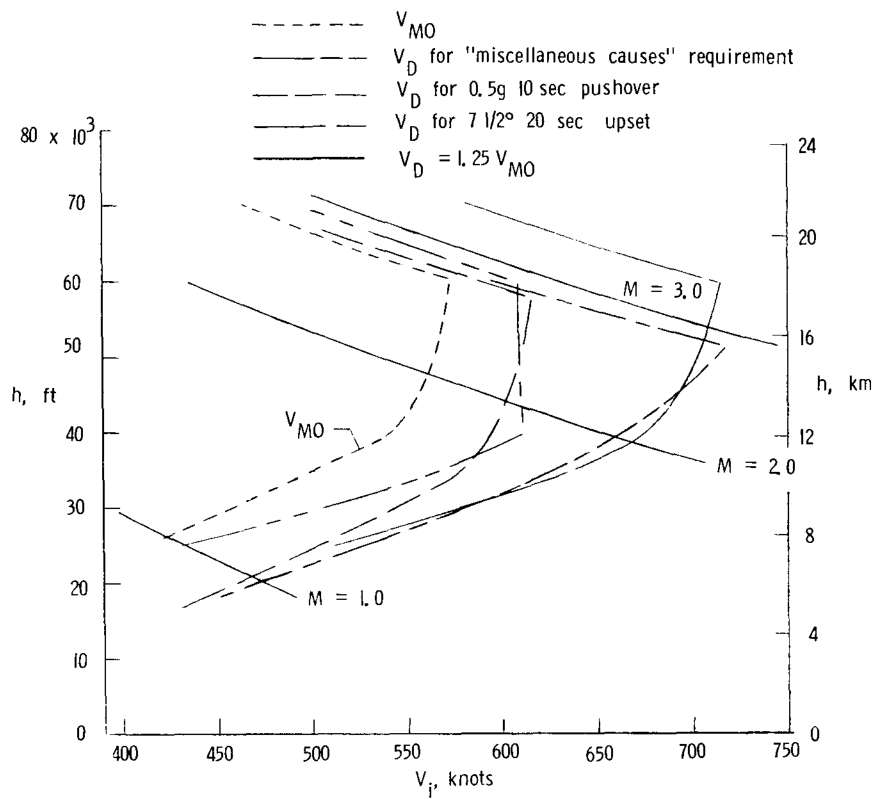


Figure 9.- Comparison of speed-margin requirements for 0.5g 10-second pushover and $7\frac{1}{2}^{o}$ 20-second upset maneuvers with "miscellaneous causes" requirement. Speed margin for optional calculation method ($V_D = 1.25V_{MO}$) also shown.

CONCLUDING REMARKS

Speed-margin requirements for a generalized supersonic transport (SST) configuration with a variable-sweep wing have been examined with the use of a fixed-base piloted aircraft simulator. Measurements were made of the speed and altitude excursions for a $7\frac{1}{2}^{o}$ 20-second upset in pitch maneuver and a 0.5g pushover maneuver for 10-, 15-, and 20-second time intervals. The investigation covered level, climbing, high-speed descent, and emergency descent flight conditions at both subsonic and supersonic speeds. The subsonic speed tests were conducted at wing-sweep angles of 42^{o} and 72^{o}; the supersonic speed tests were conducted at a wing-sweep angle of 72^{o}.

At subsonic speeds, the 0.5g pushover maneuver for 10 seconds was found to provide about the same speed margin between the maximum operating speed and the design dive speed as the $7\frac{1}{2}^{o}$ 20-second upset maneuver. The 10-second pushover maneuver was approximately equivalent to the $7\frac{1}{2}^{o}$ upset maneuver for both wing-sweep conditions tested.

Over the supersonic speed range, below conditions at which the aircraft is Mach-limited, the speed margins for each of the 10-, 15-, and 20-second 0.5g pushover maneuvers were approximately constant; whereas the speed margin for the $7\frac{1}{2}^{\circ}$ upset maneuver increased greatly with increase in speed. Over this speed region, the speed margin found for the 10-second 0.5g pushover maneuver generally exceeded the speed margin for the "miscellaneous causes" requirement. Over the Mach-limited flight region, the speed margin for the "miscellaneous causes" requirement exceeded the speed margins found for each of the 10-, 15-, and 20-second 0.5g pushover and the $7\frac{1}{2}^{\circ}$ upset maneuvers.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., May 18, 1967,
720-05-00-04-23.

REFERENCES

1. Anon.: Tentative Airworthiness Standards for Supersonic Transports. Revision 2. Flight Standards Service, FAA, Dec. 30, 1966.

2. McLaughlin, Milton D.: Simulator Investigation of Maneuver Speed Increases of an SST Configuration in Relation to Speed Margins. NASA TN D-4085, 1967.

3. Sawyer, Richard H.; Stickle, Joseph W.; and Morris, Richard: A Simulator Study of the Supersonic Transport in the Air Traffic Control System. 1964 Proceedings National Aerospace Electronics Conference, IEEE, May 1964, pp. 352-356.