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AAF Technical Report 5242

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STABILITY AND CONTROL FLIGHT TEST METHODS

ARMY AIR FORCES

AIR TECHNICAL SERVICE COMMAND

Wright Field Dayton, Ohio

Unclassified

UNCLASSIFIED

Report No. 5242
Date: 14 July 1945

WAR DEPARTMENT
ARMY AIR FORCES
AIR TECHNICAL SERVICE COMMAND
DAYTON, OHIO

AAF TECHNICAL REPORT
NO. 5242

STABILITY AND CONTROL FLIGHT TEST METHODS

BY

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FOREWORD

Comments are solicited on the nature and contents of this Report, especially from pilots and flight test engineers concerned with determining the stability and control characteristics of aircraft by means of flight tests.

Letters should be addressed to:

Commanding General
Army Air Forces
Air Technical Service Command
Wright Field
Dayton, Ohio

Attention: TSEAL-2C

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SUMMARY

This report presents methods for conducting flight tests of airplanes for the evaluation of their stability and control characteristics. The flight tests discussed are those required to demonstrate compliance with the AAF Specification R-1815A "Stability and Control Requirements for Airplanes." Each particular flight test is discussed from the points of view of the reason for the test, the airplane configurations to be investigated in each test, the pilot technique required to make the actual flight test, and finally the reduction of the data and the curves required for the presentation of the data. Two appendices are included which give the types and accuracies of the flight test instruments required for these tests, and a table for use in reducing the flight test data.

DATE AND PLACE OF INVESTIGATION

The investigation was conducted at Wright Field, Dayton, Ohio from 1 October 1944 to 1 February 1945.

OBJECT

To present information for flight test pilots and engineers on methods for conducting flight tests for the stability and control characteristics of airplanes.

INTRODUCTION

In the past few years a great deal of flight testing of the stability and control characteristics of various airplanes has been done for the Army by the flight sections of the National Advisory Committee for Aeronautics. This work has been supplemented by other stability and control flight tests conducted at Wright Field by the Flight Section under the supervision of the Aerodynamics Branch of the Aircraft Laboratory. A direct result of all this flight test work has been the development of a specification on airplane stability and control, AAF Specification R-1815A, "Stability and Control Requirements for Airplanes." The publication of this specification, together with a large increase in the interest by the AAF in the airplane's stability and control characteristics, has led to an ever-increasing volume of stability and control flight testing in the Government agencies listed above and in the flight test organizations of the various manufacturers. A great deal of this flight test work is done with improper pilot technique, inadequate instrumentation, and faulty presentation of data. An attempt has been made by the AAF and the NACA to outline satisfactory methods and procedures to insure that adequate tests are run, with proper pilot technique and form of data presentation. Although stability and control flight tests may be performed in many ways, the methods and procedures presented in this report are in current use and are considered satisfactory by the Army Air Forces.

The report is presented in the form of a manual, giving all of the flight tests required to determine whether or not the stability and control characteristics of an airplane satisfy the requirements of AAF Specification R-1815A. Each test is covered separately by a discussion of the reasons for the test, the airplane configurations required for each test, the pilot technique to be used to conduct the test, and finally the methods of data reduction and proper presentation of results. In Appendix 1 the proper instrumentation for these tests is discussed and the required instrument accuracies are given, and in Appendix 2 a data reduction table is presented for use in transcribing data from the photo observer record.

The various airplane configurations referred to throughout this report are as follows:

Configuration A. Approach. 50% normal rated power, flaps and gear down.

Configuration CR. Cruise. Power for level flight at speed for maximum range (in most cases L/D max.), flaps and gear up.

Configuration D. Dive. 25% normal rated power, dive braking devices in operation, flaps and gear up (unless used as dive brakes).

Configuration G. Glide. Power off, unless otherwise specified, flaps and gear up. Power off is defined as throttle closed, propeller windmilling.

Configuration L. Landing. Power off, flaps and gear down.

Configuration P. Power-On Clean. Normal rated power, flaps and gear up.

Configuration PA. Power Approach. Power for level flight at $1.15V_{S_L}$ flaps and gear down.

Airplane accessories such as cowl flaps, oil radiator flaps and shutters, controllable wing slots, gun turrets, blast tube covers, etc. should be in their necessary settings for the particular configuration; that is, for a fighter type airplane in Configuration L, the cowl flaps and oil shutters might be partially closed. Tests for the stability and control characteristics of the airplane when equipped with external fuel tanks shall be run with the airplane in Configurations P and CR. Unless otherwise specified, the center of gravity position and the airplane gross weight shall be the normal center of gravity position for the configuration and the approximate design gross weight respectively.

ACKNOWLEDGEMENT

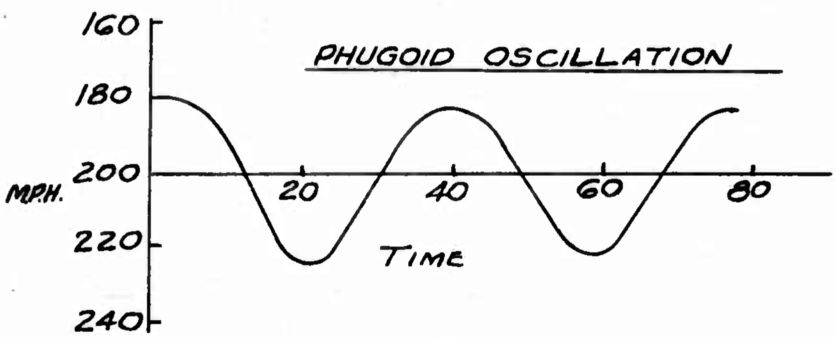
The authors wish to acknowledge the work of the N.A.C.A. Laboratories' flight sections at Langley Field and Moffett Field. The flight work done by these flight sections for the AAF has been of high order in accuracy, speed, and spirit of cooperation. To them goes the major credit for the development of these tests. The authors would also like to acknowledge the help of Mrs. N. A. Cox and Sgt. Gordon A. Durnbaugh in preparing this manuscript for publication.

SECTION I

LONGITUDINAL STABILITY AND CONTROL

A. DYNAMIC LONGITUDINAL STABILITY

1. There are two modes of longitudinal pitching motion. These are the long period and short period airplane oscillations. The second of these is sometimes coupled with a very short period control surface (elevator) oscillation. The long period mode of longitudinal motion is an oscillation with a 20 to 60 second period. This is the well known "phugoid" oscillation in which the airplane goes through successive cycles of climbing with decreasing speed and then diving with increasing speed. Graphically:



The long period of this oscillation makes it very easy for the pilot to control and it has been determined through many flight tests that the tendency of the airplane to stop oscillating (damping) has no correlation with the pilot's judgement of the airplane's handling characteristics, and therefore, NO FLIGHT TESTS OF THIS MODE OF OSCILLATION ARE REQUIRED.

The second type of longitudinal motion is an oscillation of much shorter period (approximately 2 seconds) than the long period or phugoid mode. The pilot will feel this motion as a rapid oscillation of the normal acceleration, at constant airspeed. With the controls held fixed, this oscillation always dies out quickly (is heavily damped) and is of no importance; but with the longitudinal controls free, the tendency of this oscillation to die out can be reduced to a point where this oscillation will continue and become objectionable to the pilot. The oscillation manifests itself as a rapid pumping of the stick, as well as a rapid oscillation of the normal acceleration. This mode has been encountered on high speed airplanes and is referred to by the pilots as "porpoising" or "elevator snake." It is required that this mode of oscillation be completely damped in one cycle, i.e. that it disappear by itself completely in one cycle. With some airplanes, there may also be a very rapid oscillation of the elevator about its hinge. This motion is so rapid that the airplane does not respond to it. It is required that this oscillation damp completely in one cycle.

2. Configurations.

The airplane configurations to be tested for dynamic longitudinal stability are as follows:

a. Long Period Oscillations

No flight tests of this mode are required.

b. Short Period Oscillations

No tests of this mode are to be made with the longitudinal control fixed, but control free tests should be made with the airplane set up as follows:

Configuration (P) power-on, clean, with the airplane trimmed at level flight speed and at 80 percent of the limit diving speed.

3. Pilot Technique.

Starting in steady trimmed flight in the given configuration at the given trim speed, the pilot should abruptly deflect and release the elevator in not more than .2 second. Continuous photo-observer records should be taken during the whole maneuver. The elevator should first be given an abrupt downward deflection to an accelerometer reading of approximately 0.0 g. Following this, the elevator should be given an abrupt upward deflection to an accelerometer reading of 2.0 g.

4. Reduction of Data.

These data should be presented in the form of time histories of airplane normal acceleration and elevator angle. The typical time histories of satisfactory and unsatisfactory characteristics are shown in Figure 1.

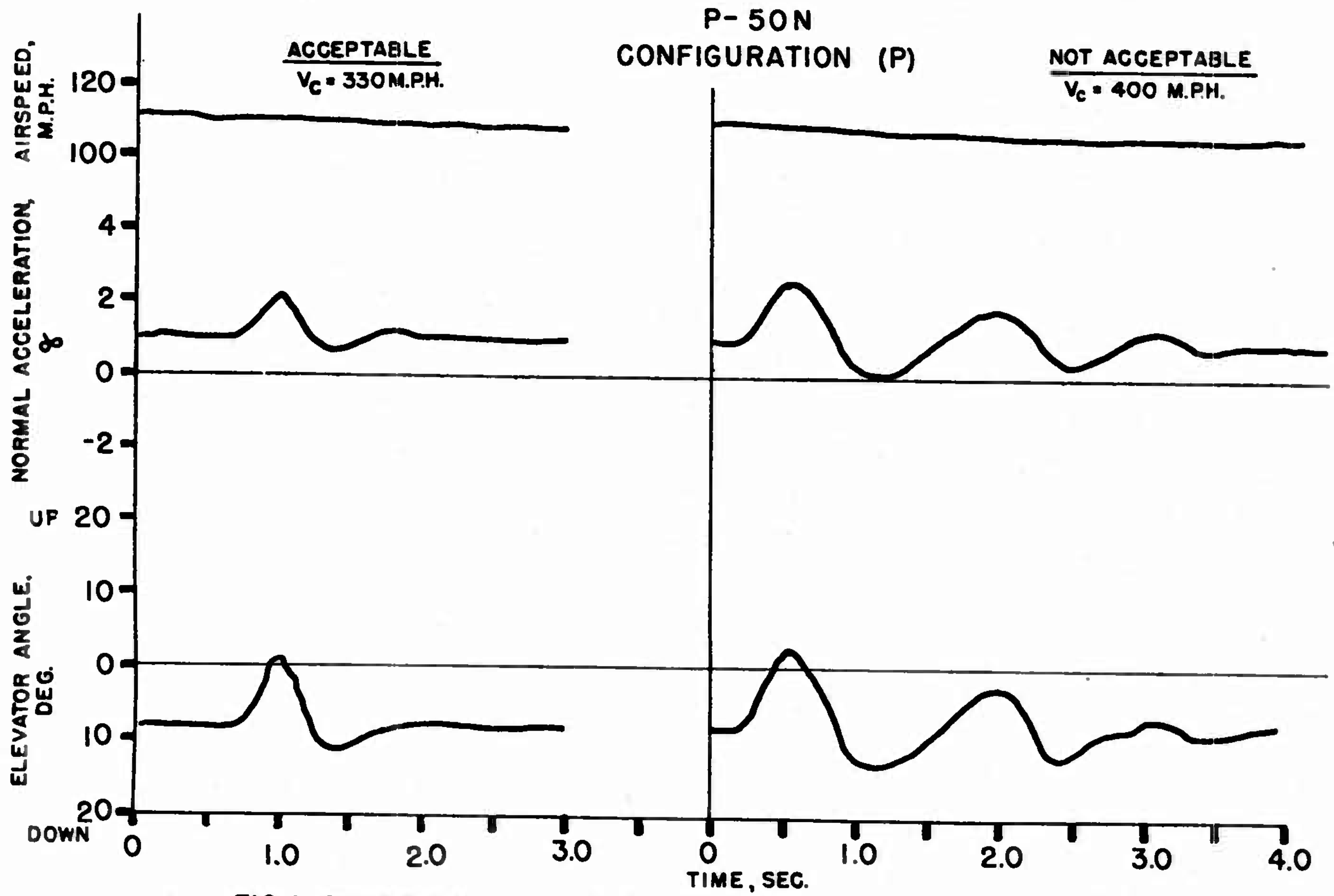


FIG. 1- SHORT PERIOD LONGITUDINAL OSCILLATIONS CONTROL FREE

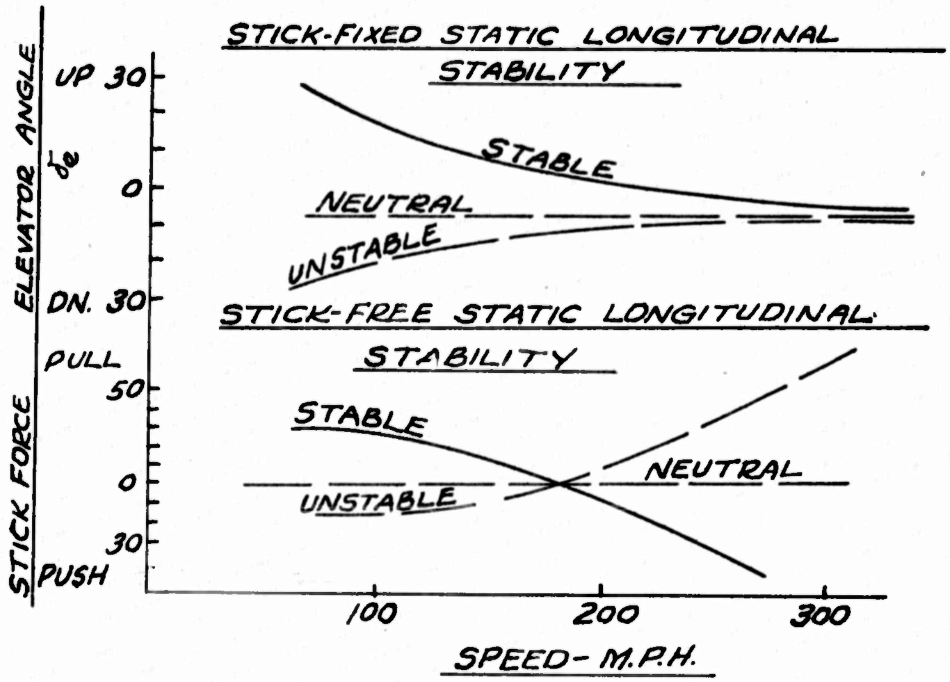
B. STATIC LONGITUDINAL STABILITY

1. Discussion

Among the most important handling qualities of the airplane are its static longitudinal stability characteristics. The pilot feels these characteristics through the variations of stick position and stick force required to fly the airplane at different speeds throughout the speed range. An airplane that is adequately stable longitudinally will require the simple control movement of stick back to reduce the speed and stick forward to increase the speed, and if the stick forces are trimmed out at a given speed, the airplane will continue to fly at this speed resisting all disturbances that tend to change it. The only way the speed can be changed for this stable case is for the pilot to supply force at the stick, a pull force to reduce the speed from trim and a push force to increase the speed from trim.

The variation of stick-position or elevator angle with speed is a function of the airplane s stick-fixed stability. An airplane that is longitudinally stable stick-fixed will require up elevator to fly at lower speeds and down elevator to fly at increased speeds. The variation of stick force with speed is a function of its stick-free stability and an airplane that is longitudinally stable stick-free will require a pull force to fly at lower speeds than trim and a push force to fly at increased speeds from trim.

The static longitudinal stability of any airplane varies rapidly with change in the airplane's center of gravity position.



As the c.g. moves forward the airplane becomes more stable, and as the c.g. moves aft it becomes less stable. If for a certain c.g. position, the airplane can be flown at speeds varying in small increments from the original trim speed with the same elevator angle, the airplane is said to be neutrally stable stick-fixed and this c.g. position is referred to as the "STICK-FIXED NEUTRAL POINT" for this particular trim speed and for that condition of flight. If for a certain c.g. position (not necessarily the same) and trim tab setting for zero stick force at a certain speed, it is possible to fly the airplane at speeds varying in small increments from the original trim speed with zero stick force and with the same tab setting, the airplane is said to be neutrally stable stick-free and this c.g. is referred to as the "STICK-FREE NEUTRAL POINT" for that particular trim speed and for that condition of flight.

There are several factors which complicate the simple stability picture at both the low and the high ends of the speed range. These factors include compressibility effects at high Mach Numbers, distortion effects at high indicated airspeeds, and premature wing stalling at low speeds. Any of these factors can stabilize or destabilize the stick position and stick force versus airspeed curves excessively for a poor design. For these reasons the stick-force and stick-position curves versus speed should be obtained for a complete analysis of the longitudinal stability characteristics over as wide a speed and altitude range as possible.

Static longitudinal stability not only varies with center of gravity position but with power, flying configuration, and, in most cases, with speed. To establish the stability characteristics of any airplane, flight tests must be run in all of the critical flight configurations through the usable speed range of each configuration. Flight tests to determine the stick force and elevator position versus speed curves are essential and from these curves the airplane's stick-fixed and stick-free neutral points can be determined.

2. Configurations

The airplane should be flight tested for its static longitudinal stability characteristics in the following configurations, for atleast THREE C.G. POSITIONS as widely separated as possible:

Configuration	Trim Speed	Speed Range
(A) Approach	$1.4\ V_{S_A}$	All permissible speeds down to $1.2V_{S_A}$.
(CR) Cruise	Speed for maximum range	90% to 120% of speed for maximum range.
(D) Dive	Trim for Dive at pilot's discretion 1/2 way between V_{MAX} level flight and MAX permissible diving speed suggested.	High speed level flight to maximum permissible diving speed.
(G) Glide	$1.4\ V_{S_G}$	All permissible speeds above V_{S_G}.
(L) Landing	$1.4\ V_{S_L}$	All permissible speeds above V_{S_L}.
(P) Power on clean	$1.75\ V_{S_G}$	All permissible speeds above $1.4\ V_{S_G}$.

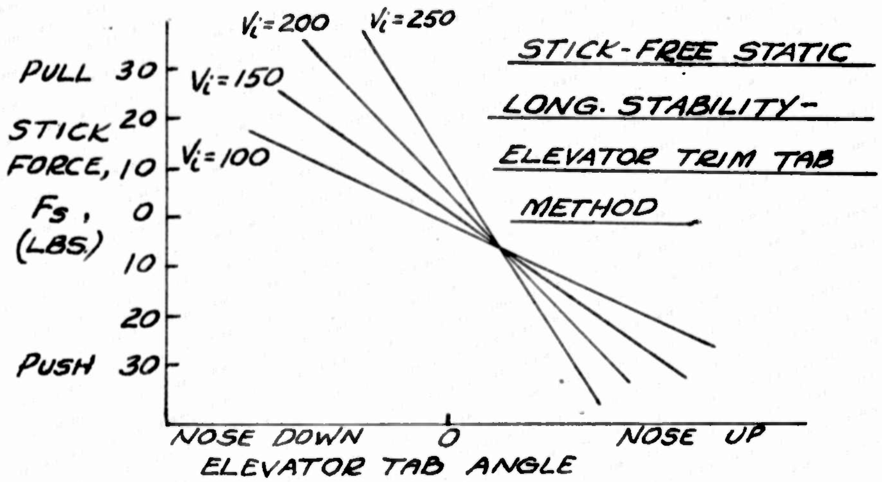
3. Pilot Technique

To start the test, the pilot stabilizes the airplane at the given trim speed with the given power settings. The trim tab is adjusted to trim out the stick force at this speed. Once the trim tab is set, it is imperative that it not be moved until the run is completed. It is also essential to maintain the same engine power throughout the run. The pilot stabilizes the airplane at each of a series of speeds above and below the trim speed by movement of the control column only, keeping the airplane's wings level and the ball centered during the whole maneuver. Records are taken at each stabilized speed.

As the airplane's speed is reduced, every effort should be made to obtain data at stabilized speeds. However, if it becomes impossible to maintain a stabilized speed, the pilot can take continuous records as he gradually eases back on the control column so that the speed is reduced at a slow rate (not more than 1/2 mph per second) until the slowest speed required or the stall is reached. All control movements should be made as smoothly as possible. This type of maneuver is usually resorted to only at the low speed end of the speed range.

It is obvious that the airplane will not remain at constant altitude during this test. If too much altitude is gained or lost during a run causing considerable change in power, it will be necessary to break the test up into several runs so that the test altitude can be held more closely. However, if the test is broken off to climb or dive the airplane back to test altitude, great care should be taken to insure that this is done without changing the trim tab setting.

A second method for conducting the static longitudinal stability flight tests is to determine the variation of stick-force with tab-angle at given constant airspeeds throughout the test speed range. These tests should be run in the same configurations and C.G. positions as those for the first method just discussed. This test takes longer to do but yields a tremendous amount of data for analysis work.



To start this test, the pilot puts the airplane in the given flight configuration with the given power settings and at the proper speed. The trim tab is rolled to approximately ten different settings throughout its deflection range maintaining the given speed. At each trim tab setting, the stick force, elevator angle, tab angle, indicated airspeed and altitude are recorded by running the recording instrument for a few frames. The stick or wheel forces may in some cases become excessive at the higher speeds at full tab deflection. In these cases the maximum tab deflection used should be limited to a corresponding control force that the pilot can safely handle. When the variation of stick force with trim tab angle is completed at one airspeed, it should be repeated at the next given test speed. Approximately ten test airspeeds should be used for each configuration tested.

4. Reduction of Data.

The flight data should be presented in the form of curves of elevator angle, elevator force, rudder angle, rudder force, angle of bank and angle of sideslip versus calibrated airspeed. The table given in Appendix II can be used for transcribing and reducing the flight observer data. A certain amount of judgement must be exercised in using this table. All of the corrections indicated in determining pressure altitude, free air temperature, and true airspeed are necessary only in very accurate work or where large corrections are known to exist, as, for example, in tests conducted at very high speeds. In low speed work with good instrumentation more approximate methods will give sufficiently accurate results. Typical examples of these curves are shown in Figure 2 for three different center of gravity positions for one configuration. Similar curves should be presented for each configuration tested.

The curves of Figure 2 should be replotted as elevator angle (δ_e) and stick-force divided by the dynamic pressure (F_s/q) versus airplane lift coefficient as shown in Figures 3 & 5. The slopes of these curves should be determined for every .1 increment in airplane lift coefficient, and plotted as $d\delta_e/dC_L$ and $d(F_s/q)/dC_L$ versus c.g. position as shown in Figures 4 and 6. The stick-fixed and stick-free neutral points occur at the c.g. locations where $d\delta_e/dC_L$ and $d(F_s/q)/dC_L$ respectively go to zero. Finally, the center of gravity location for neutral stability is plotted versus airplane lift coefficient as shown in Figures 7 and 8. The process is repeated for each configuration under test until curves similar to those shown in Figures 2 - 8 are obtained for all configurations tested.

If the second method for running the static longitudinal stability tests is used as discussed in part 3, the flight test data should be presented in the form of curves of stick-force versus tab angle at constant calibrated airspeeds for the three c.g. positions tested for each configuration. An example of these curves is shown in Figure 9. (Only two c.g. positions are shown to avoid confusing the figure.) These curves can be cross-plotted for stick-force versus calibrated airspeed for constant trim tab setting selected to give zero stick force at the required trim speed for the given configuration. These curves will then be similar to those obtained directly for stick-free stability in the first method, and the development of these curves should continue as before. An example of these cross plots is shown in Figure 10.

This second method will also yield data on elevator position versus speed for various c.g. positions. These data are used to determine the stick-fixed stability. However, the reduction of these data and presentation of results proceeds exactly as demonstrated for the first method.

The flight test curves of Figure 9 can be used for analyzing the power of the elevator trim tab and yield directly data for design of any installation (such as an elevator down-spring and/or bob-weight) required to improve the curve of stick-force versus airspeed.

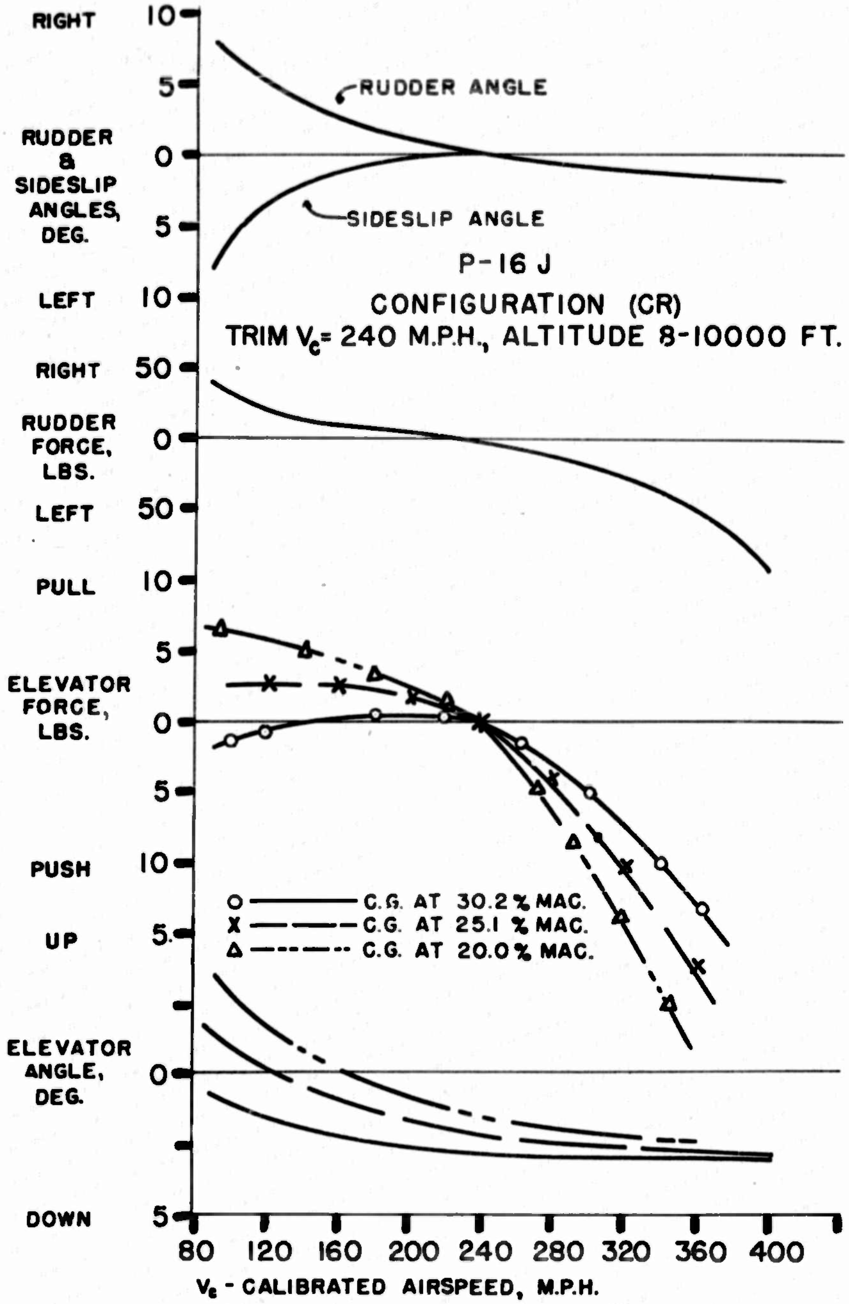


FIG. 2- STATIC LONGITUDINAL STABILITY

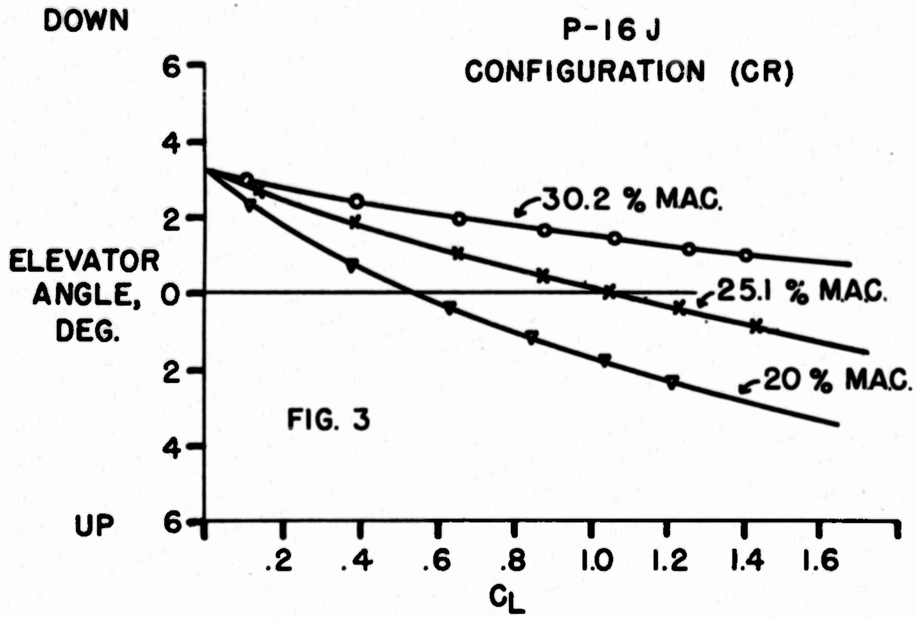


FIG. 3

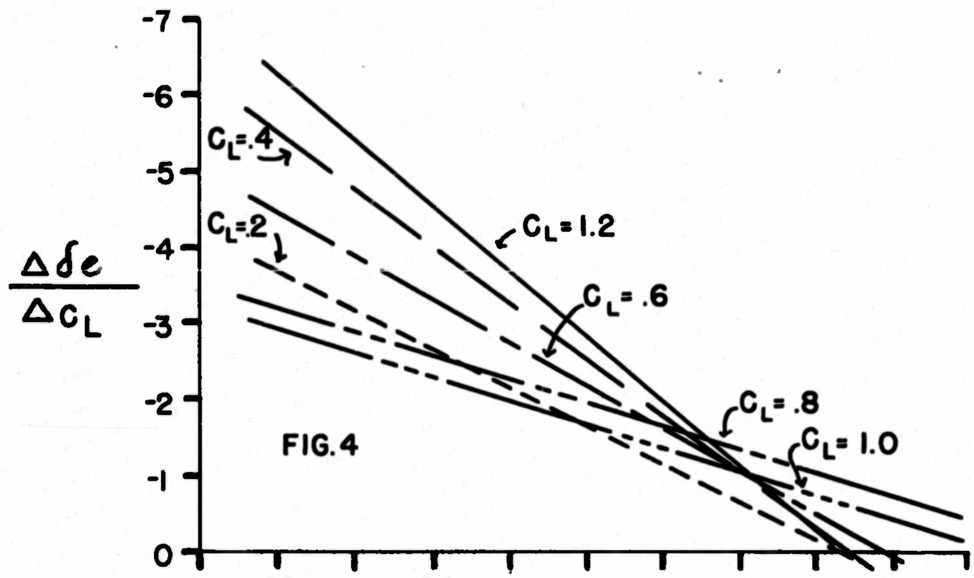


FIG. 4

STICK-FIXED STATIC LONGITUDINAL STABILITY

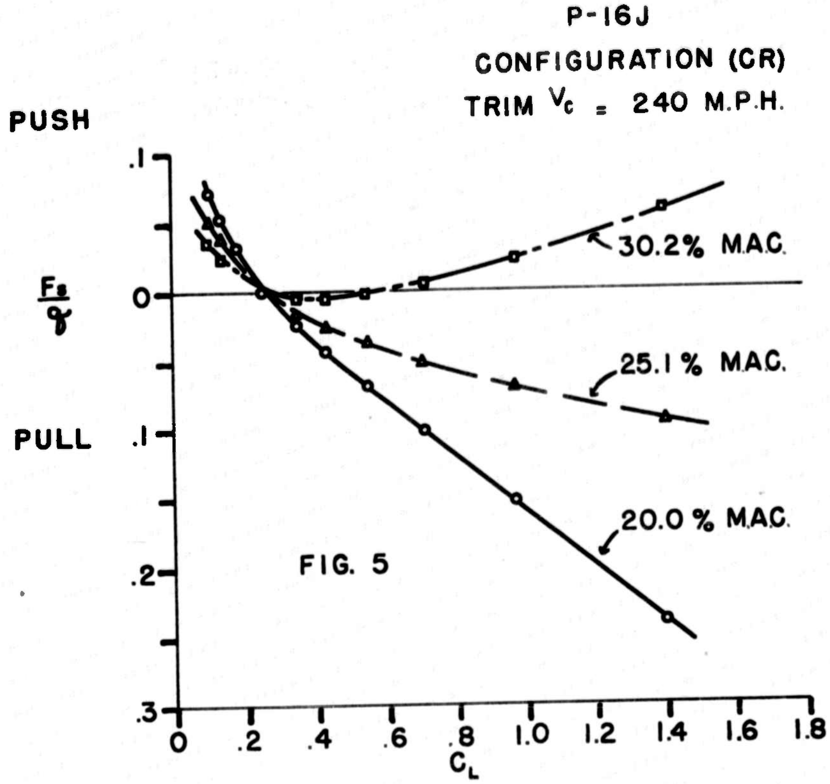


FIG. 5

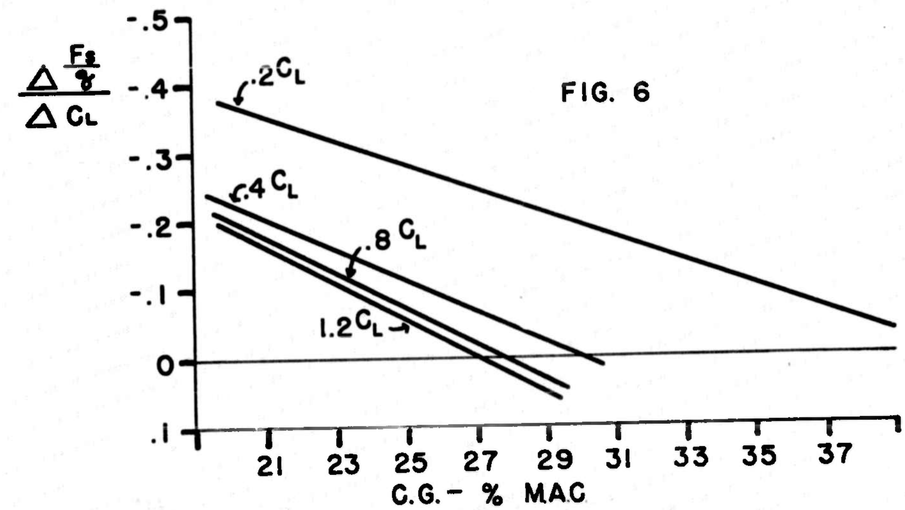


FIG. 6

STICK-FREE STATIC LONGITUDINAL STABILITY

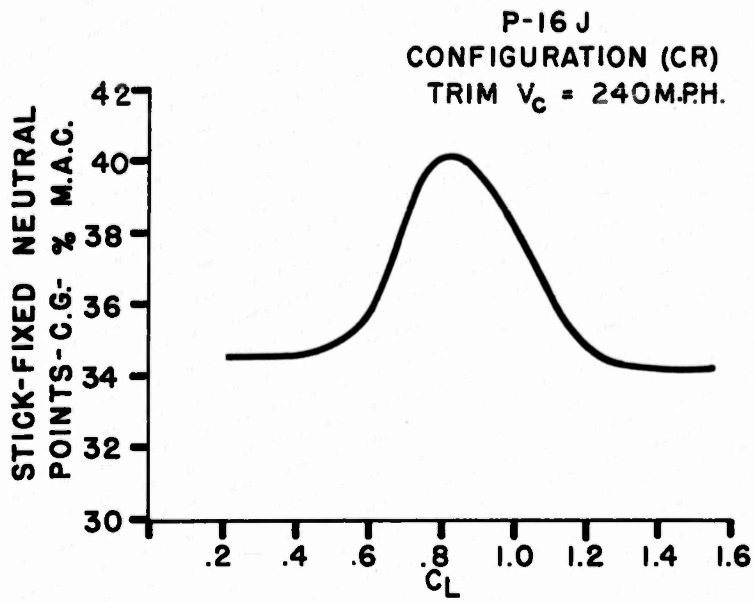


FIG. 7 - STICK FIXED

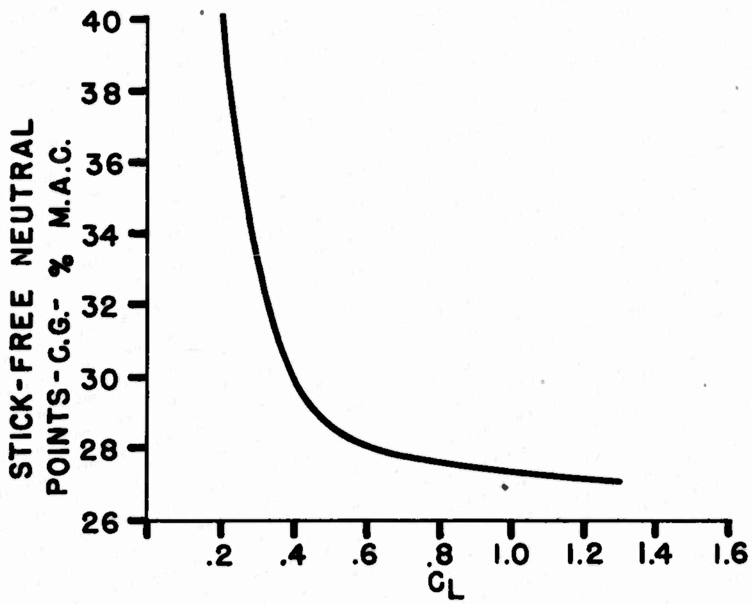


FIG. 8 - STICK FREE

NEUTRAL POINTS VS. LIFT COEFFICIENT

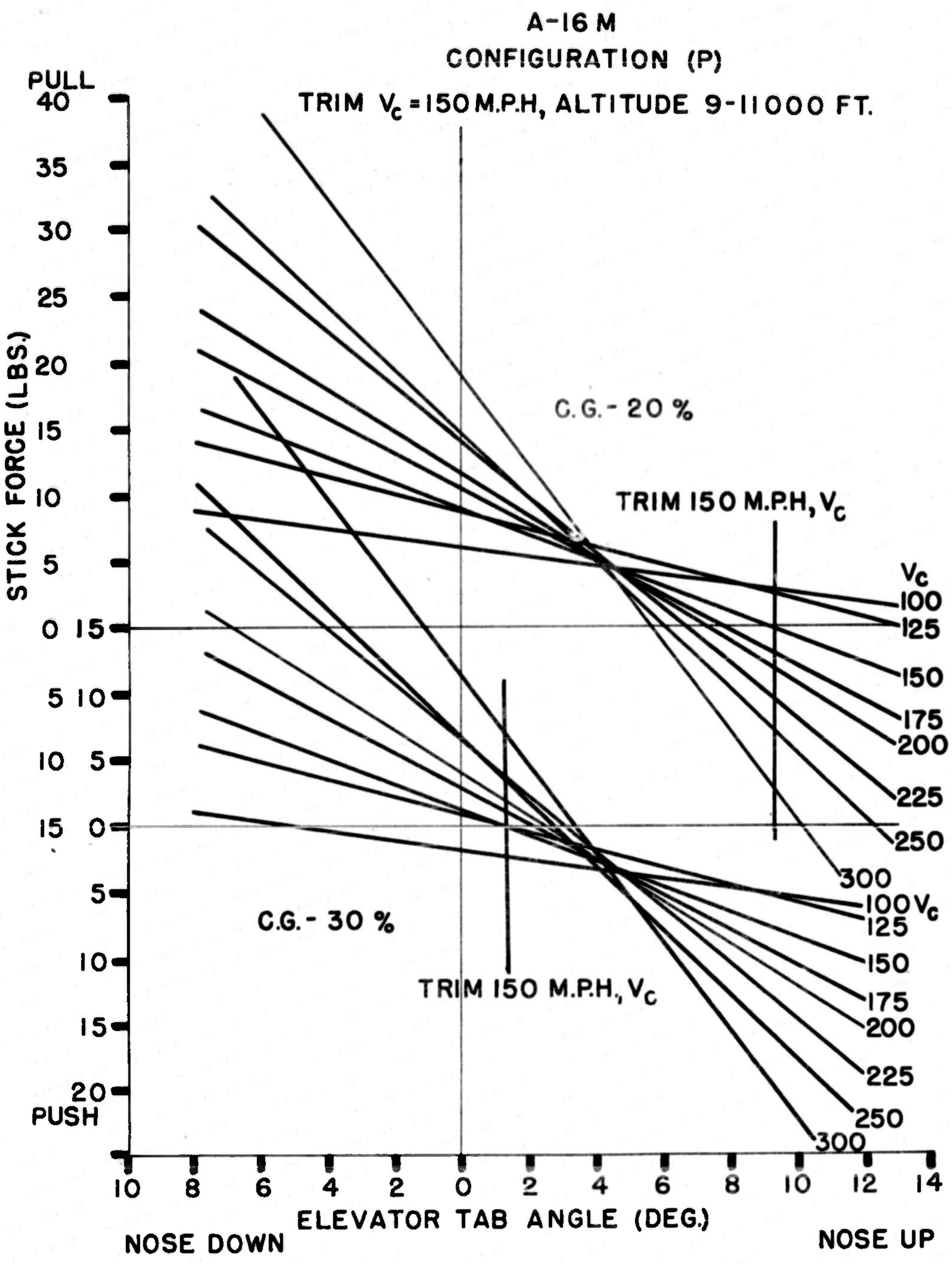


FIG. 9 - STICK FORCE VS. ELEVATOR TAB ANGLE

A-16 M

CONFIGURATION (P)

CROSS PLOT FROM FIGURE 9

TRIM SPEED 150 M.P.H, V_c

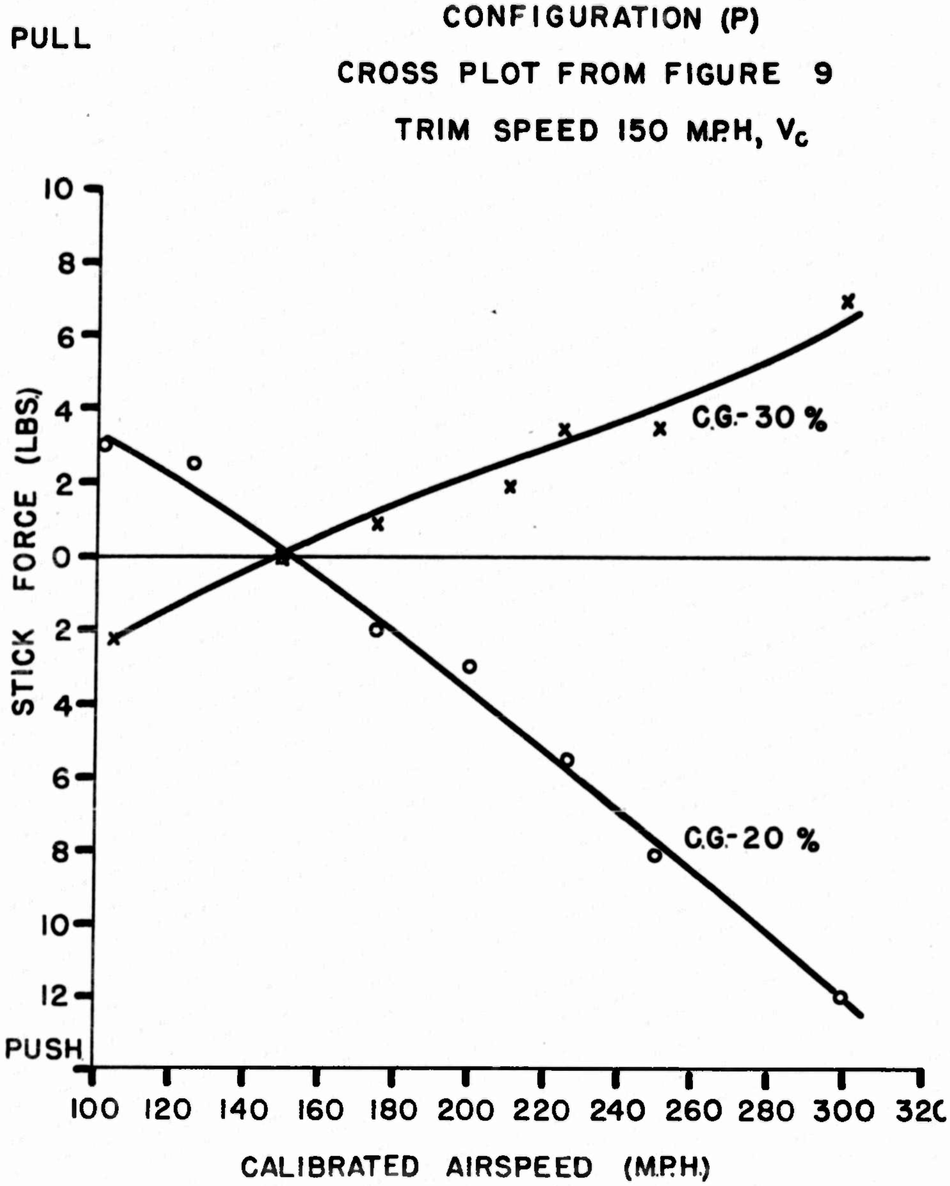


FIG. 10-STICK FORCE VS. CALIBRATED AIRSPEED

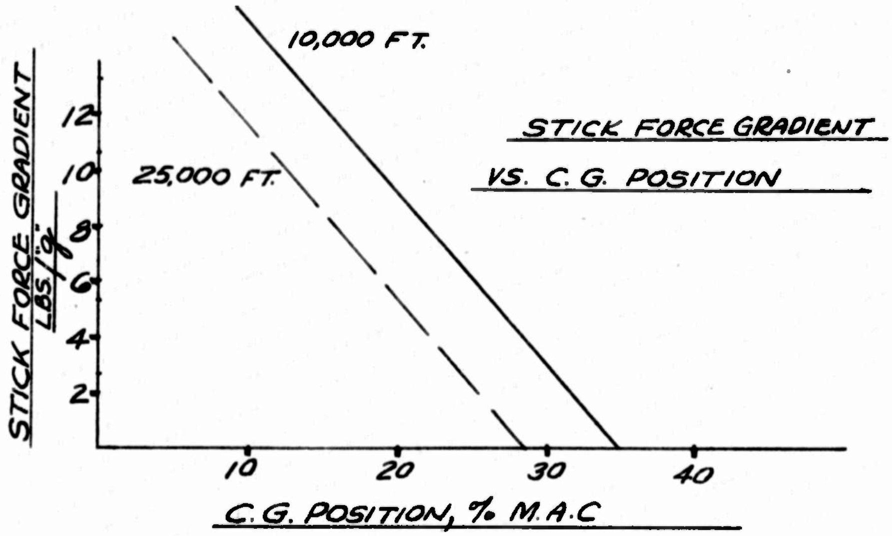
C. STICK-FORCES IN MANEUVERING FLIGHT

1. Discussion

The pilot effort required to accelerate the airplane in banked turn or a pull-up is a measure of one of the most important flying characteristics of the airplane. The stick-force required to produce one "g" unit of normal acceleration is commonly referred to as STICK FORCE PER "G". For any given airplane the stick force per "g" varies with the c.g position and with altitude, increasing as the c.g. moves forward and decreasing as the c.g. moves aft, and decreasing as the altitude is increased. For good flying qualities, it is essential that these forces never be so heavy that the pilot cannot exert enough force to maneuver the airplane, nor so light that it is possible to inadvertently place too high an acceleration on the airplane, causing possible structural failure. For airplanes that are designed for extreme maneuverability, such as fighters, the stick forces per "g" must be kept within very narrow margins, and this becomes one of the major design problems.

As the stick force per "g" varies with c.g. position it is essential to find out its value at any balance point in the c.g. range and for any altitude at which the airplane may fly. A typical variation of stick-force per "g" (Fs/g) with c.g. and altitude is shown in Figure 10 a. As the c.g. of the airplane moves aft, the gradient is reduced until at some c.g. it will go to zero. This c.g. position is defined as the MANEUVERING STICK-FREE NEUTRAL POINT.

Flying the airplane balanced at any c.g. aft of this point would be extremely hazardous; therefore, it is sometimes referred to as the DANGEROUS NEUTRAL POINT.



The stick-force gradient in accelerated flight is usually independent of speed and nearly constant over the test "g" range. However, this is not always the case due to the airplane distortion effects, non-linear elevator hinge moments, etc. In these cases the stick forces per "g" at a given altitude varies with speed and with the magnitude of the "g". Such non-linear characteristics are highly undesirable because the stick force gradient may become very low or even negative at high "g's". This means that the airplane will become "very sensitive" and very easy to pull up to a dangerously high "g" during the period when the pilot is blacking out.

Flight tests of the characteristics of an airplane in accelerated flight should be as complete as possible as they are extremely important in the analysis of the flying qualities of the airplane. This is doubly true for fighter types.

2. Configurations

The gradient of elevator control force in accelerated flight shall be investigated with the airplane in the following configurations for at least 3 c.g. positions as widely separated as possible:

	Configuration	Speeds	Altitude
(P)	Power-on Clean	At least 2 speeds, one above and one below high speed level flight	10,000 ft. and 25,000 ft.
(D)	Dive (for airplanes with dive brakes)	At the diving speed	10,000 ft.

3. Pilot Technique

The pilot first makes the proper power settings and trims the airplane at the speed and altitude specified in the flight plan. The airplane is climbed to an appropriate altitude above the test altitude without changing the elevator trim tab setting. The pilot then puts the airplane into a diving turn, maintaining the correct constant airspeed. The turn is tightened until the required constant acceleration in "g's" is being shown on a visual accelerometer. The data are recorded as the airplane goes through the test altitude at a constant airspeed and acceleration. It will be possible to use the diving turn technique only for accelerations up to 5 or 6 g. For higher accelerations the pilot follows the same trim procedure and then makes dives and pullouts so that the airplane passes through the test altitude at the proper airspeed while pulling out of the dive at a constant acceleration. The pilot should maintain his wings level during these pullouts.

A second method for conducting these tests is known as the "wind-up turn" method. In this test the pilot trims out the airplane at the test altitude as before, and after climbing several thousand feet over this altitude, places the airplane in a diving turn at a given "g". This acceleration is held constant as the speed is slowly allowed to fall off until the stall is reached. The acceleration should be held as nearly constant as possible, and the speed should be reduced as slowly and evenly as possible. This test can replace the diving turn test for acceleration up to about 5 "g", but the higher accelerations must be tested for by the pull-out method described above. The photo-observer should be run continuously during this maneuver.

4. Reduction of Data

The flight test data should be presented as plots of stick force versus normal acceleration for each c.g. and for each airspeed and altitude tested. Typical curves are shown in Figure 11. The slope of these curves is the stick force gradient. This slope is plotted against c.g. position for constant altitude. An example of this curve is shown in Figure 12. The c.g. at which this curve goes through zero is the MANEUVERING STICK-FREE NEUTRAL POINT.

Some airplanes have non-linear elopes of stick force per "g". An example of the flight test results for euch an airplane ie shown in Figure 13. For these cases the slope, etick force per "g", must be plotted against c.g. position for constant values of acceleration. The curves yield maneuvering neutral points that vary widely with the particular value of "g". An example of this ie shown in Figure 14.

Caution must be exercieed when the values of Fs/g are being determined from flight test data. It ie essential that the proper stick force be used with the proper acceleration. In the diving-turn maneuvers, this is not much of a problem as the stick force and acceleration are held constant during the time the records are taken. However, in pull-ups an equilibrium can only be established momentarily, and it is important that the record be read at the point where both the stick force and acceleration have assumed steady values.

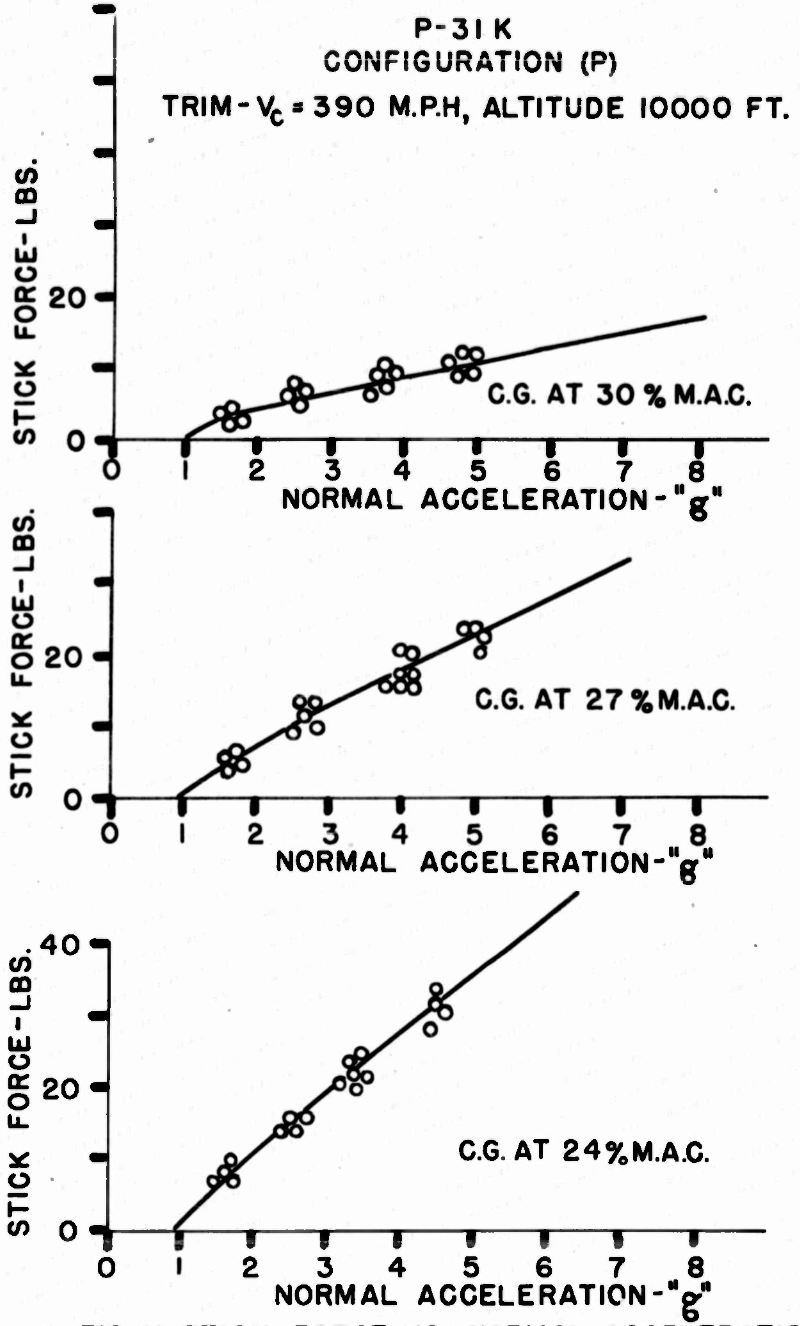


FIG. 11-STICK FORCE VS. NORMAL ACCELERATION

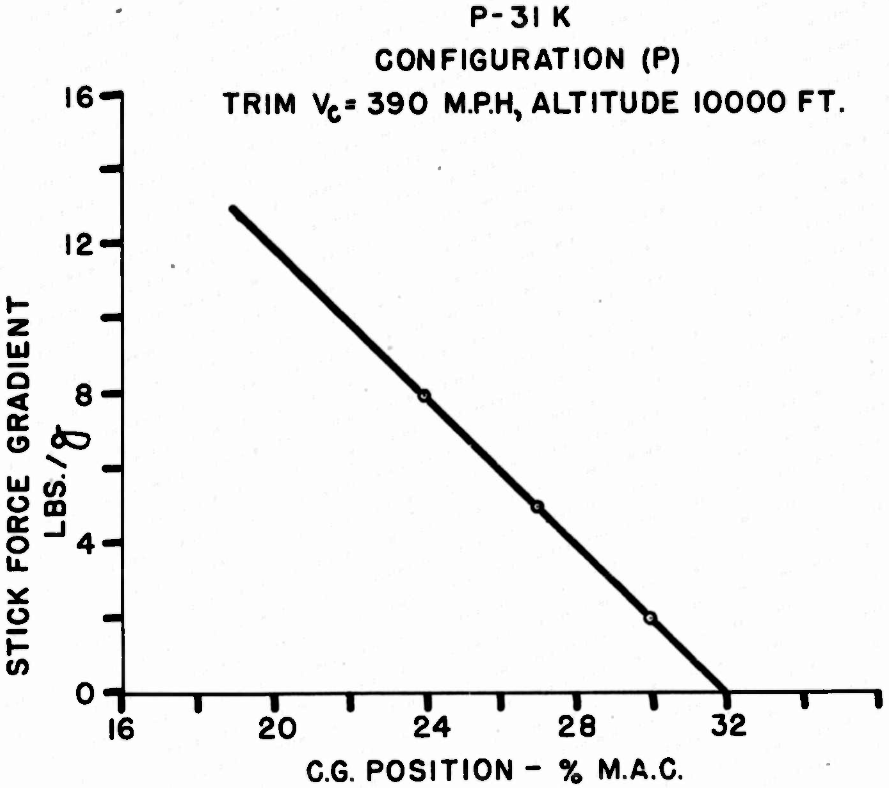


FIG. 12 - STICK FORCE GRADIENT VS. C.G. POSITION

P-44C

CONFIGURATION (P)

TRIM V_C = 395 M.P.H., ALTITUDE 10000 FT.

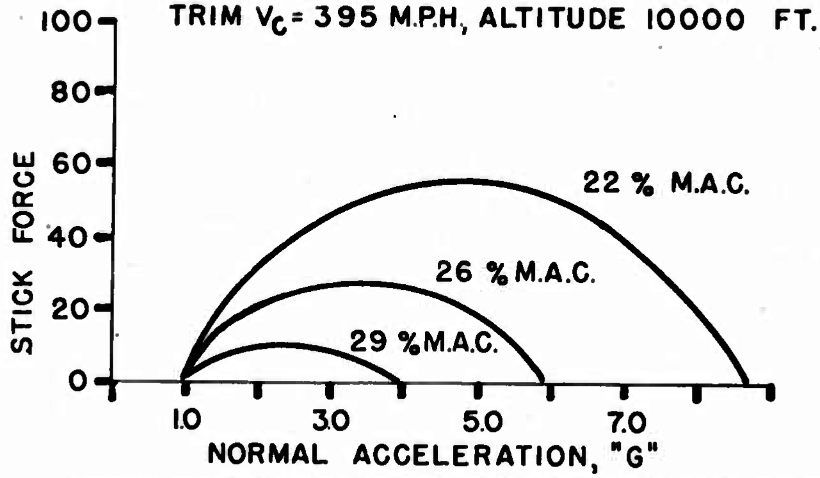


FIG. 13—STICK FORCE VS. NORMAL ACCELERATION

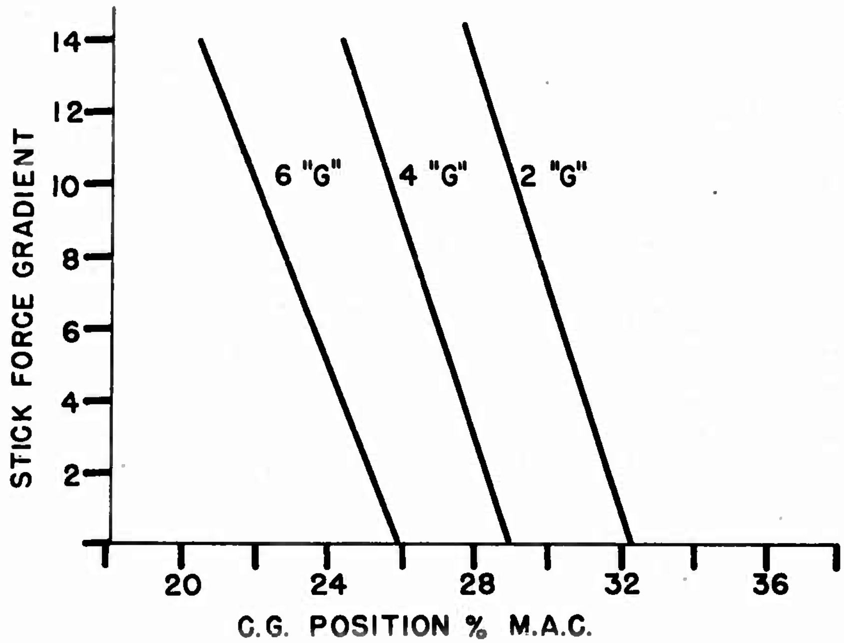


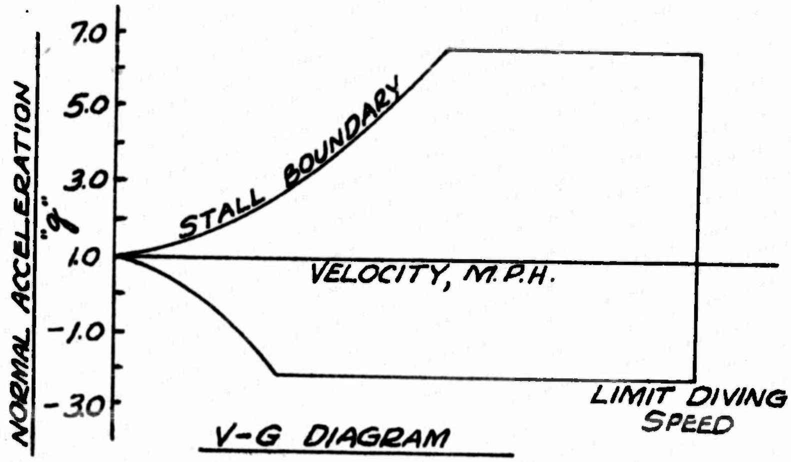
FIG. 14- STICK FORCE GRADIENT VS. C.G. POSITION AT CONSTANT ACCELERATION

D. LONGITUDINAL CONTROL (MANEUVERING)

1. Discussion

The acceleration that can or should be imposed on any airplane is limited in two ways. The upper limit on the allowable acceleration is the design structural limit load factor for the airplane. In the lower speed range it will be impossible for the airplane to reach the acceleration corresponding to the limit load factor as the wing will stall before sufficient lift can be generated. The faster the airplane goes, the greater is the acceleration that can be imposed on the airplane before the wing stalls. At some speed for a given airplane, the airplane will stall at the limit load factor. Above this speed, the possible acceleration is higher than the limit load factor and the pilot must be careful not to exceed this value.

The envelope of limiting accelerations for each speed is referred to as the V-G diagram, an example of which is shown below:



V-G DIAGRAM

One of the requirements on the longitudinal control is that it shall be powerful enough to allow the pilot to "pull-up" to the limiting value of "g" at any airspeed in either straight pull outs or in turns. This requirement on the elevator is hardly ever a critical one and complete tests for compliance are frequently omitted unless other deficiencies in longitudinal control become apparent from other tests.

2. Configuration

The configurations to be tested are the same as those given in section C, "Stick Forces in Maneuvering Flight."

3. Pilot Technique

The data for these tests can be obtained from the tests given in section C, as above, and therefore the same pilot technique applies.

4. Reduction of Data

The results of these tests should be presented in the form of plots of elevator angle versus airplane lift coefficient for constant values of airplane acceleration. These curves should be presented for each c.g. tested. The lift coefficient used in this plot is that defined as follows: $C_L = \frac{nW}{qS}$. An example of these curves are shown in Figure 15.

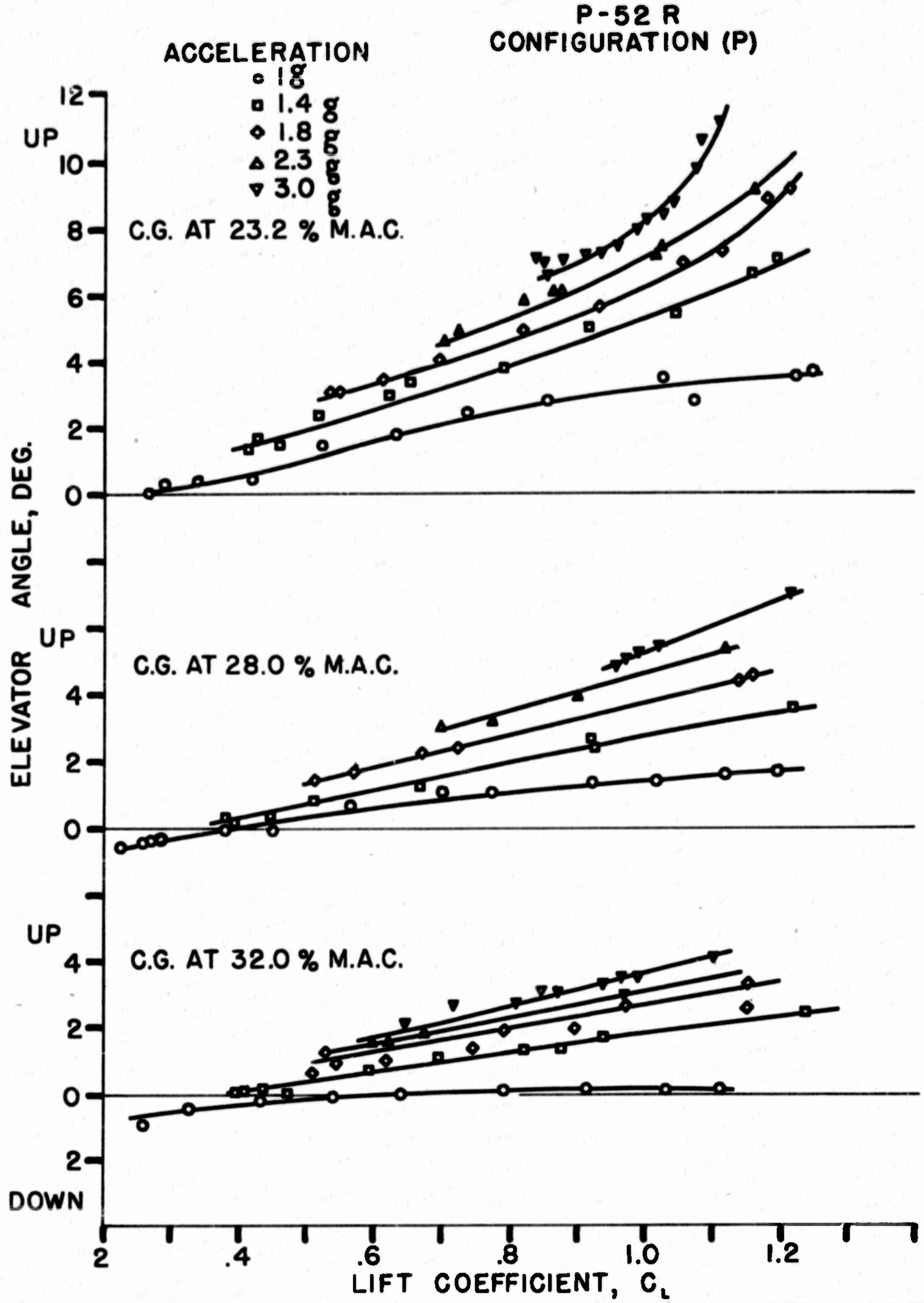


FIG. 15-ELEVATOR ANGLE VS. LIFT COEFFICIENT IN ACCELERATED FLIGHT

E. LONGITUDINAL CONTROL (LANDING)

1. Discussion

When the airplane is flying close to the ground, the downwash from the wing is reduced materially, requiring more up elevator to trim at a given speed than is required in free flight. The greatest up elevator will be required at the stall at the most forward c.g. with the airplane flying close to the ground. This, in almost all conventional airplane designs, is the critical design condition for the longitudinal control (elevator).

The tests should determine whether or not sufficient elevator control is available to hold the airplane off the ground in the three-point attitude for two wheel airplanes, or at the maximum allowable ground angle for tricycle gear airplanes. The tests should also determine if the elevator control forces required during the landing are low enough so that the pilot can safely handle them.

2. Configuration

The airplane should be tested in the landing configuration (L), at three c.g. locations as widely separated as possible. The airplane should be trimmed at a speed of 1.4 V_{S_L} in the approach.

3. Pilot Technique

The pilot should trim out the stick force with the airplane in a normal gliding approach at the specified trim speed with idling or minimum power. The airplane should be flared out and held off the ground as long as possible by movement of the control column. The hold off may be terminated as the stalling speed is reached or when the maximum allowable ground angle is obtained. The elevator trim tab setting should not be altered from its trim position during the landing unless necessary due to excessive forces. These tests can be combined with the tests of Section B, "Static Longitudinal Stability", being run during the landing after each flight.

4. Reduction of Data

The data from these tests should be presented in the form of time histories of landings showing elevator angle, stick force, indicated airspeed, and normal acceleration versus time. A typical time history is shown in Figure 16. From these time histories the maximum up elevator required at each test c.g. can be determined and then plotted versus c.g. This curve of elevator angle versus c.g. position can be extrapolated to the design most forward c.g. if the most forward c.g. flight tested is somewhat back of the design most forward c.g. It can then be determined if the maximum elevator deflection is adequate to land the airplane at the design most forward c.g. A typical curve of elevator angle and stick force required to land versus c.g. is shown in Figure 17.

P-78
CONFIGURATION (L)
TRIM V_C = 120 MPH, C.G. AT 22% M.A.C.

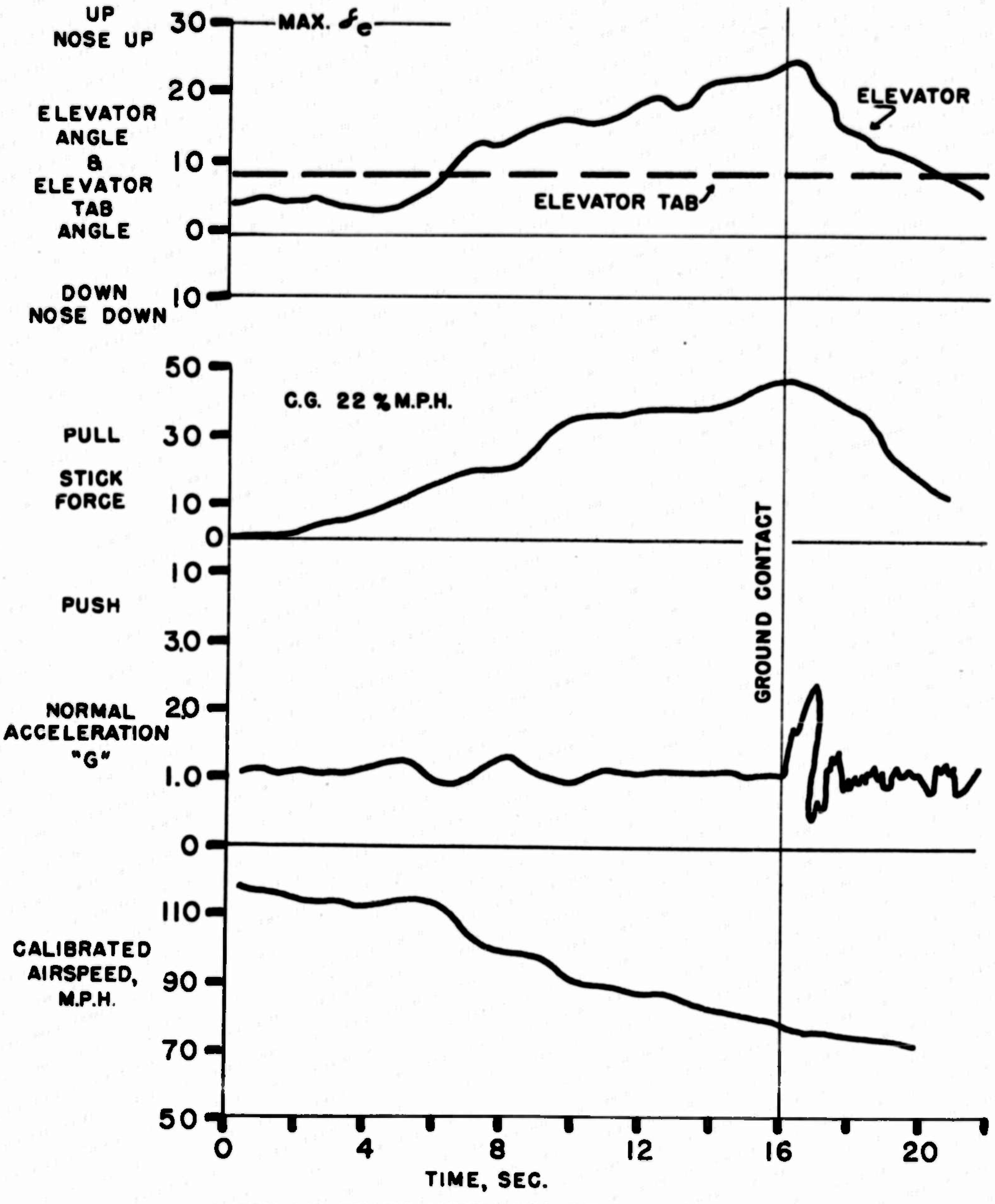


FIG. 16- TIME HISTORY OF LANDING

P-78

CONFIGURATION (L)

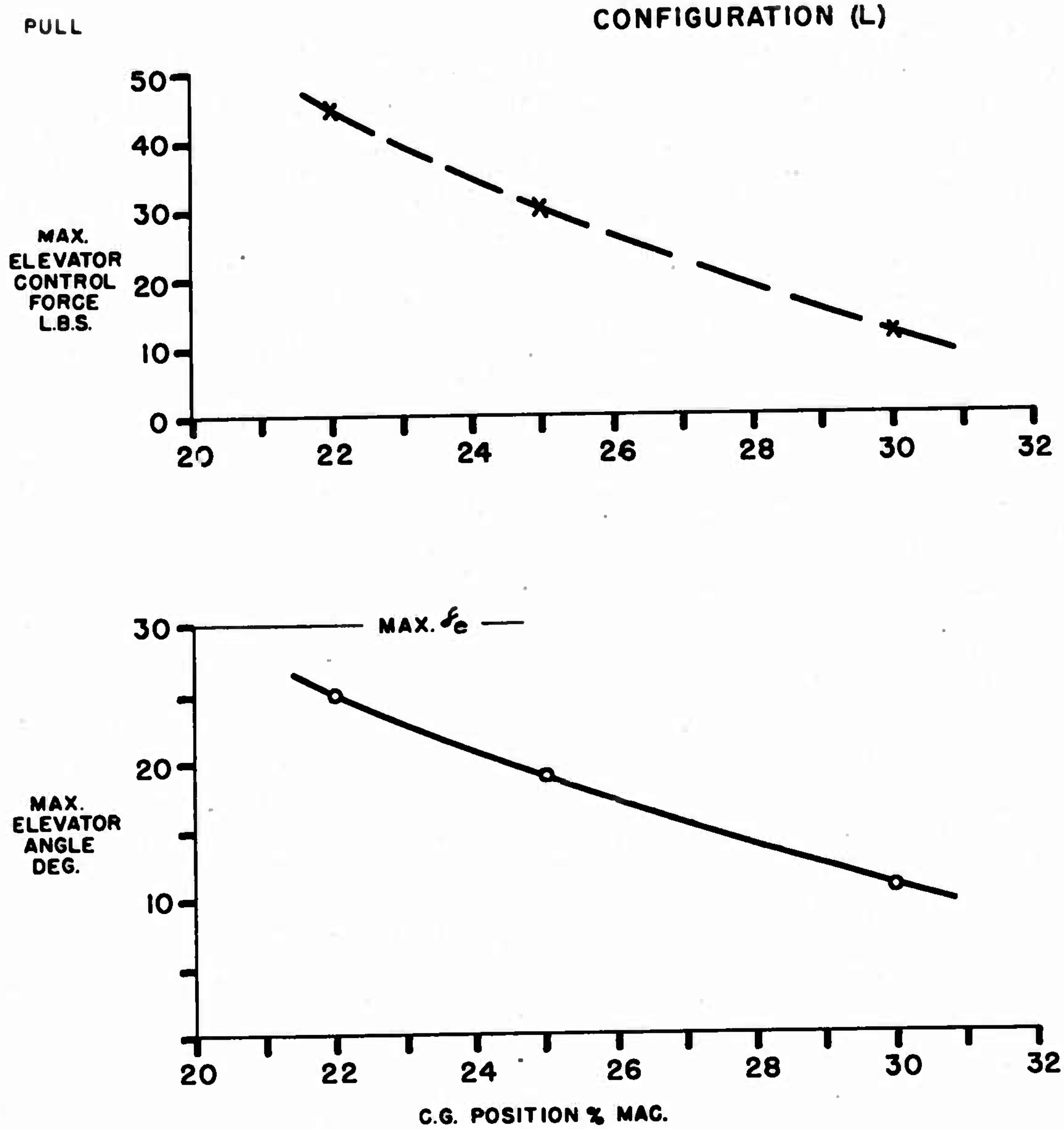


FIG. 17-ELEVATOR ANGLE & STICK FORCE TO LAND VS. C.G. LOCATION

F. LONGITUDINAL CONTROL (TAKE-OFF)

1. Discussion

The longitudinal control must also be powerful enough to permit the pilot to hold the airplane in the proper take-off attitude during the ground run. The pilot must have control of the airplane's attitude by the time the airplane has reached a speed equal to eighty percent of the power off stalling speed with gear down and flaps in the take-off position.

2. Configurations

The tests should be made at the most rearward c.g. for two-wheel airplanes and at the most forward c.g. for tricycle-gear airplanes. The airplane should be in the take-off configuration with flaps set for optimum take-off.

3. Pilot Technique

For a tail-wheel airplane, the longitudinal control is pushed full forward and held in this position during the take-off run, being eased back as the airplane comes up to a level attitude. For a tricycle-gear airplane, the longitudinal control is pulled full back during the take-off run being eased forward as the nose wheel comes off the ground. The pilot should start the recorder at the beginning of the take-off run and turn it off as soon as the proper take-off attitude has been reached.

4. Reduction of Data

The recorded data should be examined to determine the calibrated airspeed at which the airplane reaches the desired attitude.

G. LONGITUDINAL TRIM CHANGES

1. Discussion

When the airplane is trimmed for zero stick force at a certain airspeed, changes in power, deflection of flaps or dive brakes, and putting the landing gear down or up will cause changes in the original trim of the airplane. To make the airplane safe and easy to fly, it must be possible for the pilot to maintain his original trim speed, after changing power settings or gear or flap positions, without changing the original trim tab setting and without exerting a longitudinal control force greater than 35 pounds for a stick control or 50 pounds for a wheel control.

2. Configurations

The test should be made at the design most forward c.g. at close to the design gross weight. This test determines the variation in trim with change in configuration as follows:

TRIM CONDITION

No.	Speed	Class	Flap	Gear	Power	Variable
1	$1.4V_{S_G}$	All	Up	Up	50% NRP	Gear Down
2	$1.4V_{S_G}$	All	Up	Down	50% NRP	Flap Down
3	$1.4V_{S_L}$	All	Down	Down	50% NRP	Power-off
4	$1.4V_{S_G}$	I, III, & IV	Up	Up	Off	Gear Down
5	$1.4V_{S_G}$	1, III, & IV.	Up D	Down	Off	Flap Down

No.	Speed	Class	Flap	Gear	Power	Variable
6	$1.4V_{S_L}$	All	Down	Down	Off	Take-off Power
7	$1.15V_{S_L}$	IV	Down	Down	Level Flight	Take-off Power
8	$1.4V_{S_L}$	All	Down	Down	Take-off	Gear Up
9	$1.4V_{S_L}$	All	Down	Up	Take-off	Flap Up
10	$1.2V_{S_L}$	All	Take-off	Down	Take-off	Gear Up
11	$1.4V_{S_L}$	All	Take-off	Up	Take-off	Flap Up
12	High Level	All	Up	Up	NRP	Power Off
13	High Level	III, IV	Up	Up	Off	Dive Flap Open

3. Pilot Technique

The pilot should trim the airplane as listed under Trim Condition, No. 1, in the table given above. A short record should be taken on the photo observer. Without changing the trim tab setting, the action listed under Variable in the table should be taken and the trim speed maintained by proper use of the longitudinal control. When the airplane is again in equilibrium another short record should be taken on the photo observer. This process should then be repeated for test No. 2 and so on down to test No. 13.

4. Reduction of Data

The results of this test can be presented in tabular form listing longitudinal control force required to maintain the original trim speed with change in configuration.

E LONGITUDINAL TRIMMING DEVICE

1. Discussion

In order to relieve the pilot of continuous application of force at the stick or wheel to maintain a given speed, a longitudinal trimming device is provided. This device, which is usually a trim tab on the control surface trailing edge or an adjustable stabilizer, should be powerful enough to trim out the stick forces throughout the important speed and center of gravity ranges. The trimming device should be irreversible, maintaining a given setting indefinitely unless changed manually.

2. Configurations

Adequate trimming power should be tested for in the following configurations at the most forward and most aft c.g. positions:

Class Airplane	Configuration	Speed Range
All	G (Glide)	$1.15V_{S_G}$ to max. permissible
All	P (Power On Clean)	$1.15V_{S_P}$ to max. permissible
All	L (Landing)	$1.4V_{S_L}$ to max. permissible
III & IV with dive brakes	D (Dive)	Max. level flight speed to max. diving speed with dive brakes open.

3. Pilot Technique

With the airplane flying in the given configuration, the pilot should slowly change the speed, in approximately ten steps, throughout the given speed range and at each speed the pilot should trim out the stick force by means of his longitudinal trimming device. When in equilibrium the photo observer should be run for an instant to record the data. This procedure should be followed for each of the test configurations given.

4. Reduction of Data.

The data should be presented in the form of plots of tab angle or stabilizer angle required to trim versus calibrated airspeed for each configuration and c.g. tested. Typical curves are shown in Figure 18.

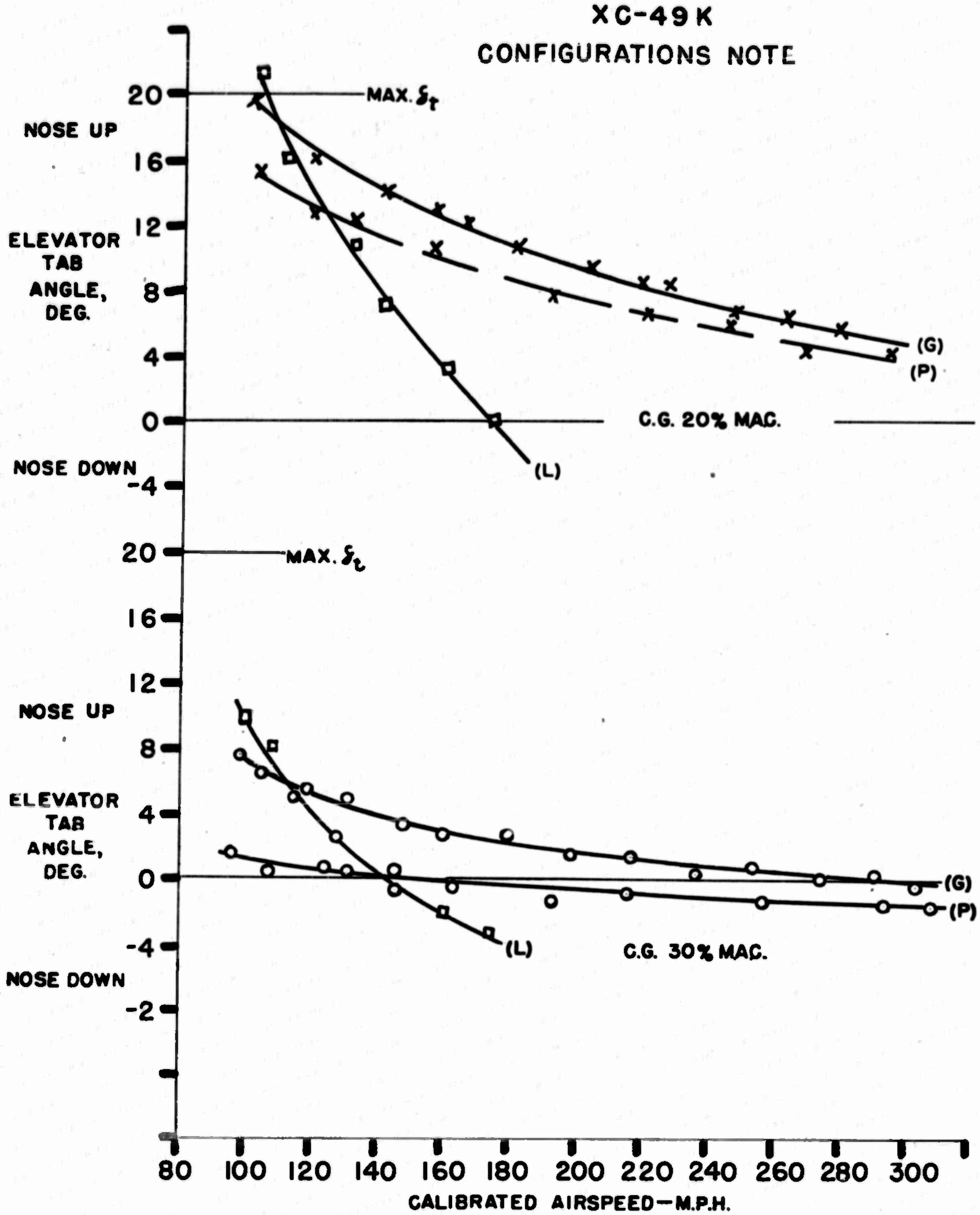


FIG. 18– ELEVATOR TAB ANGLE VS. CALIBRATED AIRSPEED

I. LONGITUDINAL CONTROL AT HIGH SPEEDS

1. Discussion

Compressibility can have serious effects on the longitudinal stability and control of an airplane. One of these effects can place a serious limitation on the ability of the pilot to recover from high speed dives with adequate acceleration. This leads to a requirement that Class III and IV airplanes be tested for their ability to recover from dives in the compressibility region. All Class III and IV airplanes must demonstrate their ability to recover from dives of at least 15,000 feet from service ceilings at a flight path angle of at least 50 degrees to the horizontal, with accelerations of at least 3 g and elevator control forces not exceeding 150 pounds. This recovery can be obtained by using a dive recovery device, if necessary.

Another high speed requirement is that the stick or wheel force necessary to hold the airplane in high speed dives shall not exceed a certain limit. With the airplane trimmed out in level flight, excessive push forces should not be required on the control column to hold the airplane in high speed dives up to the maximum permissible airspeed. This requirement protects the airplane from structural failure in case the pilot inadvertently releases the force on the control column, allowing the airplane to pull out by itself at a very high "g".

2. Configurations

The tests for recovery from high speed dives in the region of compressibility shall be demonstrated by Class III and IV airplanes in Configuration (G) with power at the discretion of the pilot, at the normal center of gravity position. The trim tab setting is at the pilot's discretion but should be somewhere between the setting for zero stick force at maximum level flight speed and the setting required for zero stick force at maximum permissible diving speed.

The tests for stick forces to hold the airplane in high speed dives should be made on all classes of airplanes in Configuration (P) with the airplane trimmed for zero elevator control force in steady level flight, at the normal center of gravity position.

3. Pilot Technique

Before beginning any high Mach number dives, it is important that the pilot familiarize himself gradually with the high-speed characteristics of a new airplane. This can be done by making a series of dives of increasing steepness, starting from an altitude near the service ceiling of the airplane. The pilot should allow the airplane to reach higher indicated speeds at higher altitudes during each successive dive, being careful to note any abnormal characteristics, serious buffetting, or other unusual behavior. In this manner, the critical test conditions are approached gradually and with the assurance that if any difficulties develop, it will be possible to terminate the dive safely. Continuous records of stick force, elevator angle, elevator tab angle, and normal acceleration should be taken during each of the preliminary dives. These data will be useful in helping the pilot determine the proper elevator tab setting to be used during each successive dive.

The test for recovery from a high speed dive should be started by a rapid push-over from level flight at the airplane's service ceiling. As the dive is entered, the recording instruments should be turned on and left on until the maneuver is completed. A dive angle of at least 50° to the horizontal should be established and the dive allowed to develop for at least 15,000 ft. A pull-out should be made by application of force to the control column, or by application of any dive recovery device installed on the airplane.

The test for stick-forces to hold the airplane in high indicated airspeed dives should be started at a lower altitude than for the dive recovery tests as high indicated speeds are required rather than high true speeds. The airplane should be trimmed out in the given configuration in steady level flight and the photo-observer run for a few frames to record the trim condition. The airplane should then be pushed over slowly into a dive; equilibrium speed points should be recorded every 20 miles per hour between $1.4V_{S_P}$ and 90 percent of the maximum permissible diving speed. The elevator trim tab should not be changed during this maneuver from its trim position. It may be necessary to break this test up into two parts in order to get all the points without going to a dangerously low altitude.

4. Reduction of Data.

The data from the dive recovery tests should be presented in the form of a time history of the dive, showing elevator angle, elevator control force, elevator tab angle, calibrated and true airspeed, altitude, Mach number, normal acceleration, and dive recovery device position (if used). A typical time history of such a test is given in Figure 19.

The data from the test for stick force to hold the airplane in a dive should be presented in the form of a plot of stick-force and elevator angle versus calibrated airspeed. The results of a typical test are shown in Figure 20.

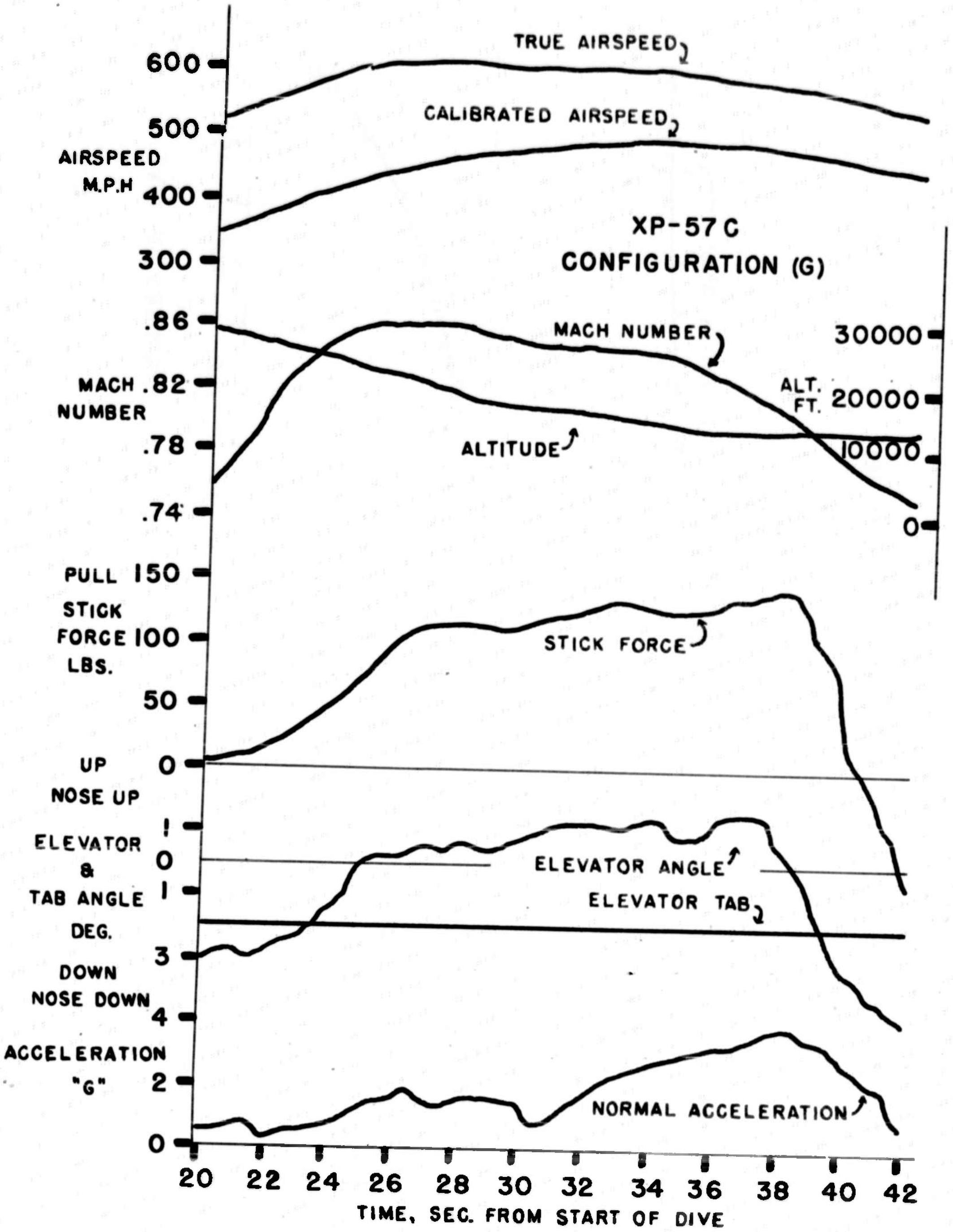


FIG. 19-TIME HISTORY OF HIGH MACH NO. DIVE

XA-27 B

CONFIGURATION (P)

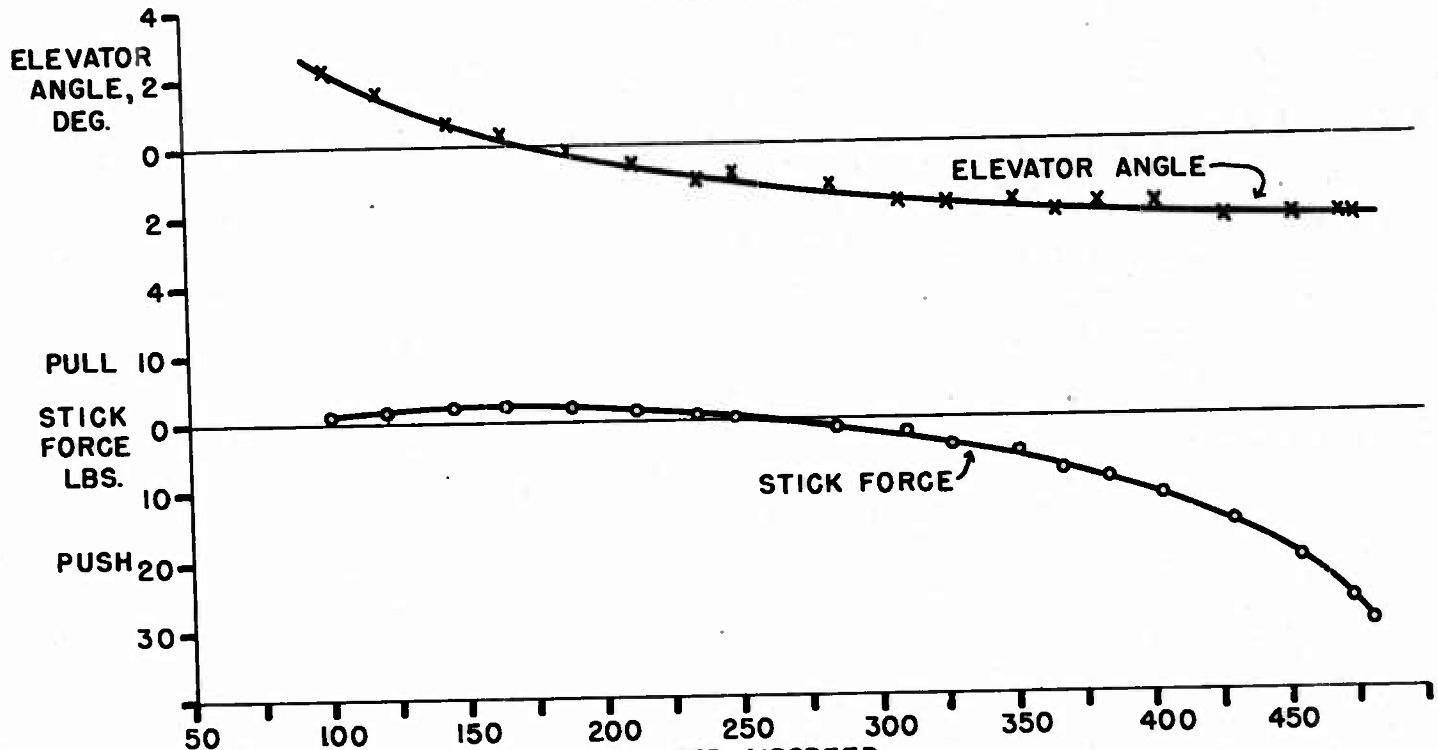


FIG. 20-ELEVATOR ANGLE & STICK FORCE VS. CALIB. AIRSPEED IN DIVE

S E C T I O N II

LATERAL STABILITY AND CONTROL

A. DYNAMIC LATERAL STABILITY

1. Discussion

The heading "Dynamic Lateral Stability" includes all modes of motion in the directional (or yaw) and lateral (or roll) planes. There are four major types of lateral motion that have a bearing on the flying qualities of the airplane, and it is up to the designer to insure that these meet the minimum requirements of A.A.F. Specification R-1815A. The types of lateral motion (modes of motion) that are important include the following:

a. Spiral Stability

Spiral stability or the "spiral mode" is the motion of the airplane that may be observed following a simple banking (displacement in roll) of the airplane from a wings level trim condition. If the airplane is spirally stable, it will return to a wings level position on a new heading; if it is spirally unstable, the airplane will go into an ever tightening spiral dive. However, the spiral dive tightens very slowly at cruising speeds and can be controlled very easily by the pilot. To design the airplane to be spirally stable would require use of design parameters that would adversely affect other more important flying qualities. There is, therefore, no requirement for this type of motion to be stable. If an airplane meets all the other requirements of R-1815A, it will usually be mildly spirally unstable at cruising speed.

b. Dutch Roll

The second type of lateral motion is usually referred to as the "Dutch Roll". This motion is a rolling and yawing oscillation with controls held fixed of short period and weak damping. This oscillation may be observed if the airplane is yawed from a given trim position, the controls then returned to their original position and held fixed. This motion can be bothersome to bombers as it can interfere with the aim of the bombardier during the bombing run, and also quite annoying to the pilots of cargo and fighter airplanes. It is required that this oscillation shall damp to one-half amplitude in two cycles.

c. Rudder and Aileron Snake

The third type of lateral motion is termed "snaking". This motion is control free oscillation in yaw and roll quite similar to the "Dutch Roll" but energized principally by the particular floating characteristics of the free controls. The snaking motion has been encountered by fighter aircraft at high speeds and by cargo and bombardment type airplanes at cruising speeds. Lateral oscillations encountered at cruising speeds may be either control-free or control-fixed oscillations. The two are often quite undistinguishable from each other until the photo-observer record is analyzed. It is required that all snaking modes be damped to one-half amplitude in two cycles, and that they disappear completely in no more than five cycles.

d. Control Surface Oscillation

The fourth type of lateral motion is a pure rudder or aileron oscillation following a disturbance from a trim position. This oscillation is of much shorter period than those discussed above, the motion being merely a pure flapping of the control surface about its hinge. The frequency of this oscillation may be so high that the airplane does not respond to it. It is required that this oscillation of rudder and aileron be completely damped in one cycle.

2. Configurations

a. Spiral Stability

b. Dutch Roll

Class II Airplanes

1. (CR) Cruise at 10,000 feet or critical altitude whichever is the lower.
2. Bombing, flaps and gear up, bomb bay doors open, normal rated power, at speed for level flight at 10,000 feet and at the critical altitude.

Class III Airplanes

1. (P) Power-On, Clean, at the critical altitude.

c. Rudder and Aileron Snake

Class II Airplanes

1. Same as "Dutch Roll"

Class III Airplanes

1. (P) Power-On, Clean, at speeds in 50 m.p.h.

increments between 150 m.p.h. V_1 and 0.8 limit diving speed or terminal Mach number.

d. Control Surface Oscillation

1. The configurations for this mode should be the same as for section (c) above.

3. Pilot Technique

a. Spiral Stability

No tests to be performed.

b. Dutch Roll

The airplane should be trimmed in level flight with power to maintain the given speed with the airplane in the given flight configuration. Yaw the airplane to a steady sideslip, with wings level, of approximately five degrees nose left, by means of applying the necessary rudder and aileron forces. After starting the recording instruments, the controls should be returned rapidly to their trim position and held fixed. The recording device shall be left on until the pilot feels that the ensuing oscillation has been completely damped, or has completed five cycles. The procedure should then be repeated for an equivalent nose right displacement. An alternate method for disturbing the airplane in yaw may be used for a multi-engined airplane. The controls can be held fixed in their trim position and the airplane made to yaw by reducing power on one outboard engine. The photo-recorder can be turned on and the power of the outboard engine reapplied. This procedure has the advantage of not requiring the controls to be moved during the maneuver.

c. Rudder and Aileron Snaking and Control Surface Oscillations

Both of the snaking modes given in l.c. and the control surface oscillation modes given in l.d. can be tested for simultaneously. For Class II airplanes the test proceeds exactly as for the "Dutch Roll" except that instead of returning the controls to their original trim positions, they should be abruptly released. For Class III airplanes, the disturbances first in roll and then in yaw should be started by abruptly deflecting and releasing the aileron and rudder controls respectively, records being taken continuously during the whole maneuver.

4. Reduction of Data

Time histories of rudder and aileron angle, angle of sideslip, and angle of bank (or yawing and rolling velocities) should be plotted versus time. Typical examples of satisfactory and unsatisfactory time histories are shown in Figures 21 and 22.

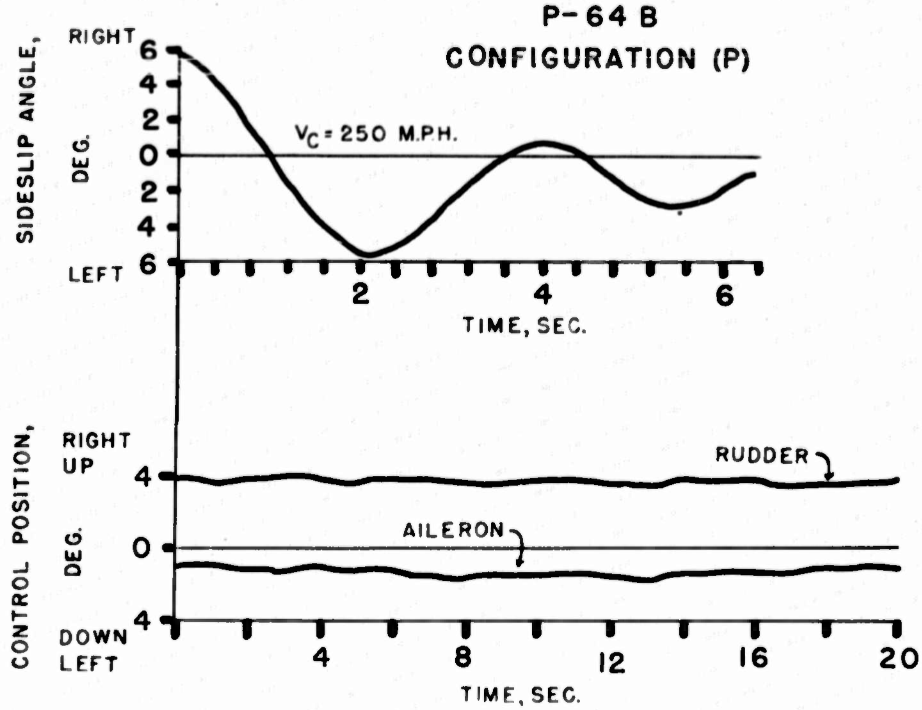


FIG. 21A-SATISFACTORY CONTROL—FIXED LATERAL OSCILLATIONS

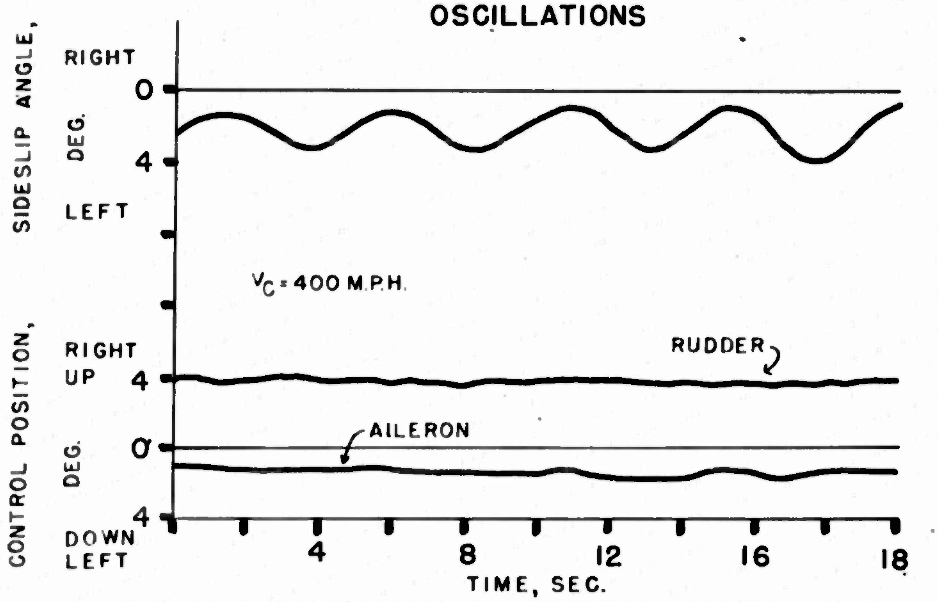


FIG. 21B-UNSATISFACTORY CONTROL-FIXED LATERAL OSCILLATIONS

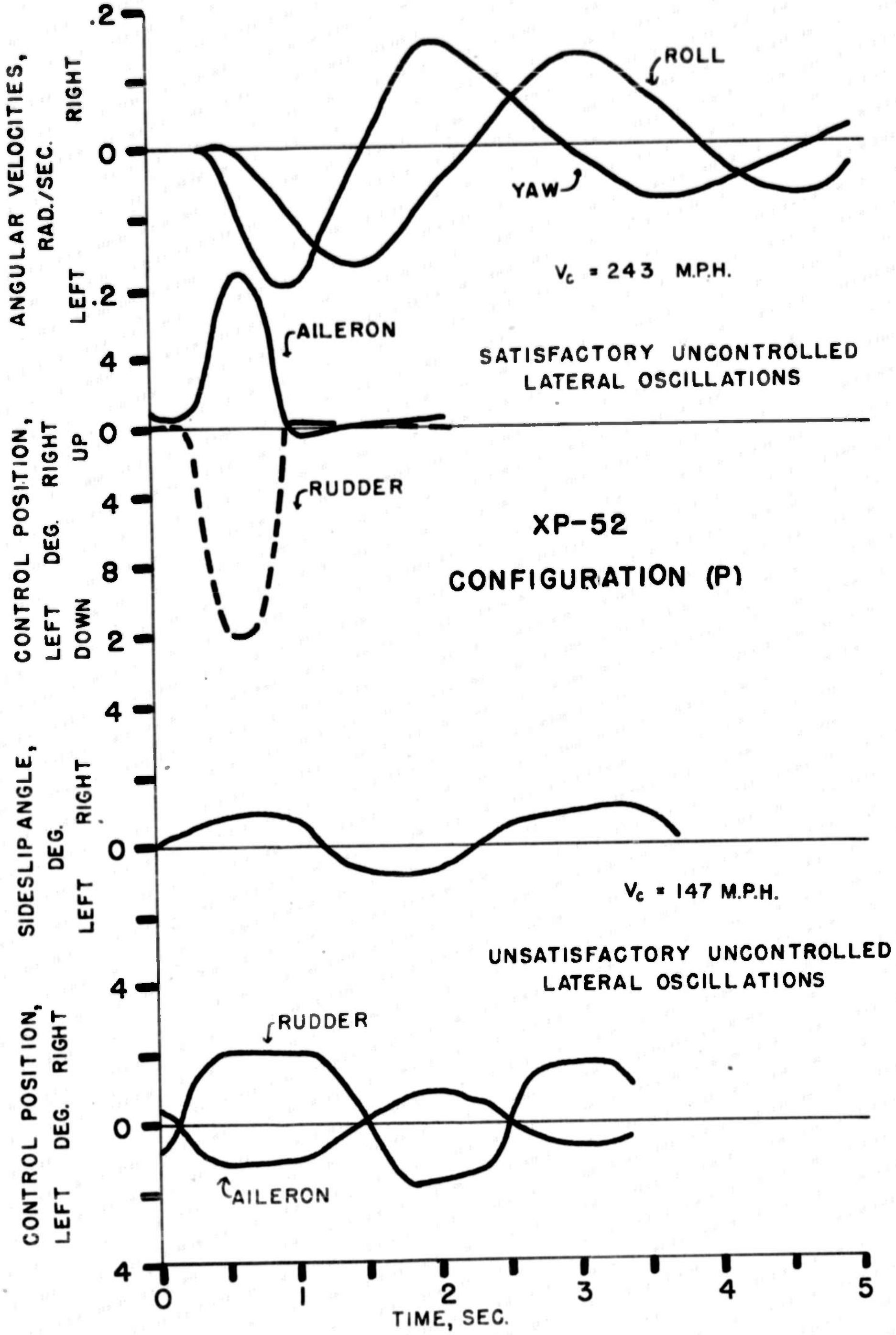

ANGULAR VELOCITIES, RAD./SEC.
LEFT
RIGHT
.2
0
.2
ROLL
YAW
V_c = 243 M.P.H.
AILERON
SATISFACTORY UNCONTROLLED LATERAL OSCILLATIONS
CONTROL POSITION, LEFT DEG. RIGHT
DOWN UP
4
0
4
8
12
RUDDER
XP-52
CONFIGURATION (P)
SIDESLIP ANGLE, DEG.
LEFT RIGHT
4
0
V_c = 147 M.P.H.
UNSATISFACTORY UNCONTROLLED LATERAL OSCILLATIONS
CONTROL POSITION, LEFT DEG. RIGHT
4
0
4
RUDDER
AILERON
0
1
2
3
4
5
TIME, SEC.

FIG. 22

B. AIRPLANE SIDESLIP CHARACTERISTICS

1. Discussion

Flight tests of the airplane in steady sideslip maneuvers can demonstrate many of the airplane's static directional and lateral stability and control features. The variation of rudder and aileron angle required to force the airplane to increasing angles of sideslip can demonstrate the existence of static directional stability and static lateral stability or dihedral effect. The exact magnitude of these stabilities cannot be determined directly from these tests, as the rudder and aileron control powers are tied up with the stabilities to give these variations. The magnitude of the rudder and aileron control forces required to produce increasing sideslip angles gives a picture of the feel of these control surfaces near zero sideslip and demonstrates the existence or non-existence of rudder lock or aileron force reversal at large angles of sideslip. The elevator angle and force required to maintain the given airspeed during these sideslip maneuvers gives an indication of the change in trim with sideslip, while the angle of bank required to maintain straight flight during these sideslip maneuvers gives an indication of the airplane's side force characteristics. The variation of rudder and aileron angle with steady sideslip is nearly independent of speed, but the angle of bank and control forces in steady sideslips vary rapidly with speed. All of these characteristics vary widely with power, altitude and configuration.

The directional stability of the airplane is adversely affected by the propeller, usually becoming more critical with increasing altitude. The lateral stability of the airplane is usually most critical with flaps down and with high power. Flight tests, therefore, should include runs to cover these critical conditions.

	2.	Configurations	Speeds	Altitude
a.	L	(Landing)	1.2 V_{S_L} and 1.6V_{S_L}	5,000 ft.
b.	A	(Approach)	1.2 V_{S_A} and 1.6V_{S_A}	5,000 ft.
c.	A	(Approach) except with 100 % NRP	1.2V_{S_A} and 1.6V_{S_A}	5,000 ft.
d.	(P)	Power on Clean	1.2 V_{S_P} to max. speed level flight (5 speeds)	5,000 ft.
e.	(P)	Power on Clean	1.2 V_{S_P} to max. speed level flight (5 speeds)	25,000 ft. or highest practical altitude below this.

3. Pilot Technique

The test is started by trimming the airplane for wings-level flight at the given trim speed and power settings. The airplane is placed in an equilibrium sideslip maintaining the same course. It should be noted that the forward wing will have to go down as the angle of sideslip is increased in order to maintain the straight flight path required. The pilot should place the airplane in a series of ever increasing equilibrium sideslips, both right and left, holding very carefully the given trim speed. Records of rudder, elevator and aileron deflections and forces, angle of bank, and sideslip angle should be taken at each equilibrium point. An alternate method can be used, after some experience in this type of testing has been acquired. This method consists of making a slow continuous sideslip maneuver (rate not to exceed one degree of sideslip per second), during which continuous instrument records are taken, the speed and course being held constant as the angle of sideslip is slowly increased until limited by full rudder travel or maximum pedal force.

4. **Reduction of Data**

Plots of rudder, elevator and aileron angles and forces, and angle of bank should be plotted against angle of sideslip. Typical satisfactory and unsatisfactory curves of sideslip characteristics are shown in Figures 23 and 24.

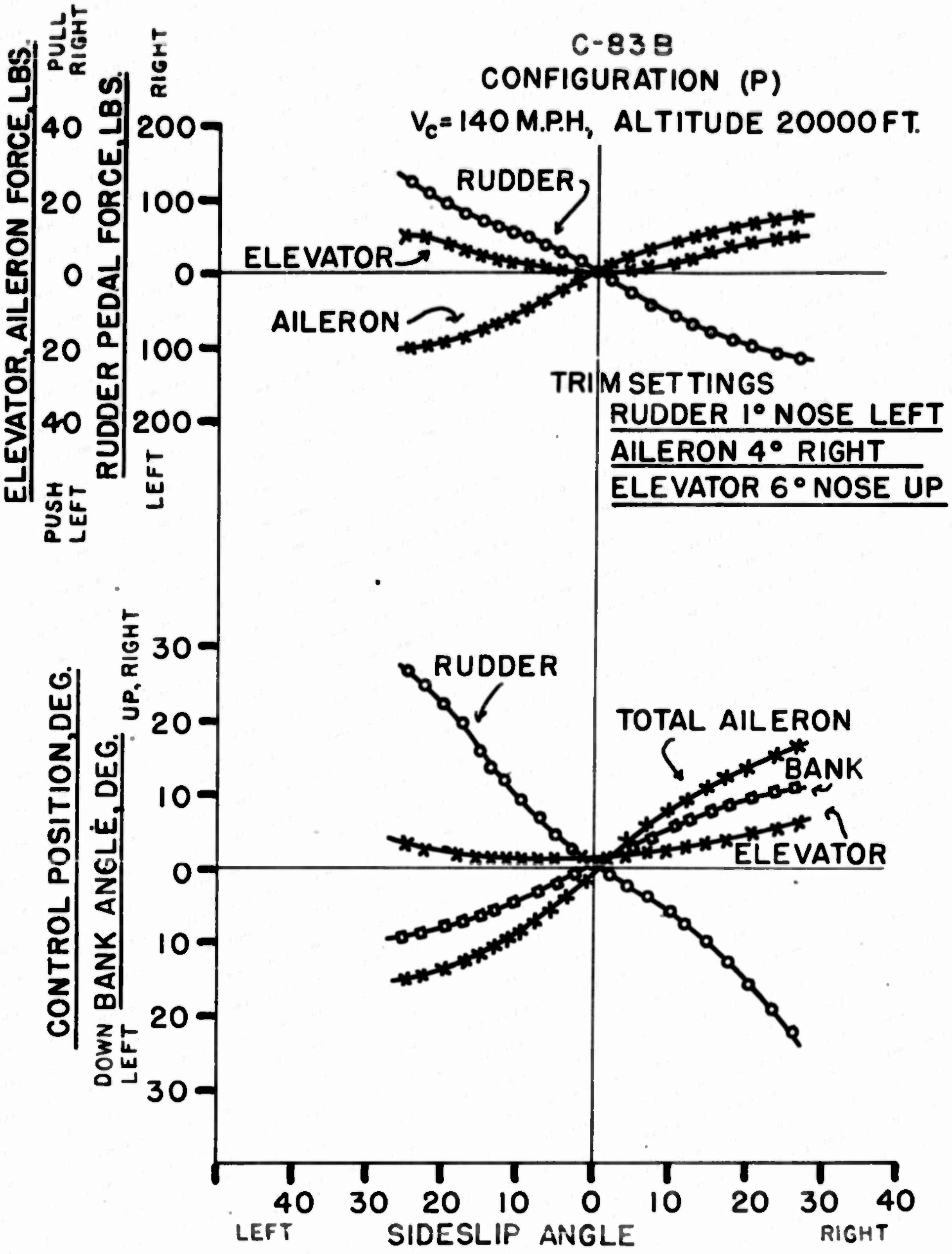


FIG. 23-ACCEPTABLE SIDESLIP CHARACTERISTICS

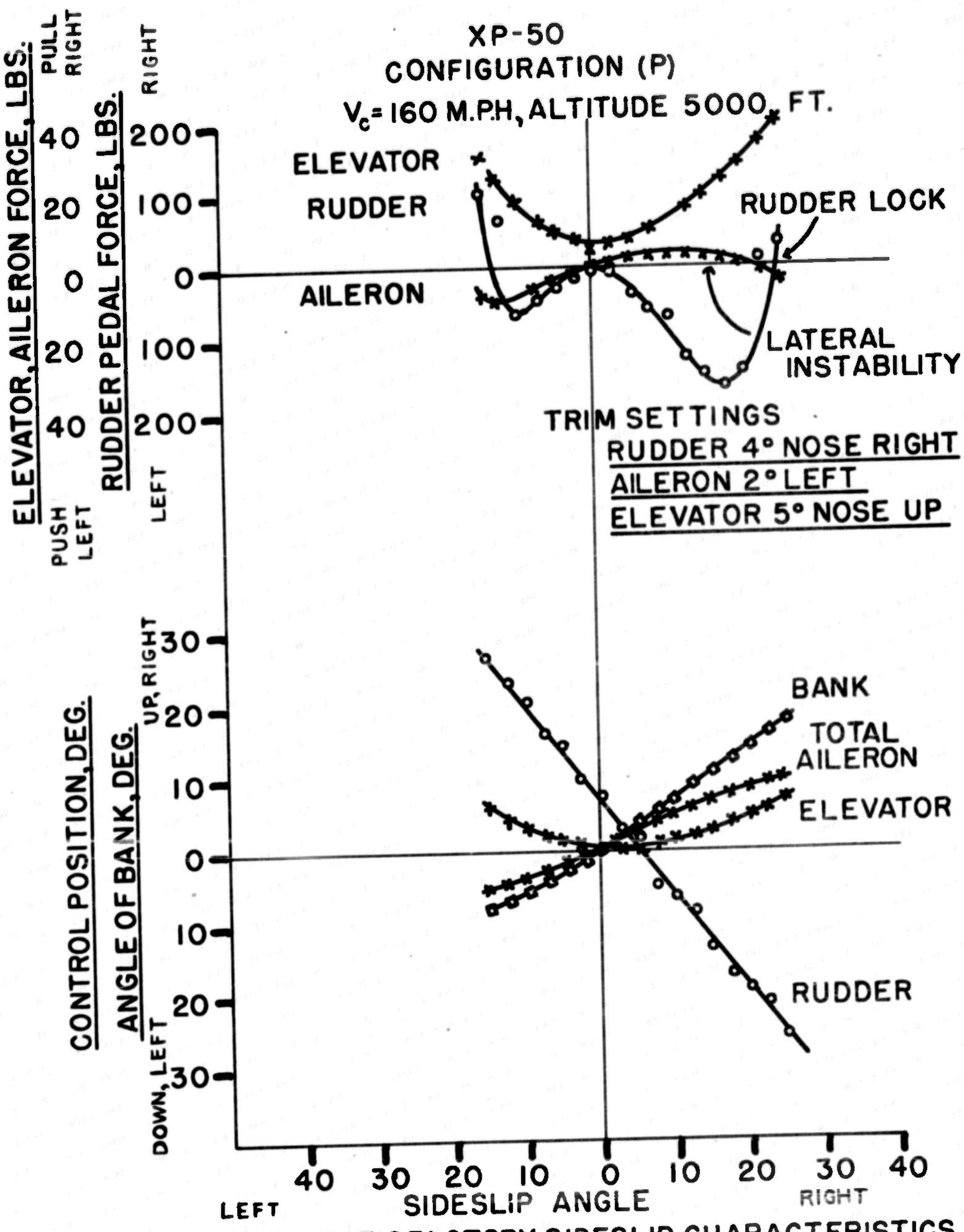


FIG. 24- UNSATISFACTORY SIDESLIP CHARACTERISTICS

C. DIRECTIONAL STABILITY, ADVERSE YAW AND RUDDER COORDINATION

1. Discussion

In any rolling maneuver, yawing moments are developed due to the aileron deflection and due to the inclination of the lift vectors on the wing during a roll which tend to make the downgoing wing move forward and the upgoing wing move aft. In a right roll, for instance, the yawing moments tend to produce right sideslip (the nose will tend to move to the left) and it is necessary for the pilot to apply right rudder to offset this. These yawing moments are termed adverse yaw, for as an airplane is rolled into a right turn, these yawing moments tend to make the airplane turn to the left and right rudder must be carried to hold zero sideslip or, to put it in other words, to coordinate the turn. The amount of sideslip developed in uncoordinated rolling maneuvers, due to the adverse yaw, is a function of the airplane's directional stability, while the adverse yaw itself is a function of the aileron geometry, and power, and the airplane's lift coefficient. If the airplane has high directional stability, the sideslip developed in an uncoordinated roll will be small compared to that for an airplane with low directional stability. Coordination of the rolls, therefore, is easier for the pilot if the airplane has high directional stability. Tests should be run on every airplane to investigate both the sideslip developed in uncoordinated rolls and ability of the rudder to overcome the adverse yaw in coordinating the rolls. The critical conditions for maximum sideslip in uncoordinated rolling maneuvers are high trim lift coefficient or low speed, and abrupt full aileron deflection. Tests should be run with the airplane in this critical configuration, firstly to determine the sideslip developed and from this the directional stability level of the airplane; and, secondly, to determine the ability of the rudder to overcome this adverse yaw, as one of the basic requirements on the rudder design is that it be able to coordinate the rolls down to speeds approaching the stall. The flight tests should investigate the sideslip developed in abrupt full aileron rolls with the rudder locked in its trim position, and then, in similar rolls, the ability of the rudder to overcome the adverse yaw and maintain zero sideslip.

2. Configurations

a. (G) Glide except with level flight power at $1.4V_{S_G}$

b. (PA) Power Approach except with level flight power at $1.4\ V_{S_{PA}}$

3. Pilot Technique

The airplane is to be trimmed at the given speed in a steady 45-degree banked turn with the airplane in the given configuration. With the rudder held locked in its trim position and the photo-observer taking continuous recordings, the ailerons should be abruptly given 1/4, 1/2, 3/4 and full deflection to roll out of the turn, the roll being continued until 45 degrees opposite bank is achieved. This test is to be made for left and right roll-outs. Following this, the test is to be repeated for the same configurations, except that the rudder shall be used in an attempt to maintain zero sideslip during the roll-outs.

4. <u>Data Reduction</u>

Plots of rudder angle, sideslip angle, angle of bank, and aileron angle shall be made versus time. A typical time history is shown in Figure 25.

It will be noted that the roll-outs were made starting in a banked turn of only 30 degrees. The flight engineer must often use discretion in interpreting requirements; in this case, a heavy cargo airplane was involved and it was considered inadvisable to bank the airplane 45 degrees.

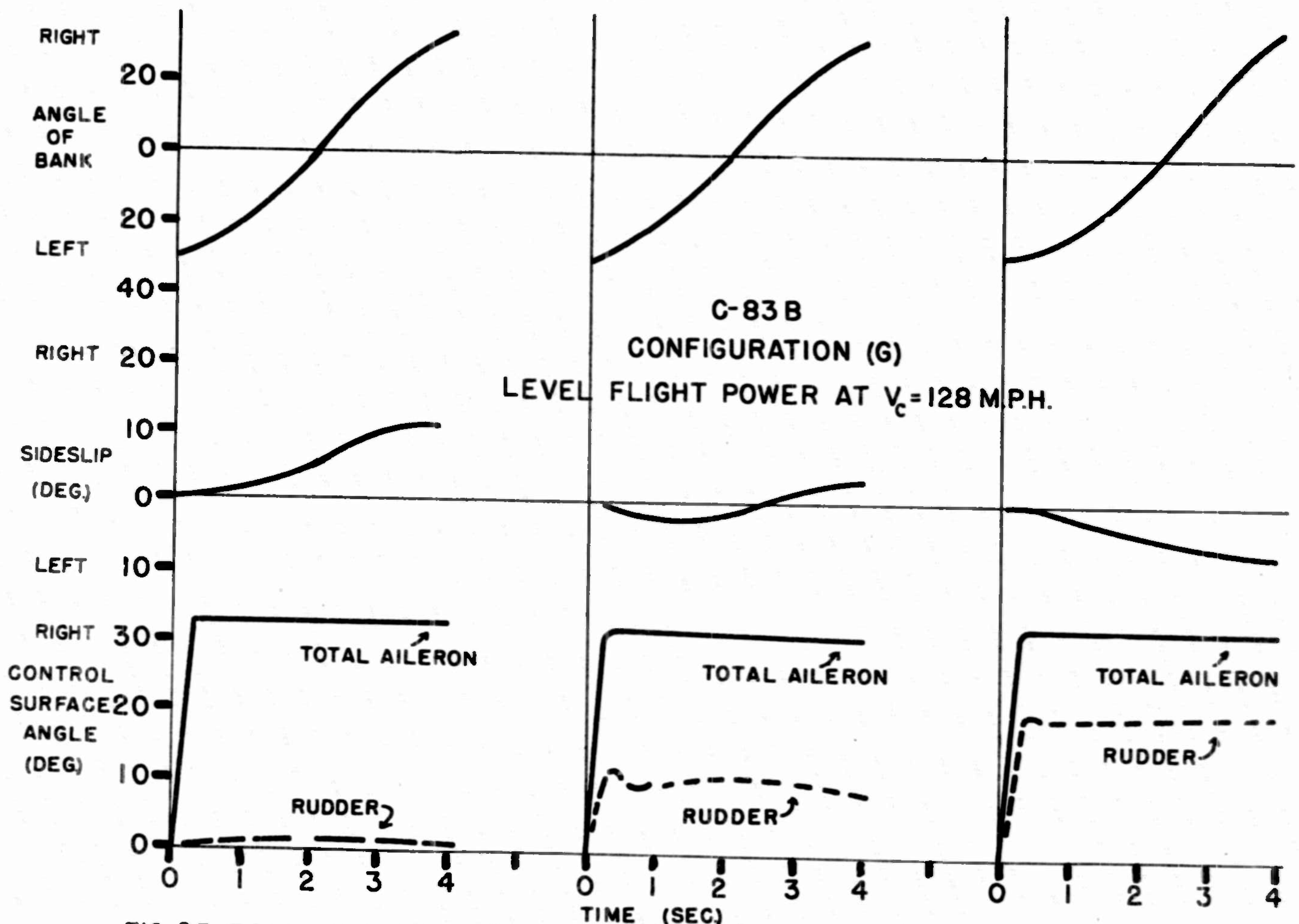


FIG. 25-ROLL-OUTS WITH FULL AILERON & VARYING AMOUNTS OF RUDDER

D. ASYMMETRIC POWER

1. Discussion

In designing any multi-engined airplane it is necessary to provide for the emergency flight condition of a power failure of one or more engines during take-off. The airplane must be provided with adequate directional stability and control to enable the airplane to be flown safely at speeds close to the stall with asymmetric power. One of the most important flight tests of any multi-engine airplane is to determine the safe minimum speed at which the airplane can be flown with one or more engines windmilling and the others drawing full take-off power. The safe minimum speed is the speed below which the airplane cannot be trimmed for zero sideslip, either due to running out of rudder travel or due to excessive pedal forces which make it impossible for the pilot to deflect the rudder to the required angle. It is also required that if an engine fails in cruising flight at the speed for maximum L/D, the equilibrium angle of sideslip that the airplane will reach with all controls left free will be no greater than 20 degrees. Finally, it is important to determine the speed below which it is impossible to trim out the rudder forces by means of the rudder trim tab.

2. Configurations

The airplane is to be tested in the take-off configuration, with the flaps in their best take-off setting, gear down, with one

›r more outboard engines windmilling (low pitch) and all other ngines developing full take-off power.

3. Pilot Technique

To determine the airplane's asymmetric power character-stics, the following tests should be made. The airplane should e trimmed out at a speed approximately 1.4 times the stalling speed, with all engines drawing full take-off power. Without changing the trim tab setting, the airplane's speed should be increased to approximately 1.8 V_S at which point the throttle of one outboard engine should be closed and the engine allowed to windmill. By means of the lateral and directional controls the airplane should be brought into equilibrium straight flight at zero sideslip. With the airplane in equilibrium, records should be taken of rudder pedal force, aileron wheel force, rudder, rudder tab, and aileron deflection and angle of sideslip. The speed should then be reduced in convenient steps, records being taken at each step, until either the rudder reaches full deflection, the rudder pedal forces become too high, or the stall is reached. This test should then be repeated with two engines on one side windmilling, and so on until full asymmetry (all the engines on one side windmilling, all of the engines on the other side drawing take-off power) is achieved. The same test should then be run again, but this time the trim tab should be used in an attempt to trim out the rudder pedal forces at each equilibrium speed. Finally, the airplane should be trimmed out at the speed for L/D max and, with the rudder left free, one outboard engine should be rapidly throttled and continuous records taken as the airplane responds and reaches an equilibrium attitude. The ailerons should be used to hold the wings level during this maneuver.

4. Reduction of Data

Plots of aileron, rudder and rudder trim-tab angle, angle of sideslip, rudder and aileron force and angle of bank should be plotted versus calibrated airspeed. There should be one plot for each of the configurations tested.

A time history should also be plotted showing the motion of the airplane and its controls following the closing of the throttling of an outboard engine at a speed corresponding to that for L/D max with the rudder left free. Plots of rudder angle, aileron angle, sideslip angle, and angle of bank should be given versus time.

Typical examples of these curves are shown in figures 26 and 26a.

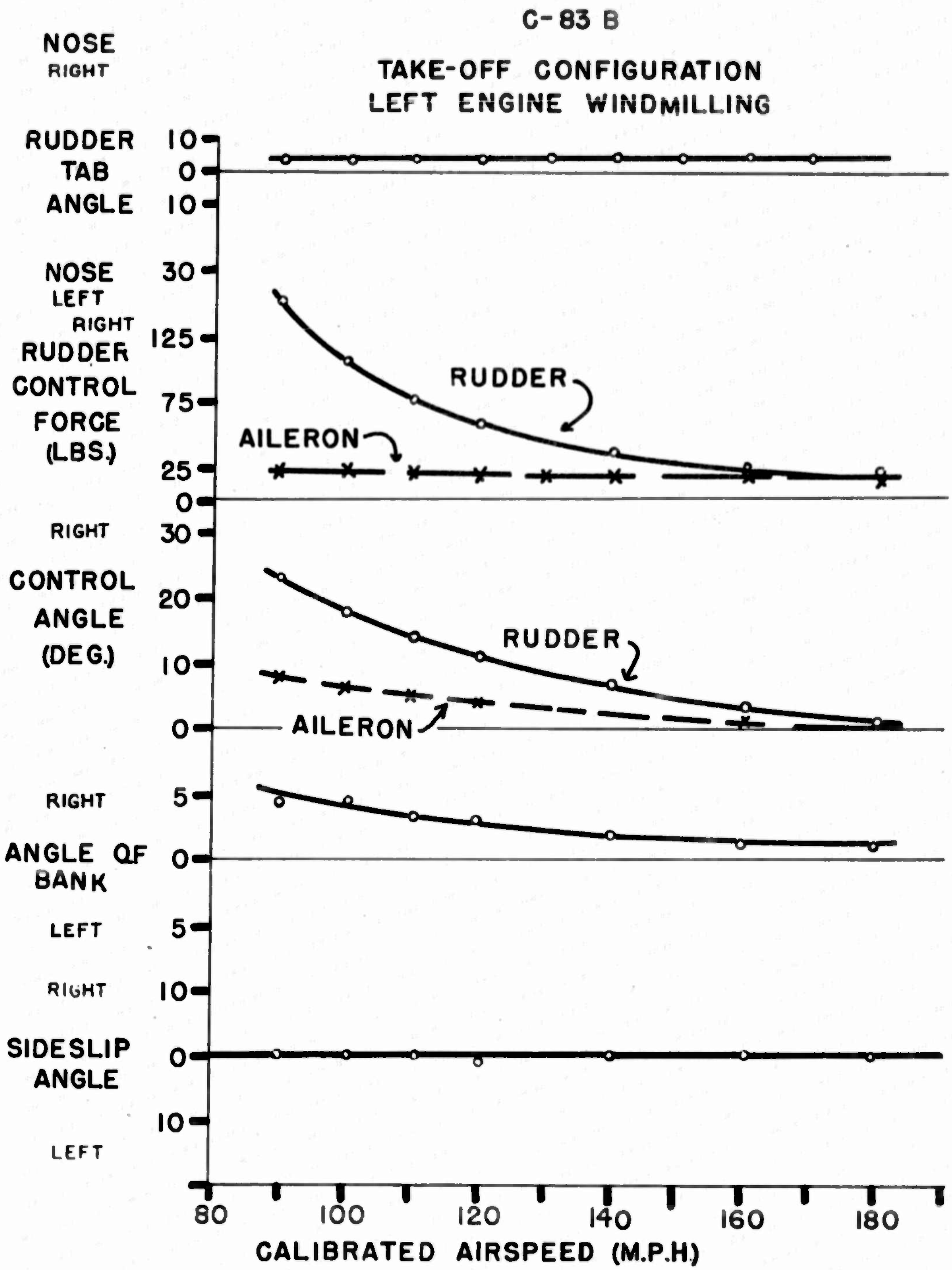


FIG. 26-STEADY STRAIGHT FLIGHT WITH ASYMMETRIC POWER

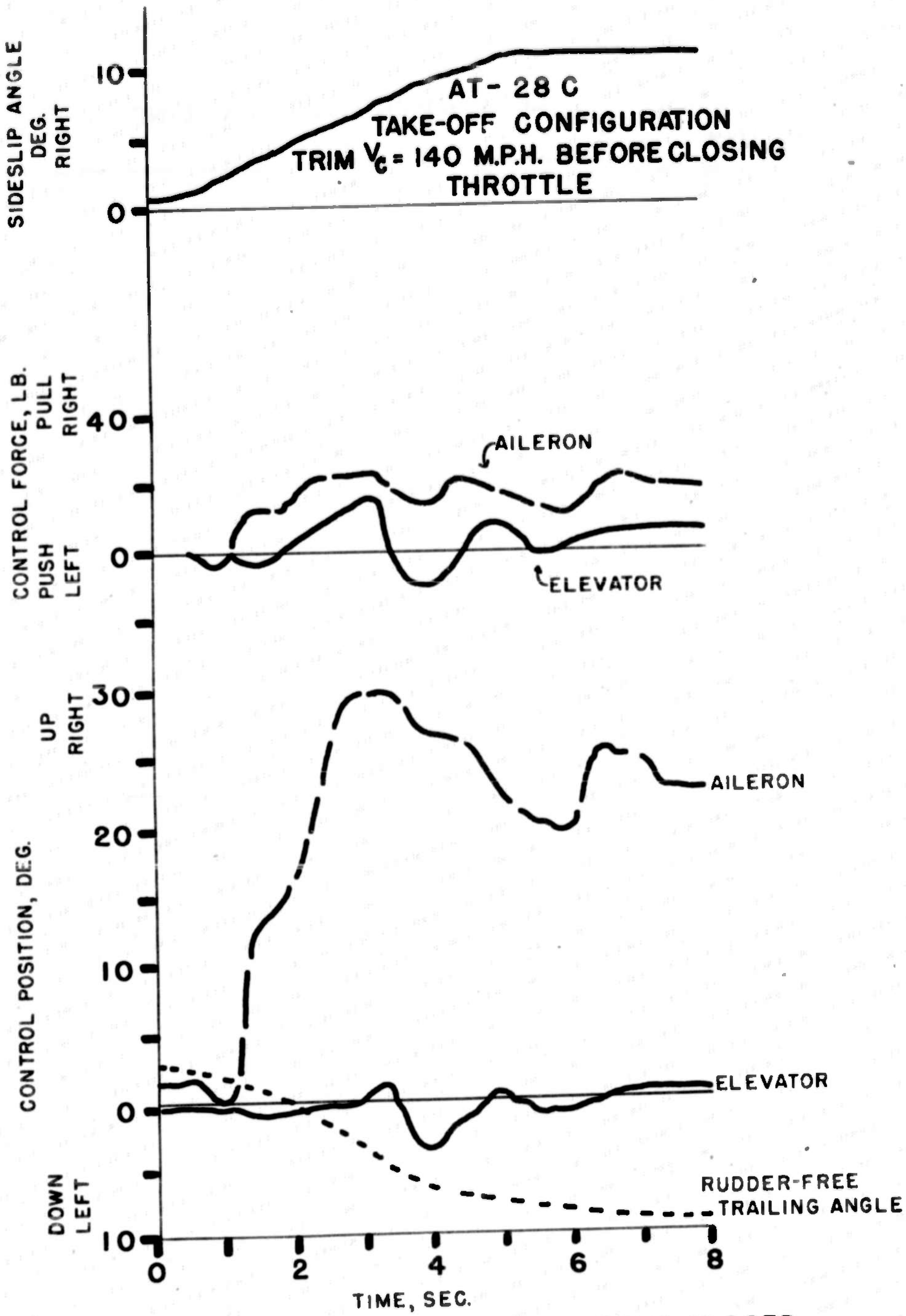


FIG. 26A– TIME HISTORY, LEFT THROTTLE CLOSED ABRUPTLY, WINGS LEVEL

E. <u>RUDDER PEDAL FORCES IN DIVES</u>

1. <u>Discussion</u>

All airplanes required to make high speed dives as a tactical maneuver (Class III and IV airplanes) should not encounter excessive rudder or aileron forces that require the pilot to constantly retrim as the dive progresses. On all normal airplanes with single rotation propellers, the vertical tail can be set to counteract the slipstream rotation at one speed only. This is usually at the airplane's cruising speed. As the speed of the airplane changes the slipstream rotational velocity also changes, which alters the angle of attack of the vertical tail and will cause the airplane to slip unless corrected by the rudder and the aileron. The rudder and aileron force required by the pilot to hold the wings level and the ball centered as the airplane is pushed over into a dive should be low enough so that is is not necessary for the pilot to reset the rudder or aileron trim tab.

2. <u>Configurations</u>

Only Class III and IV airplanes are to be tested for this characteristic. The airplane is to be tested in one or two configurations as listed below:

a. (P) Power on Clean

b. (D) Dive

3. <u>Pilot Technique</u>

The airplane is to be trimmed at 10,000 feet, in the given configuration. The airplane's speed is then increased in steps by diving, without changing the rudder trim tab setting. At each equilibrium speed instrument records are to be taken. It is not necessary to fly at the maximum permissible diving speed, as it will be possible to extrapolate the answers to this speed. It is suggested that at least ten equilibrium speeds be recorded above the level flight trim speed with the highest speed in the neighborhood of 80 percent of the limit diving speed, and that about five equilibrium speeds be recorded at speeds below the initial trim point.

4. Reduction of Data

The flight test data should be presented as curves of rudder and aileron deflection, rudder and aileron forces and angle of sideslip versus calibrated airspeed for each of the configurations tested. A typical curve is shown in Figure 27.

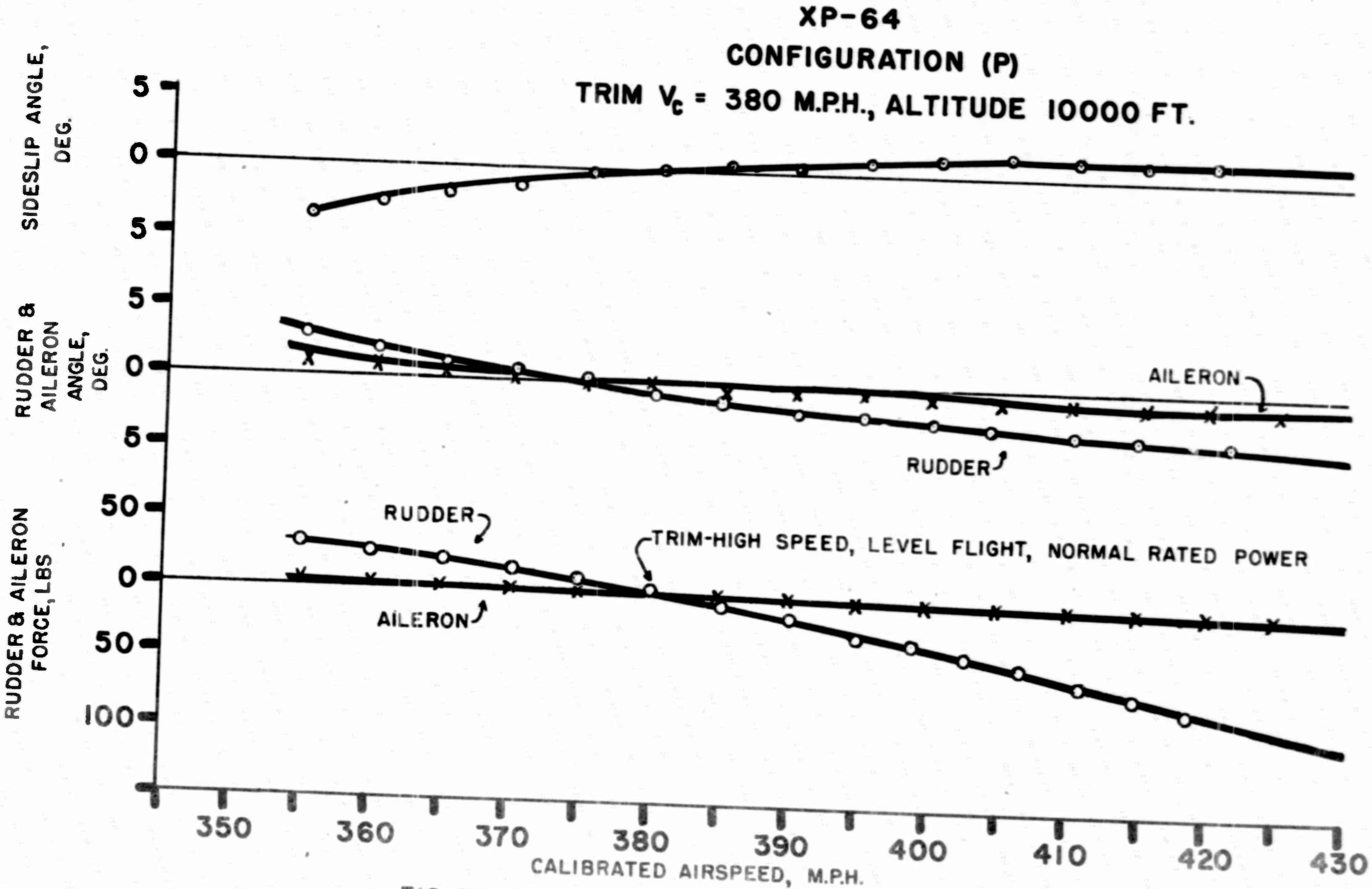


FIG. 27–RUDDER PEDAL FORCES IN DIVES

F. LATERAL CONTROL

1. Discussion

The airplane's lateral control is probably the most difficult to design. The aileron has a number of major functions; one of these is that it shall be big enough to give sufficient control to pick up a wing at low speeds, another is that it give adequate rolling velocities at high speeds without exceeding certain stick force limitations. A third function is that it must balance the rolling moments during sideslip maneuvers, and a fourth, that it must trim the airplane laterally in asymmetric flight conditions. Of these requirements, the ones on the rolling velocities are the most important and it is with these characteristics that this section will deal.

The tactical requirements on available rate of roll for a given airplane have become much more severe during the past few years, for it has been found that a slight advantage in rate of roll can be a decisive factor in combat. The flight tests of any airplane should determine the aileron control characteristics so that the airplane's tactical advantage or disadvantage can be evaluated.

2. Configurations

In order to determine these aileron characteristics it is necessary to flight test the airplane in the following configurations:

a. (L) Landing at 1.10 and 1.50 V_{S_L} at 10,000 feet.

b. P (Power-on Clean) except with power for level flight but not exceeding normal rated power in about seven speed steps from 1.2 V_{S_P} to approximately 80 percent limit diving speed at 10,000 feet.

3. Pilot Technique

The test should be started by trimming out the airplane with wings level in the given configuration at the given speed. Abrupt aileron rolls should be made both to the left and right with rudder held fixed. Continuous photo-observer records should be taken throughout each rolling maneuver. Rolls should be made at each speed with 1/4, 1/2, 3/4 and full aileron deflection applied abruptly. If a gyro-horizon is used as a recording instrument, care should be taken not to roll past 70 - 80 degrees in these maneuvers to prevent dumping the gyro. If a rate of roll indicator is being used the airplane can be rolled past the vertical. In order to facilitate abrupt deflections to a given setting, it is recommended that a chain or similar device be installed at the side of the cockpit with stops to limit the deflections to those required. During the higher speed rolls, full aileron deflection will be impossible due to force limitations, and the deflections used should be respaced to obtain four deflections up to the limiting deflection obtainable.

4. Data Reduction

The flight test data should be presented in the following curves:

a. Time histories of aileron angle, rolling velocity and angle of sideslip for the power-on configuration for left and right rolls at 1.2 V_{S_P} and at the speed for level flight with normal rated power. It is not necessary to present time histories for all the rolls made; however, the maximum rolling velocities and total aileron angles should be obtained at each speed to allow summary curves.

b. Plots of change in aileron force with change in aileron angle at the various trim speeds for each configuration tested.

c. The rolling velocity in radians/second should be combined with the airplane's forward velocity (v) in ft/sec and the wing span (b) in ft. to form the non-dimensional ratio pb/2V. Curves of pb/2V versus variation of aileron angle should be presented.

d. Curves of rolling velocity (degrees per second), total aileron angle and the helix angle pb/2V versus calibrated airspeed in mph for 10,000 feet altitude and a force limitation of 50 pounds for a stick or 80 pounds for a wheel.

e. For Class II airplanes a curve of pb/2V versus wheel throw, at 70 % maximum indicated level flight speed in configuration (P).

Typical curves are shown in Figures 28 through 30.

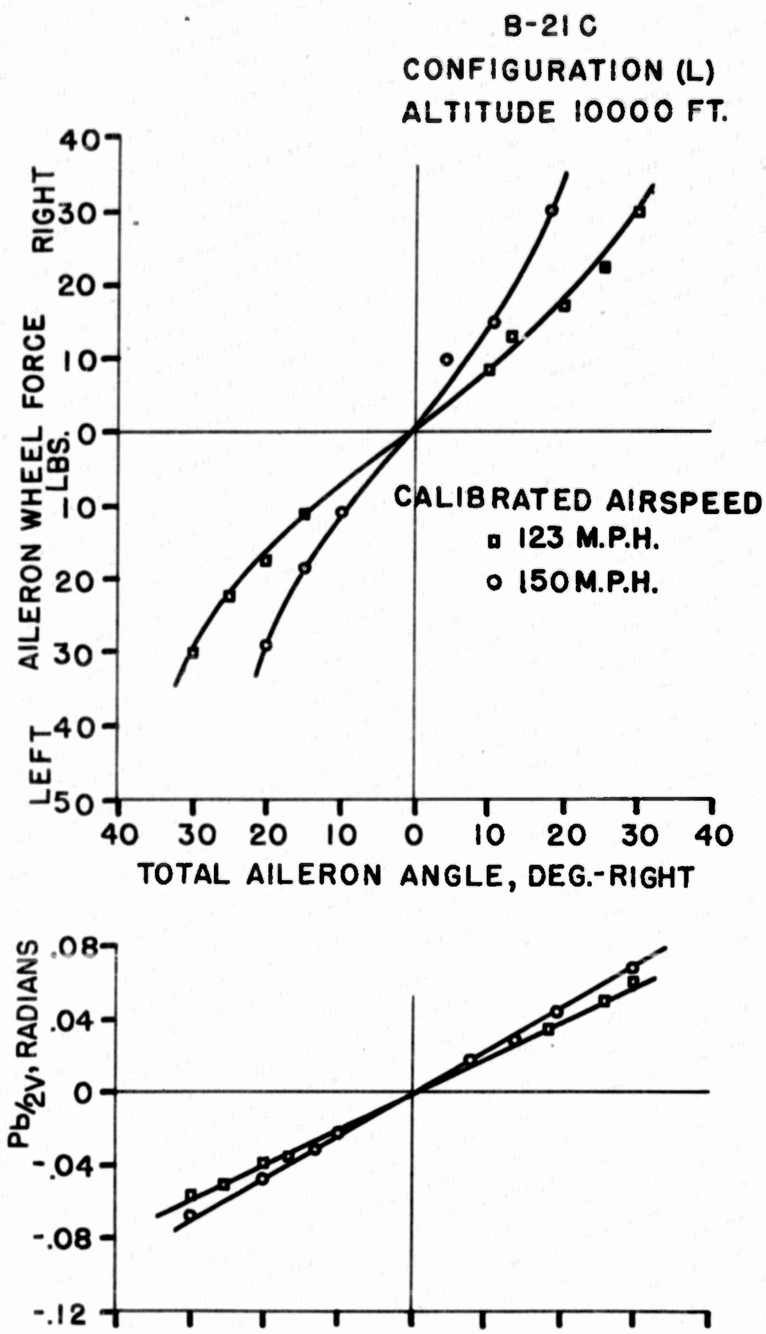


FIG. 28- AILERON WHEEL FORCE & HELIX ANGLE VS. TOTAL AILERON ANGLE

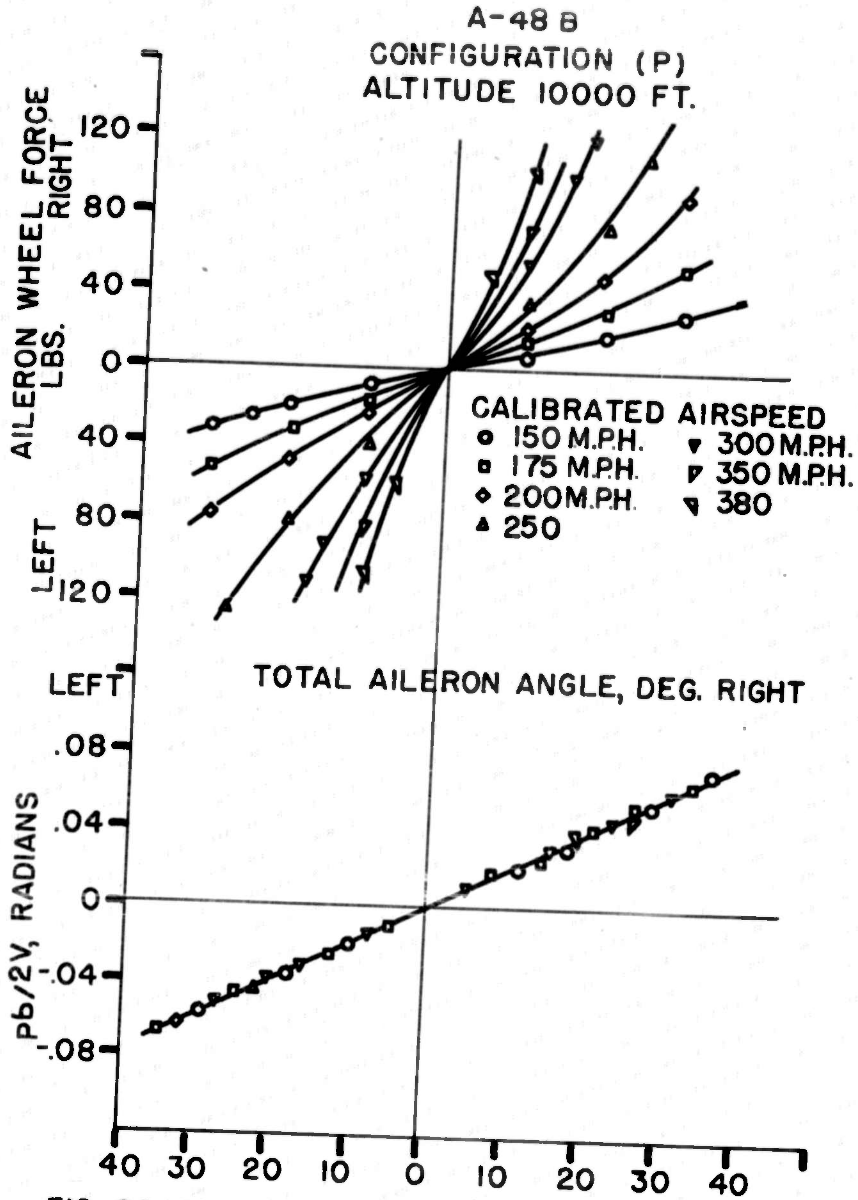


FIG. 29-AILERON WHEEL FORCE & HELIX ANGLE VS. TOTAL AILERON ANGLE

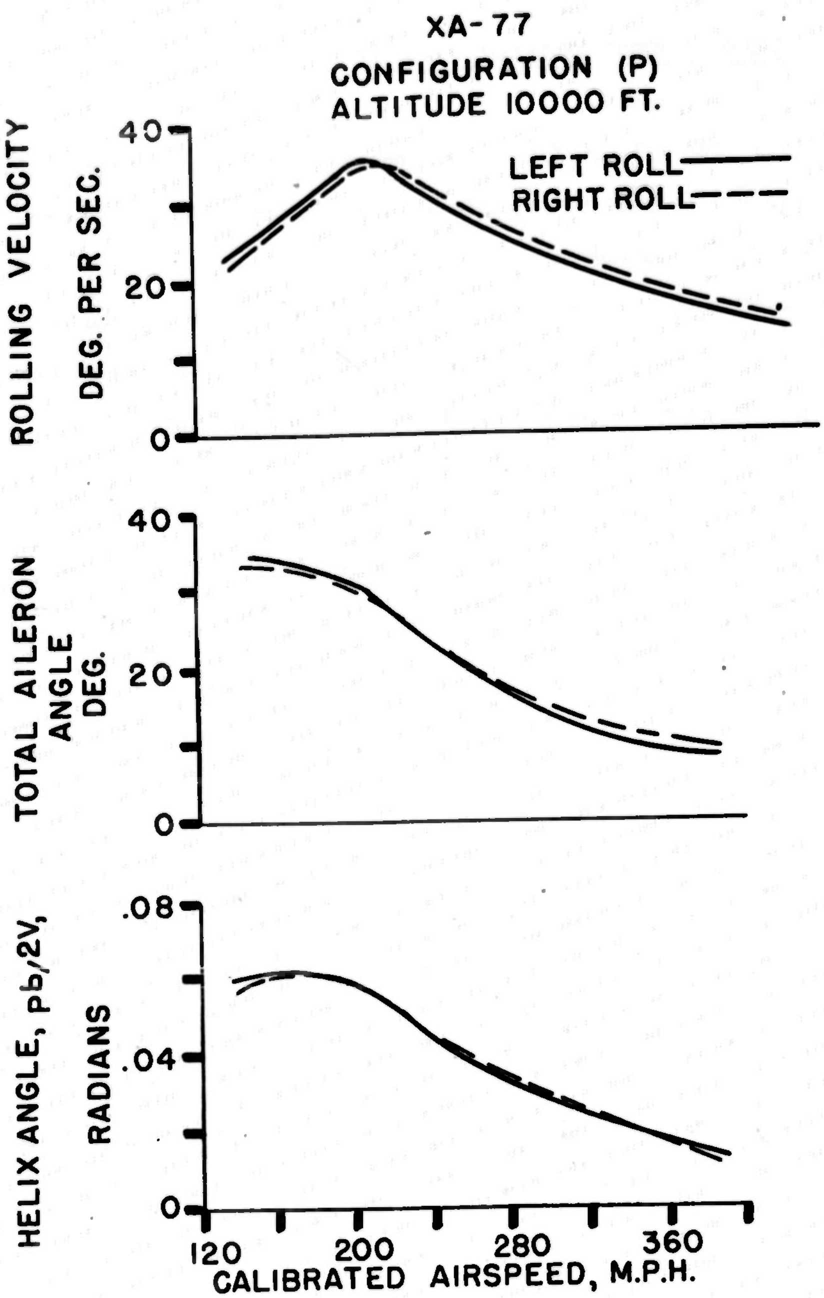


FIG. 30-ROLLING CHARACTERISTICS VS. AIRSPEED FOR 80 LB. WHEEL FORCE

G. RUDDER CONTROL IN TAKE-OFF AND LANDINGS

1. Discussion

For all airplanes it is necessary to provide sufficient directional control to maintain straight ground paths during the take-off and landing runs. The directional controls available to the pilot during these runs are the rudder, the brakes, and the throttles (for twin-engine airplanes). At the slower speeds just as the airplane starts to roll the brakes are usually used as the major directional control, and as the airplane picks up speed the rudder becomes more and more effective. Qualitative tests to determine these control characteristics should be made. Instrumented tests are not essential, as the test pilot can quickly determine the extent of this control.

2. Configurations

The airplane should be tested in the take-off and the landing configurations. Tests should be made in cross-winds of such velocity that its component at right angles to the airplane is approximately 20% V_{S_L}

3. Pilot Technique

The pilot shall make cross-wind take-offs and landings with the wind coming from the critical side. During the take-off run the pilot shall try to maintain a straight ground run by use of rudder, brakes or throttles. If instrument records are taken during this test, they should be taken continuously from the start until the airplane leaves the ground. The pilot then makes normal landings in the same cross-wind again attempting to hold straight ground paths. Any instrument records should be continuous during the whole landing from a time when the airplane is approximately 20 ft. off the ground until the airplane stops.

4. Reduction of Data

Flight test curves are not essential for this test. The pilot can rapidly determine if the airplane will meet this requirement. If the airplane is marginal in this respect, then instrumented flight tests will be necessary. Plots of rudder angle, rudder force, elevator angle, sideslip angle, and calibrated airspeed are then plotted versus time. Typical time histories of a landing and take-off are shown in Figures 31 and 32.

P-48 N

CONFIGURATION (L)

WIND - 15 M.P.H. FROM THE LEFT

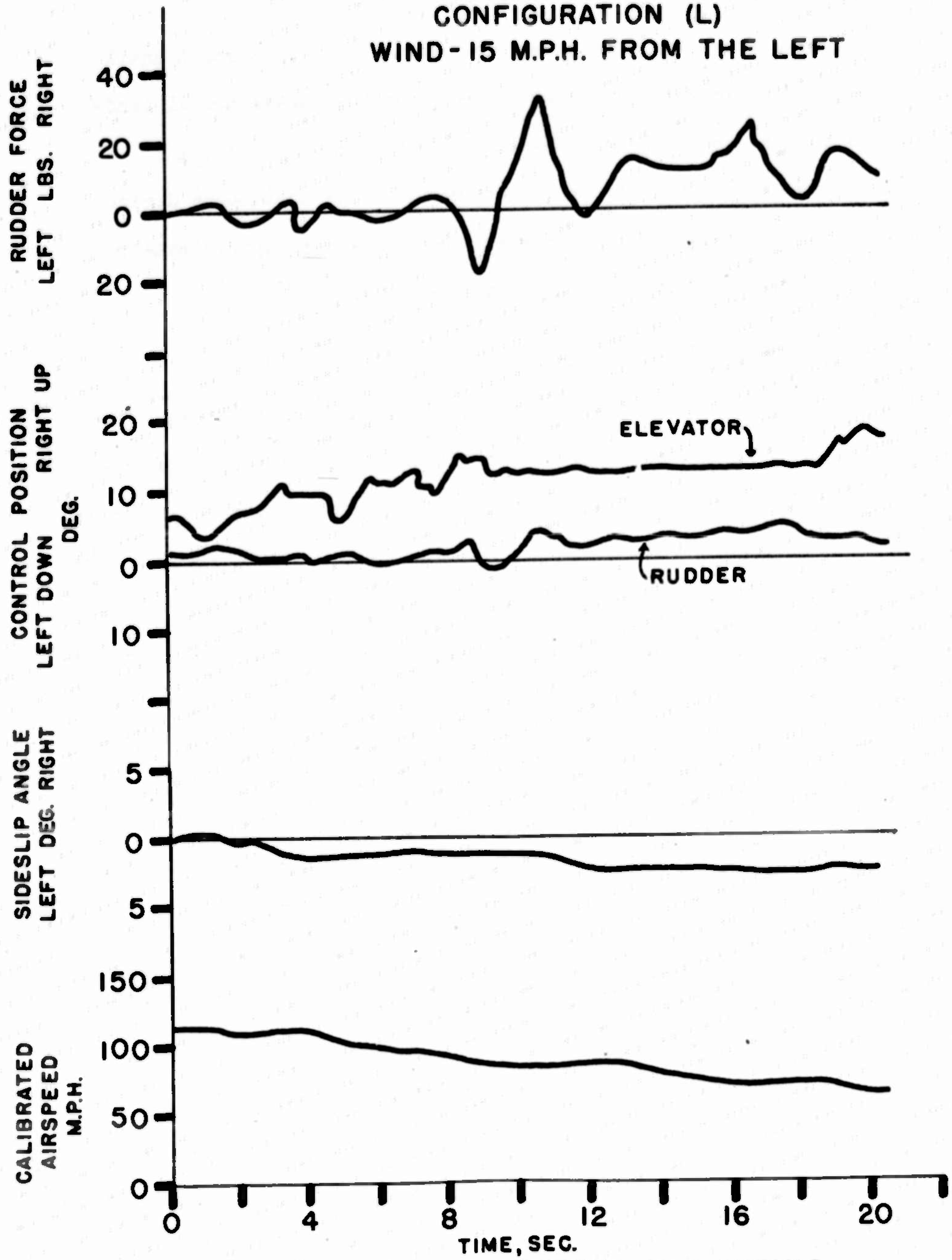


FIG. 31 - RUDDER CONTROL IN LANDING

A-16 B
TAKE-OFF CONFIGURATION
WIND- 18 M.P.H. FROM THE LEFT

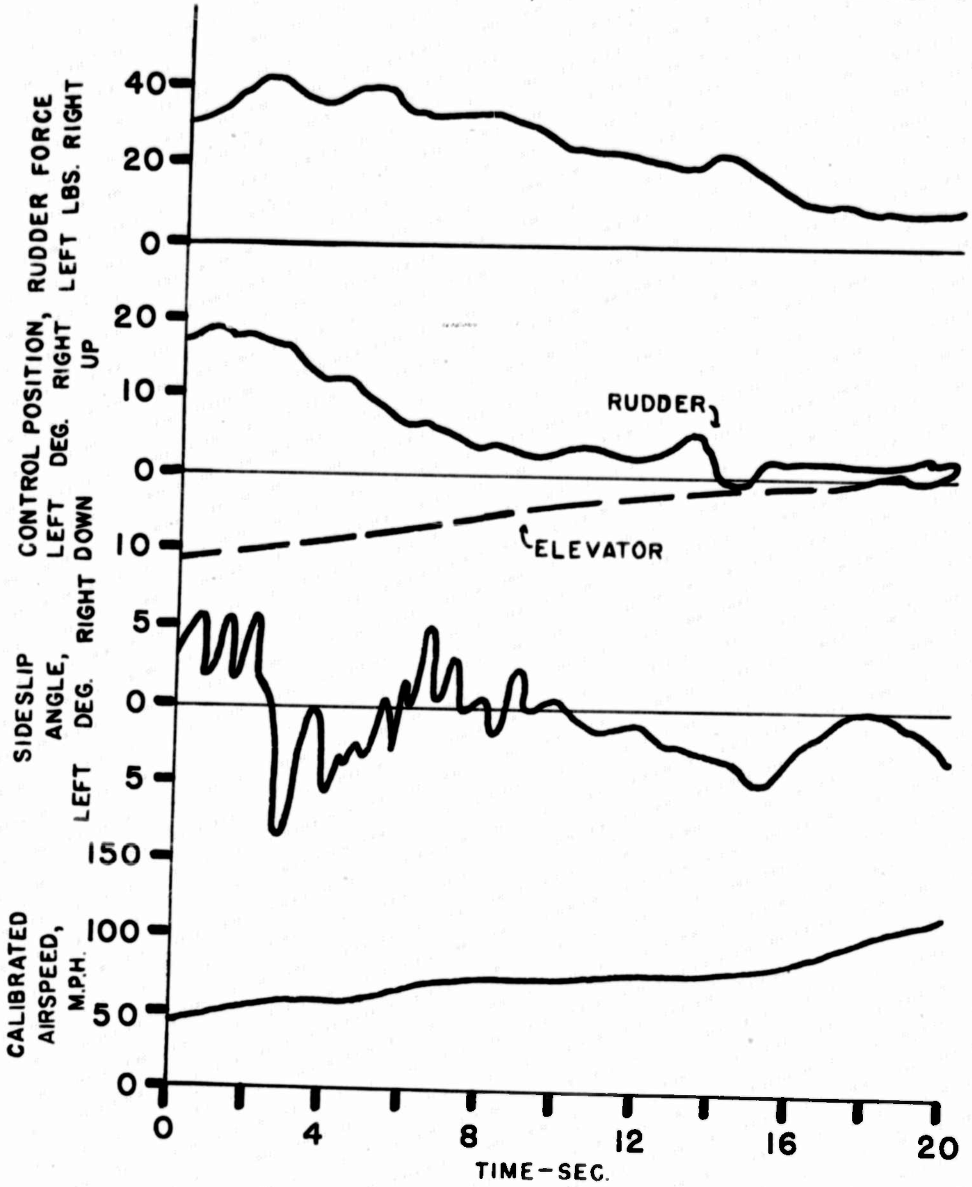


FIG. 32- RUDDER CONTROL IN TAKE OFF

H. MISCELLANEOUS REQUIREMENTS

1. Discussion and Configurations

There are several requirements for satisfactory flying qualities that can be investigated by the pilot without the necessity for making special instrumented flight tests. These requirements are as follows:

a. The directional (rudder) and lateral (aileron) control shall give sufficient control to trim the airplane in steady flight with the wings level in all configurations, at all permissible speeds.

b. The rudder and aileron trimming devices shall maintain a given setting indefinitely.

c. The lateral trimming device shall be capable of trimming out the aileron control force, with the airplane in its most severe design asymmetric loading when in the cruising configuration.

2. Pilot Technique

a. Data for demonstrating compliance with requirement (a) above can be obtained from the records taken while performing the tests for static longitudinal stability. This requirement on directional and lateral control is nearly always easily met and does not warrant a complete inetrumented inveetigation unless the pilot finds that during the longitudinal rune mentioned above, he finds hirself running out of rudder or aileron.

b. Any creep of the rudder or aileron trim tabe can be noted by the pilot during the running of the rest of the teet program.

c. The teet for requirement (c) above is to be made by loading the airplane in a condition that gives it the most extreme lateral asymmetry. The teet pilot should place the airplane in the cruising configuration and then attempt to trim the airplane laterally throughout the speed range required for the cruising configuration.

3. Reduction of Data

No epecial flight test records are to be taken for these teets unless a critical condition is found during the tests as given above. A statement should be included in the flight test report stating whether theee requirements have been met on the particular airplane under test.

It is also required that it shall be possible to prevent complete stall by normal use of the controls immediately after a stall warning occurs. Finally, it is required that no severe roll-offs occur in the straight flight stalls nor that excessive altitude be lost in recovering from the complete stall.

2. Configurations

Straight Flight Stalls	Stalls out of Turns
(A) Approach	(A) Approach
(CR) Cruise	(CR) Cruise
(L) Landing	(L) Landing
(P) Power on Clean	(P) Power-on Clean
(D) Dive	
(G) Glide	
(PA) Power Approach	

3. Pilot Technique

The pilot, in straight flight stalls, shall trim the airplane in the proper configuration at the given trim speed. With the photo-observer running continuously, the airplane's speed should be reduced as slowly as possible (rate not to exceed 1/2 mph per second), the wings being held level by the use of the appropriate control. The speed should be reduced until the complete stall is obtained. Complete stall for straight flight is defined as that flight condition in which the airplane becomes longitudinally uncontrollable as evidenced by an abrupt downward pitch of the nose, or laterally uncontrollable as evidenced by an abrupt downward pitch of the nose, or laterally uncontrollable as evidenced by an abrupt dropping of the wing.

After all the wings-level stalls are made, the stalls from turns should be investigated. In this test the airplane is trimmed in the proper configuration at the given trim speed. Holding this speed, the airplane is to be placed in an accelerated turn which is slowly tightened until a complete stall is obtained. In a turn, the stalling speed is that at which the normal acceleration decreases abruptly, or the airplane becomes laterally uncontrollable, usually resulting in a snap roll.

4. Data Reduction

The data should be presented in the form of time histories of control forces and/or deflections, rolling and pitching velocities, angle of sideslip, normal acceleration, and indicated airspeed. Typical time histories of a stall in straight flight and a stall out of turns are shown in Figures 33 and 34.

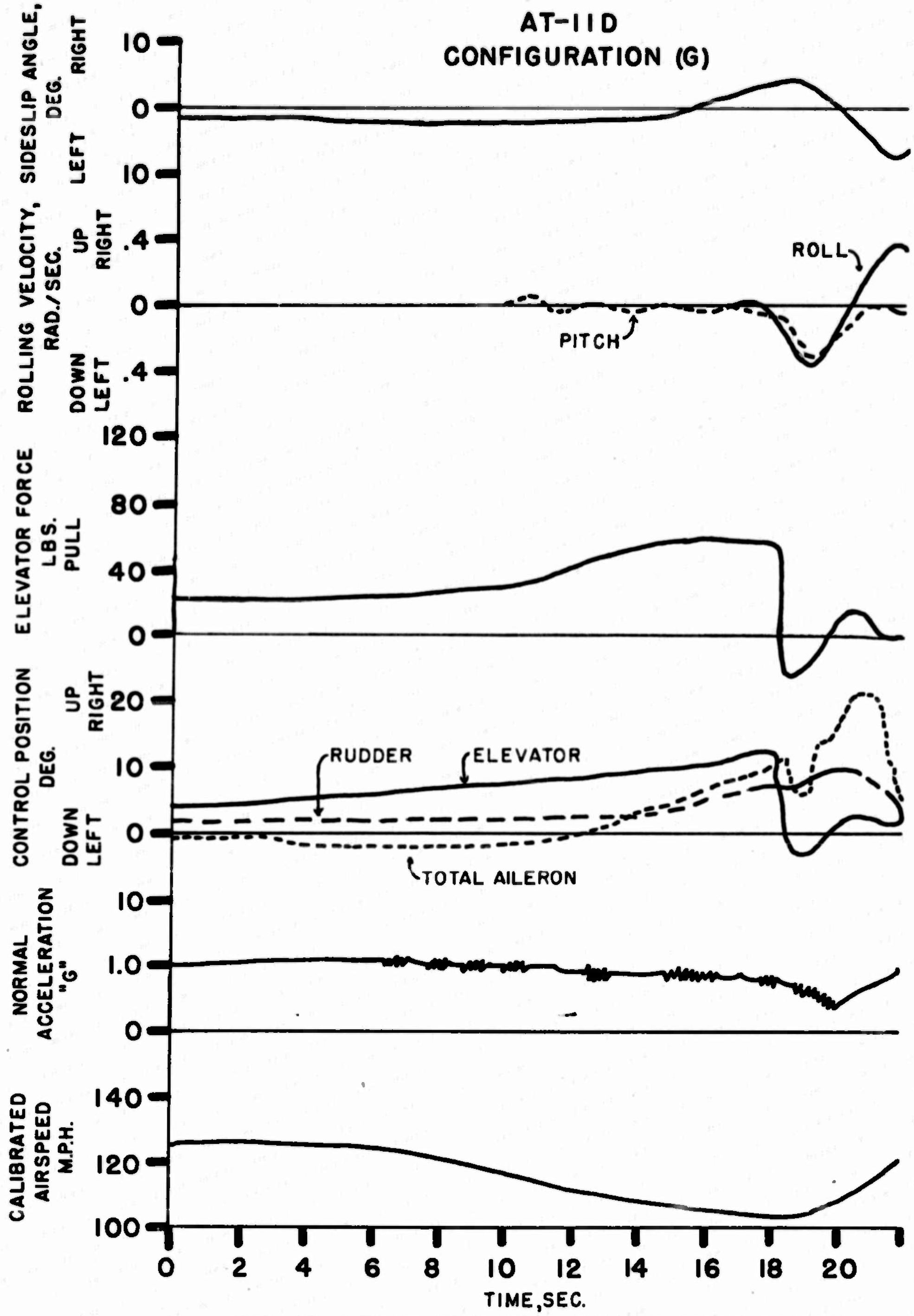


FIG. 33 — TIME HISTORY OF STRAGHT AHEAD STALL

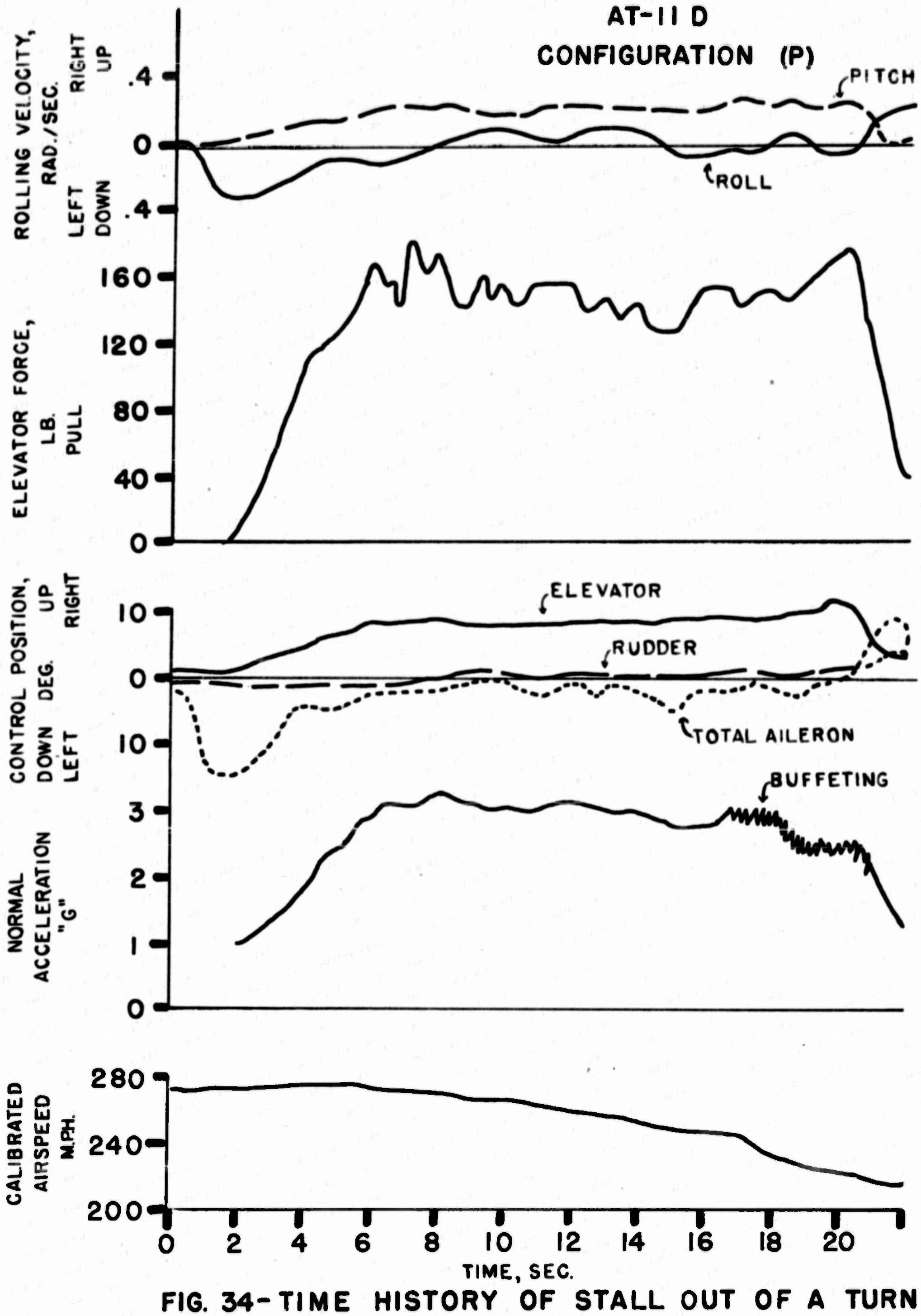


FIG. 34 - TIME HISTORY OF STALL OUT OF A TURN

APPENDIX 1

INSTRUMENTATION

All of the flight tests described in the body of this report require the measurements of control surface angles, control forces, velocity, altitude, accelerations, etc., either as functions of time during certain maneuvers or as an instantaneous picture of a steady state condition of the airplane. It is just as essential that this instrumentation be installed properly and of sufficient accuracy as it is for the pilot to perform the correct maneuver. For this reason considerable care should be taken prior to any of these flight tests to insure that the airplane is equipped with the proper instruments for the test and that they have been properly calibrated.

There are several systems in use at the present time for measuring and recording the airplane functions mentioned above. These will be briefly discussed and their advantages and disadvantages described.

The first of these systems to be discussed is the one in the greatest use by the various flight-test organizations at the present time and is also the method used by the USAAF at Wright Field. This method requires the installation of an illuminated instrument panel in the body of the airplane which contains the indicating dials. These dials are photographed by means of a moving picture camera that can be set to run at different camera speeds depending on the type of test to be made. The camera is operated by a switch located in the pilot's cockpit. To reduce the data obtained by this recording system, it is necessary to read the instruments frame by frame and the results obtained by recourse to the instrument calibration curves and plotted up as required by the particular test.

A second method of recording is used by the National Advisory Committee for Aeronautics. This method requires the separate recording on continuous film of each separate function, all synchronized by a master timer. The results are therefore obtained as continuous records on many film strips which can be reduced by means of the calibration curves and plotted as required.

A third method is to design instruments to give electrical outputs which can be recorded on a multichannel oscillation with a timing channel. The results then all appear on one wide strip of film or sensitized paper, which can then be reduced in the standard way, employing calibration curves.

It is not important which of these systems is used as long as the proper instrument dynamics and accuracies are obtained.

The necessary instruments and their required accuracies are listed below in Table I, together with the type of instrument used by the USAAF at Wright Field.

TABLE I

Measured Quantity	Type Inst.	Required Accuracy
Elevator angle	Geared up D.C. selsyn	± .10°
Elevator tab angle	"	± .10°
Rudder angle	"	± .50°
Aileron angle	"	± .5°

Measured Quantity	Type Inst.	Required Accuracy
Sideslip angle	Yaw vane	± .5°
Elevator stick or wheel force	Force indicator	± 1/2 lb.
Aileron stick or wheel force	"	± 1 lb.
Rudder pedal force	Force indicator	± 2 lb.
Rate of roll	Angular velocity indicator	± 1° per sec.
Normal acceleration	Accelerometer	± .5g
Angle of bank	Gyro-horizon	± .5°
Indicated airspeed	Airspeed indicator	± .5 mph
Altitude	Sensitive altimeter	± 100 ft.
Time	Stop watch	± .01 sec.
Rate of pitch	Angular velocity indicator	± 1° per sec.

APPENDIX 2

DATA REDUCTION

The following table may be used as an aid in reducing the recorded data:

1.	Altimeter reading, ft.	Observed data
2.	Instrument correction, ft.	From laboratory calibration
3.	Speed correction, ft.	From altimeter calibration
4.	Pressure altitude, ft.	(1) + (2) + (3) or just (1)
5.	Observed air temperature, °C	Observed data
6.	Instrument correction, °C	From laboratory calibration
7.	Speed correction, °C	From temperature calibration
8.	Free air temperature, °C	(5) + (6) + (7) or just (5)
9.	Density altitude	From density altitude chart (8) & (4).
10.	Density ratio, σ	Corresponding to (10) from Standard Atmosphere Tables.
11.	Indicated airspeed, mph	Observed data
12.	Calibrated airspeed, V_c mph	From airspeed calibration
13.	Compressibility correction, ΔV_c, mph	Fig. 3 (C3-c) AAFTR 5069
14.	Equivalent airspeed, mph	(12)-(13) or just (12)
15.	True airspeed, mph	(14)/square root (10)
16.	Dynamic pressure, q, lb/sq.ft.	$.00256 \times (14)^2$

17.	Test gross weight, lb.	Gross weight at take-off minus wt. of fuel consumed.
18.	Lift coefficient, C_L	(17)/(16) x S (S = wing area)
19.	Test c.g. location, % m.a.c.	c.g. at take-off with allowance for fuel consumed and any ballast shifted in flight.
20.	Elevator angle, deg.	From observed data and instrument calibration.
21	Elevator tab angle, deg.	"
22	Rudder angle, deg.	"
23	Aileron angle, deg.	"
24	Elevator force, lb.	"
25	Aileron force, lb.	"
26	Rudder force, lb.	"
27	Angle of sideslip, deg.	"
28	Angle of bank, deg.	"
29	Rate of roll, deg/sec.	"
30	Normal acceleration, g's	"
31	Time, seconds	From observed data.
32	Flap position	"
33	Gear position	"
34	Dive brake position	"
35	Rate of pitch, deg/sec.	From observed data and instrument calibration.

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ABSTRACT:

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Methods are presented for conducting flight tests of airplanes for evaluation of their stability and control characteristics. The flight tests discussed are those required to demonstrate compliance with AAF Specification R-1815-A. Each particular flight test is discussed from the point of view of the reason for the test, the airplane configurations to be investigated, the pilot technique required, and the methods of data reduction and proper presentation of results. A data reduction table is appended.

NTIS; auth: AFLC ltr, 8 May 73

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