NACA - Langley

FLIGHT RESEARCH PROGRAM FOR NACA ANNUAL INSPECTION

The following program was arranged and presented by the Flight Division for the 1949 NACA Annual Inspection:

Hammack, Hart or Sawyer:

"Gentlemen, this is the Flight Research Division. As our name implies, most of our research is conducted on full-scale airplanes. I would like to emphasize, though, that these airplanes are not tested as a particular type, but rather are used as vehicles for some form of basic research. Here at your first stop, you are to hear about some of the work we are now doing on the problem of aircraft controls. Mr. Hunter will discuss a specific problem associated with the control of light aircraft."

Mr. Hunter: (Hewes, or Cheatum)

"During the last few years there has been an increasing desire to improve the spiral stability of airplanes, especially small personal owner type.

"A study is therefore being made to see how this can be done. This study has brought into clearer light a point which has been recognized for some time - that many light airplanes are inherently spirally stable in the cruising condition even though they show unstable spiral tendencies in flight. Two reasons for this are: (1) A lack of means of trimming in flight makes it impossible for many light planes to ever be perfectly trimmed for level flight; (2) Even if trimming means are available, even a small amount of friction in the control system will prevent control surfaces from centering after a deflection and the airplane will be out of trim. Flight records of an airplane are shown in this chart to illustrate the second point. Starting from a trim position a time history of a rudder kick and the resulting changes in attitude and flight path shows that friction prevents the rudder from returning to the trim position with a resulting gradual increase in the angle of bank and a corresponding change in heading. The ultimate result is a steep power spiral.

"Here at Langley, we have tried one way of overcoming this adverse effect of control friction by installing preloaded centering springs in the control system. This chart shows the spring device in the trim and deflected positions, and the resulting variation of force with deflection. This device gives a positive centering action, as indicated on the chart by the stepped force gradient at the trim position. Notice the preload that the pilot must overcome before deflecting the controls. The mock up of the installation shows the centering device connected to the control system, the fixed clamp which engages the centering by clamping one end of the piston, and the locking handle.

"In addition to overcoming friction, a simple means of trimming the airplane is provided. In operation, the pilot engages the device with the controls held for trim. The centering hold the controls there until the pilot provides a force greater than the spring preload. The surface returns to the trim position whenever the controls are released. With the centering disengaged, friction prevents the surface from returning to the trim position.

"Flight tests with centering give results as shown here. The rudder returns to the trim position. If the airplane is perfectly trimmed, the inherent spiral stability will gradually reduce the angle of bank caused by the rudder kick to zero. There is a small change in heading while the angle of bank is returning to zero, but after that the flight path is straight. In practice, the airplane may not be perfectly trimmed and the airplane goes into a steady turn, but the resulting attitude does not become dangerous."

"Next, Mr. Mathews will discuss a phase of the work being done with respect to large aircraft controls."

Mr. Mathews: (Johnson, or Brown)

"Many large airplanes incorporate control surface boosters. We will discuss two problems connected with boosters: (1) How much control effort should be left to the pilot to obtain the best airplane handling qualities? (2) How fast must a booster move the control surface in order to avoid any objectionable lag in airplane response?

"The Flight Research Division has installed a booster in the elevator control system of a large four-engined airplane weighing 125,000 pounds. This booster was adjustable in flight so that the total control effort could be distributed in any proportion between the pilot and the booster.

"The first chart illustrates the first problem. We have plotted pilots' control force against normal acceleration measured in maneuvers. This shaded area represents the range of stick force considered satisfactory for large airplanes by the military services. The top curve shows that the test airplane without boost had much larger stick forces than those considered satisfactory. These heavy stick forces are typical of nearly all large airplanes without boosters. Actually there has been very little flight experience in the satisfactory range. When the booster in the test airplane was adjusted to give a pilot's control force variation falling near the upper limit of the specified range, all the pilots noted marked improvement in their ability to handle the airplane. Adjustment of the pilot's effort to the middle of the range gave no further improvement but was just as satisfactory as this condition (point). When the pilot's effort was adjusted to fall near the lower limit of the range specified, the pilots felt that the control forces were too light and that there might be danger of overcontrolling or inadvertently applying excessive loads on the airplane. As a result of these tests, it appears that the range specified is correct with the possible exception that the lower limit should be raised slightly.

"An example of what correct control forces mean to a pilot is shown in the lower figure. These are time histories of two landings, one without boost and one with the control effort in the middle of the satisfactory range. Pilots' control force is plotted against time. Without boost the pilot held about 80 pounds just before ground contact. This force is close to the pilot's maximum strength especially if one hand is adjusting throttles or trim tabs. With boost, this force was reduced to 15 pounds, well within the capability of the pilot.

"So much for control forces. Now we'll take up the second problem - rates of control motions.

"A booster should position a control fast enough so that a pilot thinks he is connected directly to the control surface. High required rates mean more powerful and therefore heavier boosters. The booster tested had a very high maximum rate, but could also be adjusted for any lower maximum rate.

"This chart shows results of the control rate investigation. Two landings are shown. These two plots are for an unrestricted maximum rate of control motion (point top). These two plots are for a restricted rate of control motion. Everything is plotted against time. We'll talk about the unrestricted case first (point). There are actually two curves here (point), a black curve representing the control position called for by the pilot, and a red curve representing what he got. These curves nearly coincide, which means the control was positioned very accurately with no perceptible lagging. Rate of control motion is shown here. The highest rate used by the pilot was about

30° per second, a typical value for this airplane. Demands for such high rates are of extremely short duration. Since the airplane can't respond in these short times, possibly the pilot could make good landings with much lower maximum rates of control motion. This case is shown here (point), where the maximum available control rate was restricted to slightly under 10° per second. In spite of the restricted control rate, this system was rigged so that the pilot could still move the stick as fast as he wished. Occasionally, the pilot called for rates higher than the maximum available. This resulted in some lag in positioning of the control. Because the demands for higher rate of control motion were very brief, this lag never got large enough to be detected by the pilots. Consequently, the pilots thought the airplane handled just as well with the restricted rate as with the unrestricted rate.

"This result indicates that for large airplanes satisfactory handling qualities can be obtained with boosters having maximum available control rates less than those normally used by pilots."

Hammack, Hart, or Sawyer

"Here we have another problem in the control of airplanes which is often times referred to as 'snaking' or 'Dutch roll.' In any event, this phenomenon is very undesirable to the pilot, both because of the work required to correct for the condition or inability to line up gun sights on a target in the case of a fighter aircraft. Mr. Beckhardt will now discuss this problem and someof our ideas for solving it."

Mr. Beckhardt: (Kraft or Adams)

"With the advent of high speed, high altitude flight, and small heavy airplanes the problems of constant amplitude lateral oscillations and poorly damped lateral oscillations have become more acute. The research program at NACA in connection with this problem may be broadly divided into two parts. The first phase of the investigation is concerned with the effect of varying the period and damping of the lateral oscillations on the pilot's opinion of the flying qualities of the aircraft. The second phase of the investigation is concerned with means of preventing these oscillations.

"This chart presents some preliminary data which were obtained by the Ames Laboratory using an apparatus which varies the effective dihedral angle of the airplane. By operating the ailerons with a servo motion whose output is proportional to the angle of sideslip. Whown on this chart is the time to damp to 1/2 amplitude against the period of the oscillation. These colored lines show the period and damping that were obtained in the cruising and approach condit' with the various amounts of dihedral noted on the chart. This li shows the present Army-Navy requirements. The different colors indicate the pilots opinion of the flying qualities of the aircraft. In this region of dihedral angles, the characteristics were rated intolerable, this region tolerable, this region good. In the cruising condition, the pilots feel that the damping required is approximately the same as the requirements, whereas in the low speed approach condition, the pilots appear to be able to tolerate less damping.

"Here at Langley, tests are to be conducted on this nose fin to obtain similar pilot opinions. The movable portion of the auxiliary vertical tail will be operated by a gyro which will move in proportion to the yawing velocity. In this way, the damping of the lateral oscillations can be varied over a wide stable and unstable range and evaluation made of the flying qualities.

"One method which appears promising in preventing these oscillations is the use of an automatic control sensitive to yawing accelerations. On this chart is shown a time history of the yawing displacement, velocity, acceleration, and rudder position with time. The yawing velocity and yawing acceleration are 90 and 180 degrees out of phase with the yawing displacement. If the rudder motion is controlled to oppose the yawing acceleration with no time lag, the rudder would be in phase with the displacement, and hence supply no damping force. However, with a finite time lag, a component of the rudder deflection would oppose the yawing velocity and provide a damping force.

"In order to illustrate such a system this simple set-up has been made. This bar with the model mounted on it represents an airplane oscillating in yaw. The signals from the angular accelerometer are fed into this amplifier which operates a servo motion and applies yawing motion to the model through springs which simulate the moments applied to the full scale airplane by the rudder. Without the automatic control in operation, the system, when deflected, will oscillate indefinitely. When the automatic control is connected, the oscillation dies out in a relatively short time.

Hammock, Hart, or Sawyer

"There are instances in our flight work that require quick qualitative answers to act as a check or guide to large-scale work. Here we have an inexpensive piece of equipment that has helped us in our study of interference effects on the drag of wing-body combinations at supersonic speeds. Mr. Yeates will now tell you something about the apparatus, the results so far obtained, and demonstrate its operation."

Mr. Yeates: (or Green)

"One of the greatest obstacles to flight at supersonic speeds is the very high drag of airplanes at these speeds. Known ways of keeping this drag down include the use of sweep and very thin airfoils to reduce the drag of the wings and high fineness ratios to reduce the drag of the fuselage. There is one other possibility, however, that has not been so thoroughly explored. This is the possibility that the swept wing and the slender body can be combined in such a way that the drag of the combination is less than the sum of the drag of the parts. There is some indication from free-fall tests that such favorable interference effects can exist, at least in the transonic speed range. For example, in the free-fall tests covered by this chart, it was found that at a Mach number of 1.1 moving the wing from the forward to the rearward position on the body reduced the drag of the body to a value below that of the body alone. The wing drag was little affected by the change.

"In order to learn more about this wing body interference phenomenon, without tying up any of our major high-speed research facilities, we tried to devise a simple and inexpensive apparatus to make comparative measurements of drag at zero lift for a wide range of body shapes and wing-body combinations. We ended up with this apparatus you see before you. Here we have an evacuated tank and a supersonic nozzle, separated at this point by a thin plastic diaphragm. When the diaphragm is shattered, air flows from the room through the nozzle into the tank creating supersonic flow. The test section is 12 inches square. The Mach number is 1.5. The apparatus has two novel features, the first being the very short duration of the test run. Air flows past the model at M = 1.5 for only about 0.03 second. That interval, however, is sufficient for the flow about the model to stabilize and for a drag reading to be taken.

"The other novel feature is the scheme of suspending the model by the nose and measuring the drag on a strain-gage dynamometer above the entrance of the nozzle. This feature is obviously limited to the study of drag at zero lift. It has the advantage, however, that the supporting sting is in tension and can be very much smaller than the more conventior tail sting. It does not compromise the shape of the rear part of the body, the part that is most influenced by the presence of the wing. The fact that the body lies in the boundary layer of the nose sting is not necessarily a disadvantage in that most of the compara free fall models are tested with long nose booms carrying pilot-st heads.

"This equipment has just recently been placed in operati far, we have studied the effect of locating untapered wings 63° sweepback at a series of positions on this fineness rat

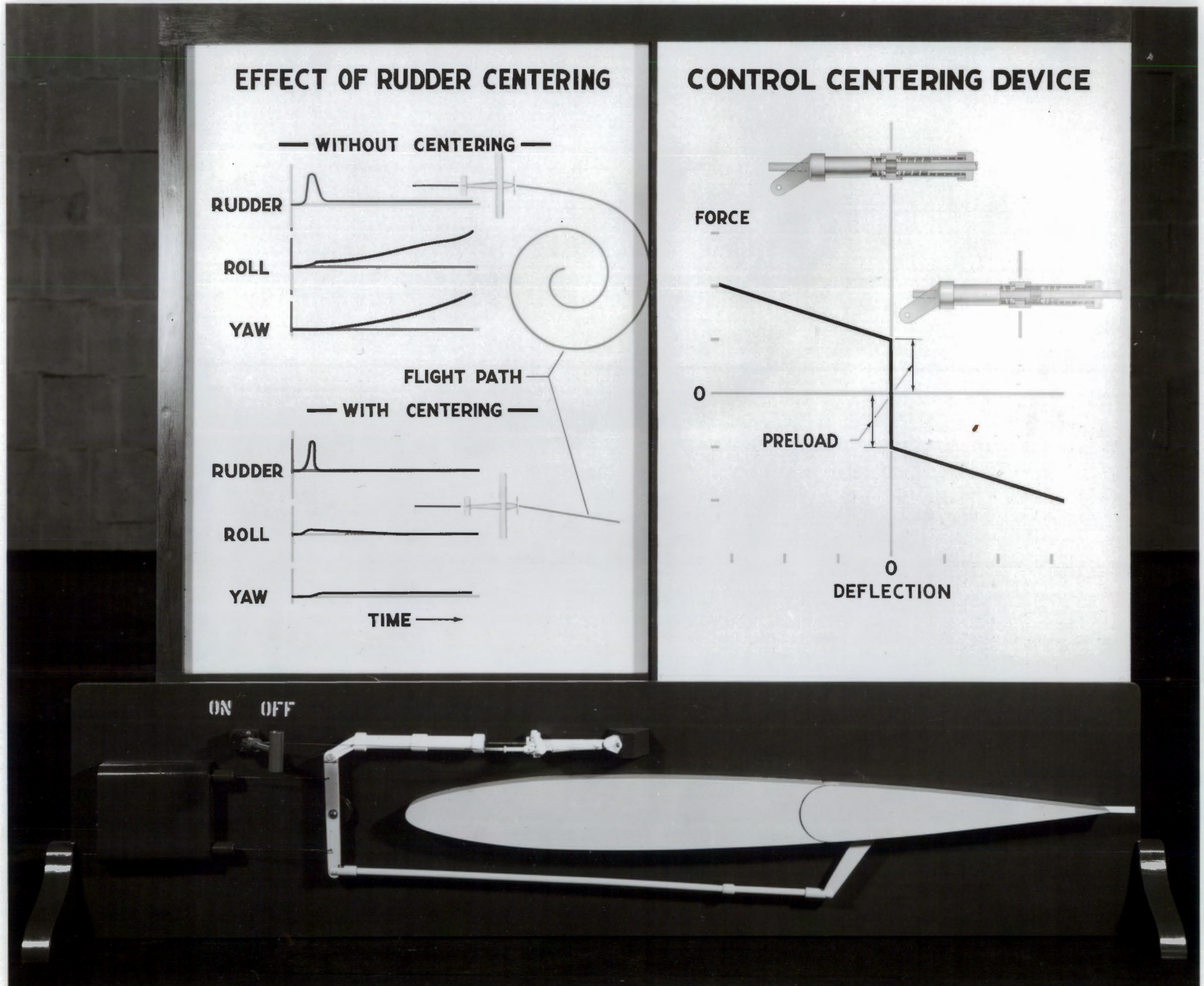
As you can see by this chart, the changes in drag resulting from changes in wing position have been quite small at the supersonic Mach number of 1.5. Thus far, at least, it appears that interference effects of appreciable magnitude may be confined to the transonic speed range. In the future, we plane to cover a much wider range of configurations. Arrangements or trends that this apparatus shows to be interesting will of course be studied in greater detail by free-fall or wind-tunnel techniques.

"We will now demonstrate operation of the equipment. The tank has been evacuated. Pushing this button will puncture the diaphragm. A time history of the drag as measured by the strain gages has been recorded on a magnetic tape and will be played back on this screen for you to examine. The motion of the model that you will se occurs only after the test run is over. Be prepared for a rather loud bang when the tunnel operates."

Mr. Hammack: (Hart, or Sawyer)

"Gentlemen, this concludes your tour of Flight Research. I hope you have enjoyed your brief stay with us and that we shall see all of you again in the very near future. Your bus is waiting outside the hangar door to take you to the next NACA facility that you are scheduled to visit."

NACA
LAL 61079



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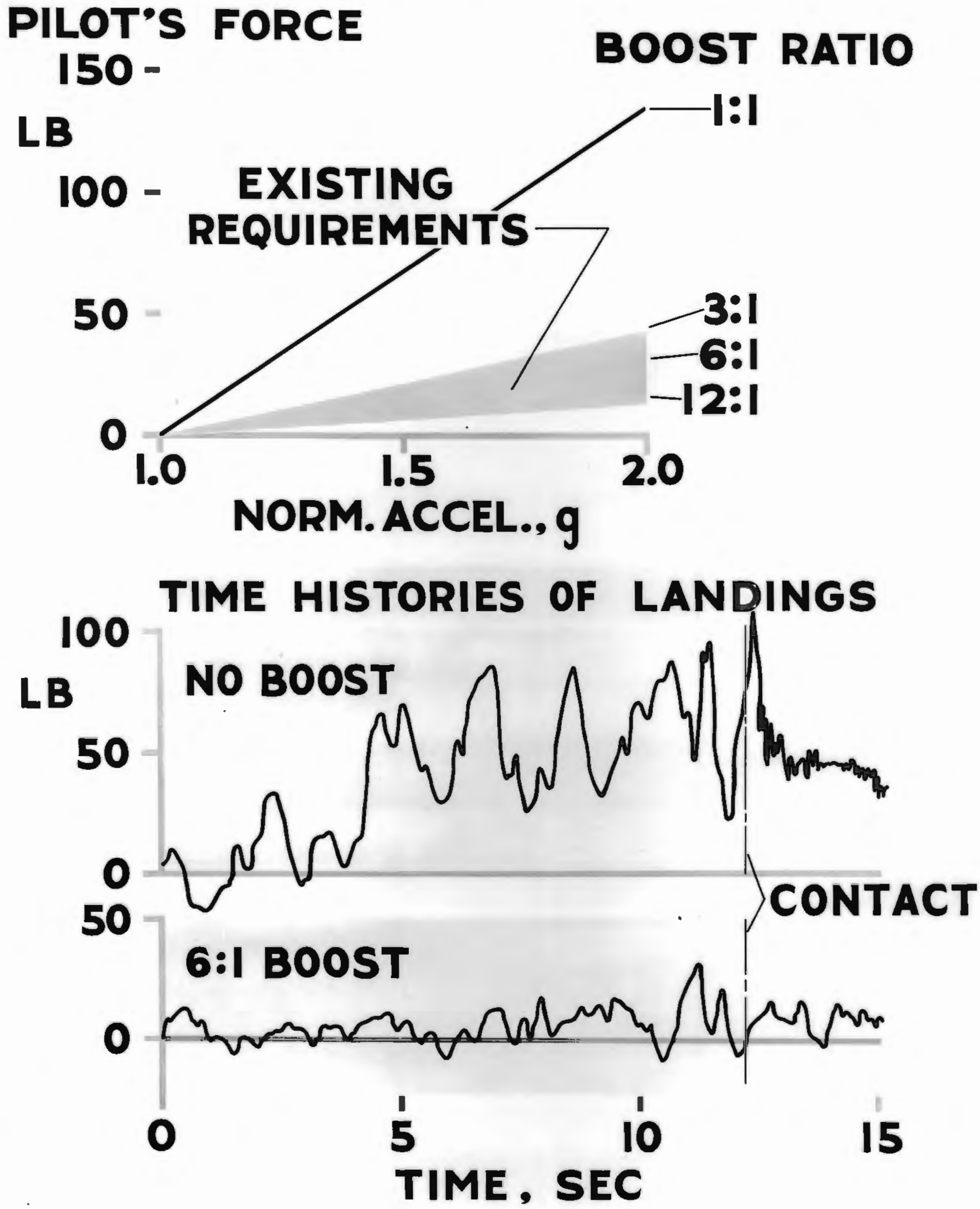
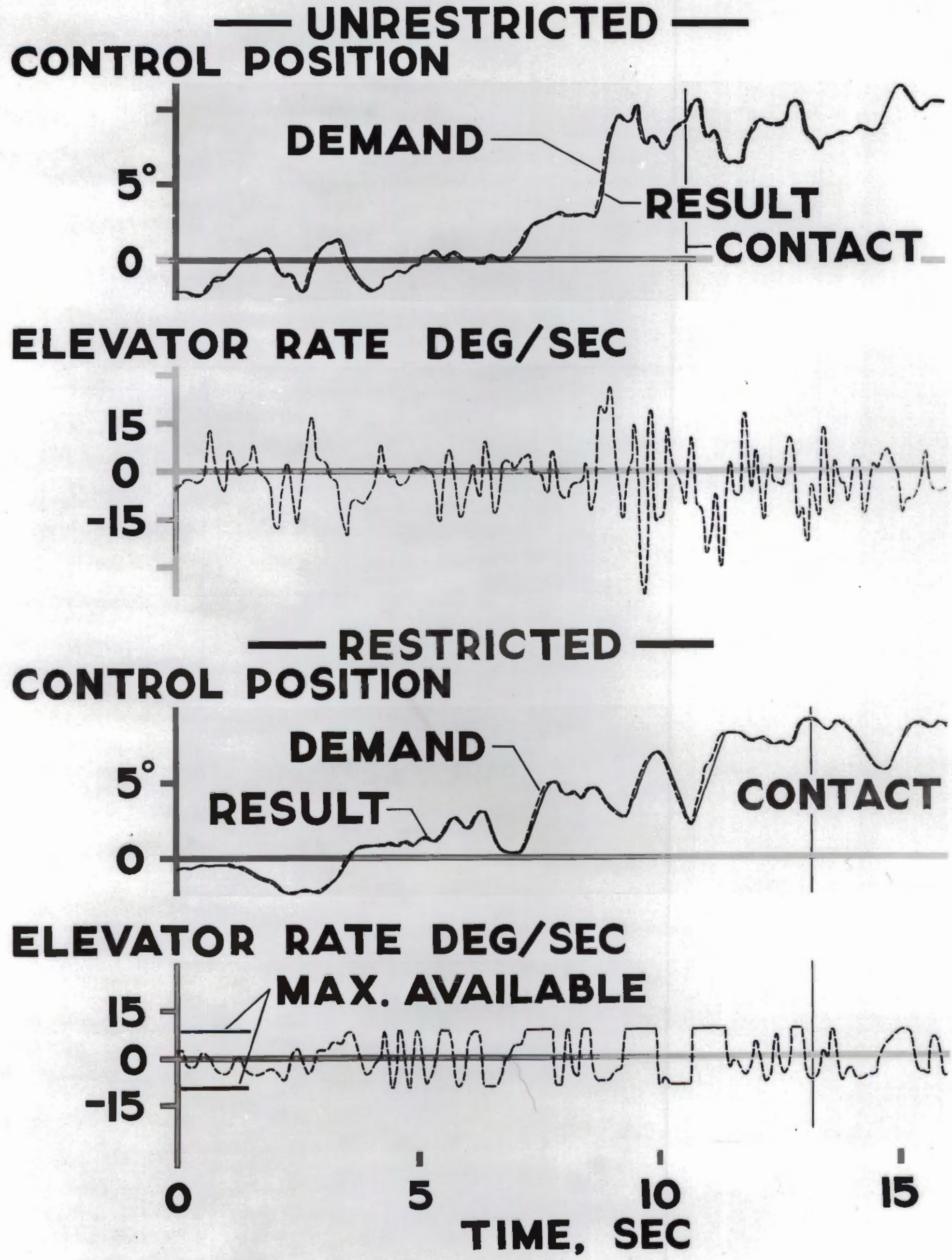
ELEVATOR FORCES ON LARGE AIRPLANE



LAL 61081

ELEVATOR RATE INVESTIGATION



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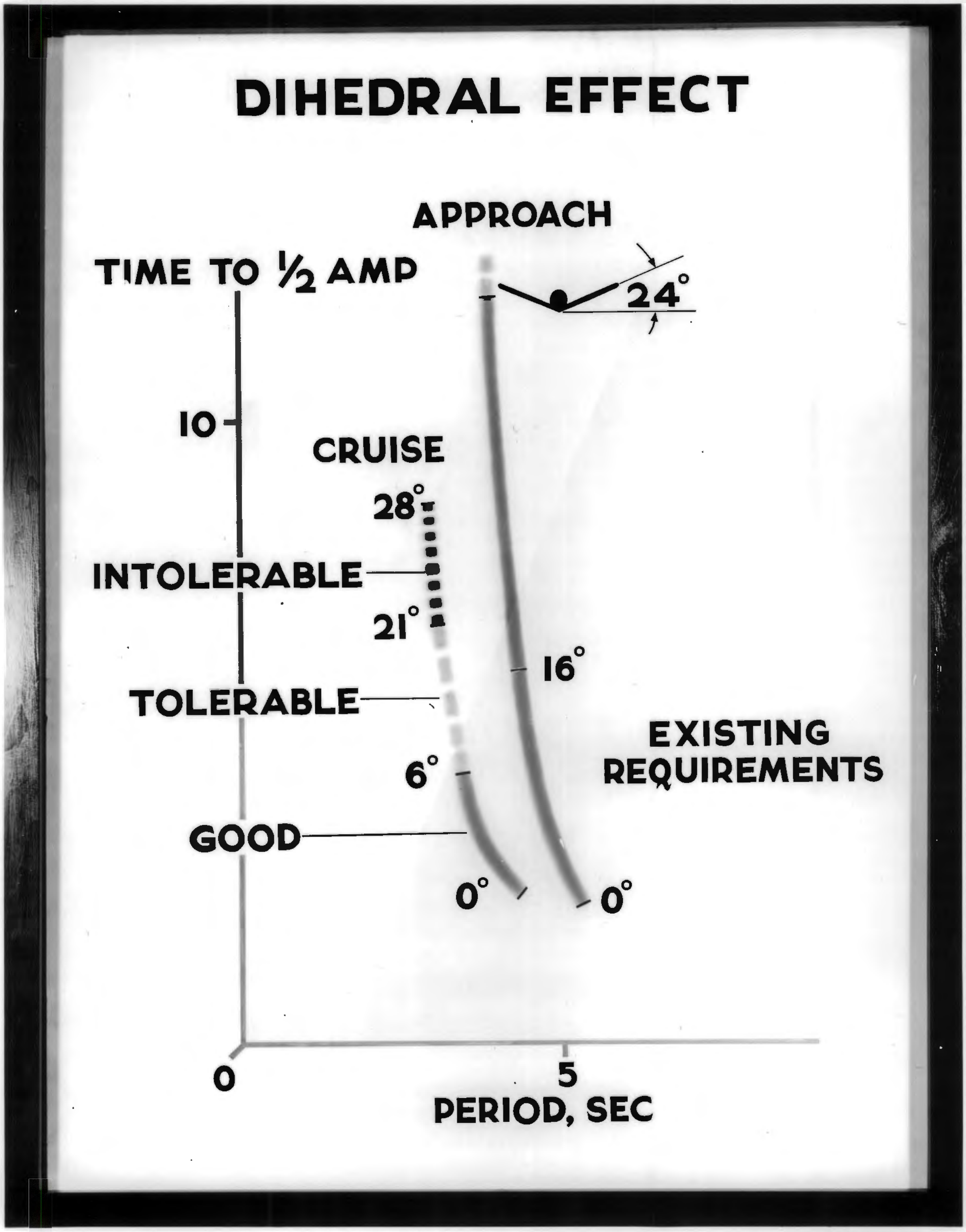
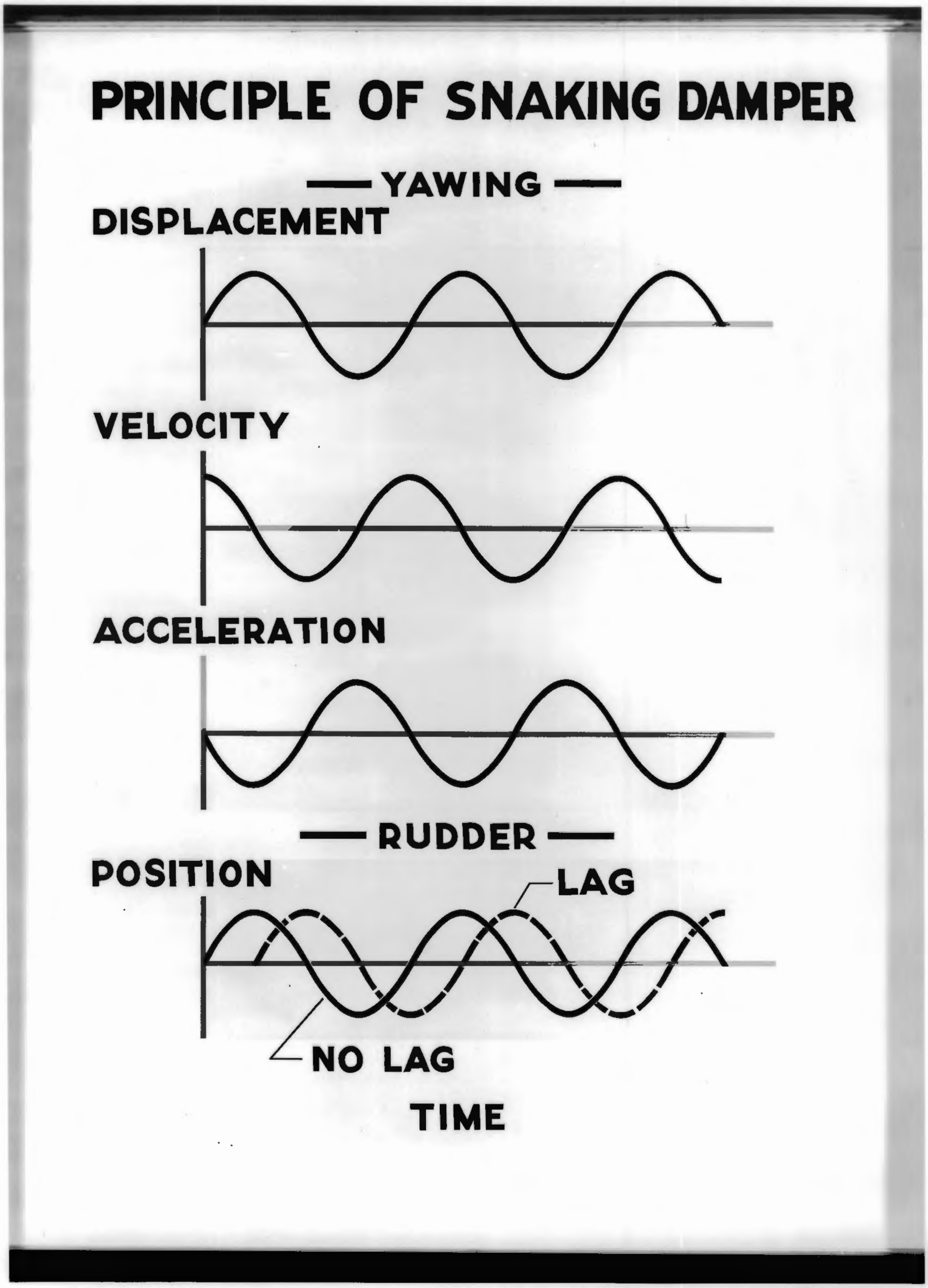

DIHEDRAL EFFECT
APPROACH
TIME TO ½ AMP
24°
10
CRUISE
28°
INTOLERABLE
21°
16°
TOLERABLE
EXISTING REQUIREMENTS
6°
GOOD
0°
0°
0
5
PERIOD, SEC

LAL 61083



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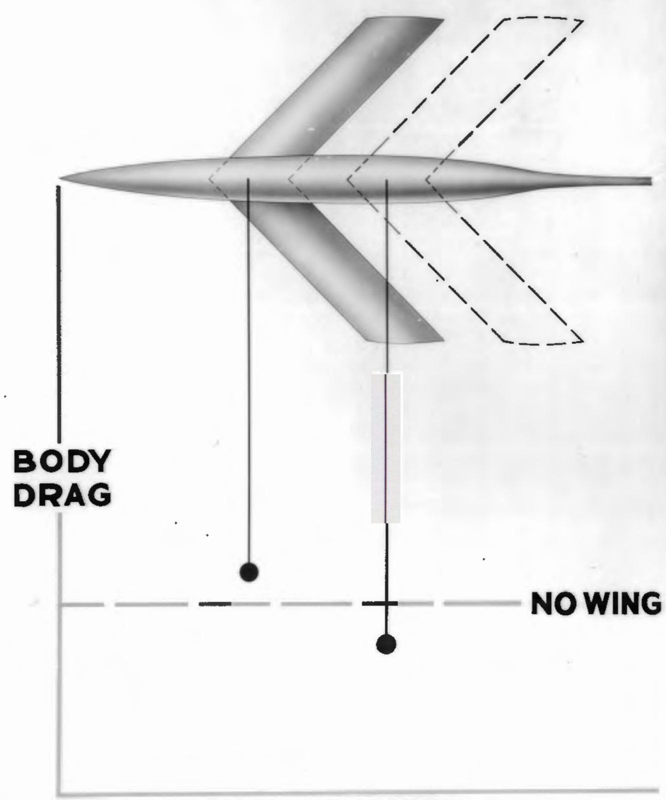
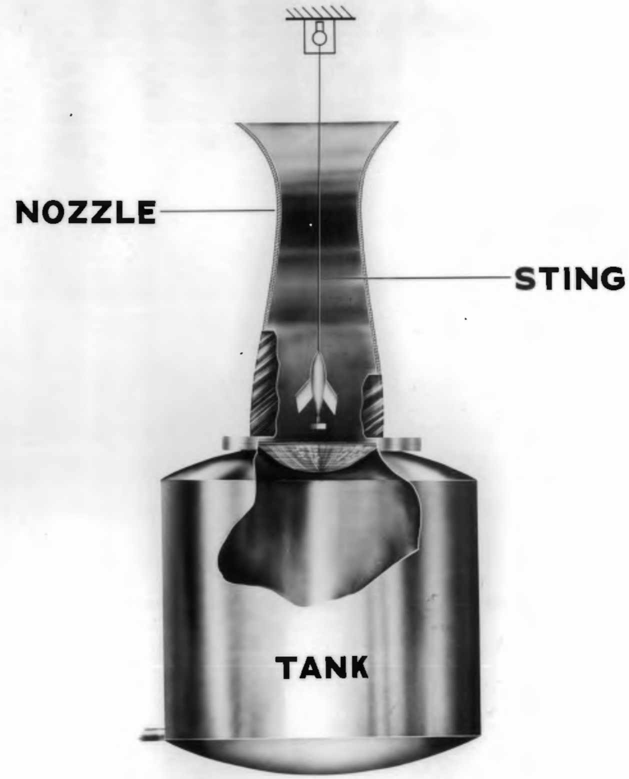
EFFECT OF WING POSITION

M=1.1



DRAG MEASURING APPARATUS



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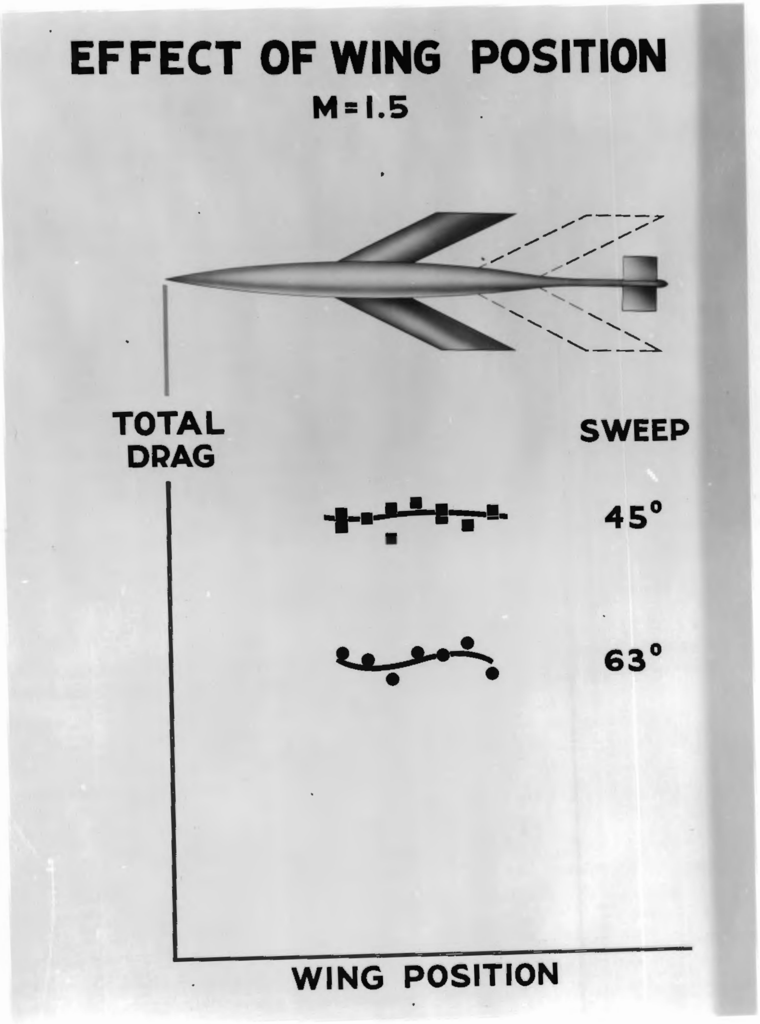

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