Speaker - John [illegible] Mayer Alternate - Paul W. H[illegible]er Maneuver Loads Branch

1951 BIENNIAL INSPECTION

May 1951

LOADS CALIBRATION LABORATORY

TALK NO. 1

The building that you are now in is the Loads Calibration Laboratory which is a part of the NACA facilities devoted to aircraft loads research. The subject of Aircraft Loads Research will be discussed here along with other work being conducted in this facility. The machine that was operating when you entered is being used for making fatigue tests on full-scale aircraft structures and will be discussed later.

The net or structural loads acting on an airplane are determined by the interrelated action of aerodynamic, inertia, and elastic forces, and may be imposed on the airplane in steady flight, maneuvering flight, gusts, or in landings. It is important to know the magnitudes and the distribution of these loads over the aircraft structure so that adequate structural designs may be obtained.

Loads may be determined in flight by means of acceleration measurements, pressure measurements, and deflection measurements as indicated on the first chart. Acceleration measurements are useful in obtaining the overall airplane loads and the inertia loads. In this case an accelerometer is shown at the airplane center of gravity in order to measure the overall loads. Pressure measurements obtained at orifices such as these on the wing determine not only the load on the surface but also the distribution of load as well. Deflection measurements are useful

in obtaining loads induced by elastic deformation. One form of deflection measuring device is shown on this chart. It consists of a camera which photographs a grid on the wing tip. From the distortion of this grid the bending and twisting of the wing can be determined.

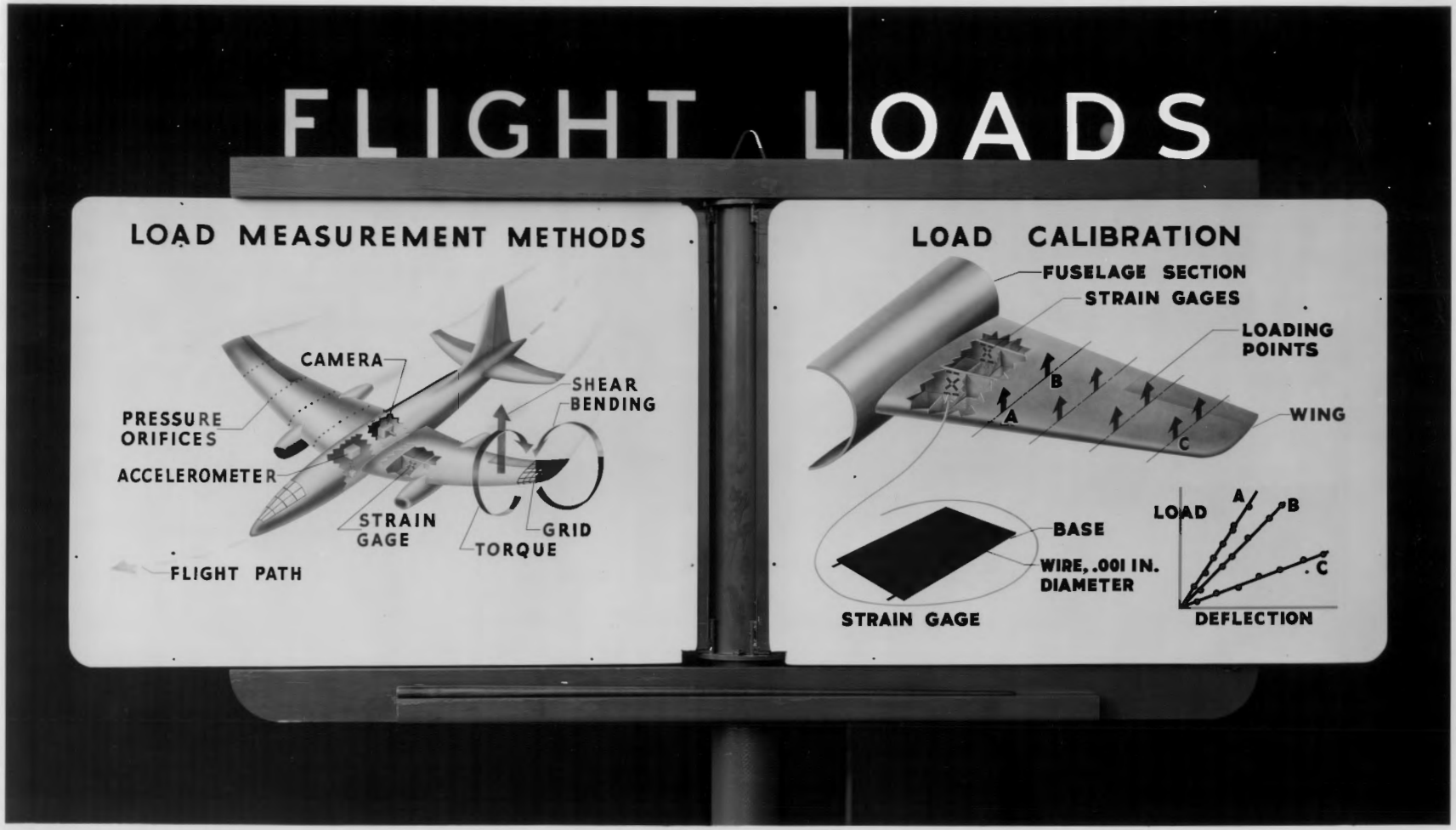
Another important form of deflection measuring device is the electrical wire-resistance strain gage which consists of a length of very fine wire cemented to a piece of paper or other material whose size may even be smaller than a postage stamp. (On this frame are several such strain gages.) In practice the strain gage is cemented to the structure on which the measurement of strain is desired. When the structure deforms due to some load the fine wires in the strain gage are stretched and this stretching causes a change in the electrical resistance of the wire.

The actual stress measurement at the strain gage location is not of primary importance in flight loads measurement. More important, however, is the relationship between the load applied to the structure and the response of the gage attached to the structural member. A method for determining this relationship has been developed through research at this laboratory within the last ten years. The measurements which are usually desired are the shear or vertical load, the bending moment or bending load along the wing, and the torque or twisting load. It would be desirable to locate a strain gage at such a place on the wing so as to measure only shear, or only bending moment, or only torque; however, this is seldom possible so we try to locate the strain gages

in the wing structure at locations where the principal influence on the strain gage is either to shear or moment or torque. Therefore, for the usual airplane structure, shear gages are placed on the spar or beam shear webs; bending moment gages are placed usually on the upper and lower beam flanges; and torque gages are usually placed on the spar webs or on the wing skin. At these locations, for instance, the shear gages respond mostly to shear, although the gages probably will still respond to bending moment and torque to some extent. For instance, one shear gage, located here, will respond differently to loads A, B, and C as indicated in this figure. It is our problem in calibrating the structure to separate out the combined effects of bending moment and torque on a shear gage installation, and, similarly, to separate the effects of shear and torque on bending moment gages, etc.

The strain gages are calibrated by placing approximately 200 individual concentrated loads on the wing at about 20 different spanwise and chordwise locations as shown on this chart. The strain gage deflections are then interpreted in terms of wing load by means of a rather elaborate mathematical procedure from which equations are determined which relate the strain gage deflections to the desired loads. Once the equations are determined it is then possible to combine two or more strain gages electrically so that only one measurement is necessary to obtain shear, and one for bending moment. Thus, in effect, we have found one strain gage which measures shear and one which measures bending moment.

The next speaker will now discuss applications of strain gage measurements to flight loads research.



NACA

LAL 70586

Speaker - John B. Irvin, LCL Alternate - J. O. Thompson Maneuver Loads Branch

1951 BIENNIAL INSPECTION

May 1951

LOADS CALIBRATION LABORATORY

TALK NO. II

One service airplane on which loads measurements have been made by means of strain gages is the B-45 jet propelled bomber which you see on your right. Strain gage measurements of the loads on the wing, horizontal tail, and vertical tail have been made on the airplane throughout the speed range. Later you may inspect an installation of strain gages used in this airplane for the measurement of wing loads by looking up into the wheel well where the gages have been illuminated for ease in viewing. The purpose of the flight program carried out on the B-45 was not to determine the conditions for maximum load, but rather to establish the agreement which might be expected between flight parameters and those available to the engineer at the design stage. During the course of the flight tests a series of abrupt push-down pull-up maneuvers were made in order to compare measured and calculated tail loads in abrupt maneuvers. Analysis of these data indicated among other things that the flexibility of the rear fuselage and tail combination affected the calculation of the tail loads. It was found that the tail portion of the fuselage oscillated through several cycles every time there was an abrupt elevator deflection. This chart shows time histories of some measured quantities during an abrupt pull-up. The elevator angle is shown at the top. Next the normal acceleration in gravity units is given. Below that, the pitching angular acceleration is shown and at the bottom the incremental tail oscillatory accelerations are indicated. Ordinarily for a rigid airplane

the top three quantities are sufficient to determine the tail loads with the methods usually used. The tail oscillatory acceleration would be zero for a rigid airplane. You can see here that the B-45 deviates from a rigid airplane. These incremental accelerations represent an oscillating vertical bending motion of the rear part of the fuselage.

In the next chart are shown the horizontal tail loads during this maneuver. The black symbols represent the measured values of the tail load as obtained from strain gage measurements. The dashed line represents the tail load calculated from the parameters shown on the preceding chart but neglecting the flexibility parameter. The solid line represents the calculated tail loads including the effect of flexibility. It may be seen that the agreement is fair for the case where flexibility is neglected but the average errors in the calculated tail loads are about 500 pounds while the maximum errors are as large as 2400 pounds: In the case where flexibility was included in the calculations, however, the agreement is excellent.

The B-45 is actually a rather rigid airplane and flexibility may not be too important here; however, for larger and more flexible airplanes it is indicated that flexibility should be considered in methods used to calculate horizontal tail loads since large oscillatory loads due to the flexibility might be superposed upon the critical maneuvering tail loads.

Another type of information that is being obtained in flight by means of strain gage measurements is the distribution of the load among the wing, fuselage, and tail of the airplane. It is important to know how much of the total load on the airplane is acting on the wing, how much is acting on the fuselage, and how much is acting on the tail. In this next chart

is shown the distribution of the total airplane load among the wing, fuselage, and horizontal tail at two angles of attack for one of the current airplanes being tested. It can be seen that the fuselage carries an appreciable amount of the total load in both cases. At an angle of attack of 5° the wing carries about 73 percent of the total load, the fuselage about 25 percent of the load, and the tail about 2 percent. At an angle of attack of 20°, it can be seen that the fuselage carries a larger proportion of the load. Here the wing carries 60 percent, the fuselage 37 percent, and the tail 3 percent.

Some insight into the way the fuselage carries the load is shown in the next chart. Here the distribution of the load over the fuselage is shown at an angle of attack of 20 degrees. These data were obtained in the Langley 8-Foot High-Speed Tunnel by means of pressure distribution measurements. The dots on the fuselage indicate the location of the pressure orifices. It can be seen that the major contribution to the fuselage load is in the vicinity of the wing body intersection. Also shown is the load distribution over the body alone. It may be noted that the major portion of the load on the body with the wing present is caused by the effect of the wing on the body.

In the next chart are shown the spanwise distributions of the load over the wing and the body at two angles of attack. At an angle of attack of 8 degrees the loading is fairly uniform and the fuselage carries about 15 percent of the total load. At an angle of attack of 20 degrees, the load has shifted inboard, the tip losing load, and the inboard part of the wing and fuselage gaining load. It may be seen that

the component of load carried by the fuselage is larger at the higher angle of attack in agreement with the trend shown by the previous strain gage results. The next speaker will now discuss the operation of the fatigue machine which was in operation when you entered this building.

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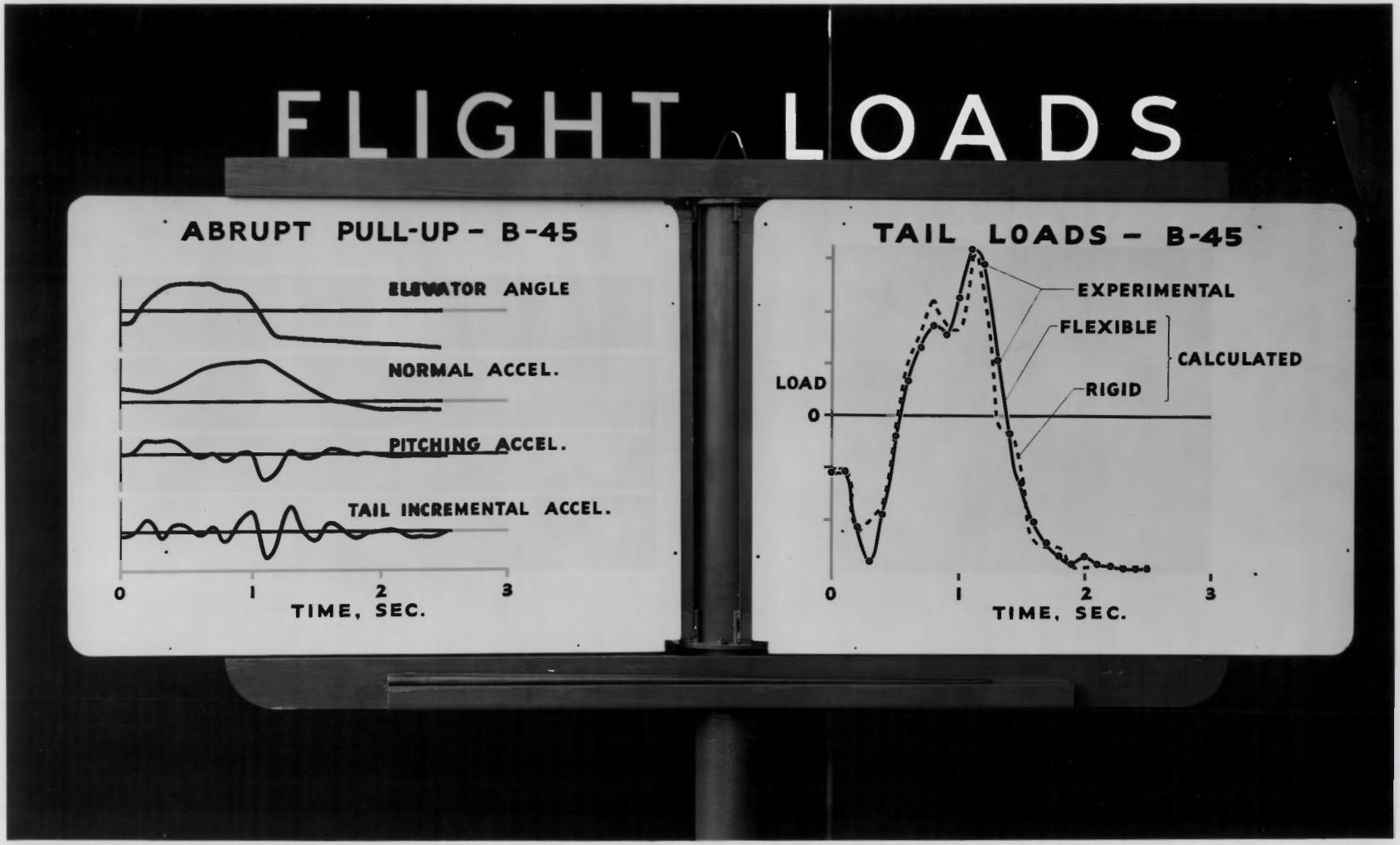
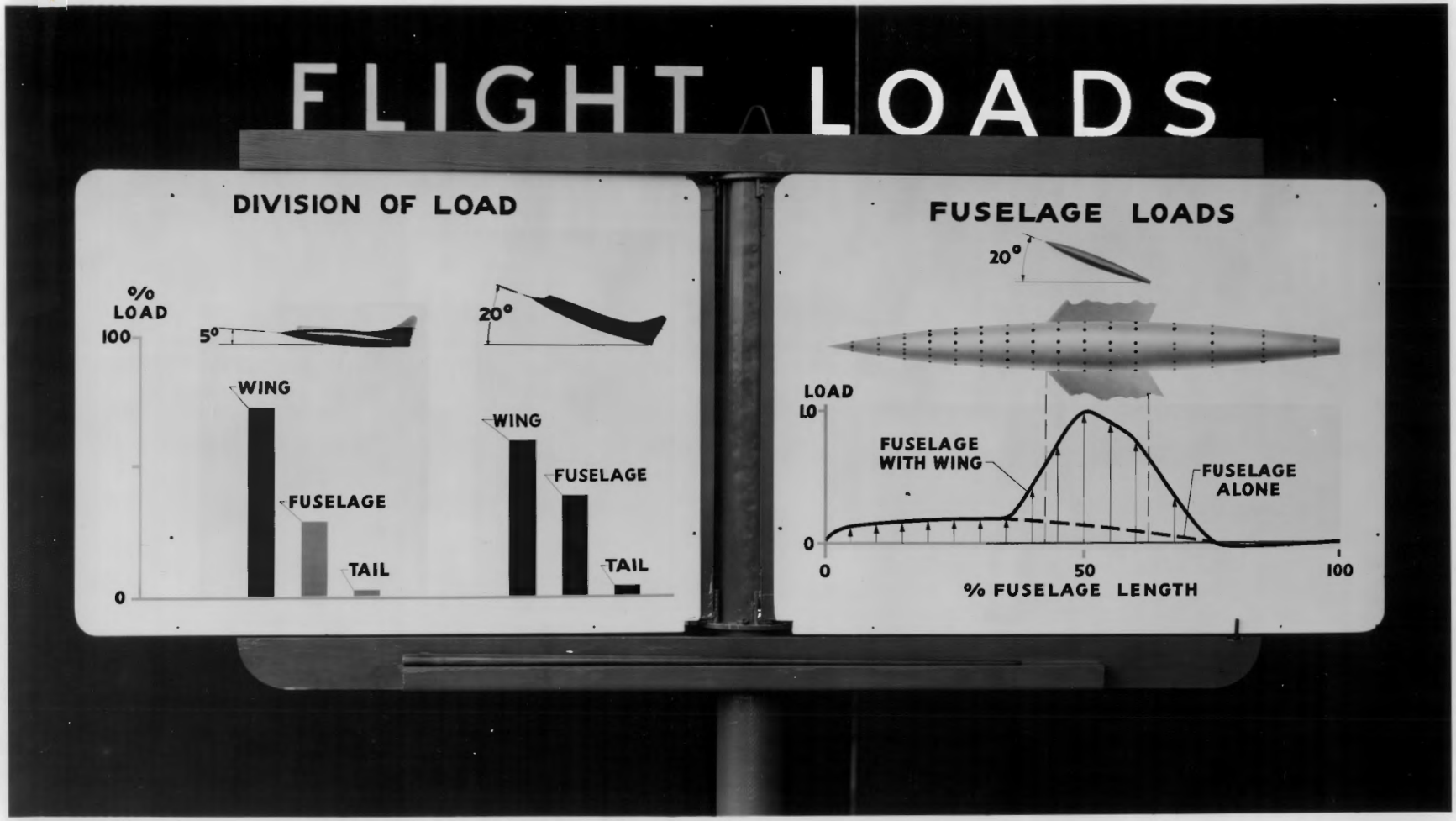

FLIGHT LOADS
ABRUPT PULL-UP - B-45
ELEVATOR ANGLE
NORMAL ACCEL.
PITCHING ACCEL.
TAIL INCREMENTAL ACCEL.
0
1
2
3
TIME, SEC.
TAIL LOADS - B-45
EXPERIMENTAL
FLEXIBLE
CALCULATED
RIGID
LOAD
0
0
1
2
3
TIME, SEC.

LAL 70588



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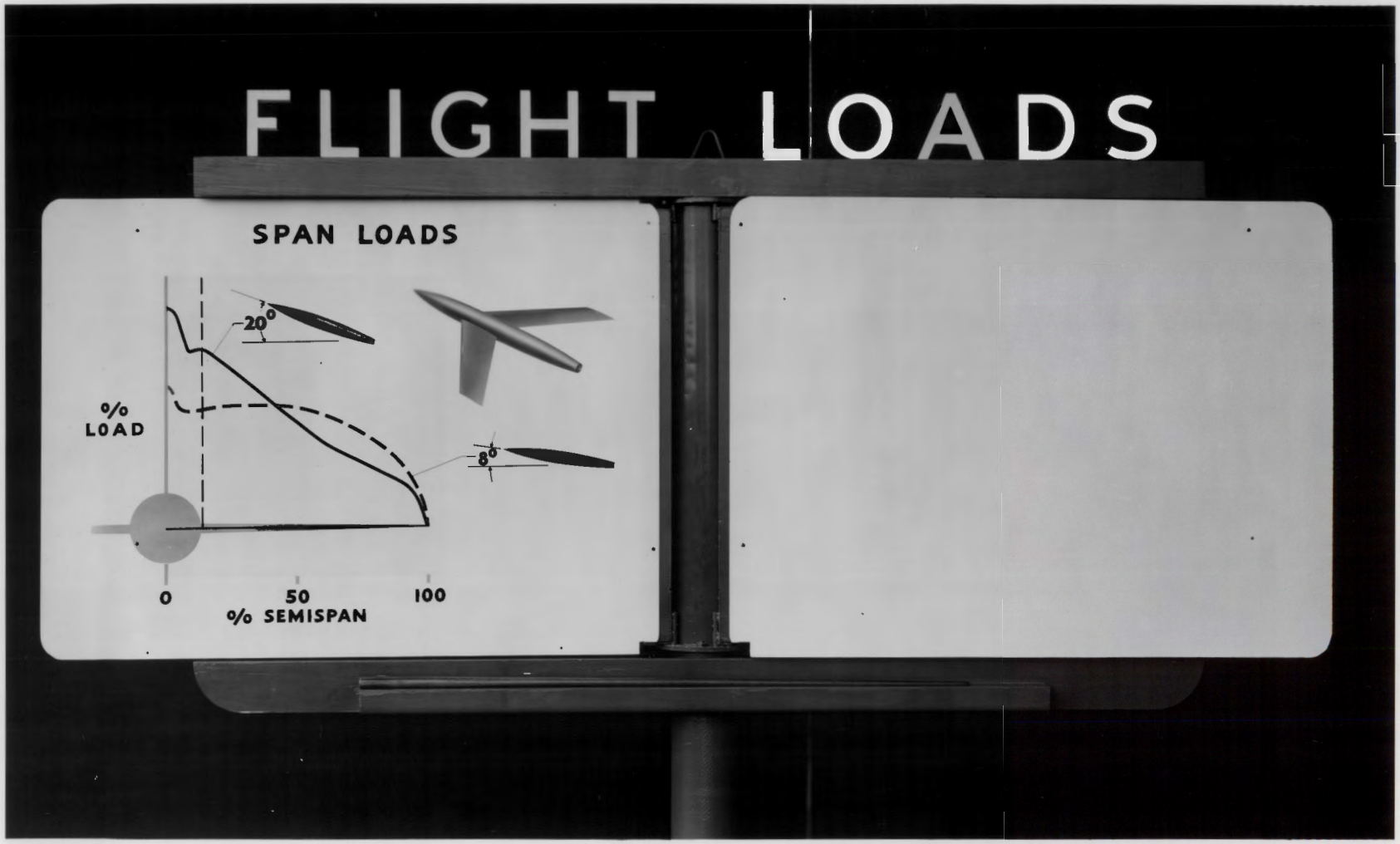

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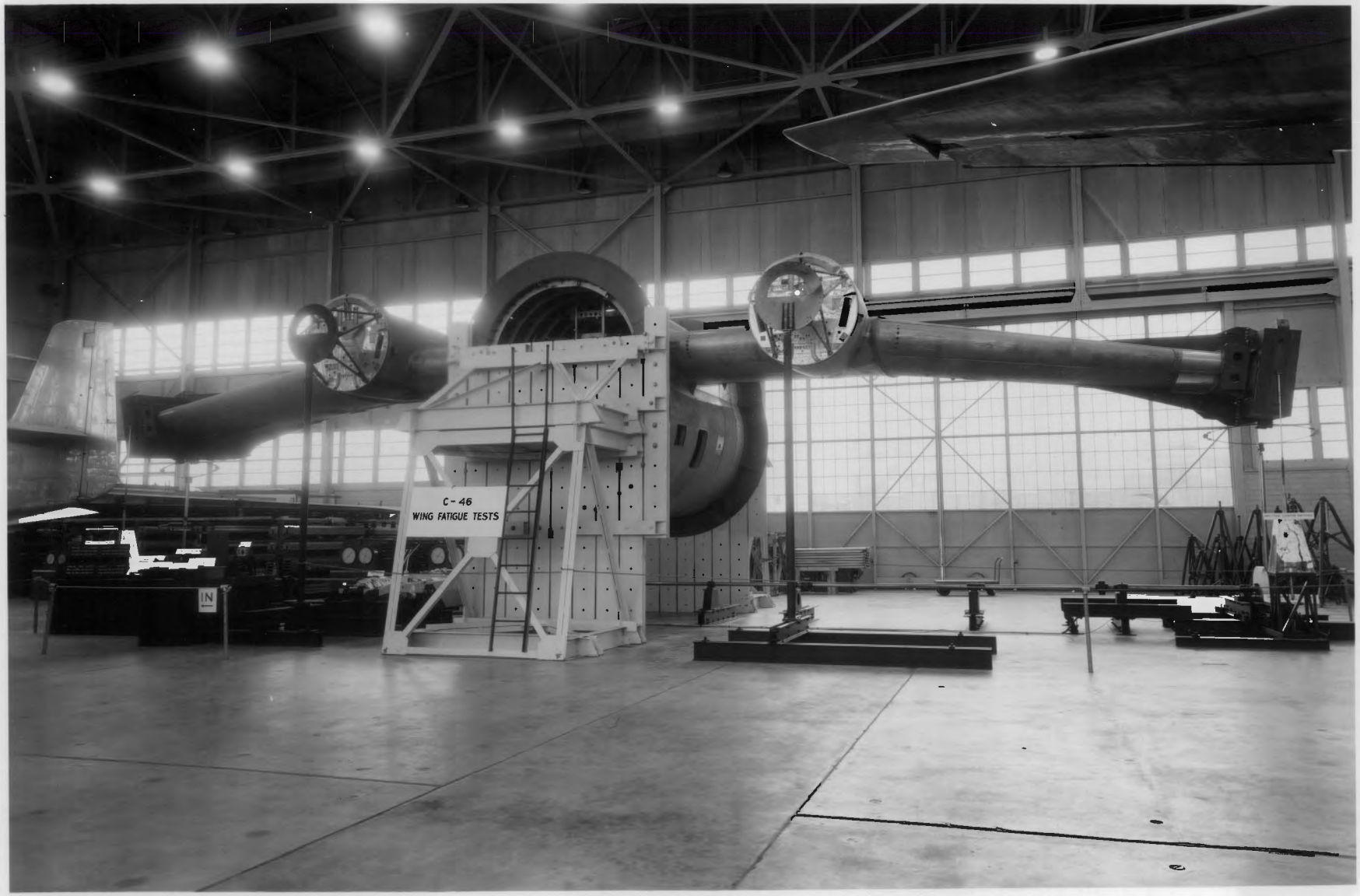
means of a resonant vibrator driven by an electric motor. Two of these fatigue machines are used for these tests. One appears here to your left and incorporates a very versatile loading mechanism for applying random type loads to simulate the flight history of an airplane, while the machine across the laboratory, which will be demonstrated later, applies loads of a more or less constant amplitude to the wing. Two specimens giving fourteen fatigue failures have been tested to date, and although the amount of data collected is too meager to draw broad conclusions, there are certain facts which seem worthy of note even at this time. These are first, that there is a relatively narrow spread in fatigue life of the specimens tested even though the points of failure in all specimens have not occurred at identical points in the structure, second, neither natural frequency nor damping appear to be changed by fatigue damage until after a fatigue crack has originated, and third, the rate of crack growth is quite small until the crack has included approximately 7.5 percent of the tension material of the wing after which the crack growth increases very rapidly.

At this time the fatigue machine near the back wall will be started up again and you will be able to watch the operation of the constant level machine. There will also be time while this machine is running for you to walk around and inspect the other airplanes on exhibit in this laboratory. A wing strain gage installation is illuminated for your inspection in the B-45 airplane on your right; and on the right in front of you is a F-82 airplane on which a strain gage calibration is now in progress.



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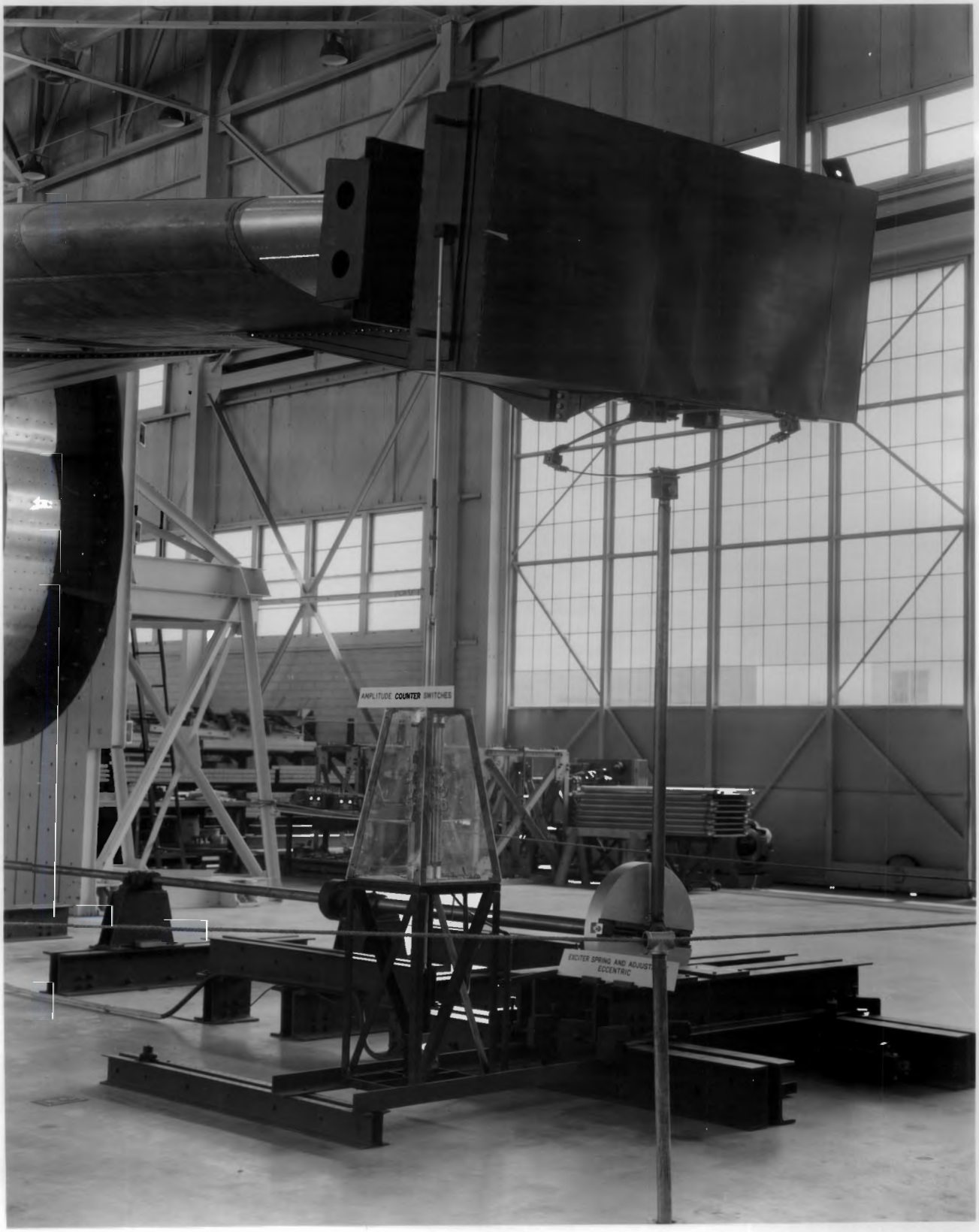

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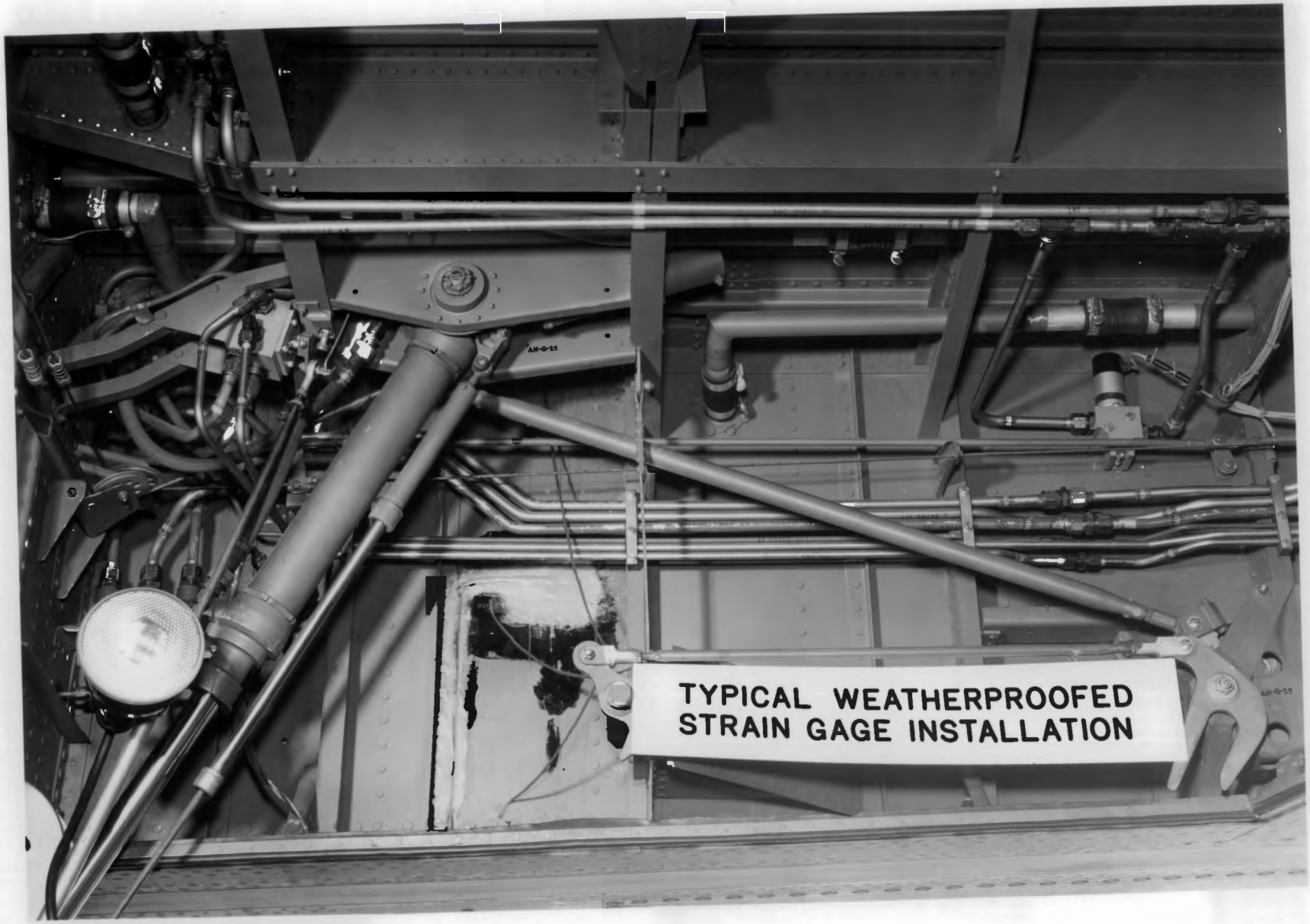

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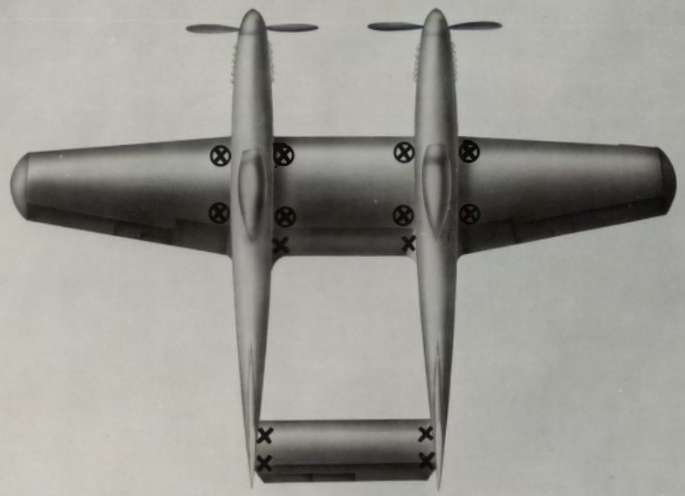
LAL 70581

SET-UP FOR STRAIN GAGE CALIBRATION ON DIVISION OF LOAD

THE F-82 IS ONE OF A SERIES OF AIRPLANES ON WHICH THE DIVISION OF LOAD IS BEING INVESTIGATED.

IN THIS INSTALLATION THE STRAIN GAGES ARE NOT VISIBLE. THEIR LOCATION IS INDICATED ON THIS CHART BY CIRCLES AND CROSSES.



STRAIN GAGES

× SHEAR
○ BENDING MOMENT

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LAL 70590

Speaker - David Bryan Alternate - Creighton . Lee - Loads Calibration Lab.

1951 BIENNIAL INSPECTION

May 1951

LOADS CALIBRATION LABORATORY

TALK NO. III

This laboratory in addition to providing facilities for the calibration of load measuring airplanes also is suitable for conducting other types of research. One of these projects is that dealing with the problem of fatigue in a full scale airplane wing structure. Fatigue is, as you may know, that phenomenon which causes the progressive fracture of a material under repeated loads. For many years it has been known that if a material is loaded at stresses which are considerably less than the ultimate for a sufficient number of times a failure will eventually occur. Why this phenomenon occurs has not yet been satisfactorily answered. The solution of such a problem will involve considerable research on small polished specimens such as you will hear described at another stop. However in addition there must be established the relationship between the results from the small polished specimens and those for completely fabricated wing structures. The primary objective of the fatigue study being conducted here is to establish a better practical knowledge and definition of fatigue as applied to full-scale airplanes.

The vehicle used as a test specimen is the C-46 cargo-type airplane obtained as surplus after World War II. The airplane is prepared for mounting between two backstops as you see on your left. The wings are fitted with weighted attachments to simulate the level flight loadings over a considerable portion of the wing. The repetitive loads which accumulate to cause the fatigue failure in the wing are applied by

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Talk for Biennial Inspection 1951

Gust Tunnel

By Reisert and Cahen

Gentlemen, today we're going to discuss some airplane operating problems and some recent information obtained from gust research. Atmospheric turbulence or gustiness poses a number of problems relating to the safety of flight. Many techniques are involved in studying these problems and one of the tools used is the gust tunnel. You see the tunnel running over here and since most of you have been here before, no doubt you're expecting one of our demonstrations which, as you know, consists of a loud bang and a model streaking by here so rapidly that hardly anyone can see its action in a gust. We realize this, so today we aren't going to demonstrate the equipment, we just have the tunnel running for ventilation. If we were going to demonstrate today we would fly two small models side by side through this gust. They would be identical except that one would be twice as heavy as the other and naturally they would behave differently in the gust. Now to show you what you should see, let's have some slow motion movies, in which we hope everyone will see how the models behave.

Movie.

These pictures are being shown at 1/8 speed.

The first shot shows the models flying side by side with no gust and you can see they are flying parallel paths.

The second shot shows the same models flying in a gust. Note that the heavy model, which is the one to your left, does not rise as much as the other but that it does pitch down a good deal.

(3rd flight) Now this is exactly the same flight, just to give you another look at it. (end movie)

This effect of wing loading is not something new but we thought it would make a good thing to show in order to give you an idea of how changing one of the parameters of an airplane might affect its behavior in a gust. Now, we study many problems with this equipment. One of our current programs is to study the airflow over swept wings in gusts. This morning at your first stop, at the full-scale tunnel, they presented a chart which showed that in steady flow at relatively high angles of attack on wings having certain degrees of sweep and leading edge radius, leading edge separation occurred in the form of a vortex. Now our problem is to find out if this same phenomenon occurs in the gust condition where the wing undergoes a very rapid change in angle of attack. In order to obtain this information we selected a model which according to steady flow data should generate a vortex. Then we glued tufts on the wing surface and photographed them as the model passed through the jet.

The chart I have here shows a comparison of the tuft behavior on this wing in the gust tunnel and in a wind tunnel. This picture shows the tuft behavior on the model in steady

flight just before it enters the gust. This one shows how the tufts behave in the unsteady flow conditions of a gust, where the model undergoes a change in angle of attack from 6 to 15 degrees almost instantaneously. Now for comparison, this picture was taken of the model in the steady flow conditions of a wind tunnel at a corresponding angle of attack. In this picture at 6 degrees, the tufts are parallel and indicate a flow straight back. Now in these two at 15 degrees, if I place the pointer here, the tufts below the pointer are still parallel but those above the pointer indicate a lateral flow outward toward the tip. This type of tuft pattern has been identified with a leading edge vortex. Comparison of these two pictures shows that the flows are similar for the two conditions. This was contrary to our expectations because we didn't think that the vortex would have time to develop in the gust before the model reached peak load. Since this vortex pattern is associated with increased lift its appearance here in the gust has led to the tentative conclusion that it may be present on actual swept-wing airplanes in rough air and may result in increased gust loads. Further study of this problem is now in progress.

Introduce next speaker.

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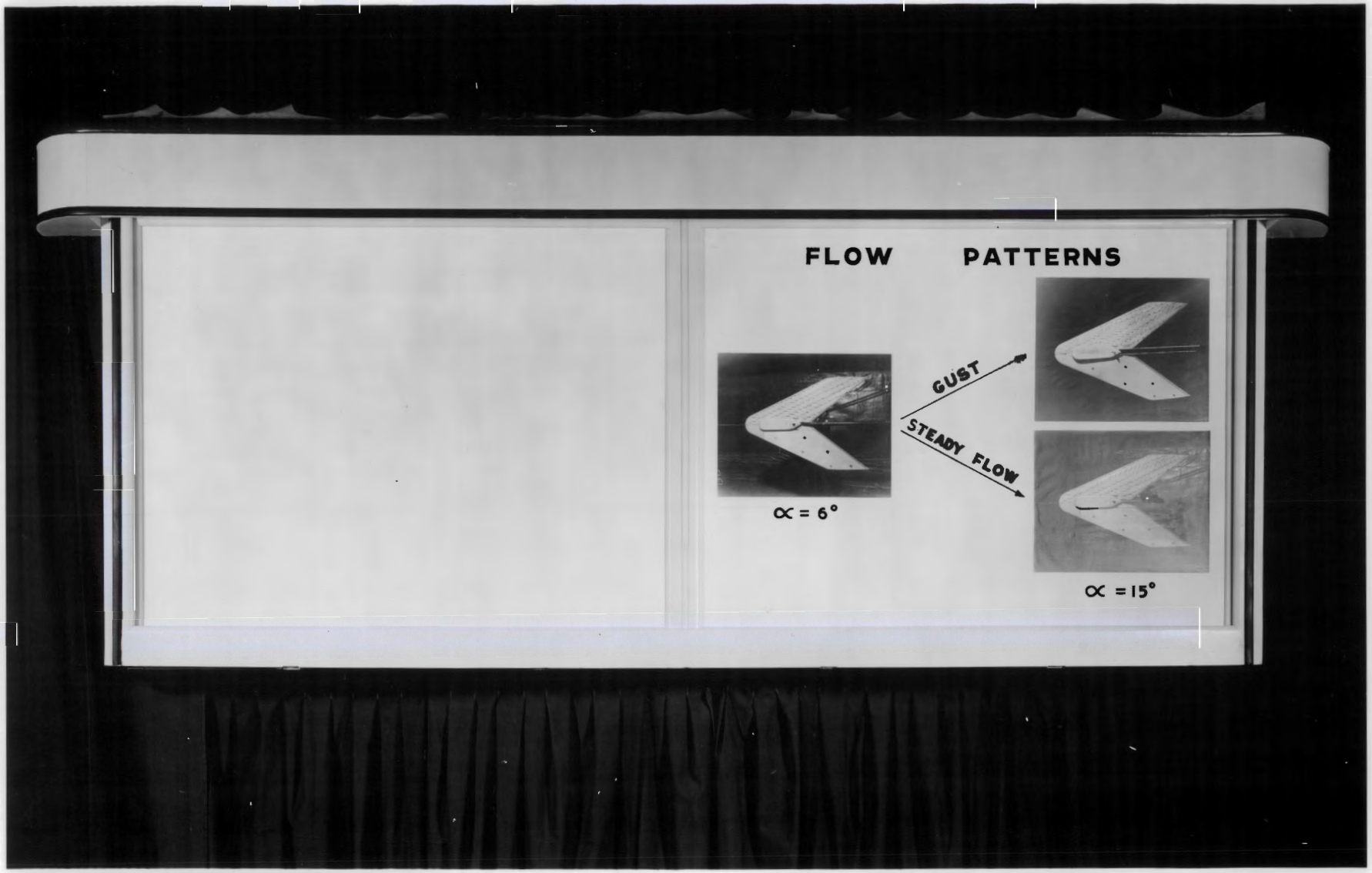

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