Talk presented at Flight Research.
Alternate Speakers: R. C. Dingeldein, FST, and A. Gessow, Flt. Res.

Helicopter Research

Talk Presented by Full-Scale Tunnel at May 1949

Biennial Inspection at Langley

HELICOPTER RESEARCH

Helicopter research is conducted at the Langley Laboratory by means of various experimental methods as well as by theoretical studies. Experimental data are obtained on full-scale and small-scale models in flight, in wind tunnels, and on the helicopter test tower.

One of the problems to which we are giving a great deal of attention at present concerns the stability and control and handling qualities of helicopters. A convenient way of determining the effects of gross changes in helicopter design variables on the stability characteristics is by means of small-scale models. This model is used to measure the aerodynamic damping in roll or pitch. You'll note that there is no damping present when the model is disturbed. With the rotor turning, however, the motion is damped rapidly. This aerodynamic damping is a stability characteristic that is very important in determining how a helicopter reacts to a disturbance.

This model is used to determine the static stability characteristics of tandem rotor configurations. Similar single rotor and tandem models are to be flown in the free-flight tunnel.

The overall aerodynamic characteristics of various rotor configurations are being studied in detail at the full-scale tunnel. Having initially worked with the basic single-rotor case, the tunnel staff is having built an adaptable apparatus to cover multiple-rotor systems such as tandem and side-by-side arrangements having various amounts of rotor overlap and stagger. The setup covering the coaxial configuration was seen by you this morning in the full-scale tunnel.

This coaxial model is used for flow studies that aid in the understanding of full-scale results. The flow pattern is obtained by photographing the streamlines formed by balsa dust illuminated by a flat beam of light.

This upper photograph shows a flow pattern such as may occur during a jump takeoff. The starting vortex is shown as it progresses downward from the rotor. This other photograph shows the pattern after the flow was steadied down. More quantitative results obtained on the test tower indicate a similar flow pattern and also show that the thrust may be as much as doubled momentarily following a sudden pitch increase.

Mr. Carpenter will now tell you of some further studies made with the test tower, which you will pass on your visit to the West Area.

Part II of Helicopter exhibit

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One of the investigations has been a study of the problem of oscillatory drive-shaft torque and lag-angle motion in helicopter rotors with the usual hinged-blades. Lag-angle motion being this motion (show) of the blade in the plane of the rotor disk about this hinge.

The need for this study became apparent as the result of several blade failures which were thought to have been caused by large torque and lag-angle motion oscillations. The object of these tests wasthe experimental determination of the natural frequencies and of the damping required to prevent excessive response of the lag-angle motion, as compared with those calculated from the available theory- aerodynamic damping being one factor of doubtful predictability. We will discuss the symmetrical type of lag angle oscillations, which may result from a hunting governor or pitch and throttle control movements of the pilot. The symmetrical type is the one in which all blades lead and lag together giving large torque oscillations.

(turn to chart) The curves shown are for various settings of the viscous dampers located at the blade roots (point). The 100% curve represents the amount of damping that will prevent resonance and still not be so stiff as to induce high bending loads at the blade roots and hence may be considered a normal design value. The vertical axis (point) is the lag-angle amplification factor which represents the amount the lag angle and the torque load is increased for an oscillatory control movement as compared with a fixed displacement. The horizontal axis is the ratio of rotor speed to exciting frequency. If the particular configuration has no dampers or if they are ineffective, dangerous amplitudes of the lag angle and drive shaft torque might be reached as represented by the curves of 0 and little viscous damping.

It is seen from this curve that the air damping alone is insufficient to control this oscillation and it is possible for the blades to hit the stops and for the drive shaft to twist off if the resonant frequencies are approached. Good agreement was obtained between the experimental resonant frequency and the predicted frequency. Likewise it was found that the necessary damping could be predicted.

Some of the current work being done by the Flight Research Division will now be discussed by Mr. Amer.

Part III of Helicopter exhibit -

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In the Flight Research group, current helicopter studies are primarily concerned with stability and control and other features which together determine the ease and safety of flying a helicopter.

One very important problem encountered in our investigations is the undesirable longitudinal control characteristics in high speed forward flight which are present in many helicopters. The ease of flying in forward flight depends to a very important degree on the manner in which the pitching motion, and changes in lift or normal acceleration, occur after moving the longitudinal controls.

This chart gives * the time histories of control stick position, pitching angular velocity, and normal acceleration during pull-up maneuvers in three helicopter configurations which are progressively better from the consideration of safety and ease of piloting. These pull-ups were maneuvers in which the ship was trimmed in level cruising flight and the stick then moved backwards abruptly about an inch. The dotted lines shows these quantities during the recovery from the maneuvers.

The first case, A, which is typical of many present day helicopters, caused great apprehension owing to the presence of a tendency to diverge. Once a nose-up pitch was initiated the ship tended to dig in with pitching and acceleration continuously increasing * until the pilot was forced to recover with considerable opposite, i.e., forward control * to prevent a dangerous condition. *

Case B is for a helicopter in which this divergent tendency is not present. The chart shows a reasonable angular velocity build-up and the normal acceleration reaches a maximum and then falls off. Recovery was not necessary until maximum acceleration was passed and was much simpler than in case A. The pilot's comments were that his apprehension was much less and

that the presence or absence of this divergent tendency is the most important factor in evaluating the flying qualities of the helicopter. However, he felt that it was still difficult to accurately control the flight path of the helicopter because the final acceleration was difficult to anticipate in the early stages of the maneuver. In this connection, the time history shows a pause in the development of acceleration and shows that the time to reach maximum acceleration is fairly long. *

Finally, similar data were obtained on a helicopter, case C, which the pilots considered satisfactory. This case caused no apprehension and further no difficulty in anticipating the final acceleration, and hence in controlling the flight path. The difference appreciated by the pilot apparently is not a reduction of time to maximum acceleration, since it is the same as before, but the early development of acceleration in which there is no longer a momentary pause. * It is interesting to note that such differences in manner of development of acceleration can be significant to the pilot when the numerical differences between the two acceleration curves are quite small.

This concludes your visit to the helicopter exhibit.

time-history is represented by the sine pulse shown in green. This particular sine curve was chosen to give the same total impulse, or change in momentum, as the experimental load, and reaches a maximum value at the same time as the experimental load. The response to the sine pulse is shown by the green curve (on the right).

The significance of this figure lies in the substantial differences in response, both in magnitude and variation, produced by apparently reasonable approximations to the applied load time history. These results indicate that a dynamic landing loads analysis requires the accurate determination not only of the maximum values of the applied load, but of the entire time history, as well.

In order to permit the prediction of landing gear performance, it is necessary to study the elements which determine landing gear behavior. Such factors as tire springing, shock strut springing, orifice coefficients associated with oleo resistance and metering pin design, internal friction and binding in shock struts, tire skidding friction, and the effects of wing lift are currently being investigated. The synthesis of these elements is expected to provide the basis for rational methods of calculating landing gear behavior for use in landing gear design as well as in dynamic landing loads analyses of flexible structures.

In order to illustrate some of the previously mentioned transient phenomena which may be produced during a landing, you will see a landing impact simulated with the impact basin test equipment. Since the time is short, it would be appreciated if you will follow me and gather around both sides of the equipment as quickly as possible..... In this demonstration wing lift will be mechanically simulated by means

of a pneumatic cylinder and cam system acting through these cables. The effects of forward speed, and the associated drag loads produced, will be simulated by spinning up the wheel backwards before the impact. During the impact the sudden arrest of the sinking speed will cause the wings to deflect and vibrate in bending. The sudden rise and decay of the wheel drag load will cause the landing gear to deflect horizontally producing fore and aft vibration of the gear when the load is released. The impact will also cause the fuselage and tail to oscillate with a fairly large amplitude. Although the landing conditions will be moderate, the deflections and vibrations will be large enough to see. The wheel will now be spun-up.

When the wheel is up to speed the motor will be disengaged and the landing will be made. The whole impact will be over in a very short time so it will be necessary to watch closely once the motor is disengaged. If you watch the landing gear fore and aft deflection first, then look at the wing and fuselage, you should be able to see all the different types of vibrations.

Dynamic Response in Gusts

Harold B. Pierce and Mason T. Charak

Airplane structures are generally designed for loads which are assumed to be applied slowly as compared to the natural rates of vibration of the structural components. In some cases, such as when flying through gusts or on landing, the rate of application of load is high compared to the natural rate of vibration of the wing and under these conditions dynamic effects appear together with stress amplification. The trends in design over the past 10 to 20 years would indicate greater dynamic response to gust loads and it would be well to review the pertinent factors and summarize the present knowledge.

Some factors of importance and the trends shown by calculation are illustrated here on the first chart. The increase in airspeed from the old transport to the modern jet airplane has increased the rate of application of the gust load, whereas higher altitude operation of aircraft has reduced the aerodynamic damping of the oscillatory wing motion. Both factors would be expected to increase the dynamic response of airplane wings to gusts. Modern, thin, internally braced airplane wings tend to have a lower natural rate of vibration than the wings of the older airplanes. In addition, the greater amount of mass distributed along the wing of the present day airplane, also tends to lower the natural rate of wing vibration. As a result of all these trends, the rate of load application is brought closer to the natural rate of vibration of the wing by about 50 percent so that calculations indicate a relative increase in the wing stresses of some 10 to 30 percent for the modern transport airplane. Such an increase is of concern for both the large single loads and for the fatigue life of airplanes.

A preliminary flight investigation was undertaken with a small jet propelled fighter, in order to examine experimentally two of the factors listed on the chart, namely the effect of a change in airspeed and of a change in mass distribution. The method employed was to fly the airplane through gusts at two airspeeds and with different amount of fuel in the tip tanks. The wing bending moments were

measured by strain gages near the root and the accelerations were measured at the airplane center of gravity. Similar measurements were also made in relatively slow or steady pullups to establish a datum for comparison.

The results of the tests are shown as relative dynamic stress versus percent fuel load in the tip tanks where relative dynamic stress is the ratio of the bending moment per g in gusts to the bending moment per g in the slow pullup. The lower line represents the results at 200 miles an hour and the upper line for 450 miles an hour. Both curves show an increase in dynamic response as the fuel load in the tip tanks increases. Since the increase is about 10 percent at 200 miles an hour and nearly 20 percent at 450 miles an hour, it can also be seen that the increase in speed has also increased the dynamic response.

Although the expected trends in dynamic response were observed, the fact that all the relative dynamic stresses have values less than one seems to indicate that the net dynamic stresses are well below the static values. It should be pointed out, therefore, that the c.g. acceleration measurements in the gust condition are somewhat amplified by wing vibrations which are not present in slow pullups. In addition the span load distributions are not in general the same for the two conditions. Therefore, the absolute values of the relative dynamic stress have no complete meaning here and further research is required to establish the necessity of taking dynamic response into account for the single design gust load. In this connection, more complete tests are currently in progress on a transport type airplane.

IMPACT BASIN
1949 BI (DOF)

A Review of Some Factors Affecting the Fatigue Life of Transport Airplanes

by Dwight O. Fearnow and Creighton C. Lee

The problem of fatigue in airplane structures has become increasingly important to the aircraft industry in recent years. A few years ago fatigue was considered merely as a nuisance since it was primarily a maintenance and inspection problem involving replacement of skin and minor structural elements. In those few cases where fatigue failures caused accidents, the blame was generally placed entirely on poor detail design. There are however, a number of factors in addition to the detail design that affect fatigue life and, although a full discussion is not possible here, some of them will be reviewed. The charts to follow refer to a typical transport airplane and it is assumed that the static strength of the wing structure is based on gust load requirements.

On the first chart is shown a plot of fatigue life as a function of stress concentration factor, which is a measure of detail design. An example of one form of stress concentration is shown here by a hole in a flat plate under a uniform load. The local stresses across the specimen vary according to this stress distribution pattern with the peak stress at the edge of the hole. The stress concentration factor is defined as the ratio of the maximum stress to the average stress in the specimen. Concentration factors from 2 to 6 bracket conditions normally found in airplane structures. Note that the fatigue life is shown in miles on a logarithmic scale where each mark or division represents a change in life by a factor of 100. The importance of detail design

is obvious, since a relatively small change in concentration factor, changes the fatigue life to a marked degree. For example, the fatigue life can be made nearly 200 times greater when the stress concentration factor is changed from 4 to 2.

The trend toward increased speed has frequently been thought to have an adverse effect on fatigue life since the wing loads increase directly with speed when a gust is encountered. The next chart shows a plot of fatigue life as a function of design speed for stress concentration factors of 2.4 and 6.0. The results of the analysis indicate that doubling the design forward speed reduces the fatigue life by a factor of only two for the low concentration factor, while the effect is negligible at the high concentration factor. On the whole, therefore, the effect of the trend toward increasing design speeds has an unimportant effect on fatigue life.

Increased wing loading has also been thought to have an adverse effect on fatigue life since, as the wing loading increases, the stress in level flight is higher. On the next chart the fatigue life is shown as a function of design wing loading for the same two stress concentration factors of 2.4 and 6.0. The results of ~~the~~ this analysis actually show an increase in fatigue life with wing loading, the effect being appreciable at the lower values of stress concentration factor.

Another factor that has been cited as causing reduced fatigue life is the trend toward higher design stresses. This trend has been caused by improvements in structural design and by the development of high strength materials. In order to show the trend in fatigue life as affected by increasing design stress,

an analysis was made for a hypothetical airplane ~~having~~ ASSUMING a stress concentration factor of 4.0. The next chart shows the results of this analysis, and, as can be seen, the fatigue life is adversely affected by increasing design strength to a marked degree. For example, an increase in design stress from about 20,000 to some 60,000 pounds per square inch would cause a reduction in fatigue life of about 100 fold for the hypothetical airplane.

per JP This means that greater attention must be paid to the detail design so that the effect of increased allowable stress can be offset by reductions in stress concentration factor.

In conclusion, fatigue has become of greater importance in recent years because of the tendency toward the use of higher design stresses. The trends in airplane design have otherwise had a secondary influence on the fatigue life. In order to insure adequate fatigue life it is necessary not to use too high a design stress and to keep the stress concentration factors low by refined detail design.

1949 BIENNIAL INSPECTION

LANDING LOADS RESEARCH

By Benjamin Milwitzky and Dean Lindquist

Landing loads research is concerned with the behavior of the landing gear itself, as well as with the loads imposed upon other parts of the airplane structure during landing.

The basic function of a landing gear is the dissipation of the vertical velocity of the airplane in sufficiently gentle a manner so as not to overload the gear or the airplane structure. There are also a number of other landing gear problems, not directly connected with the vertical velocity. The sudden application and decay of wheel spin-up drag and braking loads can result in dynamic stresses in the gear considerably greater than those which would exist had the loads been statically applied. An allied problem is that of continuous fore-and-aft vibration of the landing gear during taxying, due to variations in tire skidding friction. Very high take off and landing speeds introduce several additional problems. Shimmy control at high speed requires large damping forces which may become difficult to apply because of airframe flexibility. Taxying over bumps at high speed when small hard tires are used requires increased oleo action due to loss of tire springing, and may result in excessive loads on the airplane due to oleo resistance or locking.

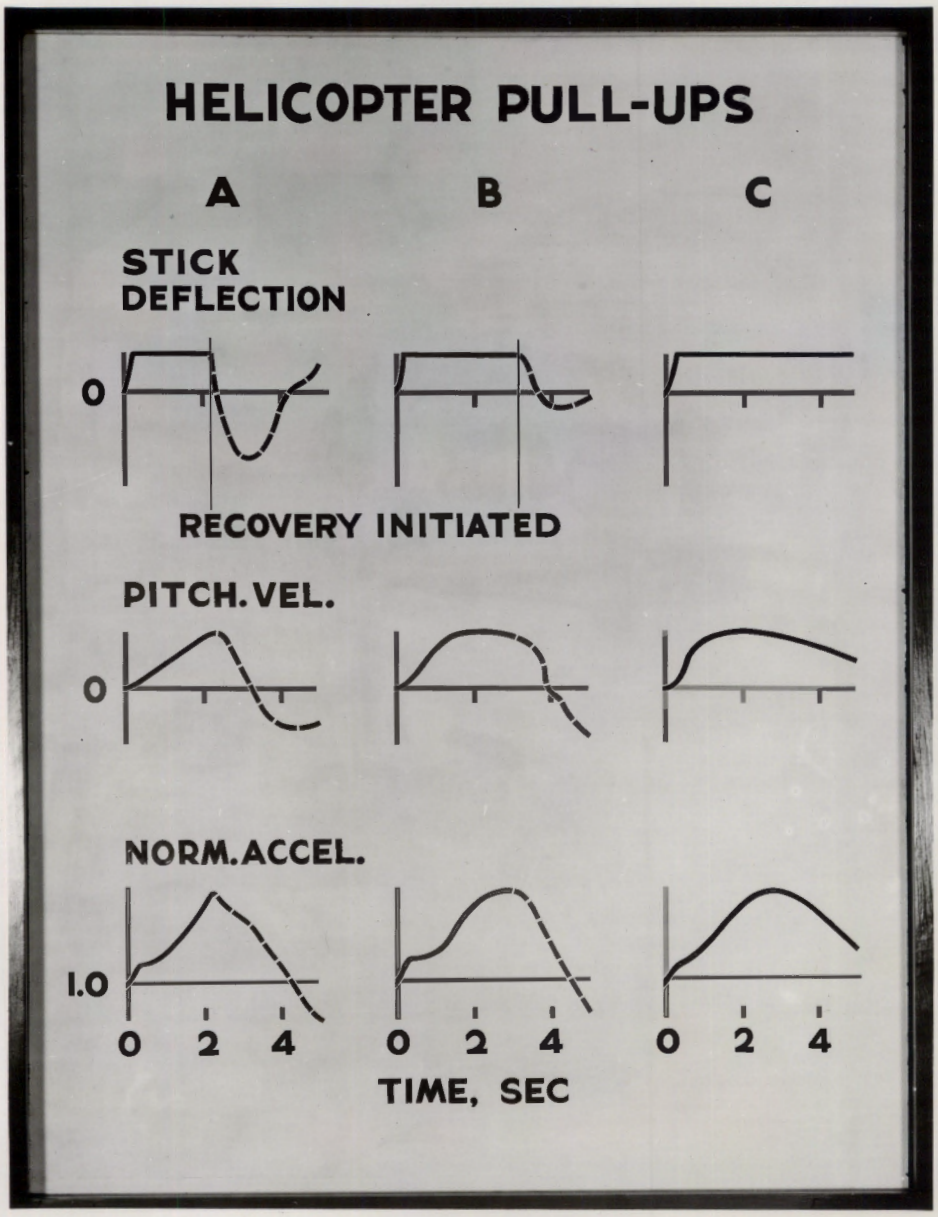
All of these phenomena are basically landing gear problems. Equally important is the behavior of the airplane structure during landing. Various components of the airplane, such as the wing, fuselage, or tail, can be excited by any of the several types of transient or oscillatory landing gear phenomena previously mentioned. For example the sudden arresting of the vertical velocity of an airplane

produces dynamic loads in the wings, the magnitude of which depends on the flexibility of the structure, the mass distribution, the location of the landing gear, and the rate of load variation.

Since the landing loads problem is essentially dynamic in nature, the structural loads and stresses produced by a landing impact depend not only on the maximum values of the applied load, but on the manner in which the load varies, or in other words, on the time history of the applied load.

The chart shows graphically how much effect the rate of force application can have on the loads induced in a flexible structure. The black curve on the left represents an actual applied-load time history measured in a full-scale landing test of a small twin engine airplane. The black curve on the right shows the corresponding wing response time history. It can be seen that the loads induced in the structure had a very irregular variation, quite unlike the applied load, and reached a maximum value equivalent to that which would be produced by a static load approximately 23 percent greater than the actual applied dynamic load.

The pronounced effect that even minor changes in the applied load time-history can have on structural loads and stresses is shown by the other curves. The red curve (on the left) is a triangular approximation to the actual loading function. The slope of the triangular pulse was chosen to closely approximate the average slope of the experimental time history. The response to this pulse is also shown in red (on the right). Another approximation to the applied load



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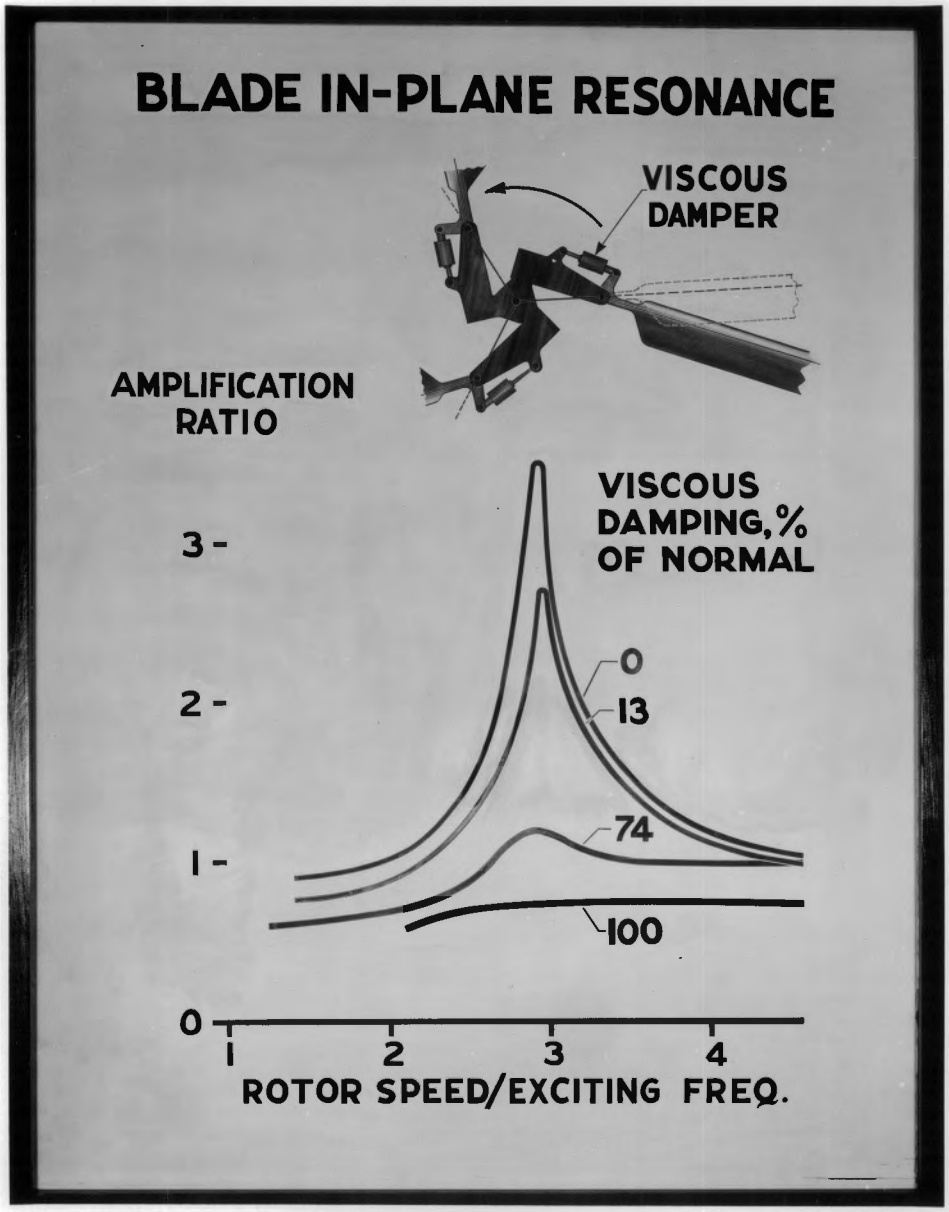

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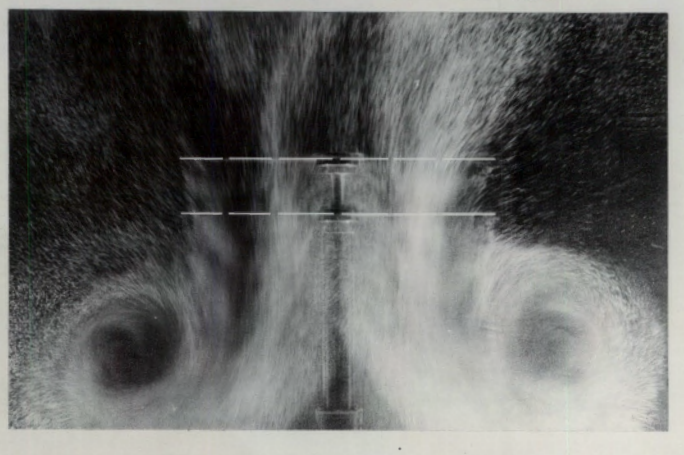
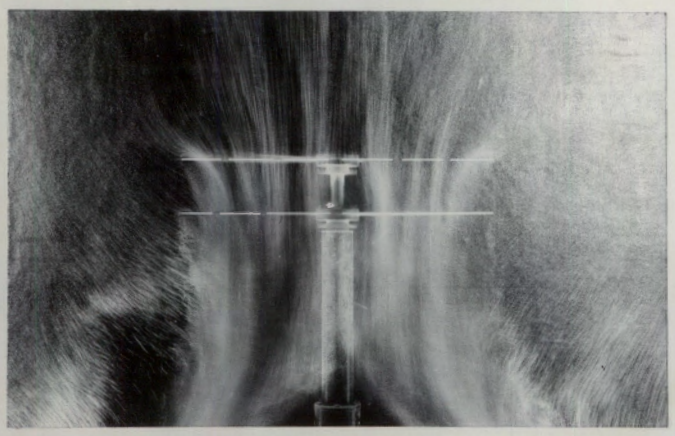
HELICOPTER AIR FLOW

RAPID THRUST INCREASE



STEADY HOVERING FLIGHT



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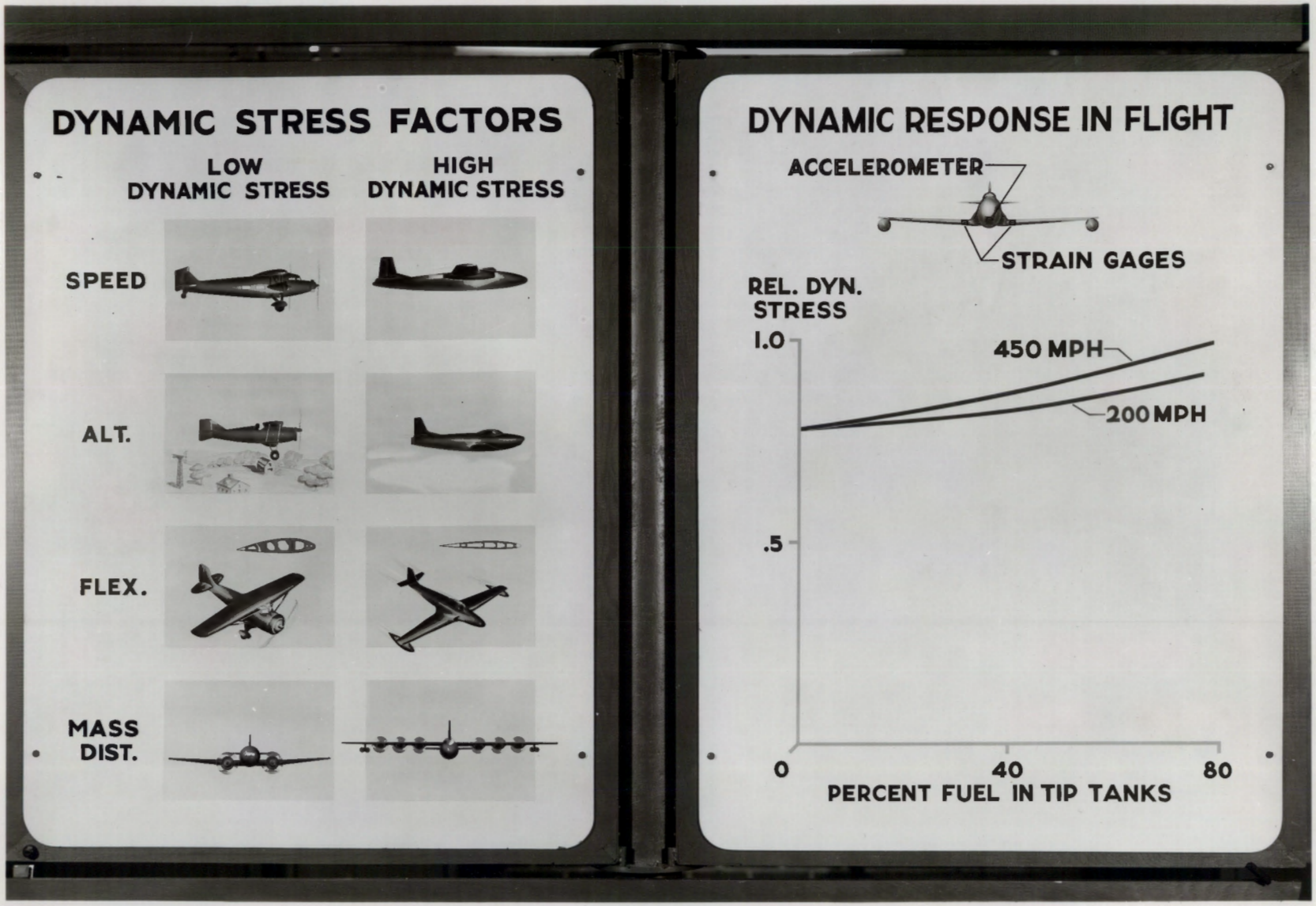

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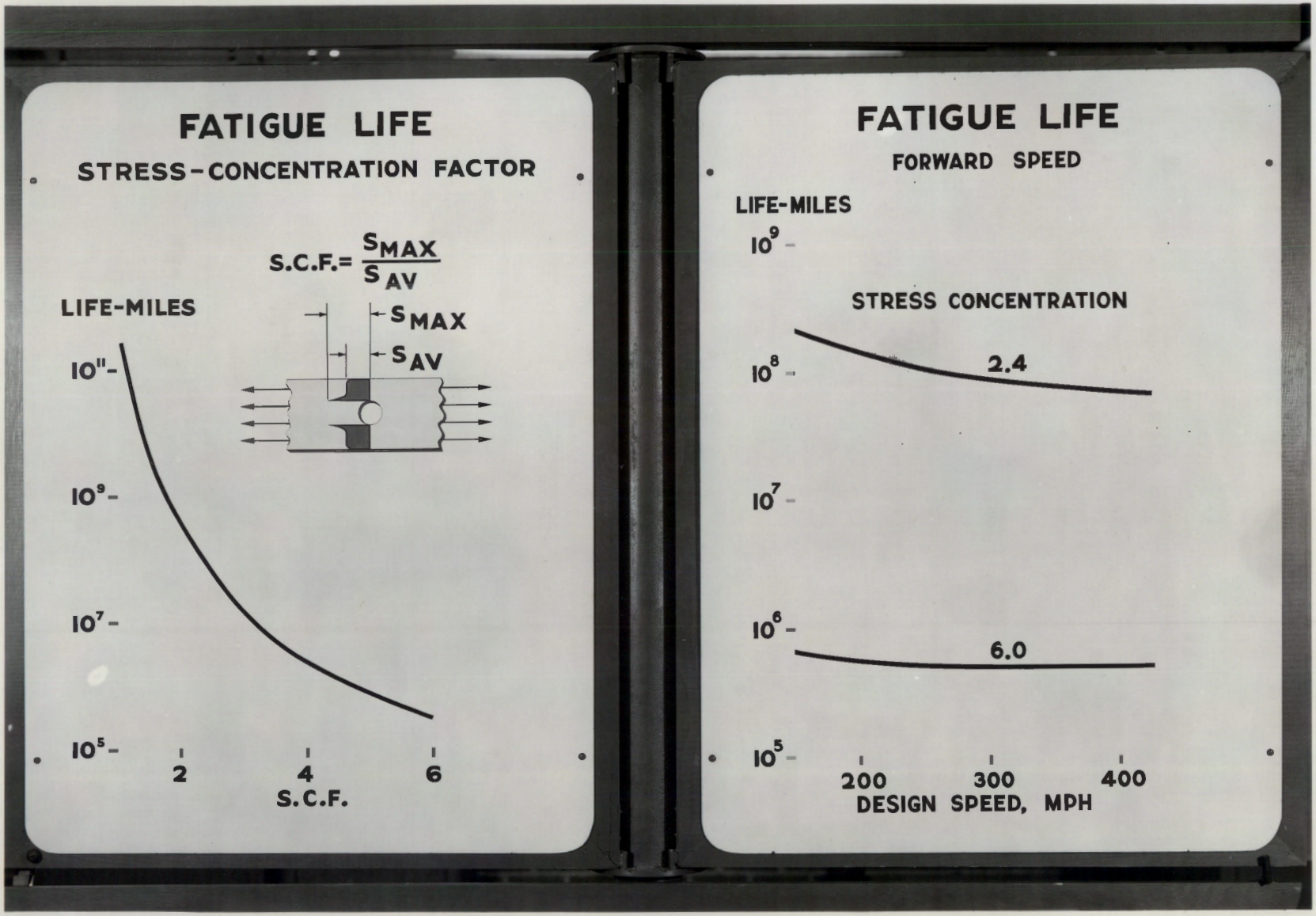

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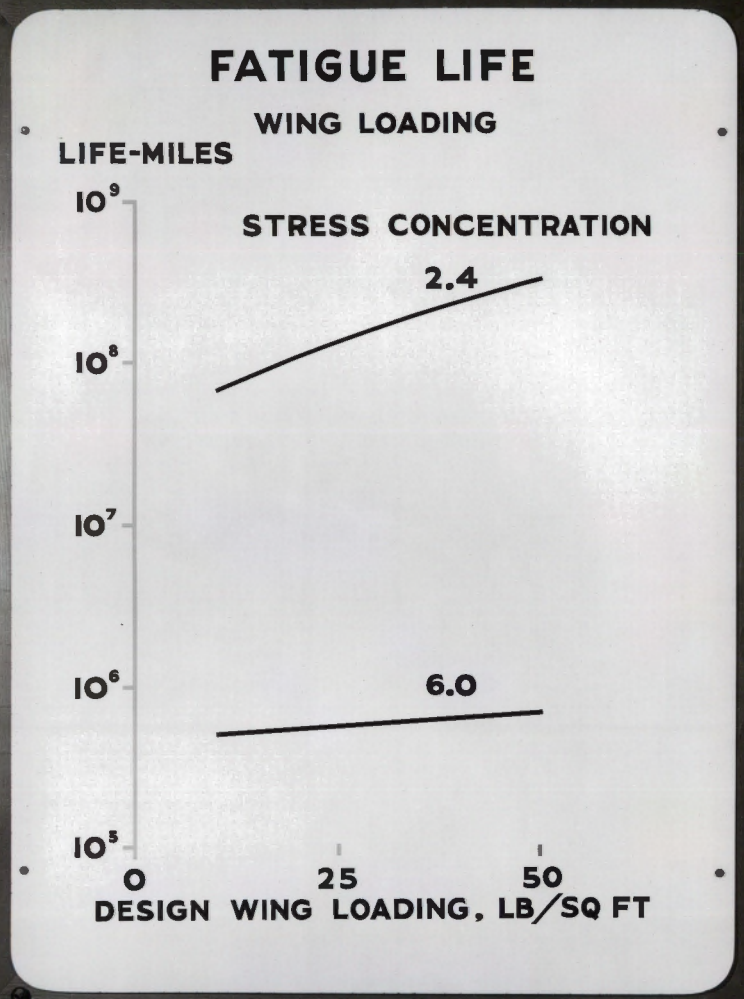

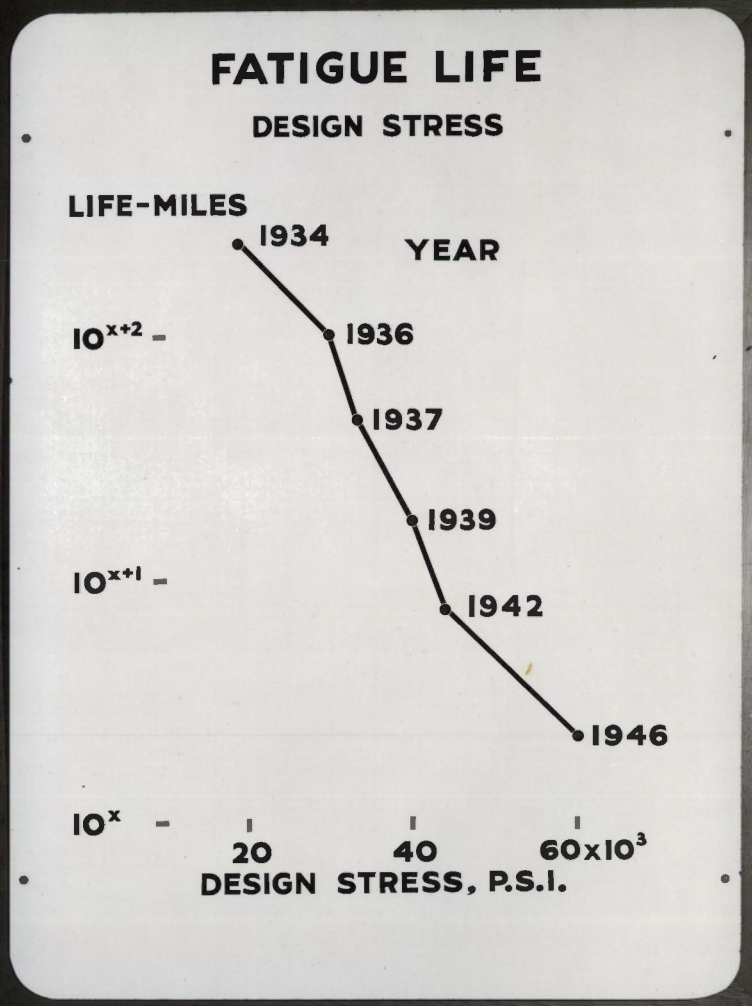

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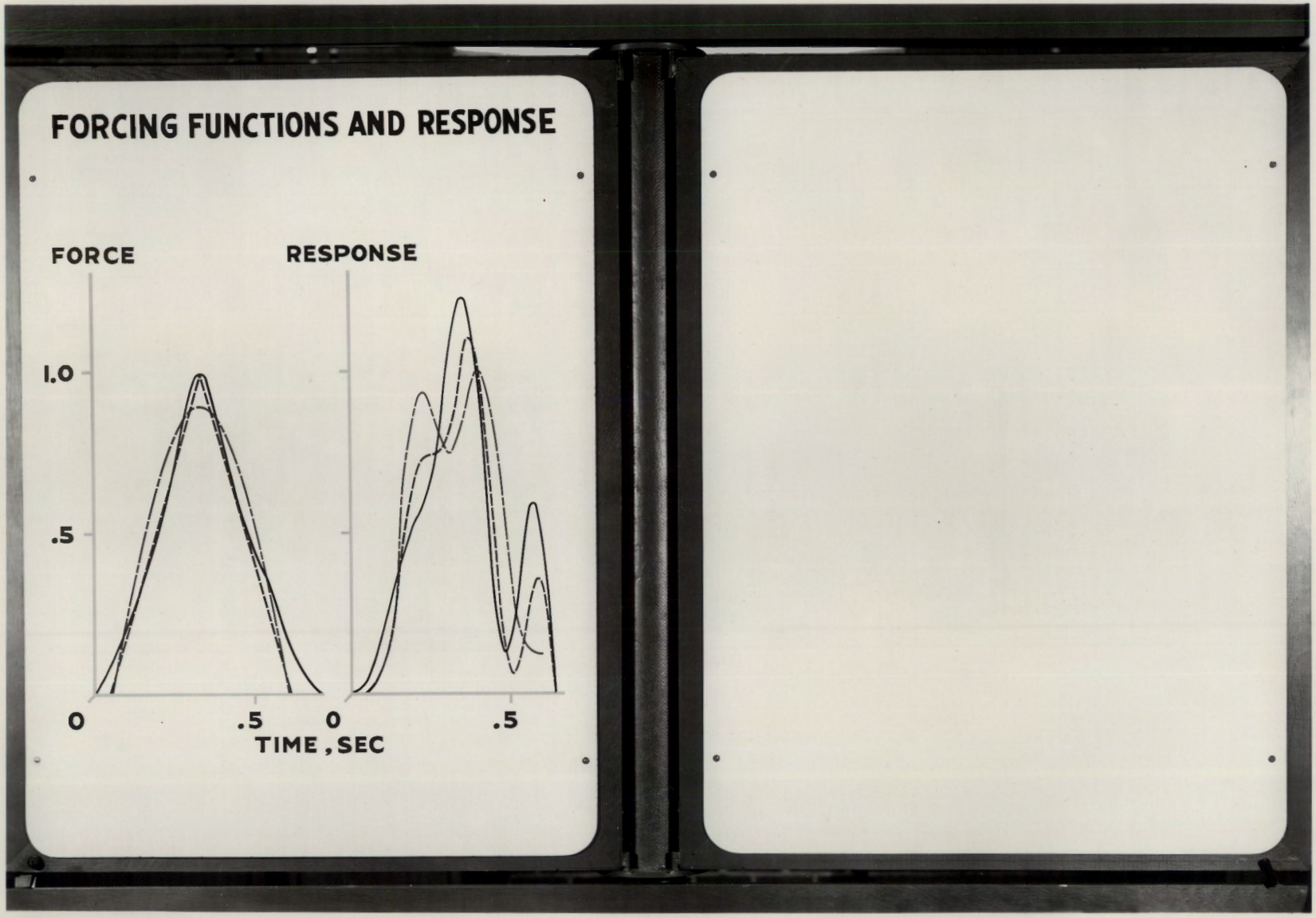

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