Talk for 1953 Langley Inspection

GUST LOADS ON HIGH-ALTITUDE TRANSPORTS

The work of the Dynamic Loads Division embraces problems of unsteady loading conditions which involve combined effects of the inertia, flexibility, and aerodynamic characteristics of the airplane. Examples of these problems are the unsteady loadings in gusts, the impact loads in landings, and the oscillatory loads of vibration or flutter. As the first speaker on some of our research on these problems, I will discuss a part of the work relating to gust loads for high-altitude transport airplanes.

In order to see just where gust loads come from, let's first look at some of the sources of turbulence which airplanes may encounter. We all know, for example, that large bumps occur within thunderstorms. Turbulence may also be encountered in clear air - at the lower altitudes from wind blowing over mountains or other rough terrain, and at higher altitudes from winds blowing part one another with different speeds or directions as in the case of the much discussed jet stream.

Based on measurements of the turbulence in these various conditions, the right-hand part of the chart shows the overall variation with altitude of the number and intensity of the gusts. The size of the circles represents the relative intensity of the gusts or bumps, and the number of the circles represents the relative number of the gusts at different altitudes. You can see that there is a relatively large number of the small gusts, and that the number and intensity of the gusts decrease quite rapidly with increasing altitude. Above, say about 40,000 feet, it would be quite unusual to encounter large gusts.

Now, if we consider this gust pattern in relation to the flight plans shown in the chart, it would seem that a jet transport which cruises around 40,000 feet should give a smoother ride than our present day operations at the lower altitudes. In assessing the loads, however, we must take into account the entire flight history from take-off to landing. Since the loads, or the severity of the bumps, increase with flight speed, the fast flying jet would experience large loads in climbing and descending through the rough air at the low altitudes.

Now in order to illustrate the probable trends in gust loads for jet transports, let's consider first the loads for our present piston-engined transports which operate around 20 to 25,000 feet. Then we can compare these loads with the loads expected for high-altitude jet transports. For this purpose, we have assumed a series of flights totaling 10,000,000 miles for each airplane. The flights are made between two points located about 2000 miles apart. For these flights, the number and intensity of the gust loads for our present day transports are shown in the next chart. We have shown the intensity of the loads in terms of airplane weight. The curve shows that actually thousands of the small loads are experienced from the many small gusts. When we get to the very large loads, we can see that only few occur.

Now let's suppose that we replace the engines in this transport with jets and make the same series of flights but at an altitude of 40,000 feet. The curve we get for this condition indicates that the overall loads picture is somewhat worse, despite the smoother air at high altitudes. The number of small loads is still about the same, but the number of large loads has actually increased because of the relatively high speed in climb and descent through the low rough altitudes.

These curves don't represent quite the whole picture, however, since the future jet transport will not look like our present day transport. It will probably have swept and low aspect ratio wings and also a higher wing loading. All these factors tend to reduce the loads.

Now when we consider this new airplane making the trips at 40,000 feet, we get another curve which looks a little more favorable for the jet. The number of small loads has decreased by quite a substantial number - but the number of large loads is still about the same as for our present day operations.

From this discussion, it seems that the designers and operators of high-sltitude jet transports will still be faced with gust load problems. Two factors that have an important influence on the gust loads are flight speed and airplane configuration. Let's point out again, however, that these large loads for the jet will occur mainly for only a small portion of the flight at low altitudes, and that the balance of the ride at the higher cruising altitude will be smooth.

Mr. ________ will now give a brief discussion on the subject of landing loads.

Speakers: D. J. Maglieri
R. H. Rhyne
H. N. Murrow

Talk on Landing Loads for 1953 Langley Inspection

The Landing Loads Branch is concerned with the loads developed during landing, taxying, and takeoff of airplanes, both ground and water based. This talk will discuss briefly some of our work in connection with the landing of ground based airplanes. At the Flight Research stop, brief mention is made of another phase of landing loads work, that is, the measurement of the manner in which the airplane approaches the ground in routine landing operations.

This model serves to illustrate the three types of load that develop on a landing gear; namely, the vertical load, which occurs when the vertical velocity of the airplane is suddenly arrested, the drag load which arises because the wheels have to be spun up from no rotation to full ground speed, and the side force which is caused by yawed rolling. These loads are surprisingly large, and cause the landing gear to oscillate in a very severe manner during landing, a fact which few people have had the opportunity to observe. We shall therefore demonstrate these oscillations by means of a short movie.

B-24 landing movie.

When the tire touches the ground, a puff of smoke will be seen, indicating extreme heating of the rubber. You will then see the wheel and strut undergo very large oscillations as a result of the imposed ground forces. The action shown here is about one quarter speed. The weight involved in gears designed to operate under conditions such as these is as much as 24 percent of the structural weight of the airplane in some cases, so that any refinement in design offers possibilities of important weight savings.

End of B-24 movie.

Now, in order to design lighter landing gears to operate under conditions such as you just saw, we must, of course, know the imposed loads accurately. I would like to describe some of our work on the determination of these loads. Let us again refer to the three loads represented on the model.

The vertical load has been studied extensively, both at this laboratory and elsewhere, and is understood quite well: we will, therefore, not deal further with this load, other than to point out that for a 70,000 pound airplane such as represented by this model, the vertical force developed in a hard landing may reach as much as 80,000 pounds, or 40 tons in each main gear!

The side load has been studied to some extent both analytically and experimentally. There still exists, however, a need for experimentally determined values of the side force that develops for the newest and largest tires now being used. Tests are underway to supply this need. In these tests we have measured side forces as large as 70 percent of the vertical load on the tire.

Now, I would like to describe our work on the determination of drag forces in more detail. As you saw in the movie, the drag force is large enough to cause severe fore-and-aft oscillations of the landing gear. We have been studying this spin-up drag load under closely controlled conditions in the Langley impact basin and I would like to show a typical landing test.

Impact Basin Movie.

The first shot is at normal speed and the second is in slow motion. The impact basin has generally been used for studies of the impact of seaplane models in water. The runway shown in these pictures was installed specially for landing gear studies and is removable.

End of movie.

The landings which you just saw are actually quite a complicated physical process. For example, the forces interact, the structure distorts severely, and the whole process takes place in a fraction of a second. Nevertheless, it has been possible to measure accurately the manner in which the forces vary with time. A sample of such measurements is shown in this chart; it can be seen that the build-up of drag and vertical load is very rapid. It occurs in about 1/20 of a second! From measurements such as this, we obtain information regarding not only the loads developed, but also the sliding friction coefficient between the tire and the runway. This friction coefficient is one of the most important and yet least understood parameters involved in spin-up drag loads. It is given by the ratio of drag load to vertical load at any time. Our next chart shows a summary of information we have thus far found on this coefficient of friction during wheel spin-up. The variation of friction coefficient with skidding velocity is shown for cold rubber by the dashed line and for smoking hot rubber by the lower solid line. The actual variation of friction coefficient during wheel spin-up in three landings is shown by the curves with arrows. The tire is cold at impact, so the initial contact is always represented by a point on the cold rubber curve, its position along the curve being determined by the landing speed, which is the initial skidding velocity. As the wheel is spun up, the skidding velocity decreases and the rubber heats up to smoking temperature as we saw in the movies. We thus go across a transition region of intermediate rubber temperature to the curve for hot rubber and follow along this curve to the point of complete spin-up. The skidding velocity of this landing (point to landing with highest skidding velocity) was about the same as the highest landing speeds used today. This figure clearly shows that both rubber temperature and skidding velocity greatly affect the friction coefficient. This information has made it possible for us to better understand the variety of reported values of friction coefficient by considering the conditions under which the values were determined.

This general picture, with the clearly defined transition region, has emerged from our recent tests and we feel represents an important step toward the complete understanding of spin-up drag loads.

Speakers were: James H. Walls
Dexter M. Potter
Robert C. Dreher
Walter B. Horne
Upshur T. Joyner

PROPOSED TALK FOR 1953 MAY INSPECTION

We will now show some samples of our work on flutter. Basically, flutter is a self-excited vibration of an airplane that arises when aerodynamic forces interact in an undesirable way with an elastic structure. Since flutter is a vibration which may quickly destroy the airplane it is mandatory that an airplane be designed so that flutter does not occur throughout its operating range.

During the opening remarks this morning Mr. Thompson ( ) pointed out that design trends that meet aerodynamic and strength requirements have resulted in dwindling margins from flutter for our future aircraft. These dwindling margins are placing a greater urgency on flutter work and it is important to improve the accuracy of flutter prediction so that performance penalties will be kept to a minimum.

There are many varieties of flutter that are appearing in the higher speed range for new configurations and it is important to identify them because the cure depends upon the type. This introductory chart serves to illustrate the speed ranges for which the designer must work the hardest to avoid flutter troubles on certain configurations. The ranges that can inherently cause the most trouble are not well defined although you can see that some configurations cause the most concern in the subsonic speed range while for others the troublesome regions extend higher into the supersonic region and for still others the problem arises mainly at supersonic speeds.

We don't have time to present a general discussion of flutter, however we would like to illustrate four interesting types with the aid of movies.

The first type of flutter we will consider is the so-called bending-torsion type involving external stores. I will illustrate this type with movies which were taken of this dynamic model which was tested in a transonic wind tunnel. Considerable emphasis is being placed upon dynamic models to aid in narrowing the margins from flutter for configurations that are difficult to calculate accurately. Inviting flutter to occur on this model at high transonic speeds raised important questions as to the protection of the wind tunnel and model. This bending-torsion type of flutter that we're now considering is very sensitive to the center-of-gravity location and use was made of this center-of-gravity effect to protect the model from destruction when flutter was encountered. A small weight located in each tip tank could be quickly moved from one position to another to arrest the flutter. We now show a movie to illustrate this type of flutter. (Movie) The airspeed is slowly increased until flutter occurs. The small weight within the tanks is quickly fired and the flutter is arrested.

The dynamic model was tested at transonic speeds and it may be of interest to show a sample of some of the results. This chart shows how the flutter Mach number is strongly dependent upon the center-of-gravity location of the tip tanks. For rearward locations the flutter speed was very low and for forward locations flutter was not obtained up to very high subsonic Mach numbers. When the tank is filled with fuel the behavior of the fuel can strongly affect the flutter speed. The behavior of fuel had been studied for tanks undergoing vertical motion and more recently for tanks undergoing pitching motion. I'll now show a sequence from a movie prepared some time ago which serves to illustrate the complexity of the fuel sloshing problem. (Movie) This movie illustrates the problem of determining just where the mass of fuel acts, its moment of inertia and its damping characteristics. Despite the apparent confused nature of fuel motion we have found it possible to obtain numbers of the moment of inertia and damping that can be put into a flutter analysis. Studies are currently being made of the characteristics of fuel in tanks of varying sizes and shapes. The tests for the case of pitching motion are being made with this equipment to help determine fuel loads and fuel distributions to provide flutter free operation of aircraft throughout the operational range.

Now let's look at another type called stall flutter. Stall flutter is related to certain types of buffeting and may be troublesome for thin airfoils at high angles of attack. Stall flutter usually occurs in only a single mode of vibration, namely torsion or twisting of the wing. I have a movie to illustrate this type. (Movie) This movie appears in slow motion, the actual frequency being about 25 times per second. The tufts indicate the nature of the flow and show that the flow separates during part of the cycle, periodically grabbing and releasing the airfoil, thus maintaining the oscillation. Incidentally, this type of flutter is most troublesome in propeller and compressor blade design.

We now turn to some newer types of flutter. One type is concerned with flutter of thin skins on airplanes and missiles. At supersonic speeds the deformations of a thin skin arising from high local pressures and thermal stresses may give rise to aerodynamic forces of such a nature that a severe destructive oscillation may be encountered. I'd like to show a movie illustrating this type of flutter which is most troublesome at supersonic speeds. (Movie) The pictures show a wing mounted in a supersonic wind tunnel. The flow is from right to left. As the airspeed is increased as shown by the Mach number indicator you may see, first, the local deformations appearing and then as the flow becomes supersonic, a severe oscillation of the skin develops and the skin fails at the trailing edge of the wing. Extensive studies of this type of flutter have been completed and criteria have been developed that permit a designer to determine the skin stiffness or rigidity to avoid this skin flutter. The criterion indicates that skins that are buckled require considerable stiffness to avoid flutter while the effect of tension or a pressure difference across the skin is to greatly reduce the stiffness requirements.

I'd like to finish by showing you a very recent type of flutter with which we have barely a speaking acquaintance. This type of flutter developed at high supersonic speeds and involved deformations of the chord. (Movie) You are looking at the end of the wing and you may see large deformations of the chord develop and the wing is quickly destroyed. The last few frames are shown again in very slow motion so you may see the deformation modes. This type of flutter has been called chordwise flutter or camber flutter although its true characteristics are not completely understood.

We have tried to show you a few of the problems confronting the aircraft industry with respect to flutter. What we at the NACA are doing is trying to define the types of flutter, to identify new types that develop and to formulate methods of predicting the flutter so that the designer may avoid it or cure it if inadvertently encountered. Other important phases of the work are the experimental measurements that are being made of the oscillating aerodynamic forces that enter into flutter.

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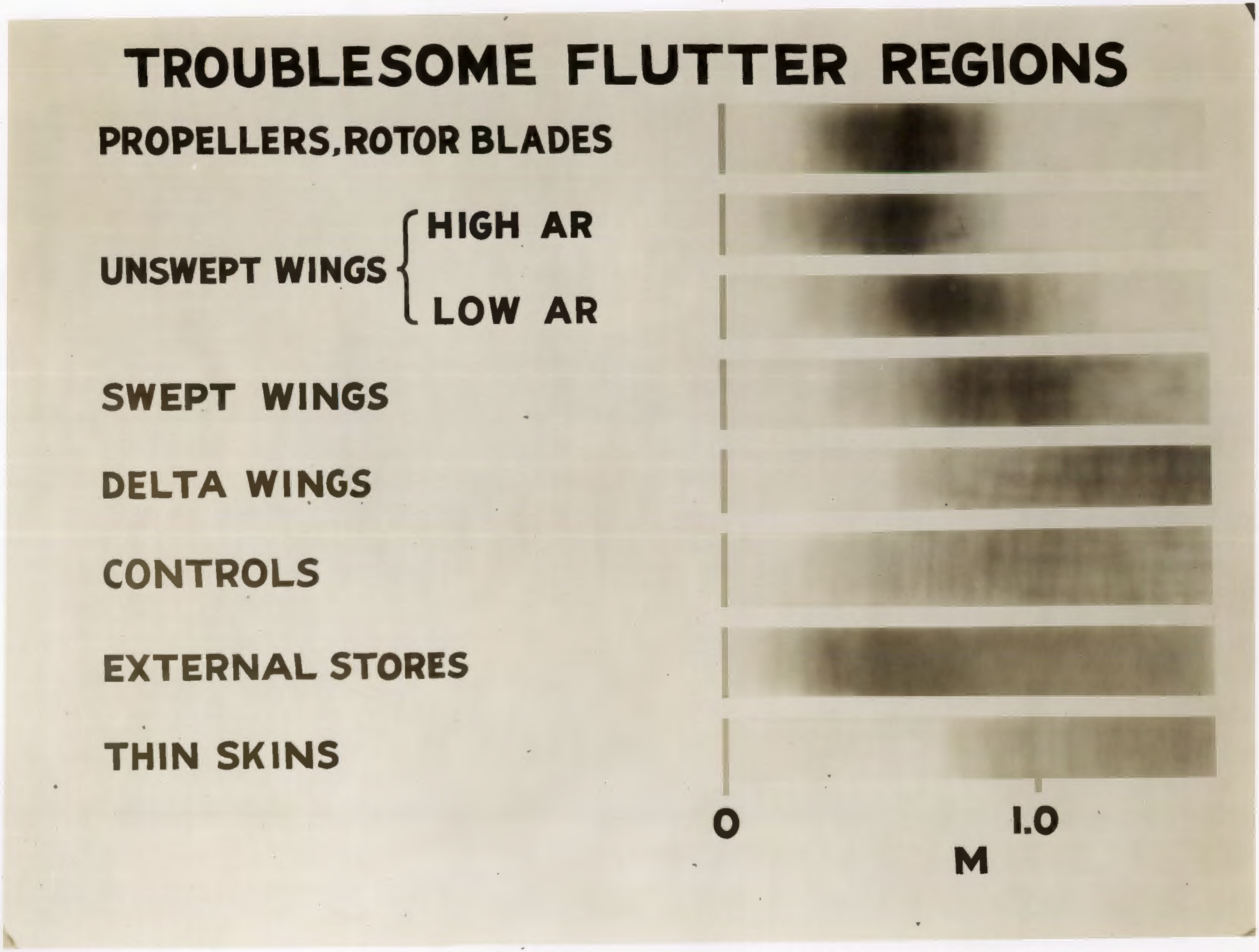
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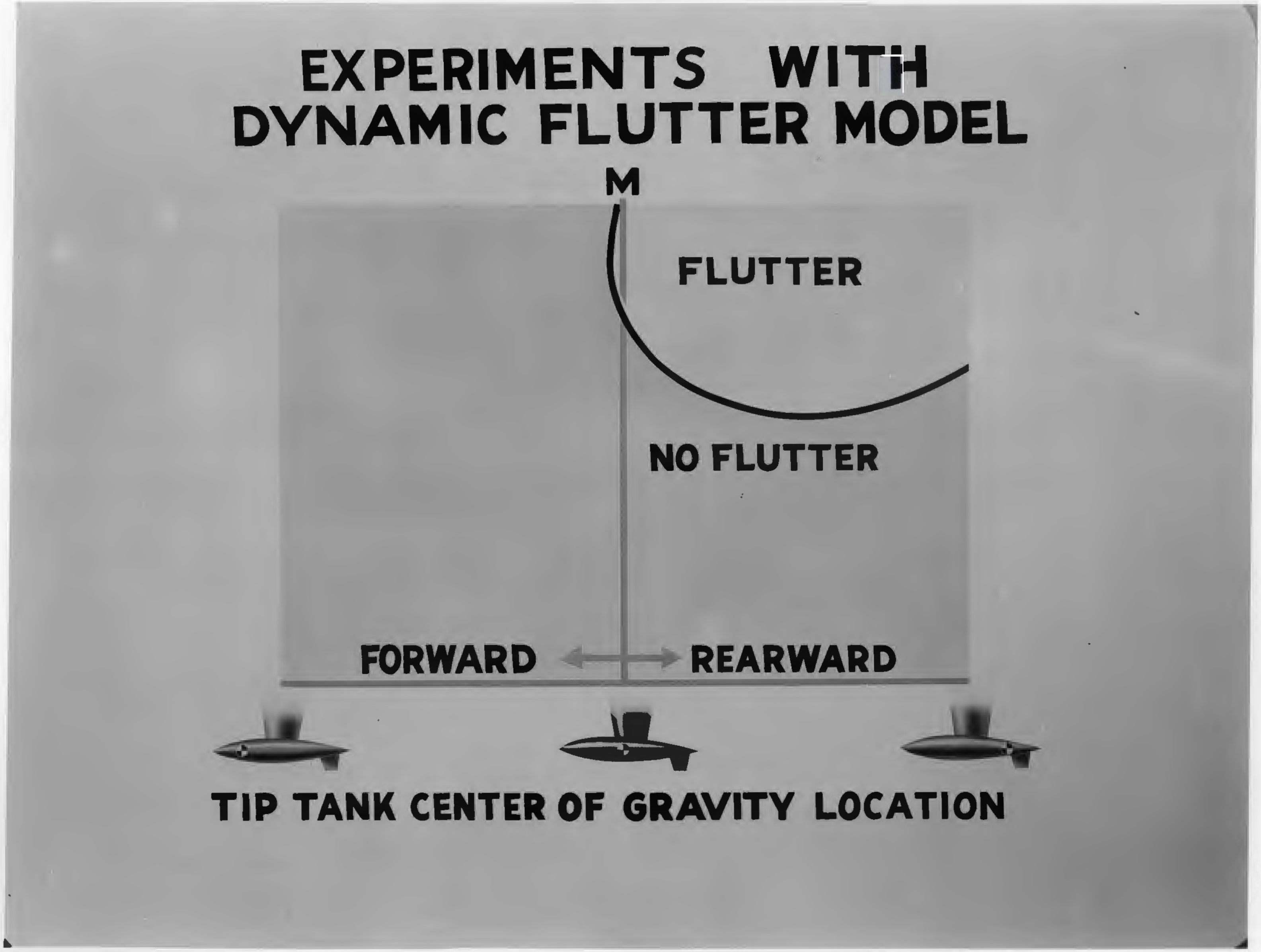
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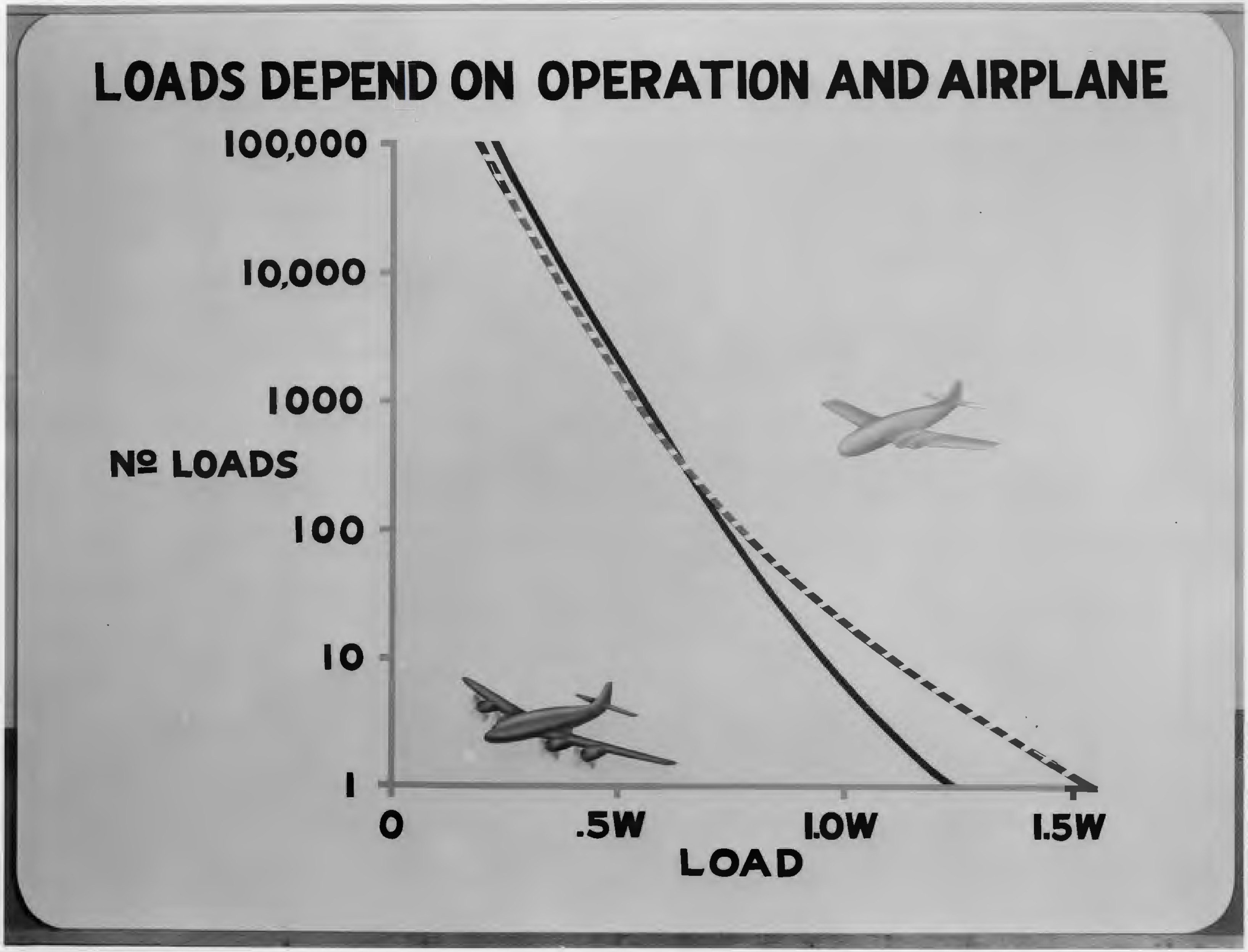
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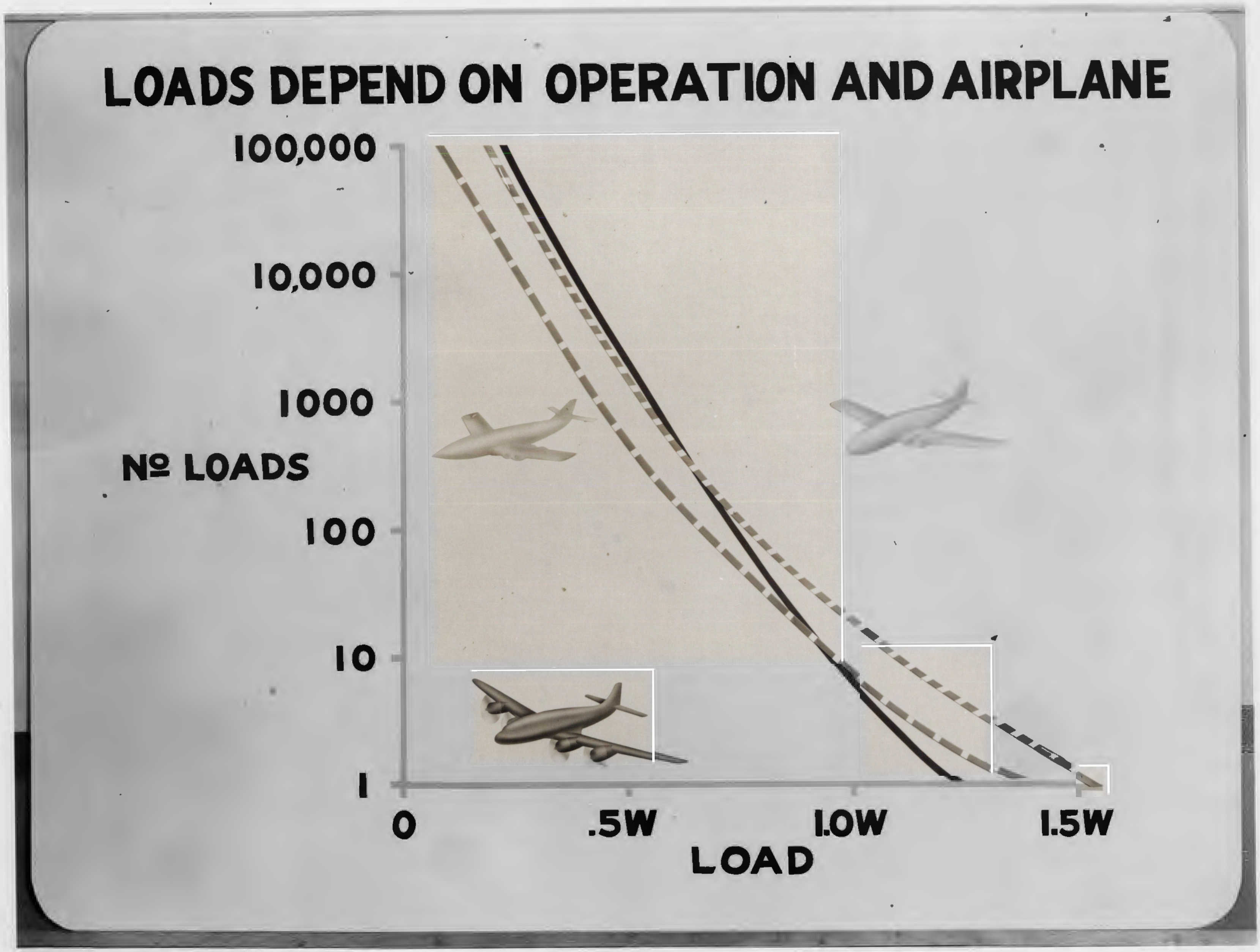
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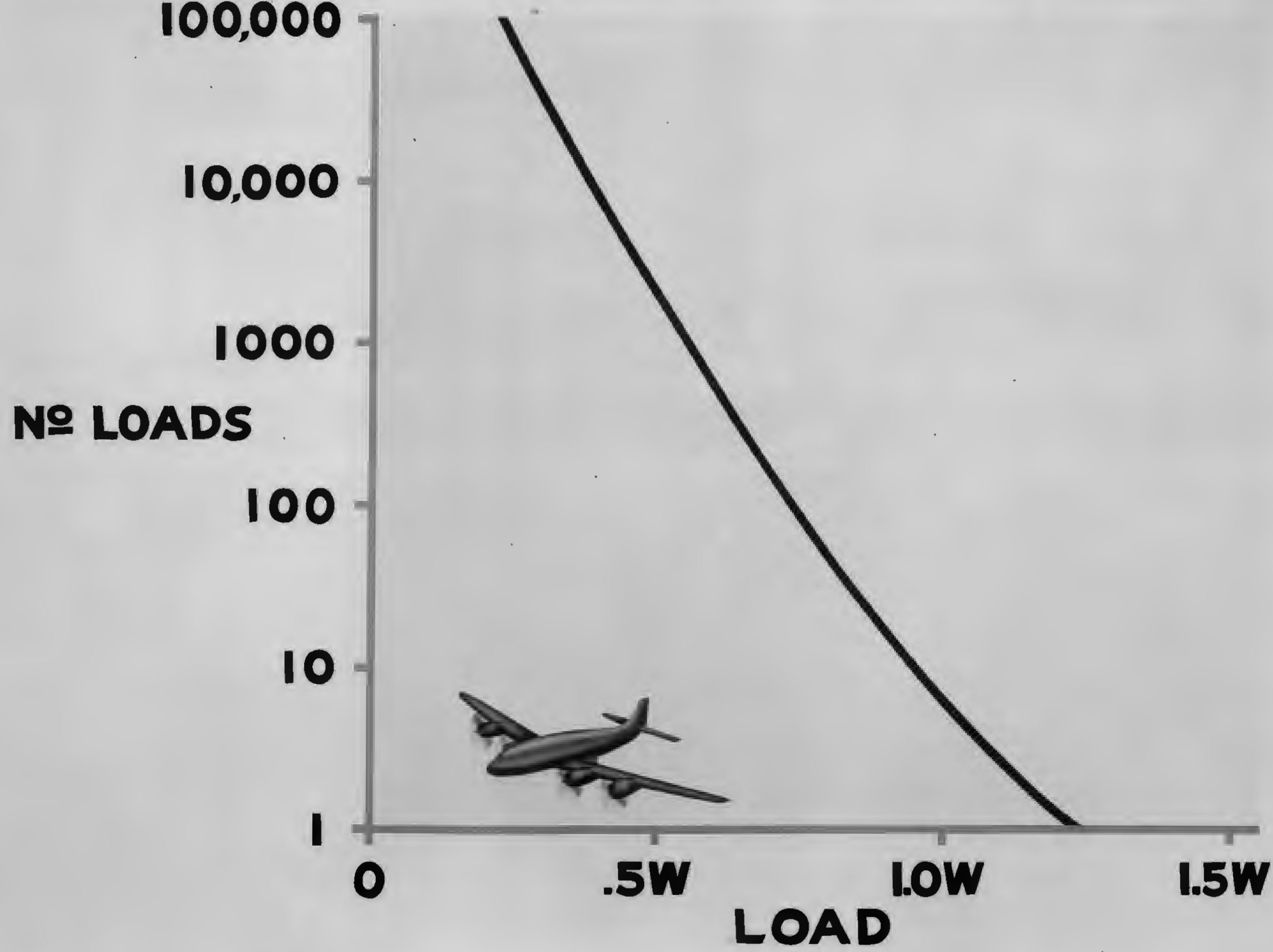

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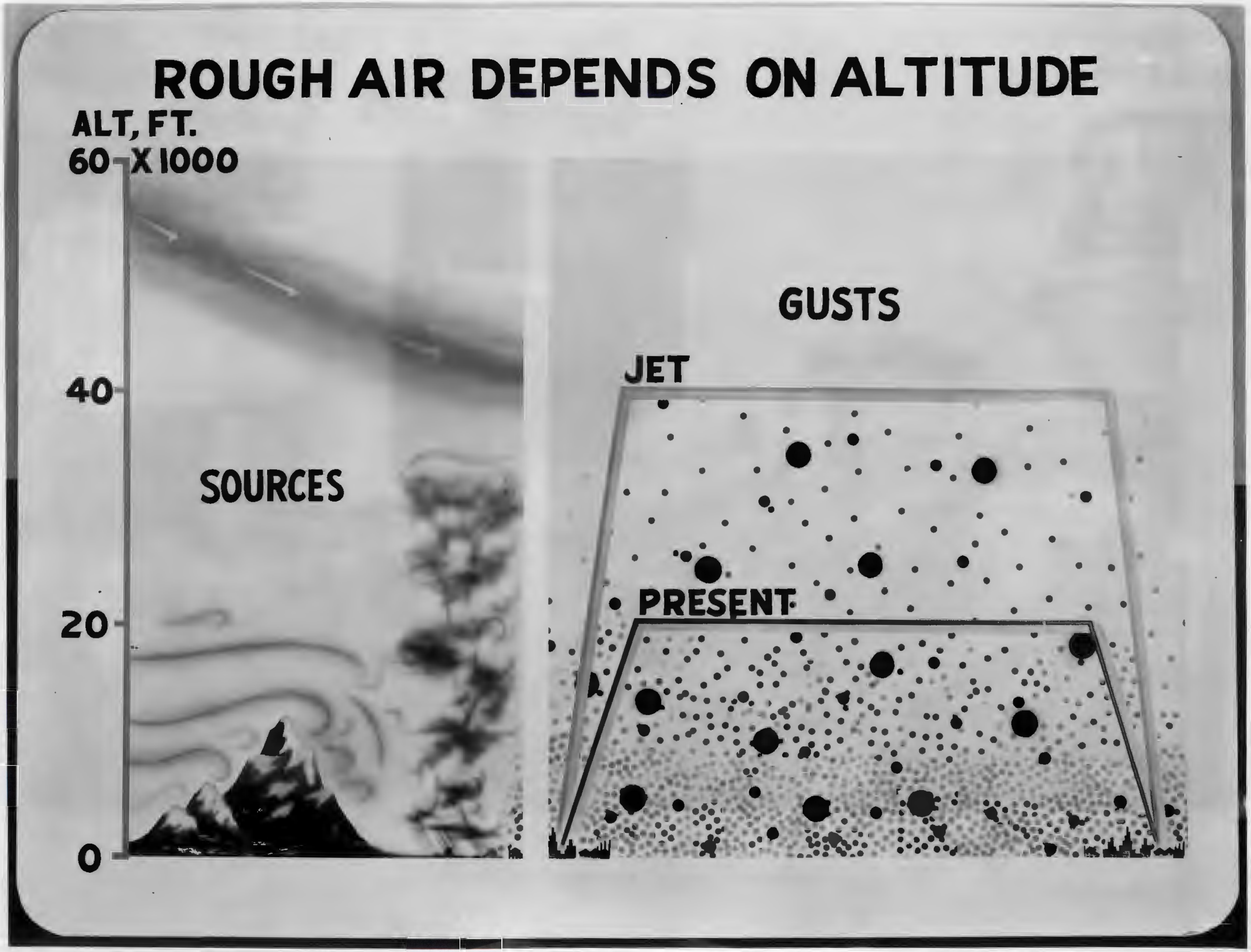

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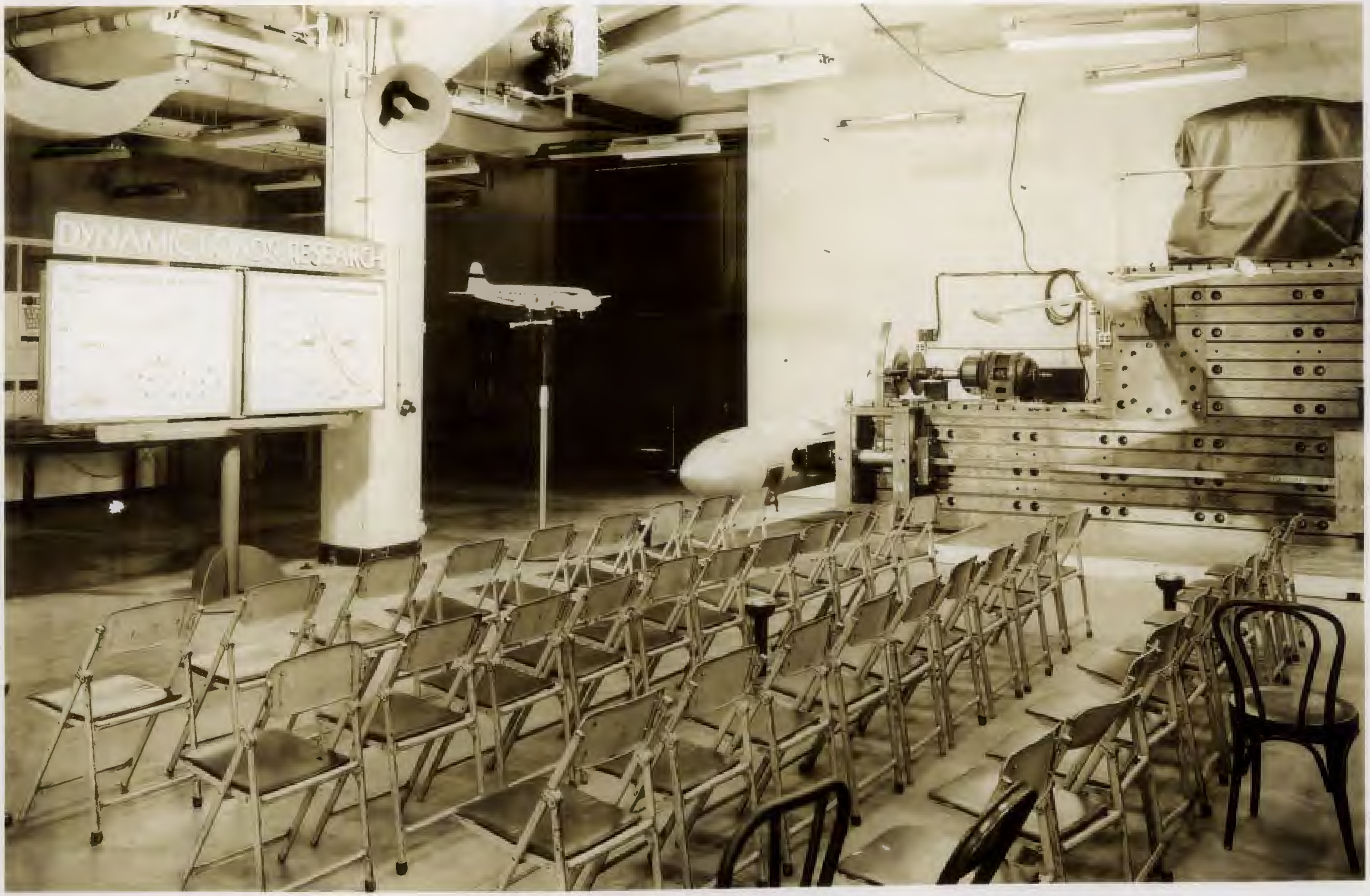

Display for Dynamic Loads Research

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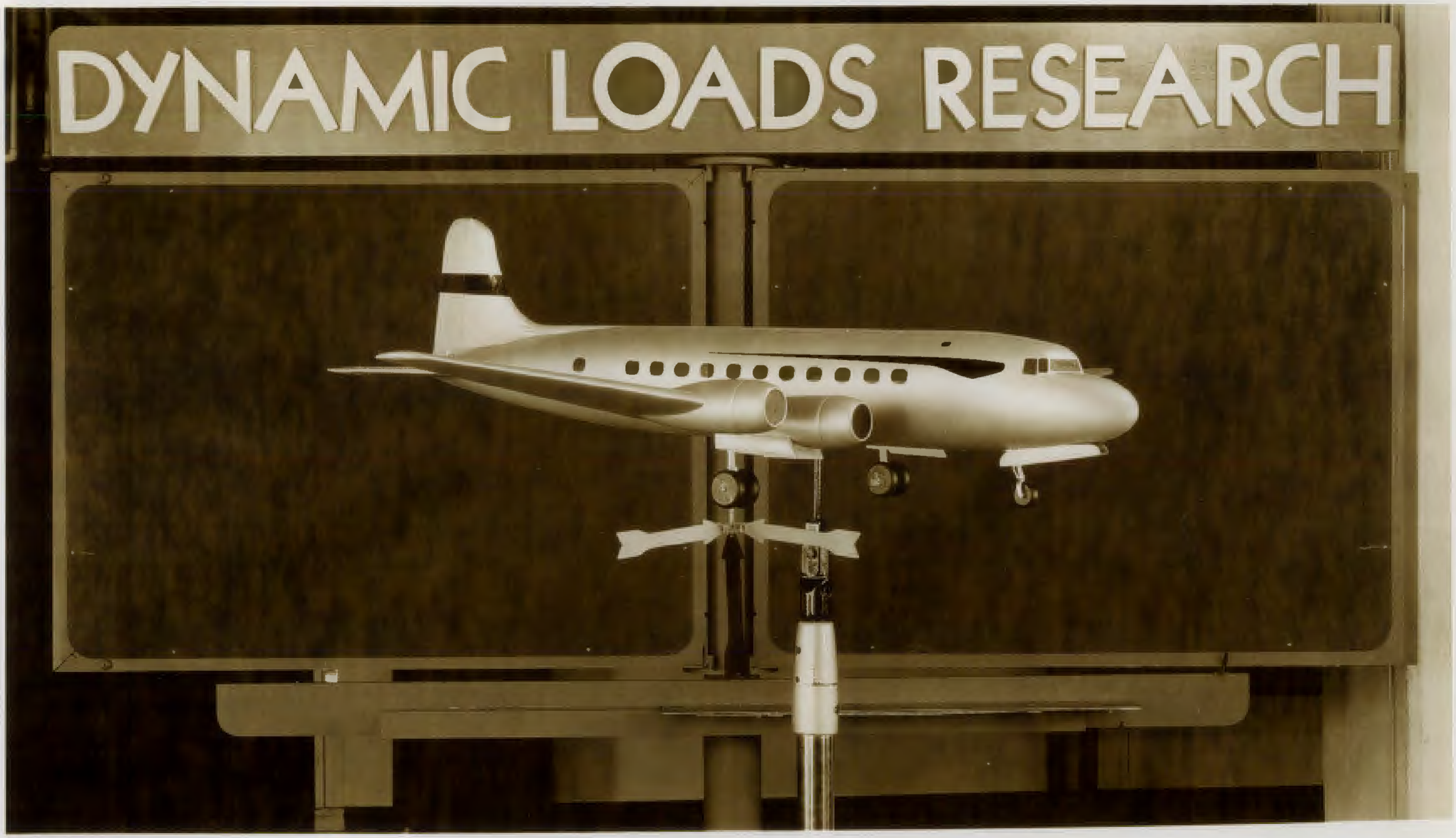

Display Model for Talk on Landing Loads

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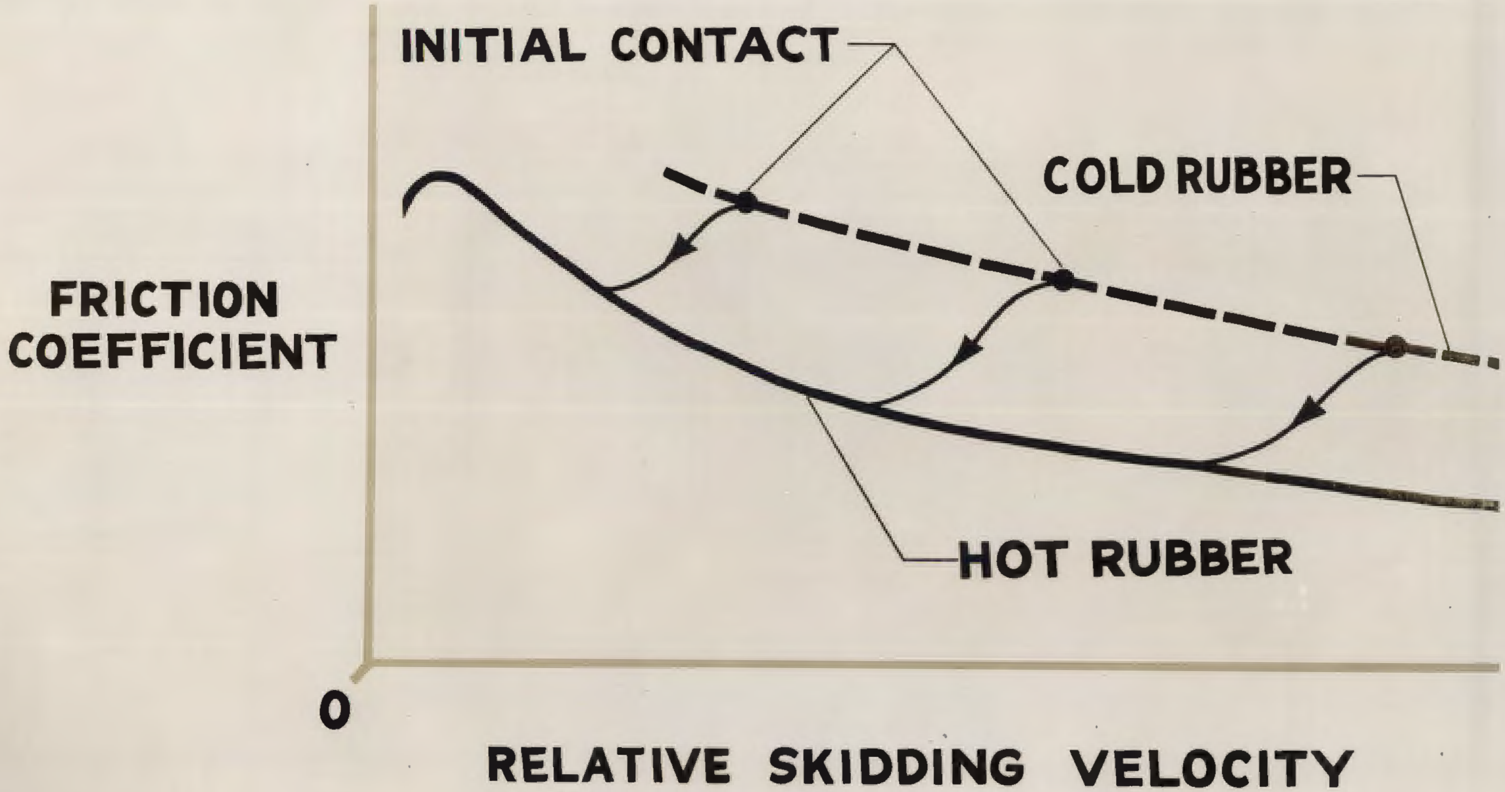
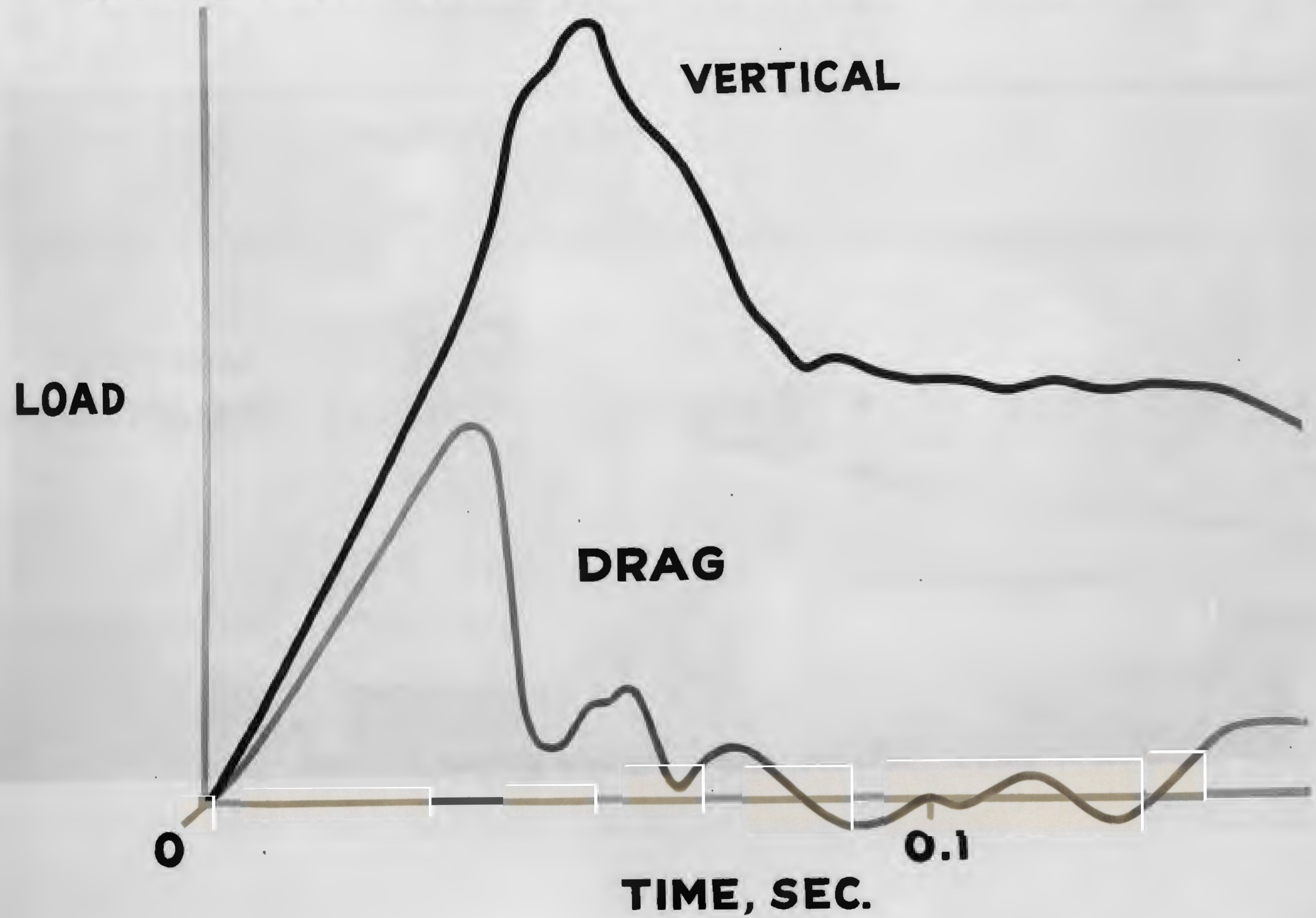
VARIATION OF FRICTION IN LANDING



LOAD EXPERIENCE DURING LANDING



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