LOADS

presented by

16-Foot High-Speed Wind-Tunnel Section

In order for an aircraft to satisfactorily perform its intended functions the designer must make it strong enough to withstand the loads to which it will be subjected. By the term "loads" we mean not just the payload, but any load which causes stress in the aircraft structure. Thus, loads include the forces of the air on the wing and other surfaces, and the reactions between the ground and the landing gear. It is essential that all components of the aircraft have adequate but not excessive strength. Unnecessary strength means unnecessary weight and reduced performance. The designer, therefore, must know the magnitude of the loads, how they are distributed or applied, and, in some cases, the frequency at which they are applied.

First, let us classify the loads imposed on an aircraft with the aid of this chart.

Loads are generally classed as steady or dynamic. The distinction between these classes is relative; there is no rigid definition separating the two. However, in this discussion we will consider as steady loads those which are constant for a period of time of, say, one minute. Dynamic loads, on the other hand, will be those whose magnitude and distribution do not remain constant but vary during such short periods of time as a fraction of a second. The magnitude and distribution of both types of loads depend upon the shape of the aircraft and on the speed and altitude at which it is operating. Dynamic loads depend, in addition, upon other factors as pictured on the chart. These loads will depend upon whether they are caused by atmospheric disturbances or gusts, by buffeting, by maneuvering, or by landing and ground handling.

The NACA is conducting investigations, both experimental and analytical, to obtain information on all of these various loads. Since it is impractical to discuss all phases of NACA research on loads in the time available, we have chosen to discuss some aspects of the gust and buffeting problems and the results of an investigation which has bearing on many dynamic problems.

Gusts or atmospheric turbulence are important to both designers and operators since they not only influence the loads on the aircraft but also affect passenger comfort. Information is required on both the intensity of turbulence and the probability of its occurring at the altitudes to be encountered by any given aircraft. Since the flight altitude of both military and commercial aircraft is rapidly increasing, attention has been focused on atmospheric turbulence at high altitudes. Although there are many aspects of the turbulence problem, I will discuss today the sources used for obtaining information on the atmosphere, and the effect of altitude on passenger comfort and structural fatigue.

The next chart indicates the sources of data and shows the number of gust loads or bumps which an airplane would encounter during flights of equal distance at various altitudes. For altitudes up to 10,000 or 15,000 feet, a great deal of data has been obtained over a period of about twenty years from instruments installed in commercial transports. For altitudes up to about 20,000 or 30,000 feet, the newer transports have been utilized during the last two years. To date, data have been obtained with commercial transports during several hundred thousand hours of flight time. High-altitude aircraft operated by the military services have been used for obtaining data at higher altitudes in the last year or so. Within the last six months, telemetering devices, which are carried aloft by balloons and make a turbulence survey while descending by parachute, have been placed in limited use. As indicated by the chart, these instruments record data on turbulence at altitudes up to 60,000 feet, much higher than present-day aircraft operate.

The length of these bars on the chart indicates the number of gusts or bumps causing accelerations of about one-half g which an airplane will encounter while flying a specific distance. This roughness level of one-half g was used because it corresponds to moderate passenger discomfort and is also important in structural fatigue studies. The chart shows that an airplane would receive five times as many of these one-half g bumps at 20,000 feet as it would at 40,000 feet. If there were a bar on this chart for 10,000 feet it would be about 25 times as long as this bar for 20,000 feet. These results show that although the chances for a smooth trip increase most rapidly up to 20,000 feet, there are still significant gains to be made at higher altitudes. For example, the chances are five times better at 40,000 feet and twenty times better at 60,000 feet than they are at 20,000 feet.

It is apparent that gust loads or bumps will cause passengers to become fatigued. Equally important, these bumps also cause the aircraft structure to become fatigued and eventually weakened. Therefore any reduction in the number of bumps encountered will materially lengthen the fatigue life of the airplane. The results show that a gain can be made by flying at a high altitude.

Regardless of the flight altitude, the airplane will have to climb and descend through the more turbulent regions at the lower altitudes. The gain actually realized will then depend upon the flight plan of the airplane. In summary, this chart indicates that, although high altitudes are not entirely free from turbulence, substantial benefits could be realized in gust loads and in smoothness of the ride in high-altitude flight.

Mr. __________ will now discuss some NACA research on buffeting.

Buffeting is the pounding of an airplane by unsteady airflow. Buffeting may occur on the part of the aircraft on which the unsteady flow originates, for example, the wing; or it may occur on some part which is operating in unsteady flow, for example, a tail operating in the wake of the wing. This discussion will be limited to the first type of buffeting, that which results from unsteady flow on the wing. Using an optical technique the character of this unsteady flow has been observed on a number of models in NACA wind tunnels. You will now be shown a film illustrating a flow typical of those observed. This film was taken in the Ames 1- by 3-1/2-foot high-speed wind tunnel at a film speed about 400 times faster than it will be projected here.

The wing is at a moderate angle of attack and the airflow is from right to left at a speed of 500 mph. The vertical waves you see oscillating back and forth above the wing are shock waves. Such oscillations cause changes in the lift acting on the wing. These changes in lift are in some cases as great as 40 percent. You will also note shock waves generated at the front of this disturbed region pass upstream periodically since the air speed is less than the speed of sound.

Unsteady flow, such as you have just seen, and the resulting load fluctuations often limit an airplane's performance. That is, the allowable speed is limited because of buffeting, not because of lack of power. It is clear then that information is needed, first, to define the conditions under which buffeting will occur; second, to determine the magnitude of the load fluctuations; and, third, to devise means to eliminate or minimize these load fluctuations.

NACA research has been patterned along these lines, and I will illustrate briefly some recent high-speed wing buffeting results.

The first results I will discuss show that wing thickness has an important influence on the buffet region. This chart (chart B) shows the buffet region in terms of angle of attack and Mach number for two wing sections of different maximum thickness. This figure, defining the buffet region for the thick wing, shows that there is a range of Mach numbers in which buffeting occurs for all angles of attack. In contrast, with the thinner wing,buffeting will not occur at angles of attack less than about 5 degrees at any Mach number investigated. It is apparent then that an airplane with a thick wing flying even at a low angle of attack must pass through this buffet region to attain the speed of sound, but an airplane with a thin wing flying at the same angle of attack will not encounter buffeting even up to the speed of sound.

Now I will discuss some results which show the effect of wing section shape on the magnitude of the fluctuating loads. The next chart (chart C) shows the manner in which the fluctuating load, measured in percent of total load, varies with Mach number for two wings having the same maximum thickness. The wings were held at a constant angle of attack as the Mach number was varied. This curve (left-hand one) shows that at a Mach number of 0.75 the load will alternately increase and decrease about 3 percent due to buffeting. These fluctuations occurred at high frequency. In contrast, note that the maximum fluctuations for this wing having a different shape are about three times as great, and also that the fluctuations persist to higher Mach numbers. Therefore, two wings having the same thickness but different cross-sectional shapes may have greatly different buffeting characteristics.

In summary then, in order to minimize the effects of buffeting care must be taken when selecting the wing shape and its thickness.

Mr. __________ will now discuss another aspect of the dynamic loads problem.

We have presented to you information regarding NACA research, relevant to two specific types of dynamic loads, buffeting and gusts. Now I will discuss an investigation of a different aspect of dynamic loads.

As you know, the large amount of fuel required by our modern military aircraft has in general made tip tanks a necessity. The weight of the fuel, which in some cases amounts to a large percentage of the total weight of the wing, can seriously affect the wing loads under dynamic conditions. Picture thousands of pounds of fuel hammering or sloshing about in the tip tanks during such unsteady conditions as gusts, buffeting and landing. You can then realize how critically important it is to know the effects of this motion in order to design a safe structure.

As part of a general investigation to obtain information on this sloshing of fuel, the Langley Laboratory of the NACA has used the test setup portrayed on the next chart. A model tank, representing the center portion of a tip tank, was mounted on a beam representing a wing. In order to permit photographic recording of the fluid motion the tank was made of transparent plastic. By deflecting the beam and then releasing it suddenly, the tank and fuel were set in motion. The information obtained from such experiments can then be used to predict the loads applied by the tip tanks to the wing of an airplane. In this investigation three factors which influence the loads imposed by the fuel sloshing were studied. They were the acceleration at the time of release, the frequency of the tank motion following release, and the tank fullness. You will now be shown a movie that illustrates the technique used in this investigation.

Data were obtained by moving pictures such as those you have just seen and by an instrument which recorded the tank motion on a moving piece of paper. A sample record is illustrated in the next chart. Records such as this, showing the variation of tank motion with time, were analyzed to determine the energy absorbed by the fuel during each cycle as shown here. This energy absorption alters the force which is imposed on the structure supporting the tank. For the record shown here we see that at the end of the first cycle the maximum motion had decreased by only a small amount and also that very little energy had been absorbed by the fuel. Motion pictures showed that the fuel was disturbed very little during the first cycle, but during the third cycle it became very turbulent. The chart shows that, during the third cycle, the maximum tank motion began to decrease rapidly and also that the greatest amount of energy was absorbed. For all the remaining cycles, the ratio between the energy absorbed and the maximum tank motion, which is a measure of the damping, was nearly constant.

This relationship during the later cycles conforms reasonably well with results predicted by a theoretical analysis assuming the fuel to be turbulent. However, for the initial cycles, such an analysis does not predict the experimental results. Consider again, for the moment, the curve representing the variation of the tank motion with time. If a line is drawn in such a manner that it just touches this curve at its peaks, we obtain what is known as an envelope curve. For cases where the damping increases, the tank motion shown by the envelope curve will decrease more rapidly.

This type of curve is useful for comparing the damping when various factors are changed.

In the next chart is shown a family of such curves obtained for different amounts of tank fullness: empty, full, 90- and 30-percent full. The results shown here are for one value of the initial acceleration and frequency. However, they are typical of the results obtained for other values of these factors. Since the curves for tank empty and tank full were found to be nearly identical they are represented here by a common curve. This curve shows a small decrease in tank motion with time. In this case, the damping is produced by factors other than the fluid sloshing, namely, the energy absorbed by the beam and the surrounding air. This curve may be considered as a reference since any deviation from it will be due to fluid motion.

These results show that the maximum fluid damping occurs when the tank is about 30-percent full. Notice that even with the tank 90-percent full there is still a significant amount of damping.

We have shown you some of the results of an investigation of the effects of fuel sloshing on wing loads. While we don't have time to discuss all the implications of these results, it is obvious that the sloshing and pounding of fuel in partially full tanks will have an important bearing on loads due to gusts, buffeting, and landing. In addition, the effects of fuel sloshing can have a marked influence on flutter characteristics.

This concludes this program in which we have presented to you some aspects of the NACA research on the problems of loads.

Please remain seated while the elevator is being returned to the first floor.

TIP TANK NARRATION

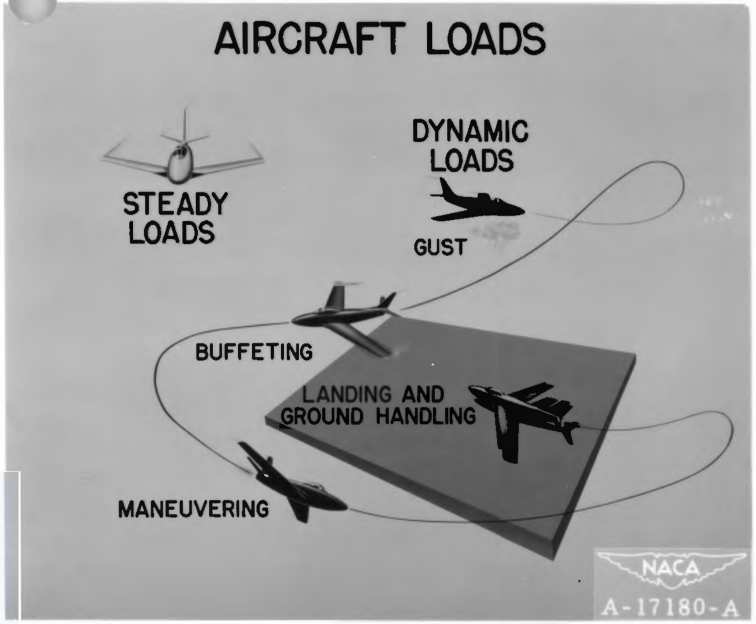
1. The first two sequences will show the effects of a change in frequency. The initial acceleration and tank fullness will be held constant. The first sequence is for a frequency of 2.6 cycles per second. Note that the fluid is disturbed very little during the first cycle, then it becomes very turbulent. This is true of all the tests.

2. The second sequence is for a frequency of 6.8 cycles per second, or about 2.5 times that of the last.

3. The next two sequences will show the effects of a change in tank fullness. The initial acceleration and frequency are held constant. The first sequence is for the tank 40 percent full. In this sequence the initial vertical motion changed to an end-to-end motion. This type of motion could have a considerable bearing on flutter involving torsion.

4. The next sequence is for the tank 65 percent full. Notice that the change in tank fullness has changed the character of the motion.

Display for presentation of "Loads"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BUFFETING
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MANEUVERING
NACA
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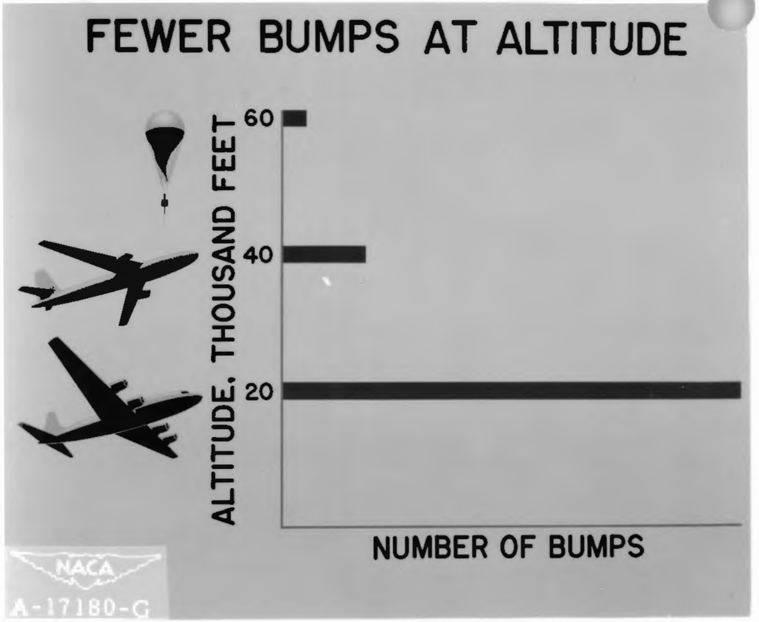
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NUMBER OF BUMPS
NACA
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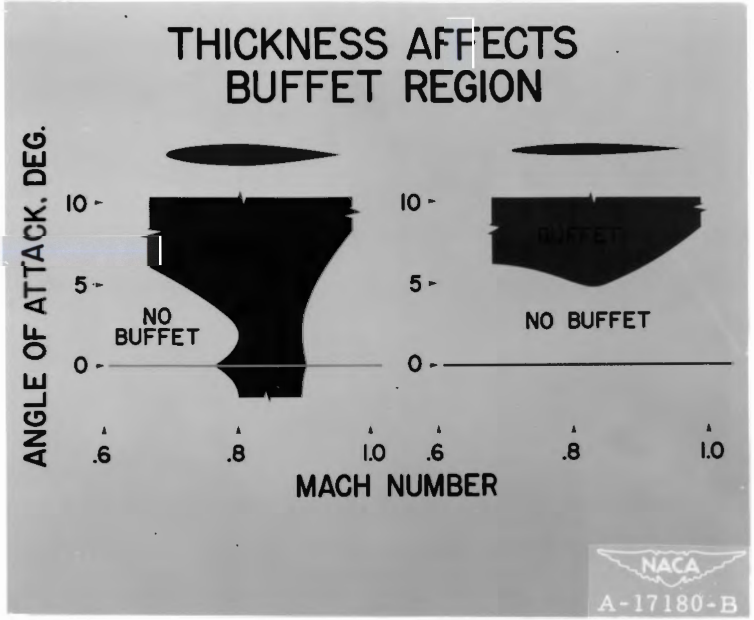
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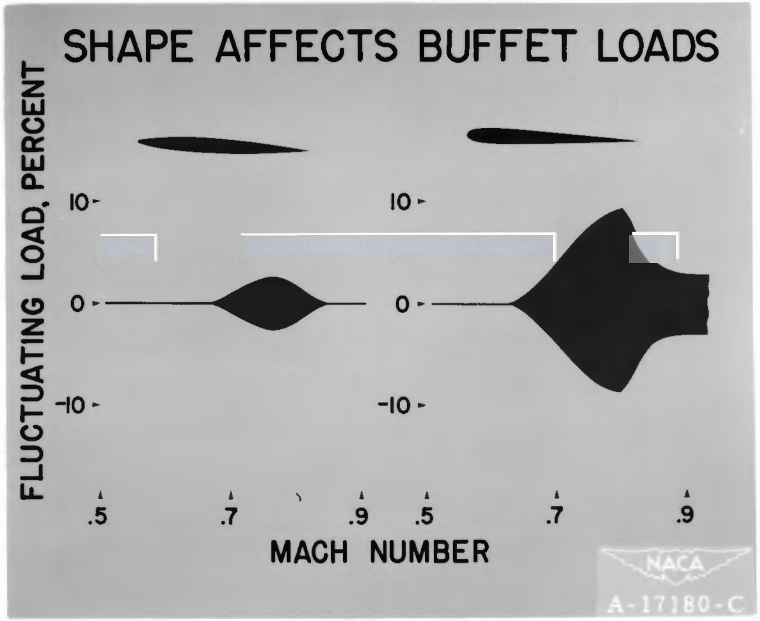
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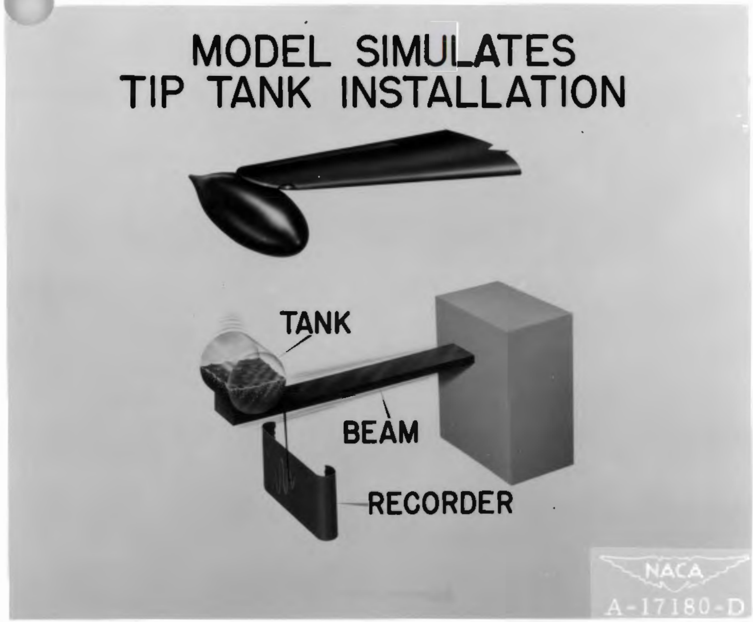

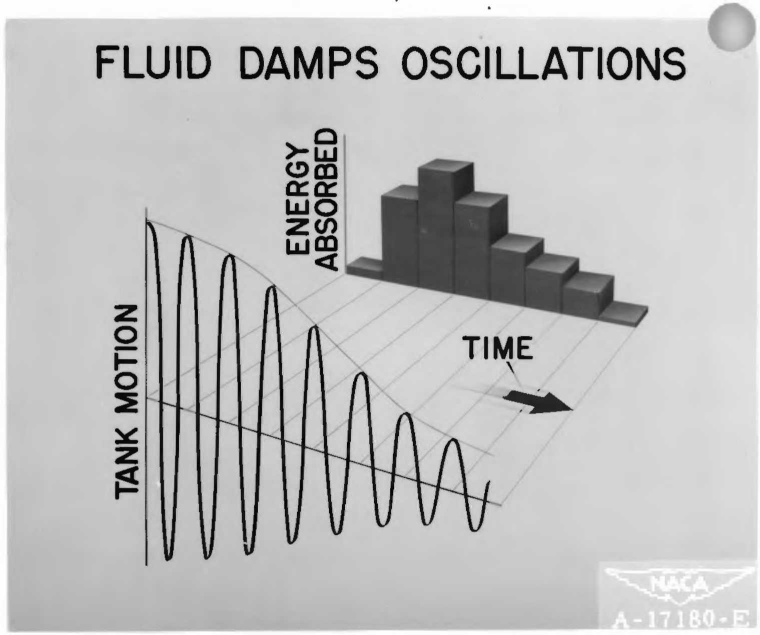

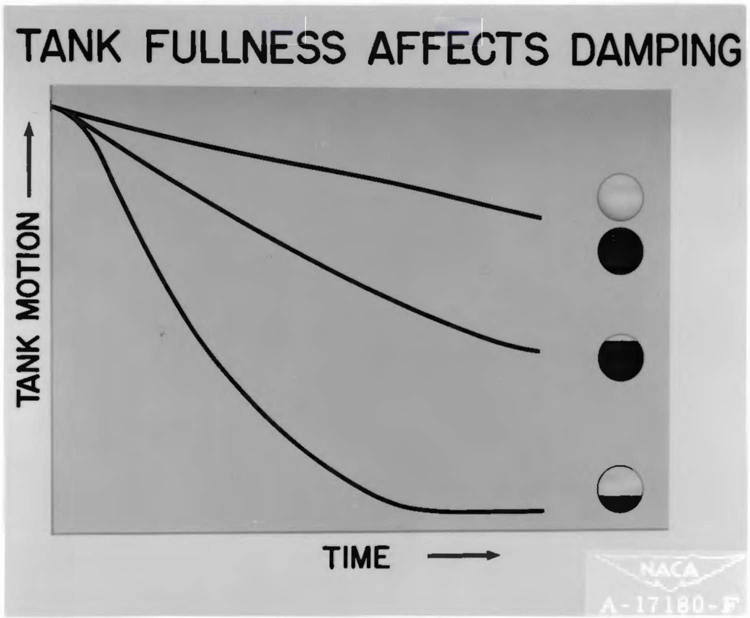

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