

LANDING LOADS INVESTIGATION IN FLIGHT

Talk Presented at the 1953 Biennial Inspection

By Norman S. Silsby and Richard H. Sawyer

The function of the Flight Research Division is to conduct the part of the Laboratory's aeronautical research that requires investigation on full scale airplanes in flight. Part of this work is done here at Langley and part at our High Speed Flight Research Station at Edwards Air Force Base in California.

The specially designed high speed research airplanes such as the X-1, D-558, X-5, and X-3 are tested at Edwards where the extensive natural dry-lake bed provides the large landing area required for such experimental aircraft. These airplanes are continuing their original role of uncovering and defining the problems associated with supersonic flight. In addition they are now being used for flight testing of design modifications developed through wind tunnel research as possible solutions to the problems that have been revealed. The classified nature of this work does not permit discussion of results at this time.

Here at Langley, more conventional types of aircraft are used to study a wider range of aerodynamic problems encountered in the design of all types of aircraft. Three examples of work at Langley will be described at this stop. The first of these is concerned with determination of the loading conditions for which landing gears should be designed.

At present, airplanes and their landing gears are being designed to satisfy landing-loads requirements which have been developed from experience with earlier airplanes. The size and speeds of airplanes have steadily increased, and it has become necessary to reexamine the landing-loads problem in order to establish up-to-date design requirements and procedures.

The first step in developing more rational landing-loads requirements is to obtain information on the severity and frequency of the load-producing conditions likely to be encountered by an airplane in landing. A program is in progress to obtain some of the required information from landing statistics of current transport airplane operations. The equipment which you see here is being used for this project. It consists essentially of a constant-speed motion picture camera fitted with a telescopic lens of 40-inch focal length arranged to track the airplane in a horizontal plane only. The camera is set up about 1,000 feet from the runway so that it offers no obstruction to aircraft on the airport proper.

The first chart shows enlarged prints of two frames from a typical landing sequence. The photograph on the left is four frames or .16 seconds earlier than the one on the right, which is within one frame or within .04 second of ground contact. The sinking speed of each wheel is determined from the change in the vertical position of each wheel between these frames.

Rolling velocity, angle of bank, and forward speed can also be determined readily from these photographic records.

So far, records have been obtained on 487 landings of transport airplanes in routine daytime operations at the Washington National Airport.

Presented on these charts are the results obtained on the first 243 landings for the frequency distribution of sinking speed, which is probably the most important of the conditions affecting the landing loads. The chart on the left is a bar graph, which is simply a tabulation of the number of landings, shown as the vertical scale, which occur in various half-foot-per-second intervals of sinking speed, shown as the horizontal scale. For example, the chart indicated that 70 landings were made at sinking speeds in the range from 1 to 1-1/2 ft/sec, and only one was in the range from 3-1/2 to 4 ft/sec.

On the right hand chart the same results are represented as a curve of the probability of equalling or exceeding given values of sinking speed. This curve was derived from the sinking speed measurements by statistical methods which provide for fairing the data, and permit some extension to give a reasonable prediction of the sinking speeds likely to be encountered in a considerably greater number of landings than were actually observed. The designer or the agency which prescribes the design requirements can thereby select a design

condition for which the likelihood of occurrence within the expected lift of his airplane is sufficiently remote. He can also determine the frequency of less severe conditions which may be of concern from a fatigue standpoint. These results indicate, for example, that for the conditions existing during these landings, one out of 100 landings will probably equal or exceed a sinking speed of 3.1 ft/sec, and one out of 1000 will probably equal or exceed a sinking speed of 3.8 ft/sec.

This curve of the probability of equalling or exceeding a given value of sinking speed has been established from a sample of landings made under clear air, daytime conditions. It is possible that this curve could be altered somewhat due to the influence of various factors, such as low ceilings, reduced visibility, precipitation, cross winds, extreme turbulence, and so forth. Continued operation of the project is expected to yield information on the influence of some of these factors.

Another phase of the problem of rationalizing design requirements and procedures for modern airplanes is that of determining the manner in which the forces develop in the landing gear and airplane structure in arresting the motion of the airplane at impact. As you have seen earlier in your tour, or will see later in your tour, facilities are available for studying landing loads problems in the Laboratory, under accurately controlled conditions. However, it is not feasible

to simulate, exactly, the actual landing of an airplane. There is need, therefore, for information on the extent to which the differences between the actual and simulated landing conditions may influence the laboratory results. This B-29 airplane behind you, instrumented as indicated by the placards, is being used to obtain information applicable to this problem.

From measurements in actual landings such as are being made with the airplane the importance of the various factors involved, and the manner in which they are interrelated can be determined to serve as a basis for establishing or verifying both design procedures and also laboratory methods of studying landing loads.

I would now like to introduce your next speaker, Mr. Matthews
Mr. Brown whose talk is concerned with power control systems.

TRANSPORT TYPICAL FILM

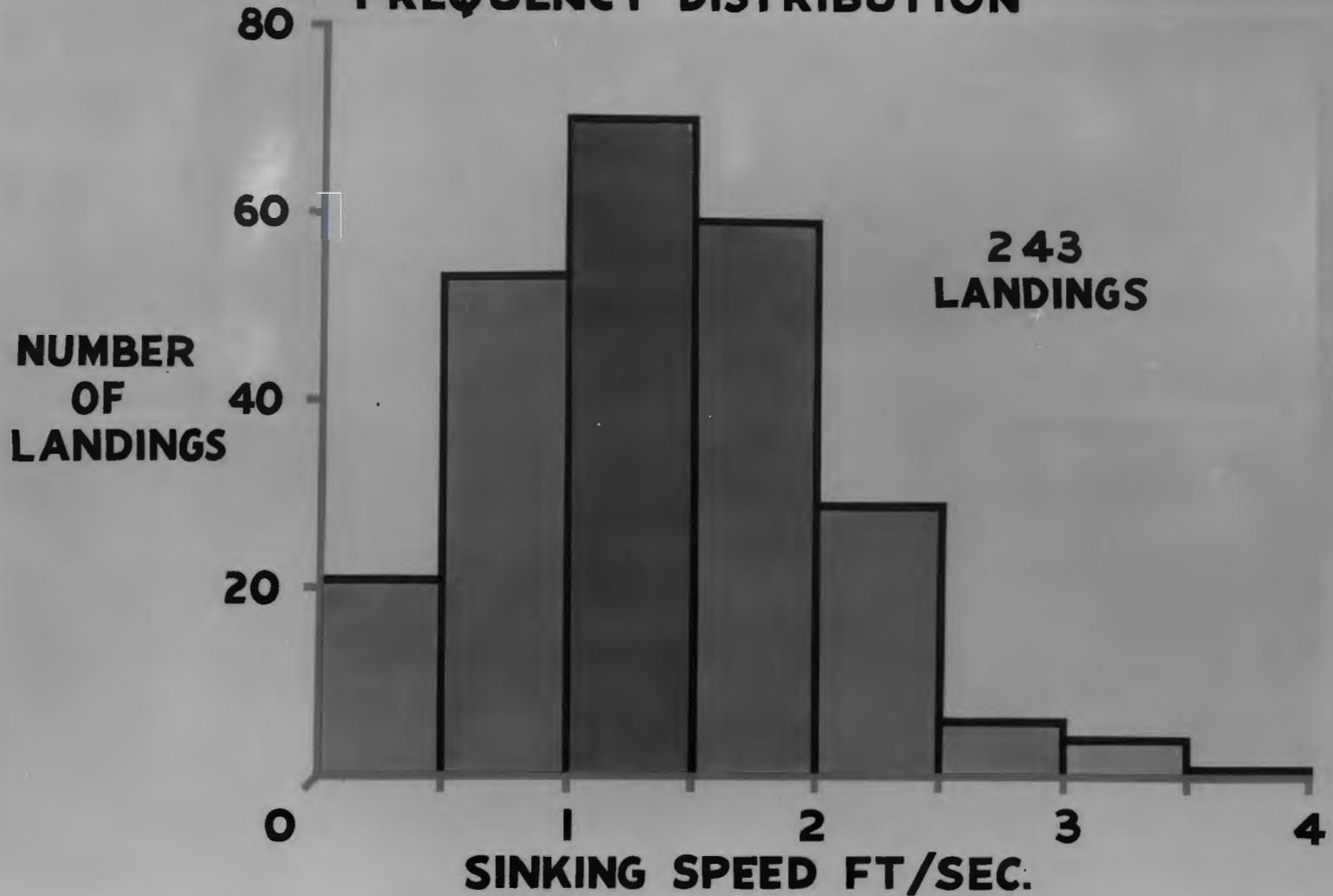
LANDINGS RECORD



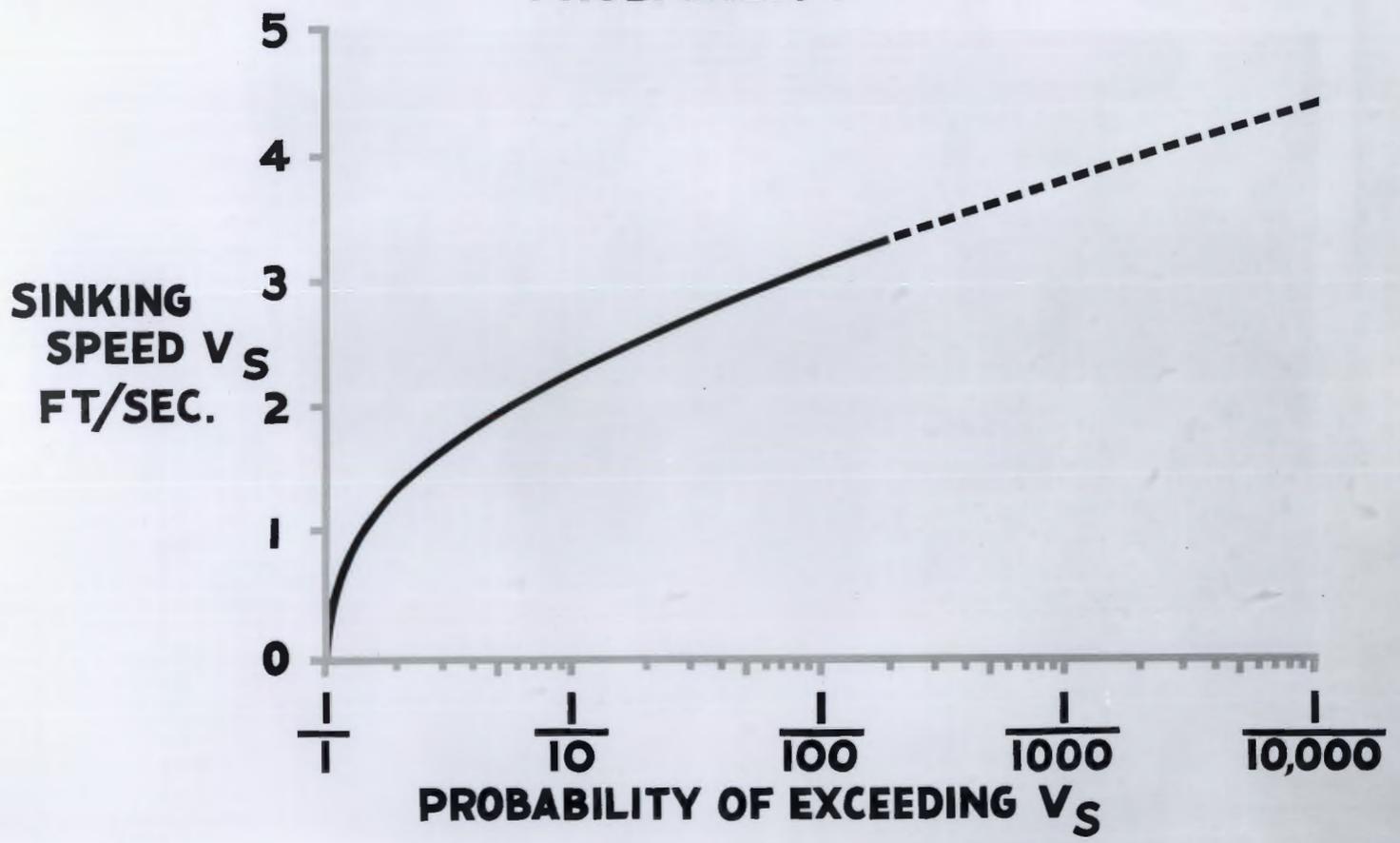


LAL 80659

SINKING SPEEDS FOR TRANSPORT LANDINGS FREQUENCY DISTRIBUTION



SINKING SPEEDS FOR TRANSPORT LANDINGS PROBABILITY





LAL 80181



B-29 Instrumented for Landing-Loads Research

A SIMPLE SIMULATOR FOR STUDYING RESPONSE CHARACTERISTICS
OF AIRPLANES WITH POWER CONTROL SYSTEMS

by J. T. Mathews, Jr., and B. P. Brown

Speech Given at the 1953 Biennial Inspection of
the NACA Laboratories

As the speed of airplanes has increased, the forces required to deflect the controls has, in many cases, increased to a point beyond the strength of the pilots. This fact is particularly true in the transonic speed range where the control forces are also subject to large abrupt variations with only a slight change in speed. For these reasons most designers now consider that power operated control systems are a necessity in transonic airplanes.

In flight the pilot controls the airplane by changing the lift, which in turn is changed by the fore and aft forces he exerts on the stick. The over-all requirement for a satisfactory control system is that each change he makes in the force must produce the expected change in lift, and at the time he expects it.

In order for the pilot to use the airplane efficiently as a gun platform or even for such a simple task as flying in formation with another airplane, it is necessary that the control system perform satisfactorily. In order to illustrate the type of difficulty that may result with an unsatisfactory system we have shown on this first chart a measure of the normal acceleration produced by two airplanes flying formation during a rapid turn. The blue line represents the lead airplane and the black line represents the wing airplane which had an unsatisfactory control system. Other flight records show that with a good system the same pilot would be able to follow the lead airplane very closely.

During an investigation to determine the requirements for power control systems, we have found that the simple piece of equipment, which you see here on the F7U, has proved particularly useful for detecting from ground tests the difficulties shown on the previous chart.

This equipment consists of a pivoted mass which is connected to the control surface through a spring. The period and damping of the mass can be adjusted to duplicate the period and damping of an airplane for any particular flight condition. This simulator, as we call it, projects a spot of light onto a screen near the cockpit. The motion of the light spot indicates approximately the lift changes that would occur on the airplane in response to movement of the control by the pilot.

We are not going to attempt to show you actual tests with this airplane; however, we would like to show you how such tests would be performed. In actual tests the pilot would be instructed to try to move the spot of light as rapidly as possible from one line to the other and hold it steady. With a satisfactory system he would be able to do it like this. There would be very little overshoot and no tendency to oscillate. On the other hand, with an unsatisfactory system the result may appear something like this. In this case there would be an appreciable overshoot and a continuous oscillation.

On the second chart we have plotted from actual flight records a time history of a pull-up maneuver using first a satisfactory and second an unsatisfactory control system. On the top part of the chart we have simulator records for the same conditions. Note the satisfactory characteristics of this system as shown by the lack of overshoot, are duplicated

by the simulator. The characteristics of the unsatisfactory system are also duplicated by the simulator.

While this simulator is only a by-product of an investigation of power control system requirements, we have found it so useful and accurate in detecting troubles of the type we have described that we believe others engaged in similar work will find it equally useful.

Our next speaker - (Messrs. Skopinski and Fisher) - will describe some of the procedures used to measure loads on airplanes in flight.



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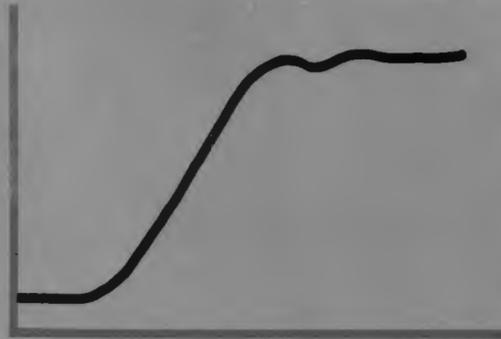
POWER CONTROL CHARACTERISTICS

SATISFACTORY

UNSATISFACTORY

SIMULATOR

LIFT



FLIGHT

LIFT



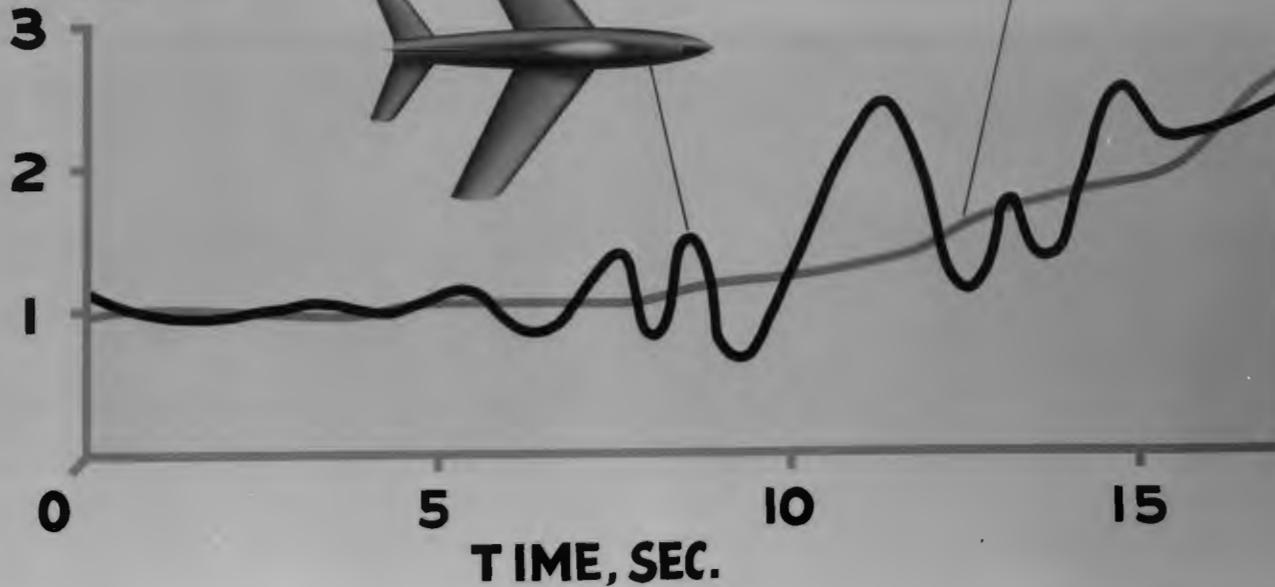
TIME



TIME

POWER CONTROL DEFICIENCIES IN FORMATION FLIGHT

NORMAL
ACCELERATION
g UNITS





F4U - Demonstration Setup of Optical Simulator

APPLICATION OF STRAIN GAGES TO FLIGHT LOADS MEASUREMENT

By Ted H. Skopinski, Raymond A. Fisher, and John F. Ward

Speech Given at the 1953 Biennial Inspection of the NACA Laboratories

In some of the flight investigations carried out on the airplanes you see in this hangar the measurement of loads is required. In fact, the first speaker briefly mentioned one case of such measurement without giving any of the steps required to convert an airplane structural component for load measurements. An engineer starting out to design a scale or balance whose function is to weigh, uses combinations of simple geometrical systems of springs, levers, and pivots. He winds up building a scale that weighs accurately no matter where the weight is laid on the platform. On the other hand, an engineer designing an airplane component such as a horizontal tail does not have this objective in mind so one would expect the conversion of such a component into a weighing device to be a somewhat difficult task.

Because the wire resistance strain gage is small, can easily be installed without modifying the structure, and can be used with rapid response remote recording equipment, it is often adapted to convert a structure for the measurement of loads. A typical wire resistance strain gage is made up of a number of loops of very fine wire mounted on a suitable support. When it is cemented at a point on the structure so that the wire loops are aligned with the direction of the principal strain the wire will be stretched an amount proportional to the strain at that point. This accumulated stretching results in a change in resistance which can then be measured on an electrical indicator. If the structure on which the gage is cemented consists of a simple geometric shape, as would be used in a weighing device such as a scale or balance, the strain measured by the gage could

be converted to vertical or shear load without regard to position of the applied load. In a complicated built-up structure, however, the strain at any point will vary with the position of the vertical load on the structure as well as with the size of the load. It would therefore be difficult, if not impossible, to locate a gage at a point in the structure where the load, no matter what its position, would be given by the response of a single strain-gage assembly. This fact, however, does not prevent us from converting the tail to a weighing device by making use of a number of strain gage assemblies that have different response characteristics. These points will be demonstrated by using a set of F-86 horizontal tail surfaces that have been instrumented and calibrated at one of the NACA facilities - the Loads Calibration Laboratory.

The left stabilizer has been instrumented at one span station with a number of four-arm strain-gage assemblies which have been cemented to the front and rear spars at the positions shown in section A-A on the chart. The red and blue gages mounted on the spar webs have been aligned to respond to the tension and compression strains in the webs. The yellow gages mounted near the rear spar flanges have been aligned to respond to the tension and compression strains in the flanges. The gages in the stabilizer have been initially balanced so that with no load on the structure the three indicators which are connected to the strain gages read zero. The top indicator will measure the response of the front web gages, the bottom left indicator will measure the response of the rear spar web gages, and the bottom right indicator will measure the response of the rear spar flange gages. When the demonstrator steps on the surface near the root the indicators all deflect to a new position. It must be pointed out that the

response rate of the recorders used in flight is about 500 times greater than the response rate of the indicators used in this demonstration. As he shifts his weight from the front spar to the rear spar it can be seen by the indicator pointer movements that the front and rear spar web gages are more sensitive to chord position effect than the flange gages. Now as he moves slowly toward the tip it may again be seen by the changes in the three pointer deflections that the flange gages are more sensitive to his spanwise position than either the front or the rear web gages. It is obvious that the changes in the deflections, on a percentage basis, are quite large. Thus, by themselves none of the individual responses would be acceptable as a measure of the vertical load imposed.

An essential step in using strain gages for flight load measurements is to recognize that load position effect on the individual gage responses is a characteristic which should be made use of. The responses of the web and flange gages are then combined electrically in proper proportion by addition of resistances in the individual circuits to give an appropriate single combined output that is only dependent on the size of the load and not on the position of the load.

In this demonstration the combination has already been set up and all we have to do to complete it is to flick a switch. The demonstrator will again step on the surface and the response for this new combined channel will now be read on the top indicator. You can now see that, as he moves along the tail as before, the indicator pointer does not move any appreciable amount from his weight of 165 pounds. Thus, without any weakening or major modifications the structure has been converted to a weighing device of sufficient accuracy for most flight investigations.

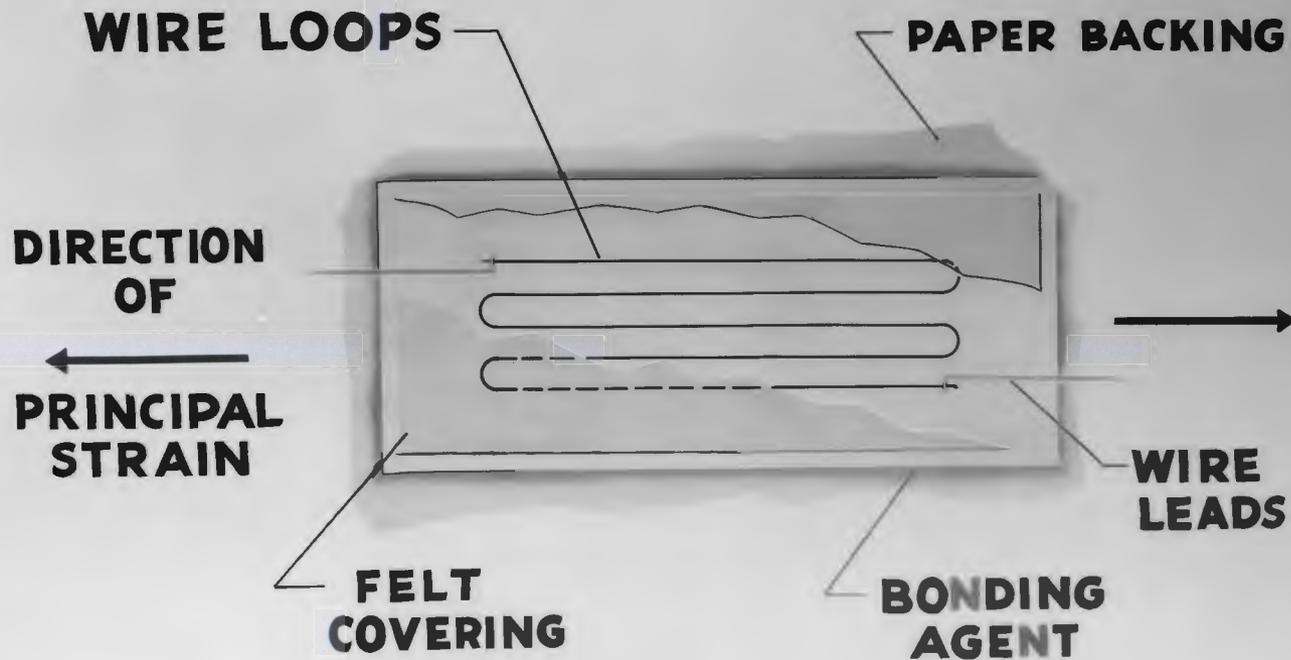


LAL 80180



Display for Flight Research - F-86 Horizontal Tail Assembly Used for
Demonstration of Strain-Gage Installation

A TYPICAL ELECTRICAL RESISTANCE STRAIN GAGE



F-86 STABILIZER STRAIN-GAGE INSTALLATION

