1951 INSPECTION - HELICOPTER TALKS

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For the uses of the helicopter which are currently unfolding, it is essential that all-weather flight be possible. However, very little blind flying has been attempted with helicopters, largely because of poor stability and control characteristics.

We have previously found that certain flying-qualities requirements must be met for satisfactory helicopter flight under conditions of normal visibility. Currently, we are checking the adequacy of these requirements under blind flying conditions.

In this machine we have installed a set of dual controls, a flight instrument panel and a hood, which permit the rear pilot to try blind flying. The instruments are those which are considered adequate for and airplane, and include a turn and bank indicator, artificial horizon and directional gyro. To vary the longitudinal stability for test purposes, we made flights with and without the tail assembly which you see (the paddles with the yellow stripes). To completely meet our flying-qualities criteria, we found it necessary in this case to link these paddles to the longitudinal control, just like the elevator on an airplane.

This chart shows one result of these blind-flying trials. Here we see longitudinal stick motion plotted against time for two cases; tail off, where the stability of the machine is such that our requirements are <u>not</u> met, and tail on, in which they are. It is apparent by comparing the motions on the two curves, that the pilot has much less difficulty in the case where our visual criteria are satisfied.

The significance of this result is that our existing stability and control requirements appear to be adequate, longitudinally, for blind flying.

However, in the case of directional control we seem to have uncovered a new problem, which is illustrated in this next chart. Here we see rudder-pedal motion plotted against time, for both visual and blind-flying conditions. This bottom curve is typical of visual flight, in which our pilots have no trouble maintaining a desired course. During instrument flight, however, they report great difficulty in holding a given heading. This is confirmed by the greatly increased motion shown on the upper record which was taken while the pilot was flying under the hood.

Thus, in this case, a machine which was considered satisfactory for visual flight was found to be difficult to control, directionally, under instrument conditions. This problem is currently being investigated, both to determine what additional stability and control requirements are needed and also to determine whether special flight instruments will be necessary for satisfactory helicopter blind flying.

Sometimes we are able to predict new problems, and solve them, before they are encountered in actual flight. The helicopter stability study about to be described by Mr. Amer is one example.

Early flight investigations indicated that one of the most important factors affecting the ease of flying the helicopter is a characteristic known as rotor damping, which is the rotor contribution to the damping in roll or damping in pitch of the complete helicopter. Thus, if we imagine this model is flying this way, if it rolls to the right like this, the rotor normally produces forces to the left to oppose the motion. A theoretical investigation of rotor damping was then undertaken which indicated that it became smaller with increasing forward speeds or with increasing rates of climb, and could in fact become unstable at very high speeds or rates of climb. By unstable damping, we mean that the rotor would produce air forces in the same direction as the rolling motion of the helicopter. Thus, if the helicopter is rolling to the right, the rotor produces forces tending to cause the helicopter to roll faster and faster to the right.

Because of the serious implications for future high-performance designs, measurements of rotor damping were then made in flight using this helicopter to check the predicted trends as far as possible. The results are shown on this chart on which is plotted rotor damping against increasing forward speed or rate of climb. The measurements confirmed the theoretical prediction that rotor damping decreases with increasing forward speed and rates of climb. However, this test helicopter did not have enough power to reach the region of unstable rotor damping. Model tests in a wind tunnel were therefore used to investigate this region experimentally. This is the model used for the wind-tunnel tests. As you can see, it is mounted on pivots of very low friction.

You will now see movies of this model mounted in a wind tunnel at a high speed, high rate of climb flight condition.

START FILM

The model, like an actual helicopter, is nosed down so the rotor can pull it forward into the wind which is coming from the right. As you can see, the swinging of the model builds up, indicating that for each swing, the rotor is producing forces in the same direction as the model is swinging. Thus, we have experimental confirmation of the theoretical prediction of a region of unstable damping.

Further study indicated that one way to prevent the occurrence of this unstable damping in high-speed flight would be to use a special rotor hub with flapping hinges offset from the rotor shaft instead of a more standard hub with hinges on the shaft. In this next scene, we will see the same model at the same flight condition, but having a special rotor hub with offset flapping hinges. The model gives the impression of having a different number of blades in this scene because of a slightly different stroboscopic effect. The model is being displaced by the operator and then released. As you can see, the swinging damps out very quickly, demonstrating that this hub change produces sufficient additional rotor damping to overcome the unstable damping normally present in this high-speed flight condition. Again the model is displaced by the operator and released, and the swinging damps out quickly.

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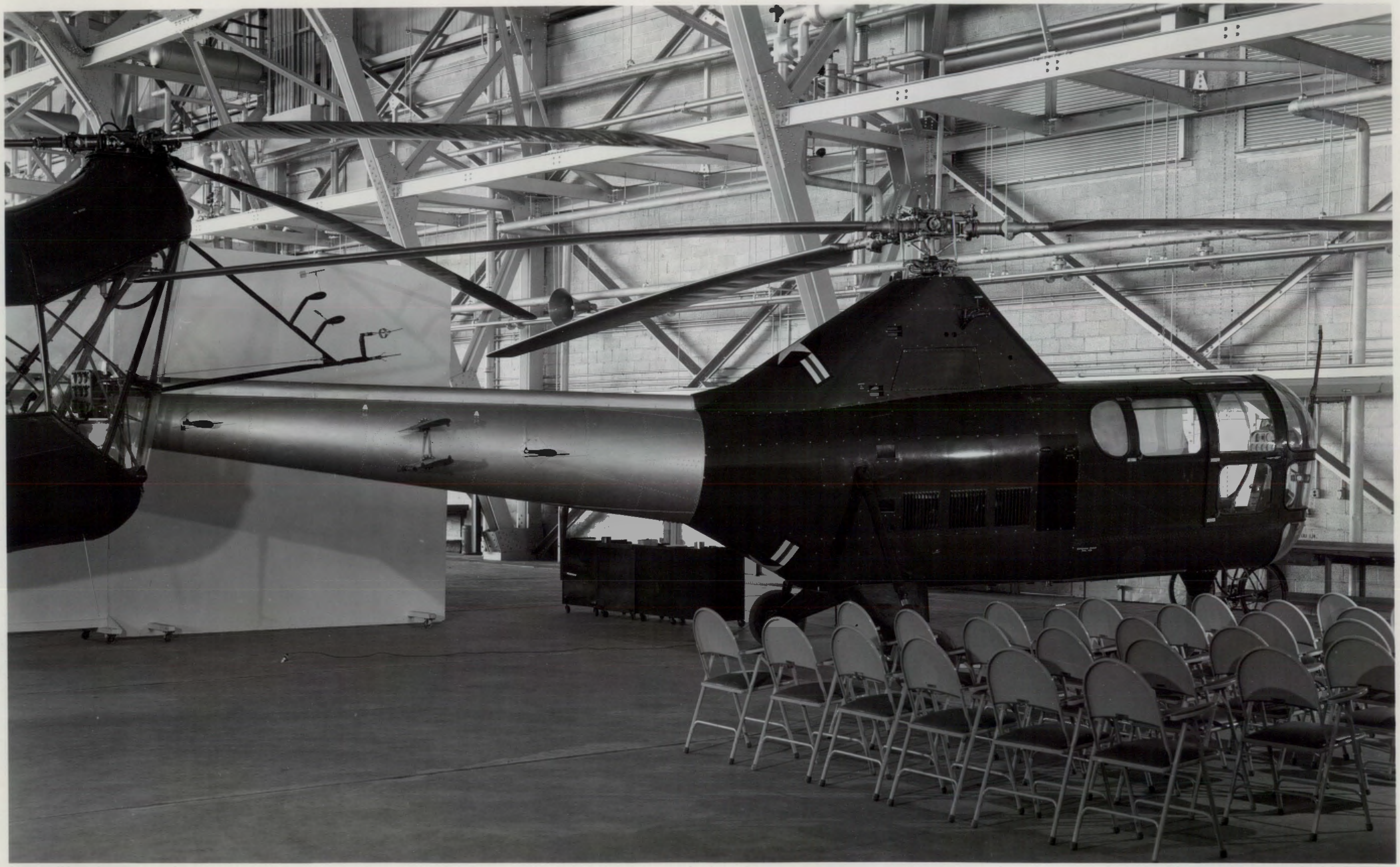
To sum up, we have found and demonstrated the problem of unstable rotor damping that designers of high-speed helicopters will have to take into account, and we have demonstrated one possible solution to this problem.

This concludes the demonstration at this step.



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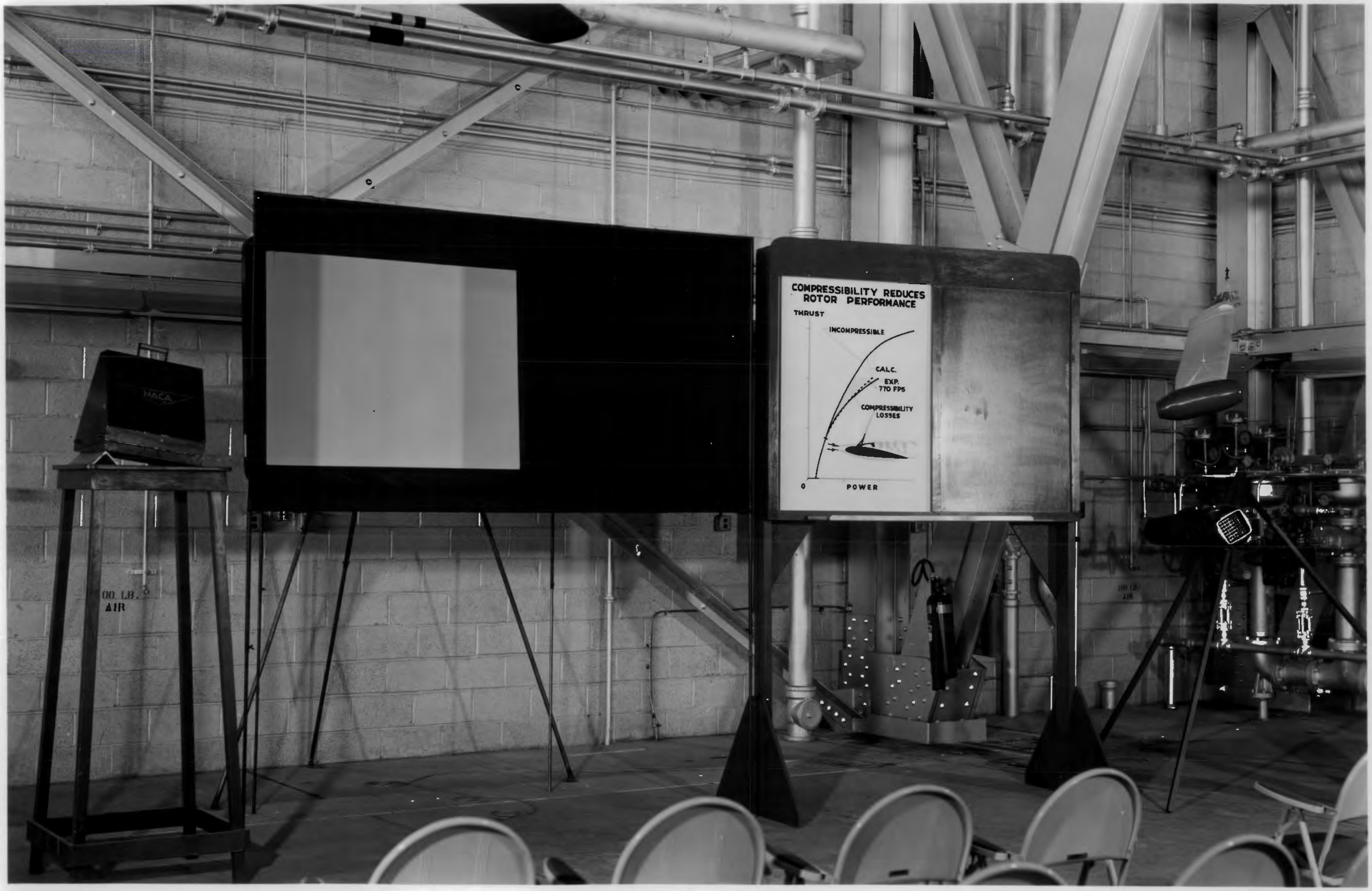

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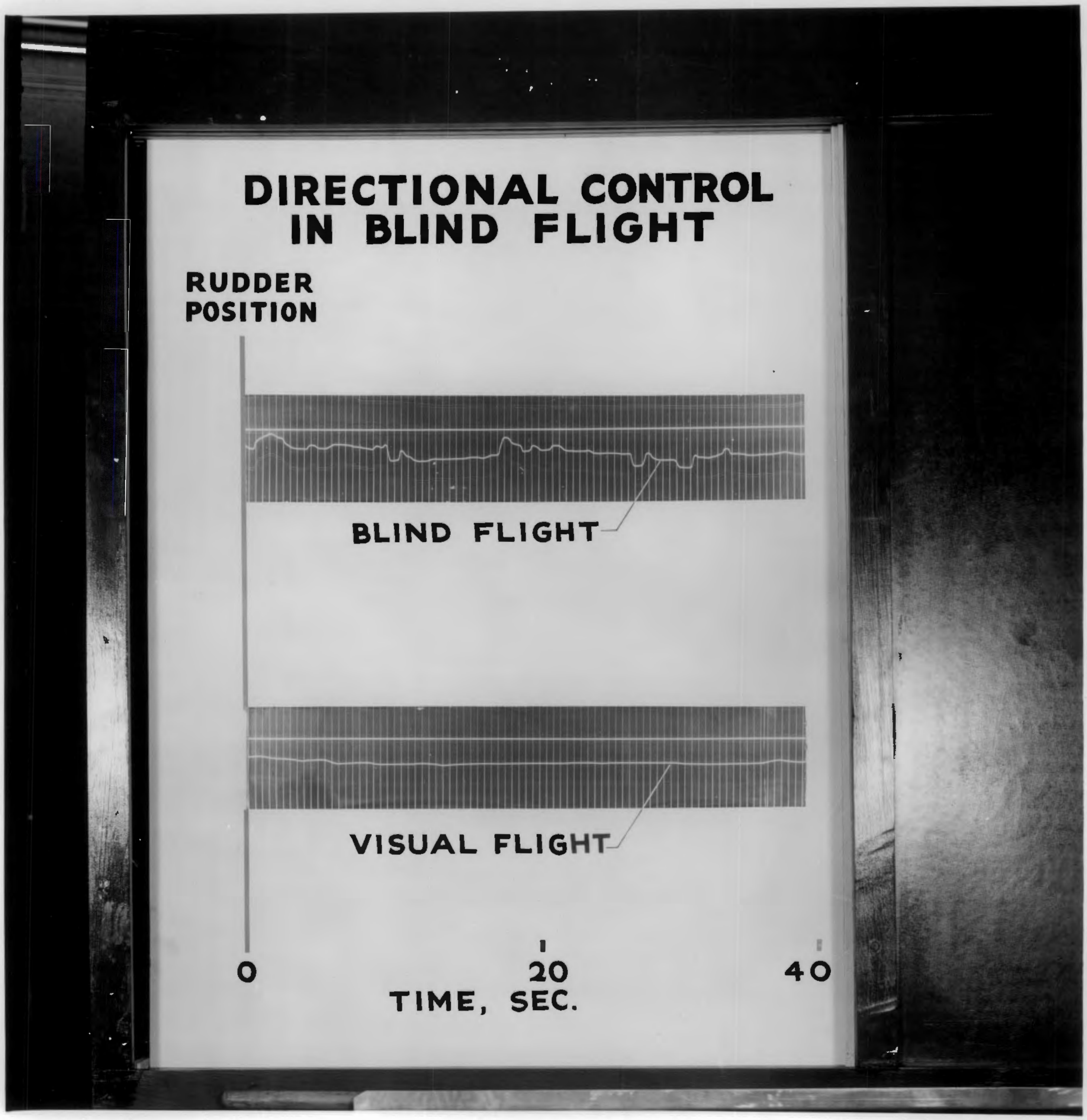

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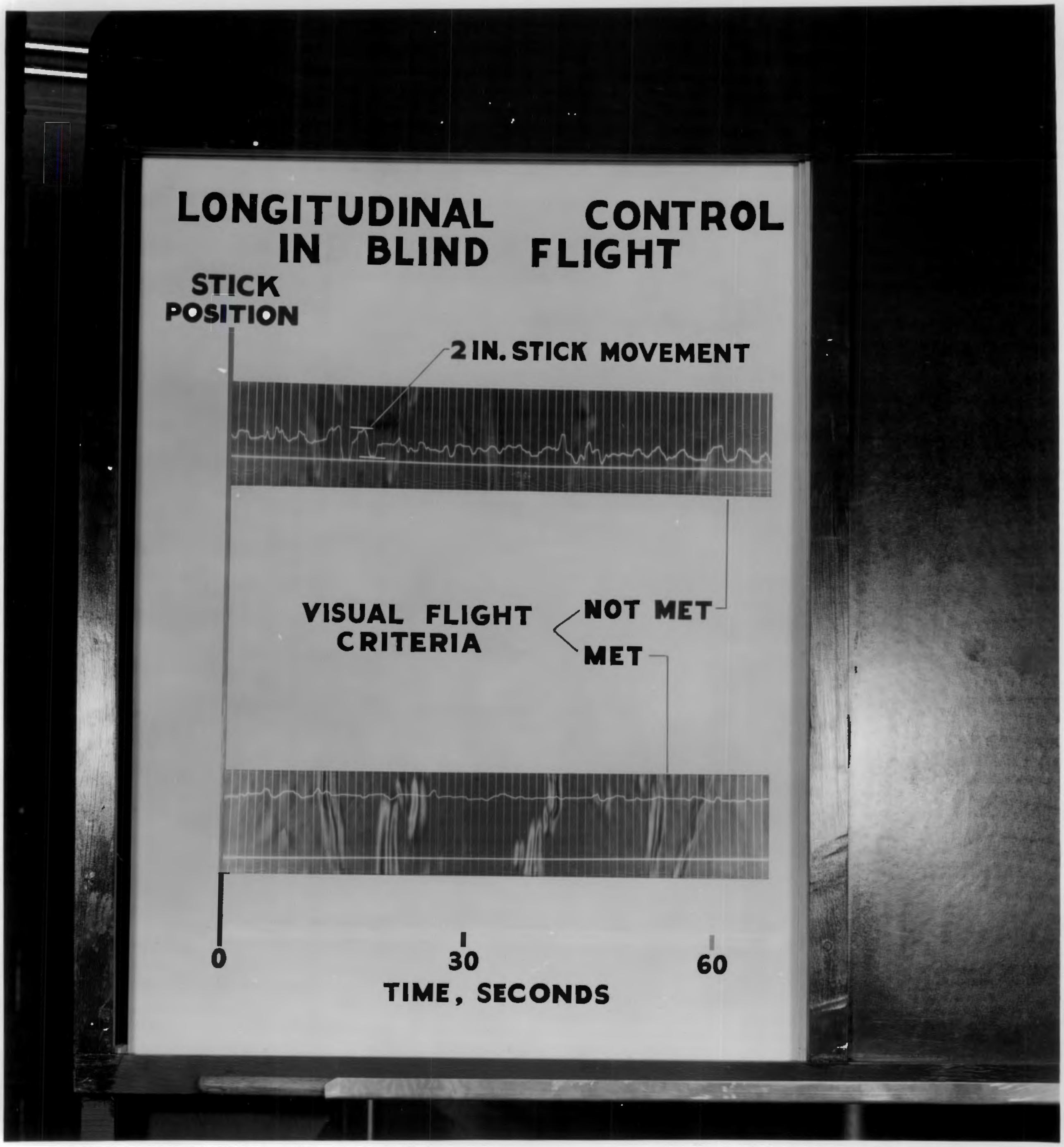

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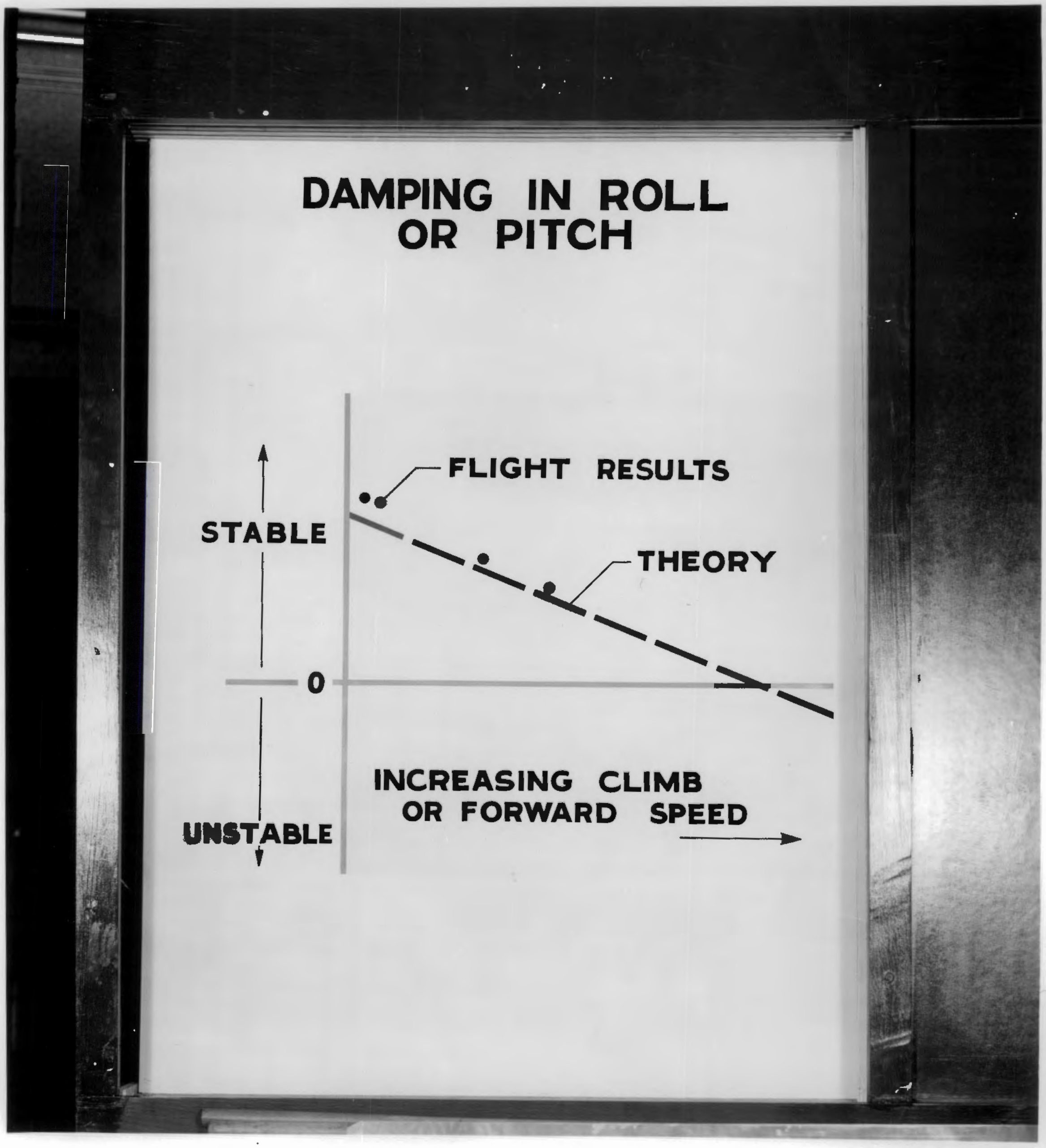

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EFFECTS OF COMPRESSIBILITY UPON THE PERFORMANCE OF HELICOPTER ROTOR BLADES AND POWER-OFF DESCENT OF JET POWERED HELICOPTER ROTORS

by Richard C. Dingeldein and Paul J. Carpenter

Presented by - Paul J. Carpenter and Walter C. Kenyon at Flight Research, Biennial Inspection, Langley Aeronautical Laboratory, 1951.

The NACA helicopter effort is directed toward improving both the performance and stability and control characteristics of the helicopter. Investigations are underway in wind tunnels, in flight, on the helicopter test tower, and in the vibration and flutter laboratory.

In order to increase the top speed of the helicopter, it is necessary to increase the rotational speed of the rotors to avoid stalling of the retreating blades. High rotational tip speed is of interest since more lift can be obtained with a given size rotor. High tip speeds are also of interest with certain types of jet power plants which have acceptable propulsive characteristics only when operating at these faster speeds; however, at these speeds rotor blades, like wings, are affected by compressibility which, among other things, causes a rapid rise in the blade drag. As a result, it is important to determine the effects of compressibility and to what extent these effects can be predicted.

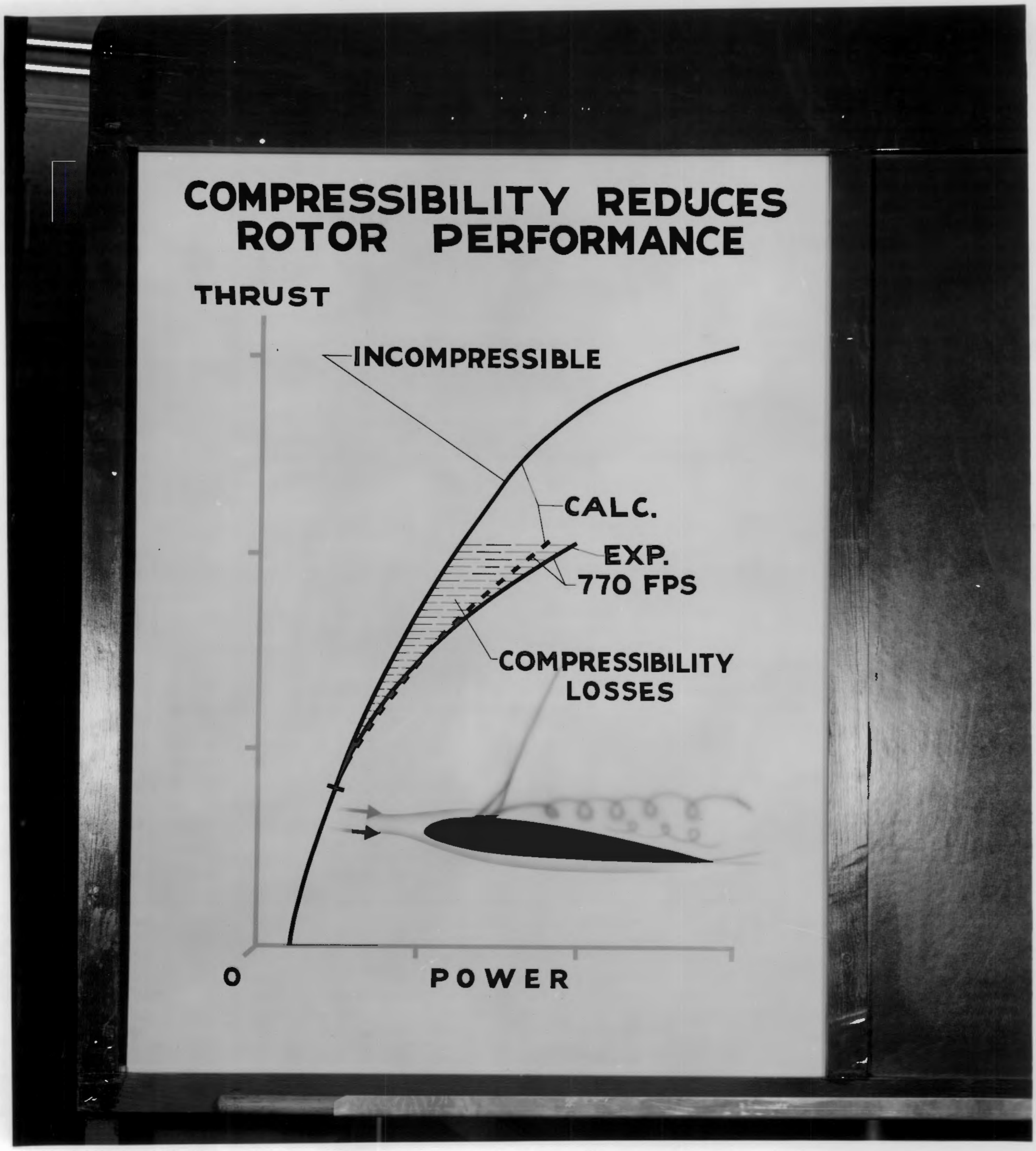
Tests of a hovering rotor operating at high tip speeds have recently been made on the helicopter test tower. Some of the results are given on this chart as a plot of rotor thrust or lift versus rotor input power. The top solid line represents a calculated rotor performance curve without compressibility effects and we have experimental data that show good agreement with this curve when no compressibility losses are present. The experimental results are shown by the second solid line which is for a rotor operating at 770 feet per second tip speed.

Above a certain thrust or blade pitch setting, effects of compressibility on blade drag cause a progressive increase in the power required to drive the rotor. This dashed curve represents the calculated rotor performance at a tip speed of 770 feet per second when compressibility effects are accounted for by using airfoil section data at the proper Mach number and angle of attack. This comparison is significant in that it is shown that wind tunnel tests of a stationery airfoil can be used to correctly predict the performance of a whirling rotor blade. This agreement leads to the belief that airfoil section data can be used in predicting the characteristics of other rotors, particularly the gains which may be expected from blades utilizing thinner airfoils than the 15-percent thick section used in this investigation.

The use of relatively light but powerful jet engines attached to the rotor blade tips for propulsion is currently being studied on the test tower. Both ram-jet and pulse-jet types, similar to these units here, are included. These simple power plants, even with their higher fuel consumption, permit a helicopter to carry larger payloads for short durations than a helicopter equipped with a conventional aircraft engine.

One of the problems with jet-powered rotors is the high rate of power-off descent due to the drag of the jet unit. This tip jet unit moving at a higher velocity than the inboard sections of the blades requires nearly as much power to overcome its drag as to support the helicopter. This is indicated on this chart (chart 2) which shows the descent speed plotted against forward speed for a rotor with and without these ram-jet units. The minimum descent speed is increased about 80 percent by the presence of these jet units. The test tower has been used to investigate various means of reducing this jet drag. As an example, this middle curve shows that completely blocking off the internal flow decreased the drag of the jet unit to such an extent that nearly half of the increase in the minimum rate of descent was gained back. Further studies to reduce the drag and to generally improve the performance of jet powered rotors are underway.

Your next speaker, Mr. ______________ will now tell you about some of the helicopter stability work being conducted by the flight research division.



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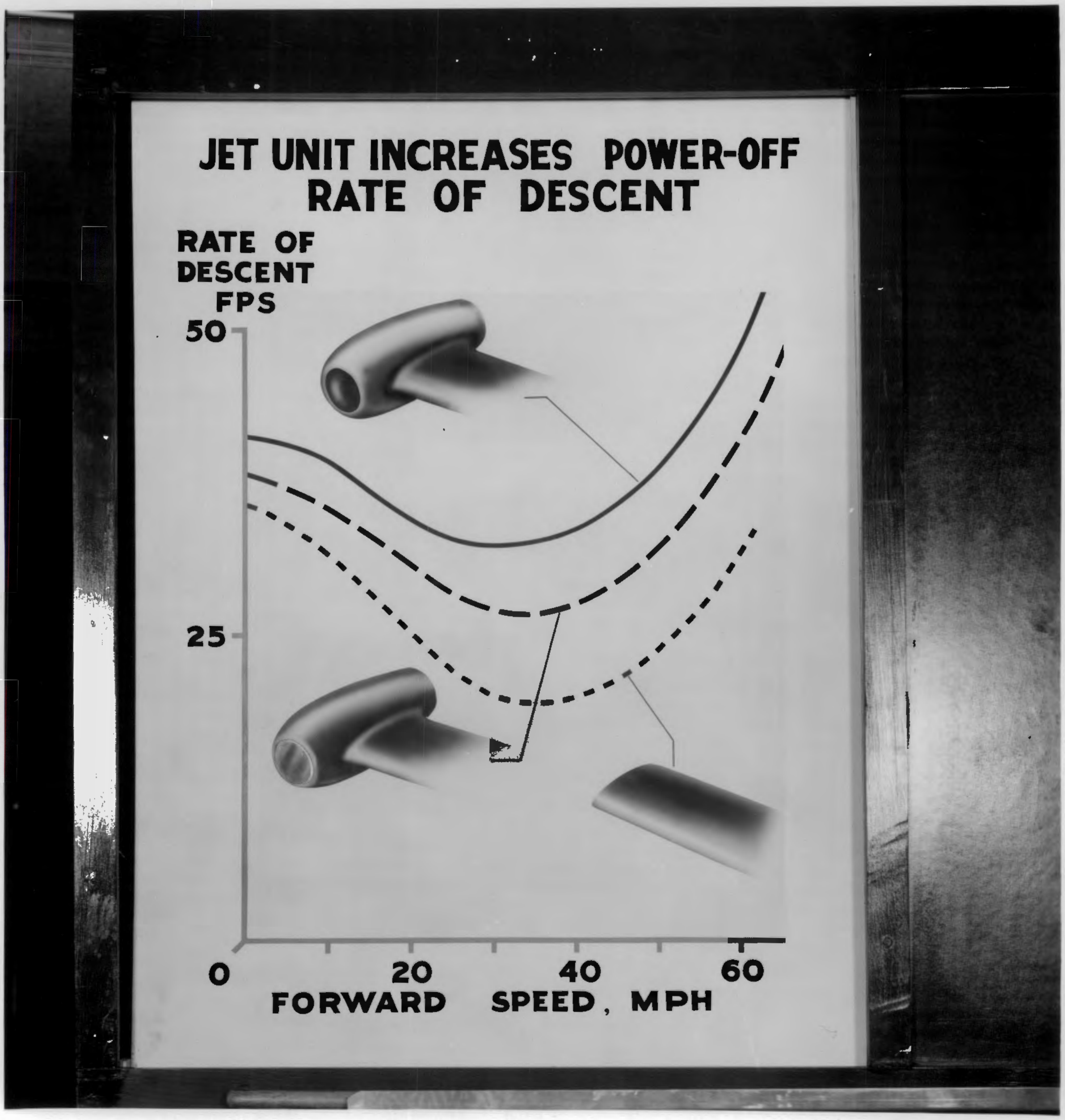

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