1949 INSPECTION

- John Stack

During your visit to the various activities at this, the 1949 Inspection, a very considerable amount of research will be discussed. A very large part of this information has become available as a consequence of the development of new research techniques. In the time available it is not possible to cover in detail these new research techniques as they relate to the information that will be shown you at each activity. It is very important, however, to the appreciation of the new research results that you have some idea of the extensive technique development necessary. As you well know, research has been done in the laboratory and in flight all through the history of aeronautics, and, in fact, methods can be described as either laboratory or free air. When we speak of laboratory information, we in general think in terms of wind tunnels, and when we think of free air, we in general think in terms of airplanes. Some of the methods that have been developed in the past may become inaccurate, and in fact can give misleading results, in the higher speed ranges. With regard to the wind tunnel, there was also the choking limitation which prevented the obtaining of data in the Mach number 1.0 range. A few years ago this "choke" range for wind tunnels extended from Mach number 0.8 to Mach number 1.3. In fact, supersonic wind tunnels were not operating as low as Mach number 1.3 in most cases because of their small size. This "choked-out" speed range was known to be very important, because it is in this speed range that the transition from subsonic to supersonic flow occurs. This region is, of course, known as the transonic speed range in which parts of the flow

have subsonic characteristics and other parts have supersonic characteristics. Shocks are present, and interacting with the boundary layer make this speed range one in which large and abrupt changes in flow characteristics occur. These changes in flow characteristics have pronounced effects on all aerodynamic characteristics which can easily lead to unmanageable vehicles. An example of such characteristics is illustrated by the first slide.

(Explain slide) Slide No. 1

The great importance of obtaining valid information in this transonic range is obvious, and a very considerable effort has been made to this end. Some of the very first reliable information through the Mach number 1.0 range was obtained by the falling body method in which a heavily weighted body, carrying appropriate instrumentation, was carried to great heights in an airplane and then dropped. Information from the flight is obtained by optical and radar tracking and by telemetered information from instruments carried within the body. It is important to note at this point that while the falling body method for obtaining information through the Mach number 1.0 range has, in a sense, always been available, it was not possible to use it fully until the science of instrumentation had been developed sufficiently. By this I mean radar and radio telemetering coupled with the development of such devices as rapid response accelerometers, pressure pickups, and strain gages. The next slide illustrates the experimental set-up. (Explain slide) So far as transonic speed obtainable, the principal limitation is the altitude to which the body can be carried. Mach numbers well above 1.0 can be obtained, but more important is the fact that the body can be released

at a fairly low subsonic Mach number and the forces acting upon it and its components can be found as it passes continuously through the Mach number 1.0 region. Changes in the weight of the body also permit information to be obtained at different rates of travel through the transonic range so that not only can steady motion results be obtained, but also the question of the virtual mass as a consequence of acceleration can be and has been settled.

The second method for obtaining information continuously through the transonic range has been the "wing flow" or "wind-tunnel bump" method. This technique was first developed here to an airplane wing and consisted of supporting a small wing in the flow field on an airplane wing, the span of the model being tested being perpendicular to the surface of the wing. The next slide illustrates the experimental arrangement. The model itself is connected to a specially developed quick response balance so that it can be rotated through an angle-of-attack range either increasing or decreasing, or both, very quickly, and the forces recorded. With such a set-up the airplane carrying the model is dived at altitude so that the critical speed of the airplane wing is exceeded. The flow over the wing surface during the dive increases through the subsonic range, finally becoming supersonic. Since the air flow can proceed smoothly from subsonic to supersonic regimes without significant disturbance, a stream of continuously varying speed is obtained. This sounds very simple, but there are several things which must be properly taken care of. Not all wings can be used, and in most cases some modification of the usual profile is necessary in the region where the model is supported.

First, the shape in the region of the model must be such that the velocity gradient along the model span must be very nearly uniform for a distance out from the wing somewhat greater than the span of the model. Second, the gradient in the chordwise direction must also be uniform. Third, the boundary layer on the main wing must either be passed around the model or it must be sufficiently thin so that it can have no important effects on the model results. Fourth, the normal shock that occurs on the main wing must be sufficiently far back of the test model so that its influence exerted forward through the boundary layer cannot reach the test model region. For a simple straight wing of low aspect ratio, these methods are relatively easy to accomplish, but for high aspect ratio wings, for swept wings, or for half models of airplanes, the region over which these conditions must be met becomes fairly large, and considerable care is necessary to insure that the results are not misleading. This same method has also been applied in high-speed wind tunnels capable of Mach numbers up to roughly 0.9. In the wind tunnel a bump or wave is placed on the floor or walls. With increase of speed the flow is accelerated over the wave or bump and again can be made to pass smoothly through sonic regimes. The model is supported in an appropriate place on the bump similar to its position on the airplane wing, and with similar instrumentation, forces and moments can be obtained. The same technique problems exist as for the original wing flow method, that is, vertical and longitudinal gradients in the boundary layer. Thus the shape of the bump or wave on the tunnel wall must be carefully studied. Not any shape can be used,

but only particular shapes meeting the above conditions are useable. Such shapes have been developed and are now in constant use.

The third method is the rocket technique. In this approach to the problem, models are fired from the ground, being driven to a very large Mach number by a rocket contained within the model. The next slide illustrates the rocket technique. The path of the model is observed by optical and radar methods; the speed is measured by the Doppler radar. Instruments contained within the model coupled to a radio telemeter relay the information to ground stations. The models are also arranged to carry actuating mechanisms to move the controls during flight. Thus, not only can lift and drag be measured, but other quantities such as the moments, the response of the controls, control effectiveness, and control hinge moments can be and have been measured.

Of the three methods so far enumerated, the falling body and the rocket methods offer the possibility of very large Reynolds numbers. In fact, for most applications, full-scale or even larger Reynolds numbers can be obtained. This is so because the models, though small, are flown in the very low levels of the atmosphere where the density is high. One-sixth scale models of research aircraft have been used to obtain full-scale Reynolds numbers for the altitude conditions at which the research aircraft make high-speed flights. The wing flow and bump methods have the disadvantage of very low Reynolds numbers, frequently in transition ranges, and thus their interpretation is much more difficult than is the case with the other two methods.

At the same time these methods were being developed, a considerable improvement in wind-tunnel techniques was being made. A few years ago, as I noted previously, the choked out range of a wind tunnel was considered to be 0.8 to 1.3. It was well known and understood that this choked out range could be reduced by reduction in model size. Reduction in model size alone, however, is not sufficient. The supporting systems of the models can give serious difficulty. Conventional types of wind-tunnel supports are asymmetrical, usually being attached to one side of the model. As Mach number 1.0 is approached, choking effect is greatest on the side where the greatest support blocking exists. At Mach numbers well below the ultimate choke limitation these asymmetrical supports cause local constriction which change the stream angularity. Thus the model, on conventional supports, which usually extend through the floor of the tunnel and are attached to the under surface of the wing, will experience an up flow angle which is of considerable magnitude as the Mach number gets large. There is no sure method for correcting for such effects. The immediate conclusion is that one must abandon such techniques to approach, if possible, the conditions such that only the model is in the test section. Such techniques have been developed in the 8-foot tunnel here over the last few years. Two years ago some of these were described to you. Hence, I shall review them only briefly. The next slide shows a plate type support.

(Describe slide)

The second type is the sting type support shown in the next slide.

(Describe slide, noting liner)

For these type supports, reasonable size models can be tested successfully to Mach numbers of the order of 0.95. Highly swept wings have been tested to the order of 0.97. This work has been carried further by the development of a supersonic throat for the 8-foot tunnel. A throat for Mach number 1.2 of 8-foot diameter was developed and placed in operation about 18 months ago. In a circular throat tunnel, difficulties due to the effects of shock or disturbances from the wall could offer serious difficulty, but fortunately these have been overcome. In the design of the throat, shown in the next slide, provision was made for a length of constant velocity ahead of the expanded 1.2 section so that sting supported models can be run over the subsonic range to the order of 0.95 and then drawn downstream to the 1.2 test section where results for low supersonic speeds are obtained. Thus the choke range for conventional closed-throat tunnels has been reduced from a range of 0.5 in Mach number to a range of 0.25. Throats for Mach numbers lower than 1.2 can be made so the choke range can be still further reduced. A very necessary part of this whole development was the new internal balance. The balance is contained completely within the model so that all struts carrying load to external balances have been eliminated. For conventional closed-throat wind tunnels the next slide, which is taken from tests of a 1/16-scale airplane in the 8-foot tunnel, illustrates the choke region remaining.

(DESCRIBE SLIDE)

The model in this example was 1/16 geometric scale but the density of the airstream is such that the Reynolds number is 1/9 to 1/5 of the full-scale value considering the altitudes at which the airplane flies. The gap is

at present being filled by the more complicated flight techniques, and the low Reynolds number bump and wing flow techniques.

The importance of a laboratory method for making continuous studies through the transonic Mach number range, and by laboratory method I mean one obtaining results with a simple model, standardized instrumentation and independent of external conditions, cannot be overestimated. We have, as a consequence, experimented with a unique equipment called a transonic tunnel. A view of this tunnel is shown in the next slide.

(DESCRIBE SLIDE)

The main results so far obtained have been from pressure measurements. Lift, moment and pressure drag are obtained from such measurements. The next and final slide shows briefly the status and speed range of the various methods for research through the transonic and into the supersonic range.

(DESCRIBE SLIDE)

Continuous effort is being put on this type of problem and new ideas can be expected, so that it now appears quite reasonable to suppose that the choking limitation can, and perhaps will be, eliminated shortly.

The final and very important method for research in this speed range, and one that is actively under way, is the research airplane method. In this application to the solution of the problems, such airplanes have been designed and built with the cooperation of military forces, industry, and NACA. These are real airplanes, of course, and carry complete instrumentation, piloted by man. The program has been under way a considerable period, and is now under the direction of Mr. Hartley A. Soule' of the laboratory, who will tell you of this phase.