TRANSONIC RESEARCH

presented by

2- by 2-Foot Transonic Wind Tunnel Branch

14-Foot Transonic Wind Tunnel Branch

In the past decade the desire for reliable aerodynamic data at speeds near that of sound necessitated the development of new methods for obtaining experimental research information. The complexity of transonic theory involving mixed subsonic and supersonic flow was so great as to discourage hope for early solution of transonic research problems by theoretical means. Hence, the NACA has stressed the development of experimental methods as the most practical approach to these transonic problems.

The inability to use conventional wind tunnels for aerodynamic investigations at transonic speeds because of the choking or blockage effect made necessary the development of a number of transonic research techniques. Several of these methods are illustrated on this first chart (chart #1). For example, some of these techniques involve wing-flow models, models dropped from high-flying aircraft, and rocket-launched models.

Some of the earliest experimental results at transonic speeds were obtained by the wing-flow method. The location of a small model in a region of increased airspeed over the curved upper surface of the airplane wing allowed the model to be tested at transonic speeds when the aircraft was dived at high subsonic speeds. The transonic bump technique which permitted at least limited use of conventional wind tunnels later evolved from this wing-flow technique.

A common advantage that the dropped models and rocket-launched models have over other techniques is that they closely approximate full-scale airplane flight under free-air conditions. A short movie will now be shown to illustrate the use of rocket models for transonic research at the NACA's Pilotless Aircraft Research Station at Wallops Island. (Movie.)

This is an aerial view of the Wallops Island installation which is located off the Virginia coast. Here is shown a radar tracking unit used to record the position of the model in flight. In a typical test, as will be shown in slow motion for a rocket-propelled model of the F4D Skyray, the model is launched by means of a booster rocket, which burns for approximately 3 seconds. After the booster drops away, small internal rockets are fired to disturb the model. Data are obtained by telemeter and radar during the following 10 seconds of coasting flight. Note the deflected ailerons on this next model, used for studies of control effectiveness at transonic speeds. Its rolling motion in flight, which you may see here, is recorded by special electronic equipment on the ground. (End of Movie.)

With advances in electronic instrumentation, research with rocket models has been broadened to allow detailed investigations of stability and control, flutter, and numerous other related aerodynamic fields. The rocket method is, in fact, the only one of the methods discussed so far which is still in general use. It must be emphasized that, although the earlier wing-flow, transonic bump, and free-fall techniques each had certain limitations and disadvantages, their results filled a critical need at the time. In many instances these results served as a basis for the design of high-speed military and research airplanes which are flying today.

Employment of specialized research airplanes such as the Bell X-1 and the Douglas D-558-II has also contributed, and continues to contribute, much to the NACA's studies of actual problems of flight at sonic and supersonic speeds.

In the first part of this presentation, emphasis has been placed upon transonic research by various flight techniques. The next speaker will discuss some developments in the design and application of transonic wind tunnels for research.

For many aerodynamic studies, in particular those involving extensive pressure measurements which are essential to the understanding of complex flows, the flight techniques just described are costly and not generally feasible. Such detailed investigations are more properly pursued in the wind tunnel. The development of a suitable transonic wind tunnel therefore has been the subject of intensive effort by the NACA and others. The conventional closed-throat wind tunnel, while useful up to relatively high subsonic speeds, and for all but the lowest supersonic speeds, is subject to "choking" at speeds near that of sound, which precludes its use in this range. The phenomenon of choking can best be described with the aid of this sketch (chart #2) depicting the flow over a winged model in a closed-throat wind tunnel at high subsonic Mach numbers.

The model, by virtue of its volume, constricts the flow in the tunnel throat. Up to relatively high subsonic speeds, this flow constriction has only moderate effects, for which corrections are easily applied. As the Mach number increases, the shock waves on the model grow in strength and extent until they reach the tunnel wall, as is shown here for a Mach number of 0.95. For this condition, which is analogous to the well-known case of sonic flow in a pipe, the tunnel speed can no longer be increased with an increase of power, and the flow is said to be choked. The forces on the model then no longer represent those which would occur on an aircraft in free flight. In a similar way, choking also prevents the use of conventional wind tunnels within a small range above sonic speed.

The successful transonic wind tunnel must satisfy three requirements:

1. Choking must not occur.

2. Speed must be controllable smoothly and continuously from subsonic to supersonic values.

3. Wall interference should be small.

It has long been recognized that the interference effects of closed- and open-throat wind tunnels are opposite and it was accordingly reasoned that a wind tunnel with a partly open throat could be devised for which zero interference would result and choking be eliminated. This concept has been verified both theoretically and experimentally and has led to the development of a number of wind tunnels in which reliable aerodynamic data are now obtained throughout the transonic speed range. In recognition of the NACA leadership in this development, Mr. John Stack and his associates received the Collier Award for 1951.

The Langley 8-foot and 16-foot transonic wind tunnels, with which some of you may be familiar, have evolved about a system of longitudinal slots to effect the partly open throat. Benefiting from the Langley Laboratory experience with slotted throats, the Ames Laboratory has developed a different type of transonic wind tunnel which more effectively reduces wall interference at low supersonic speeds. This type is characterized by a test section employing separate perforations or holes in lieu of continuous slots for the partly open area, and has an adjustable nozzle for the generation of supersonic flows.

The Ames 2- by 2-foot transonic wind tunnel was the first research facility of this particular type to be placed in service and is a prototype of the new 14-foot transonic wind tunnel. The next speaker will describe this new facility in some detail. Mr. ________________.

The newest and largest transonic test facility of the type characterized by an adjustable nozzle in conjunction with a perforated test section is the Ames 14-foot wind tunnel. This tunnel is the result of extensive modernization of the Ames 16-foot wind tunnel originally constructed in 1940 and 1941, and is exhibited for the first time to the groups of this inspection.

Air is forced through the tunnel circuit (chart #3) by a three-stage axial-flow compressor. At the maximum speed of the tunnel this compressor must handle about 4 tons of air per second while increasing its pressure by about 25 percent. The power to drive the compressor is supplied by three electric motors having a total output of 110,000 horsepower. Power is transmitted by a single shaft extending through the tunnel shell. The temperature of the air is controlled by an air exchanger here. This component removes some of the heated air from the tunnel and replaces it with relatively cool air from the atmosphere.

The nozzle and test section which are within this building are shown in more detail in the next chart (chart #4). This plan view shows only the more important features of this portion of the wind tunnel. For subsonic operation, the tunnel speed is controlled in a conventional manner by varying the compressor speed. For supersonic operation, tunnel speed is controlled by an adjustable convergent-divergent nozzle on the side walls. The test section is assembled of alternate horizontal solid rails and corrugated sections. The openings so formed permit outflow through the test section walls in the constricted region of the model, thereby preventing choking. At low supersonic speeds, shock waves originating from the model which would be reflected with undiminished strength from a solid wall are partially absorbed at the perforated wall with a consequent alleviation of interference.

With the 14-foot wind tunnel and its other new transonic wind tunnels, the NACA is now able to conduct experimental investigations at transonic speeds of considerably greater scope and complexity than previously possible.

After leaving this presentation you will reach the test section level by means of these stairs. Here you will see the control console. In this area you will see some of the electronic recording and computing equipment. As you pass through the test section and under the model support you will see the perforated walls and flexible nozzle. Located on the elevator for your inspection are displays of methods and some of the actual models used for obtaining transonic research information.

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TRANSONIC TESTING IN FLIGHT

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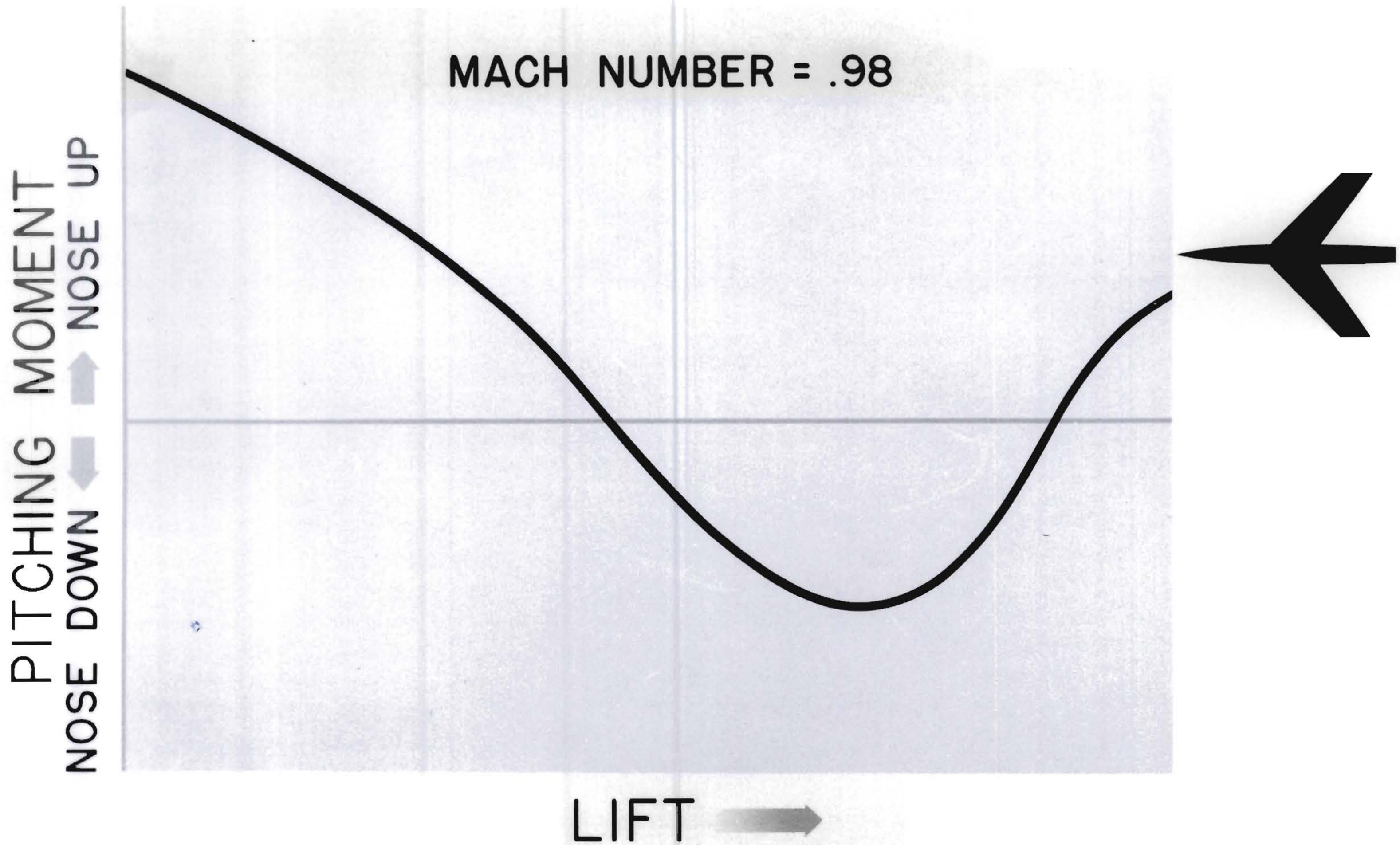
SWEPT-BACK WINGS ARE SUBJECT TO PITCH-UP



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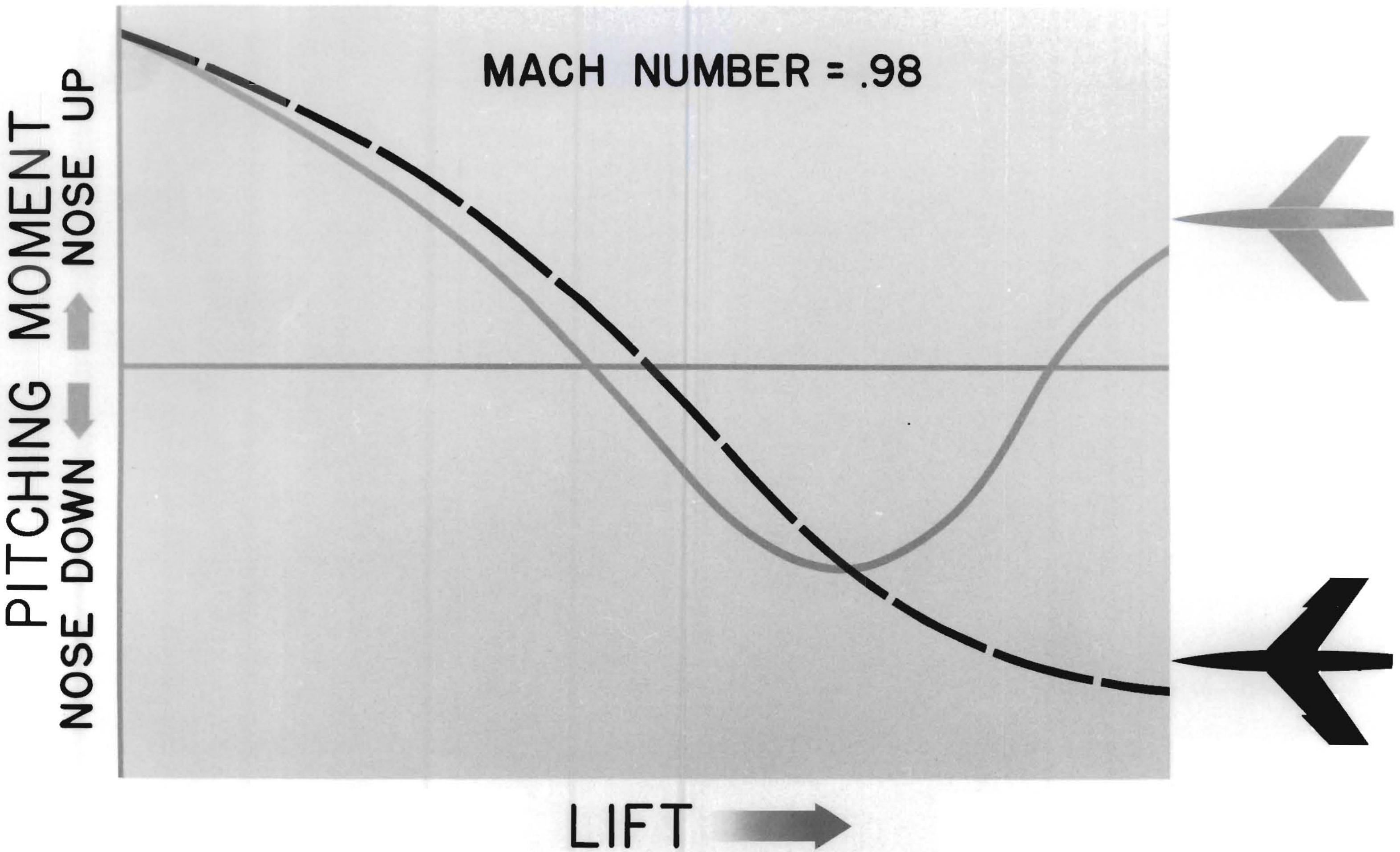
MODIFICATION OF SWEPT WINGS ALLEVIATES PITCH-UP



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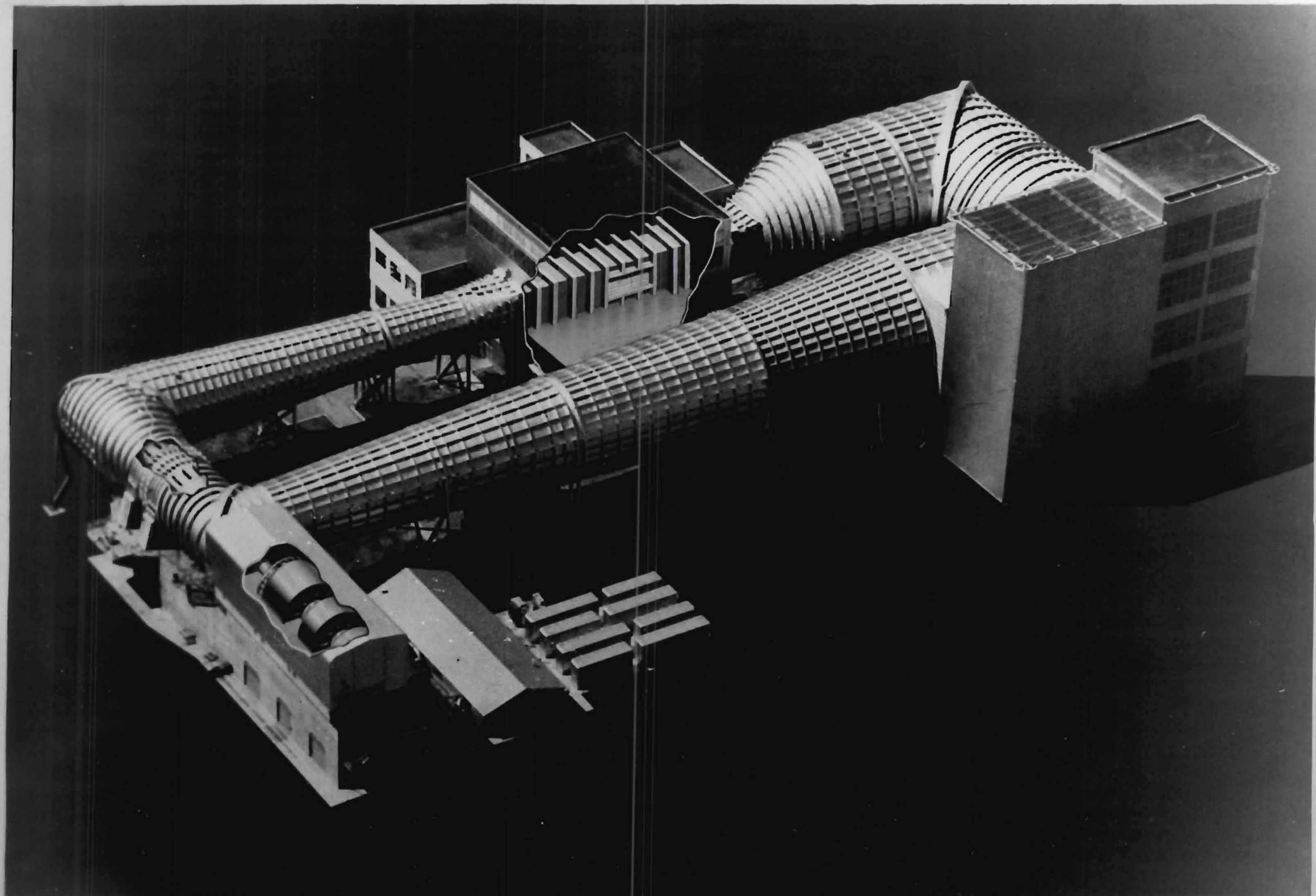
14-FOOT TRANSONIC WIND TUNNEL



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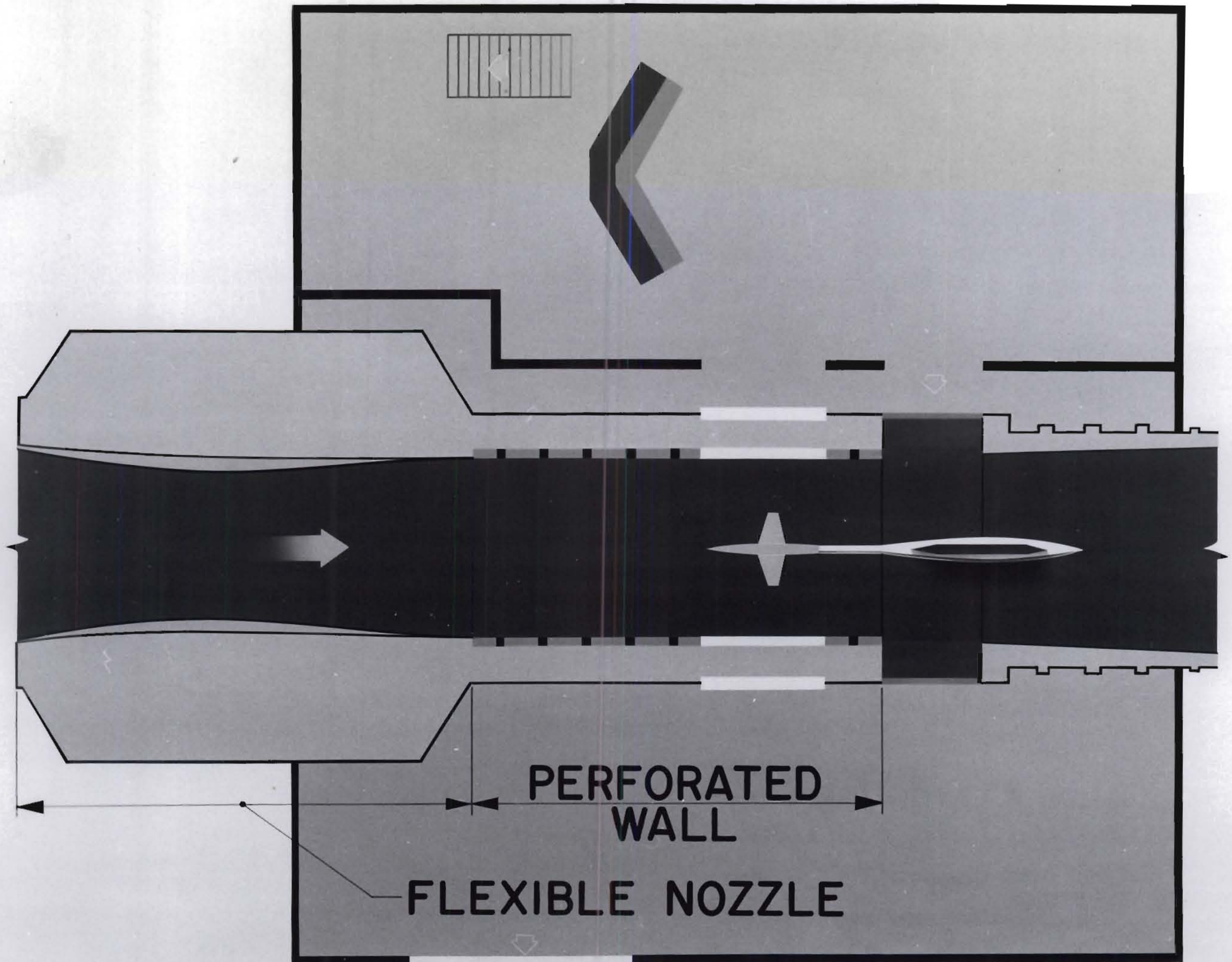
TRANSONIC TEST SECTION



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