NACA - Langley
1953 INSPECTION

OPENING REMARKS BY MR. FLOYD L. THOMPSON

A few short years ago, airplane flight beyond the speed of sound was achieved with a research airplane. This penetration of the sonic barrier with a man-carrying aircraft was based on scientific data and knowledge of the aerodynamics of the transonic and supersonic speed ranges which were meagre in scope but sufficient to guide the exploratory flight program to success. A great deal has been learned since that time in the laboratory and in flight with models and research airplanes, so that now operational military airplanes are being designed to perform in those regions which were so recently explored for the first time. It is the purpose of these remarks to review briefly some of the problems posed by the current state of our knowledge in relation to the exacting requirements of the aircraft designer who must now provide a design that meets all the operational and performance requirements of a truly effective military machine.

First, however, I would like to observe that the problems of flight, although they have increased with increases in speed, have not increased in an orderly manner. In many respects, it seems that problems have piled up and reached their maximum intensity in the transonic range wherein there is a mixture of subsonic and supersonic flows. The laws that govern these flows come into conflict in this range with a resulting confusion that is not amenable to orderly mathematical treatment. The aerodynamic problems of this region have been responsible for great difficulty in providing tools for aerodynamic research in this region and at the same time they have created a demand for an enormous amount of detailed experimental data pertaining to the design of aircraft. Over a period of years, we have been successful in contriving various means for conducting aerodynamic research in the transonic speed range, with the latest achievement being the successful development of truly transonic wind tunnels that are providing the type of detailed aerodynamic information so essential to the aircraft designer. I might add, however, that the supply of such wind tunnels and what it takes to fully exploit them has not yet caught up with the demand. A visit to our most recent addition to this type of facility, our 8-foot transonic pressure tunnel, is included in today's program of inspection.

The first major problem that I wish to discuss relates to the drag versus thrust or speed performance. The design of an airplane for supersonic flight with a reasonable duration and range is much more difficult than that of designing one that may use its fuel in one short burst of supersonic flight. If it is to have a reasonable range, the fuel consumption must be moderate. It is necessary that the drag in the transonic and supersonic ranges be reduced to such a value that the engine thrust required and hence the rate of fuel consumption is consistent with the limited fuel capacity of the airplane. The problem of combining wings and bodies into complete configurations so that the drag is satisfactorily low has proved to be a very difficult one. The design features responsible for very drastic changes in speed performance are subtle. The research equipment that we now have is beginning to give us some insight into the fundamentals of this very perplexing problem.

In order to illustrate the point I have attempted to make, I would like to show the first slide. The vertical scale pertains to the engine thrust available for propulsion and the resisting force or drag of the aircraft which it must overcome. The horizontal scale shows velocity in terms of the speed of sound or Mach number. The thrust curve is representative of the amount of thrust that it would be feasible to consider with a relatively efficient jet engine installation for the size of airplane to which this example applies. The fuel requirements for this thrust would be such that the airplane would have a reasonable duration and range of flight rather than only a short burst of supersonic speed. There are two drag curves. The maximum speed occurs where the drag becomes as great as the engine thrust. Note that the upper drag curve is intersected by the thrust curve at a Mach number slightly less than 1.0 and the airplane would be incapable of supersonic flight performance. The other drag curve does not rise so high and lies below the thrust curve until a high supersonic speed is achieved. In the supersonic range the thrust and drag curves are so nearly parallel that the differences in maximum speed represented by these two cases would be hundreds of miles per hour. The two drag curves relate to the same basic configuration with subtle but extremely important differences in the arrangement of its elements. There will be amplification of this point later on in today's program. Although we have learned some very important facts concerning how to obtain lowered drag in the transonic and supersonic speed ranges, a much more complete understanding of this problem is urgently needed.

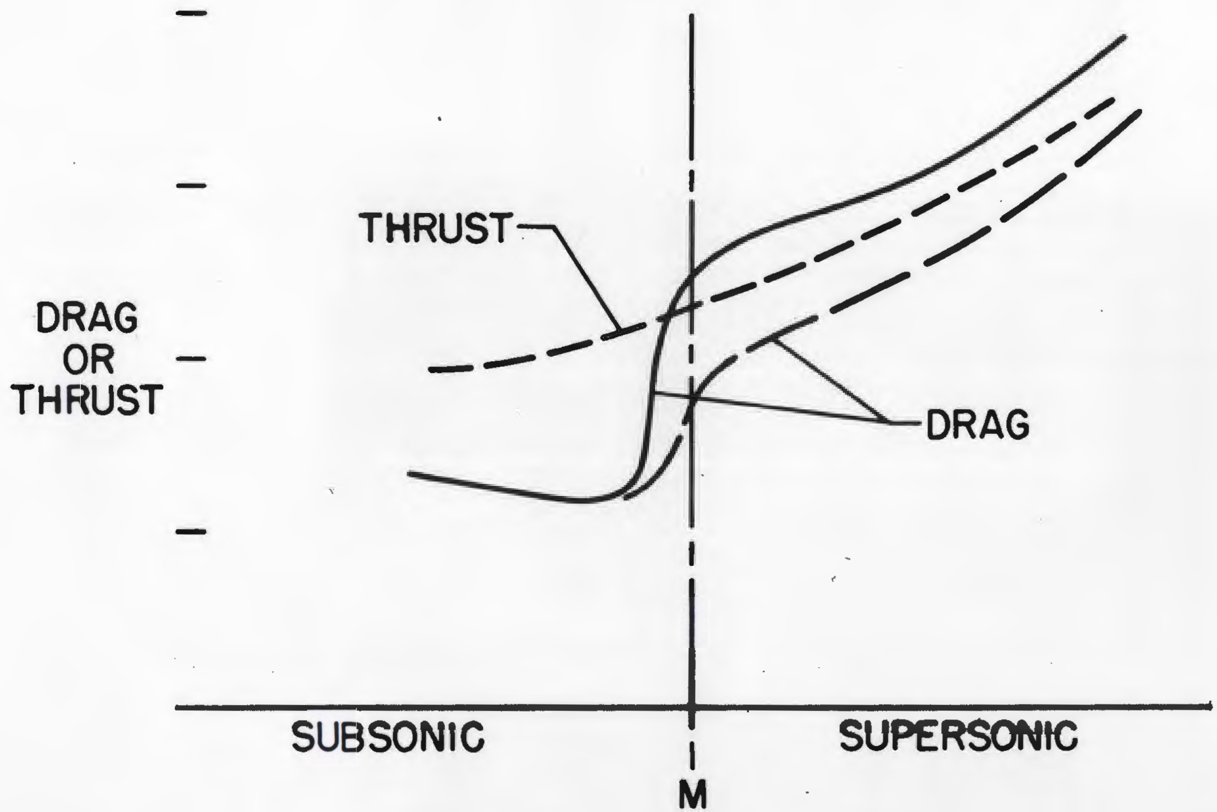
In order to be successful, an aircraft must have not only the speed performance required, but it must be sufficiently stable and controllable so that it can be flown steadily or readily maneuvered within specified operational design limits. Current design trends, however, have introduced stability problems that make the attainment of this requirement very difficult, both as regards lateral stability and longitudinal stability. In a general way, it can be said that lateral stability problems are associated with the mass distribution that results with long heavy fuselages and short-span wings, combined with the relatively high density of the airplane in relation to the air density at high altitudes. The difficulties that arise vary from small but persistent oscillations that interfere with aiming of the guns to abrupt violent motions of the aircraft. Longitudinal stability problems are associated generally with peculiarities of the air flow experienced over the wings and tail of the short-span and swept configurations with which high speeds are feasible. One particular difficulty that has acquired the descriptive name "pitch-up" and which will be enlarged upon in today's program, is the development of a very pronounced nosing up or stalling moment that makes the airplane difficult to control and dangerous. Not only may there be the danger of inadvertent stalling at low speeds, but because the airplane must fly in the very rare air corresponding to high altitudes, the same results can occur at very high speeds.

A third problem of major importance that has been greatly aggravated by high speeds and the configurations with which high speeds are feasible, is flutter. Flutter is a self-excited vibration induced by certain combinations of aerodynamic forces with the elastic and mass characteristics of the structure. There was a time when flutter was taken to mean a coupled bending torsion action of the wing. This type of flutter is still with us. The types of flutter that cause concern, however, have greatly increased. Following (SLIDE) is at least a partial listing of flutter types: bending-torsion flutter, bending-pitching flutter, stall flutter, one degree of freedom control surface flutter, coupled control surface flutter, skin or panel flutter, and chordwise or camber flutter. In addition to the multiplicity of flutter types, the problems of flutter are further aggravated by the fact that with the high operational speeds now contemplated and with the types of configurations with which these speeds are feasible, there may be only a small margin between the flutter speed and the expected operational speed. Thus, the flutter speed must be predicted with greater precision in order to insure that it lies beyond the operational speed. In addition, it is necessary to consider not only the basic airplane configuration but the airplane when modified by the addition of external stores, that is, fuel tanks, bombs, or other bodies carried externally. Nearly every airplane acquires external stores sooner or later and some of them are very large and, in effect, constitute major modifications of the characteristics of the airplane, particularly as regards flutter. Furthermore, when the external store is a fuel tank, it is necessary to consider not only the case of the fuel tank full but the case with the tank partially full and empty. Several highlights of our flutter research program will be discussed in today's program.

A fourth major problem brought about by high speeds is the structural problem associated with aerodynamic heating. This is one problem in which it can be said that the severity is directly related to the speed involved. The limiting temperatures involved as a function of speed are shown on the third slide. The temperatures shown are the stagnation or stop temperatures that would prevail in the air on the front face of an object flying at the Mach numbers indicated on the slide in a standard atmosphere at two different levels, one at sea level and the other in the stratosphere. The air in the boundary layer immediately adjacent to the body at all other points would be heated to nearly the same level as that shown on the slide. If any given Mach number were maintained indefinitely, the entire structure would acquire approximately the temperatures shown on this slide. If this were the only case to consider, the problem would be largely one of allowing for weakening and expansion of the structural materials. The problems actually encountered, however, are much more complex because the temperatures in general will be varying with time so that the structure will necessarily always be becoming hotter or cooler and will develop a multitude of problems due to the inequalities of thermal expansions of the various elements of the structure. As an example of the varying temperature conditions that can prevail, I would like to show a fourth slide that represents the time histories of Mach number and temperatures experienced by a rocket-powered missile launched from the ground at our station at Wallops Island. Note that the Mach number attained a maximum value of about 2.5 in about 3 seconds at which point the rocket burned out and the missile started to slow down. The stagnation temperature follows the Mach number variation. However, the temperatures of the body at two points, Stations 1 and 2, lag behind the stagnation temperature while it is increasing rapidly and then exceed it as it decreases. Furthermore, the temperatures at these two points vary with respect to each other, owing to the difference in the boundary layer and heat conductivity at these two points. Some of the most difficult problems as regards the effect of aerodynamic heating of the structure appear to be those related to the transient heating case; that is, the case wherein the temperatures of the structure are varying. One of today's demonstrations will relate to this subject.

Many other problems might be included in this discussion, but it does not appear desirable to take the time required to do so. It would hardly be fitting, however, to fail to note that buffeting at high speeds remains a perplexing problem. Also, as a general observation, it seems appropriate to add that as a result of the demand for increased performance we are not only confronted with new and expanded phases of old problems, but in addition, new concepts have introduced certain new and unique problems. For example, the concept of high-speed aircraft that operate from a water base on skis has been responsible for considerable research effort on problems that are peculiar to that type of operation. Also, consideration must now be given to the possibilities that with the engine powers now attainable, it may be possible, with fixed wing types, to utilize thrust so as to permit lifting the aircraft vertically. Research pertaining to both of these concepts will be discussed in today's program of inspection.

SPEED PERFORMANCE



TYPES OF FLUTTER

BENDING TORSION

BENDING PITCHING

STALL

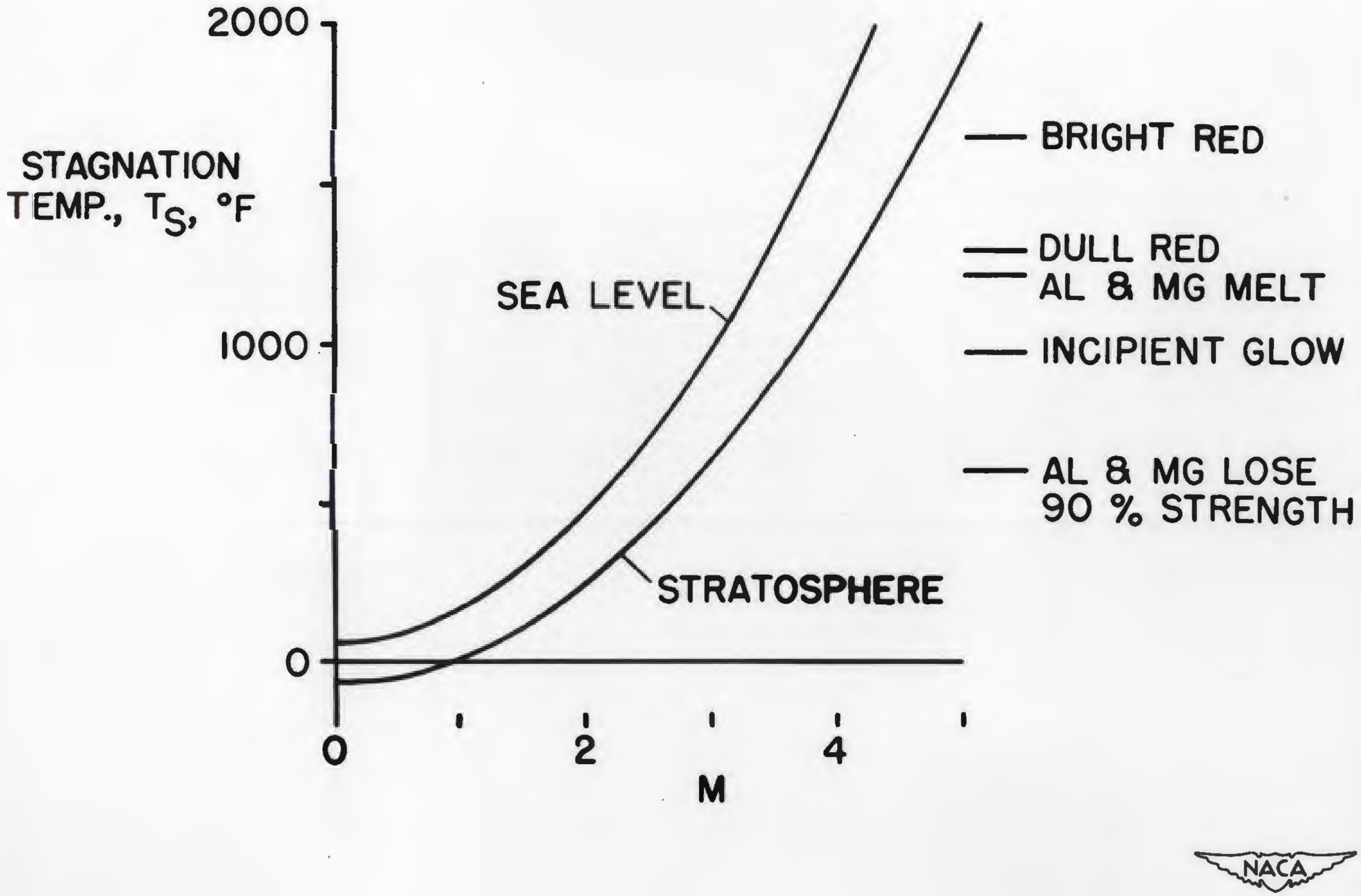
CONTROL SURFACE - ONE DEGREE OF FREEDOM

- COUPLED

SKIN OR PANEL

CHORDWISE OR CAMBER

NACA



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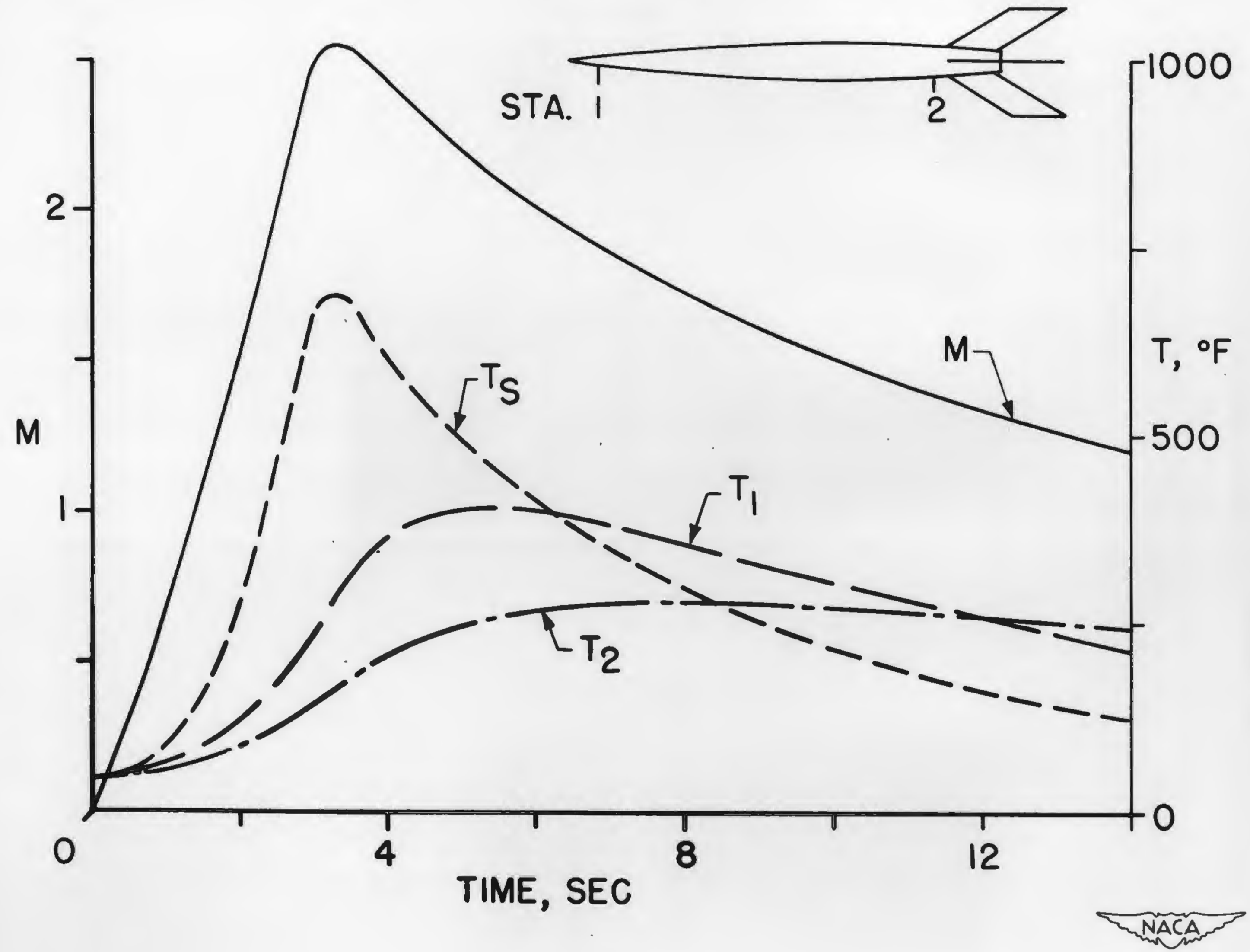
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INTRODUCTORY TALK FOR 1953 BIENNUAL INSPECTION

At the last inspection visit here at the full-scale tunnel the presentation was largely devoted to research on the landing and take-off problems of the high-speed airplane. Considerable detail was given two years ago to the flow phenomena of the thin swept and triangular wings and to the exploration of high lift and stall control devices required to eliminate serious tip stall and to increase the range of usable lift coefficients. This type work has been continuing to determine refinements in the application of slats and leading-edge chord extensions, in horizontal and vertical tail arrangements, and in methods of applying boundary-layer control. A complete study of a trailing-edge boundary-layer control system is now being conducted on the complete model mounted for tests which will allow the study of the efficiency of the internal flow system as well as the overall airplane stability and control at high lift coefficients.

The main emphasis to be placed on this year's discussion, however, is helicopter research, which by virtue of increased utility in both military and civil applications has required an expanded effort in this and other facilities.

Our current helicopter research can be divided into these four general headings:

Aerodynamic Efficiency

Design variables

Configurations

Propulsion

Flying and Handling Qualities

Loads and Stresses

Vibration and Flutter

The work is being conducted at such facilities as the helicopter tower, this large wind tunnel, in flight, and by testing dynamic models for flutter and vibration studies.

The development by industry of special types of machines for large payloads, higher speeds, and longer range has intensified the need for determining the fundamentals of rotary wing aerodynamics. In this respect, increased emphasis is being placed in these latter two areas - loads and stresses and vibration and flutter, in addition to carrying along all our former coverage. The need for lightweight efficient rotor blades and other structures having long service life is very urgent, and now Mr. ___________ will continue the discussion in this respect.