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RESEARCH MEMORANDUM

SOME EXPERIMENTS WITH INSULATED STRUCTURES

By Richard Rosecrans, Aldie E. Johnson, Jr., and William M. Bland, Jr.

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SOME EXPERIMENTS WITH INSULATED STRUCTURES

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SUMMARY

Two methods of insulating structures, one for short-time use and the other for somewhat longer protection, were studied by radiant-heating tests and supersonic-wind-tunnel tests. Results of these tests indicated that effective temporary protection can be obtained with fairly lightweight structures; however, it is emphasized that care should be given to design details to prevent flutter of the insulation cover in some cases.

INTRODUCTION

One proposed method of coping with the problem of aerodynamic heating is to provide an insulating cover or radiation shield to reduce the amount of heat entering the structural airframe. In order to be most effective, such a covering must have high insulating value and as little weight and thickness as possible. If it is necessary to protect the basic structure for only a short time, a simple, thin, lightweight system can be employed. For longer protection, a more elaborate method is necessary. Even the more extensive insulating systems permit heat to get through eventually; therefore, for very long time exposure to high temperatures, cooling must be provided. This paper discusses the first two classes - those which do not require cooling.

TESTS

Experiments have been conducted upon several devices which appeared likely to afford significant protection.

Solid Protective Covering

One short-time method involved a combination of insulation and heat storage. If the basic structure is of lightweight material incapable of

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withstanding high temperatures, it can be protected for a short period by covering it with one or more layers of heavier material which can tolerate high temperature. Much of the heat which enters the structure during the first few seconds is stored in the covering material. Heat flow to the inner structure is delayed partly by the conductivity of the material and partly by thermal resistance of the joints. If the need for protection ends by the time a damaging amount of heat enters the basic structure, as it might in the case of a short-range missile, the objective is accomplished. Such a method was used to protect some tapered fins. With no protection, the leading edge of a magnesium fin melted in less than 2 seconds. With the leading edge covered with one layer of 0.008-inch-thick glass cloth and one layer of 0.031 Inconel, the temperature of the magnesium had risen to less than 125° F in 2 seconds. A heavier covering, in which one layer covered the entire fin and a second layer covered only the leading edge, was even more effective. Figure 1 shows that, while the temperature of the outer layer of Inconel rose rapidly and reached $1,750^{\circ}$ F in 5 seconds, the temperature of the inner magnesium structure had risen to only 90° F in 2 seconds, when the unprotected fin had failed, and to less than 300° F in 5 seconds. During the first 2 seconds, less than 5 percent of the heat which entered the leading edge penetrated to the load-carrying structure.

Motion pictures of the test showed that, soon after the fin entered the jet stream, the cover became red near midspan, where the temperature of the gases from the jet were highest. Because the thickness of the covering varied between the leading and trailing sections, the temperature of the cover along the chord was fairly uniform. At about 8.4 seconds, the outer Inconel protective layer melted at the leading edge, precipitating complete fin failure immediately thereafter. A motion-picture film supplement has been prepared and is available on loan. A request card form and a description of the film will be found at the back of this paper on the page immediately preceding the abstract and index pages.

Double-Wall Construction

Two insulating configurations (fig. 2), designed to protect the airframe over a longer period of heating, were investigated. One was a single-faced, corrugated-core sandwich of Inconel X; the other was a stainless-steel honeycomb sandwich. The exposed surface was supported by the longitudinal corrugations in one case and by the core and inner face of the sandwich in the other; in both cases the sandwich was separated from the load-carrying structure by either bulk insulation or an air gap. Corrugated panels were constructed with and without bulk insulation; all honeycomb panels were made with only an air gap. Because of the very light weight of these panels, the possibility of flutter and failure existed; consequently, their structural integrity in a supersonic airstream, as well as their insulating qualities, was determined.

Corrugated panels.- The corrugated panels were designed and fabricated by the Bell Aircraft Corporation. Both the surface and corrugations were of 0.005 Inconel X. A one-quarter-inch steel plate constituted the base or load-carrying structure. Retaining straps held the panel against the supports, and provision was made for expansion in both directions. Thermocouples on the under side of the outer face and at several locations in the interior measured the temperature during a test.

In order to determine the insulating capacity of this type of construction, the outer surface was heated, in a static test, at approximately 1/2 Btu/sq ft/sec until it reached 1,500° F, after which the skin was maintained at that temperature for about 50 seconds. Temperature histories are shown in figure 3. The temperature of the exposed surface rose at a constant rate for about 70 seconds and then was held steady until 2 minutes had elapsed from the start of the test. The temperature of the inner surface of the corrugation lagged behind that of the exposed surface and finally reached an equilibrium temperature about 150° F lower than that of the outer face. The combination of the radiation shield and bulk insulation protected the load-carrying structure so that it experienced only a negligible temperature rise.

Additional tests were made in a blowdown jet at a Mach number of 1.4, sea-level static pressure, and a stagnation temperature of 600° F. In some of the tests, added heat was supplied by a quartz-lamp radiator which faced the panel from just outside the jet stream and raised the surface temperature to nearly 1,000° F in some cases. Temperature histories for a test on a corrugated panel without bulk insulation are shown in figure 4. Surface temperatures of about 800° F were reached. The temperature of the inner part of the corrugation lagged several hundred degrees behind that of the exposed surface and the load-carrying structure experienced only a small temperature rise. The data terminate after 10 seconds because of the flutter and failure of the corrugated cover. Aerodynamic heating was augmented by the radiant heater and the combined effect of the heating and the air loads caused flutter to begin about 10 seconds after the test began. The panel was mounted as an extension of the tunnel wall and was divided into three bays by expansion joints. From motion pictures, flutter was first observed in the downstream bay. It spread quickly to the other bays and the panel was destroyed after about 12 seconds. High-speed pictures taken at 640 frames per second show the very high frequency of the flutter and indicate that the mode shape was much like that of corrugated metal. (These results are also shown in the film supplement.) The corrugations were in the same direction as those of the supporting corrugations of the panel but appeared to have a longer wave length by a factor of perhaps two or three. Not all the tests of corrugated panels ended in this manner. A similar configuration, but with an improved design of the edges, survived the same test. However, the result emphasizes the need for careful experimental checking of such designs, at least until more adequate theoretical methods are available.

Honeycomb panels.- The honeycomb panels were fabricated of 0.005-inch-thick facing sheets brazed to both sides of a honeycomb core. All sandwich material was 17-7 PH stainless steel. The base or load-carrying structure was 1/8-inch-thick aluminum plate. The same type of static heating test was made on the honeycomb panels as on the corrugated panels. Temperature histories are shown in figure 5 for the outer and inner faces of the sandwich and for the base structure. The heating cycle is evident from the surface temperature and was very nearly the same as that for the corrugated panels. The inner-face temperature lagged behind and approached 1,250° F toward the end of the test. The aluminum base was heated to about 300° F, which is a higher temperature than that of the base plate behind the corrugated panel with bulk insulation, even when allowance is made for the difference in heat capacities of the two base structures. In the wind-tunnel tests, however, the bending stiffness of the honeycomb panels was sufficiently high to prevent flutter, and the only undesirable effect of the test was the pock-marked appearance of the outer surface. Thermal expansion of the heated skin caused the facing sheet to buckle over each cell of the honeycomb interior. This buckling reduced the smoothness of the aerodynamic surface but had the advantage of reducing the overall expansion of the panel.

DISCUSSION

Little difference in insulating value was found between the corrugated and honeycomb panels, so long as bulk insulation was not used between the sandwich and the base structure. The corrugated panels with bulk insulation were considerably better from an insulation standpoint than either type without it but, when bulk insulation was used, the protective covering was three times as thick as when it was omitted. The corrugated panels have certain advantages because they employ only one face; they can be fabricated by seam welding instead of brazing, which makes them easier to manufacture and, also, they can easily be bent around curved surfaces so long as the curvature is in only one direction. Similarly, the honeycomb panels have advantages because of their greater strength; they are considerably less susceptible to flutter and should require less supporting structure.

CONCLUDING REMARKS

These tests represent only a small effort in the field of insulated structures; many additional variations can be studied. Results so far indicate that effective short-time insulation can be achieved with fairly lightweight structures; however, it is emphasized that care should be given to design details in order to insure structural integrity.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 6, 1957.

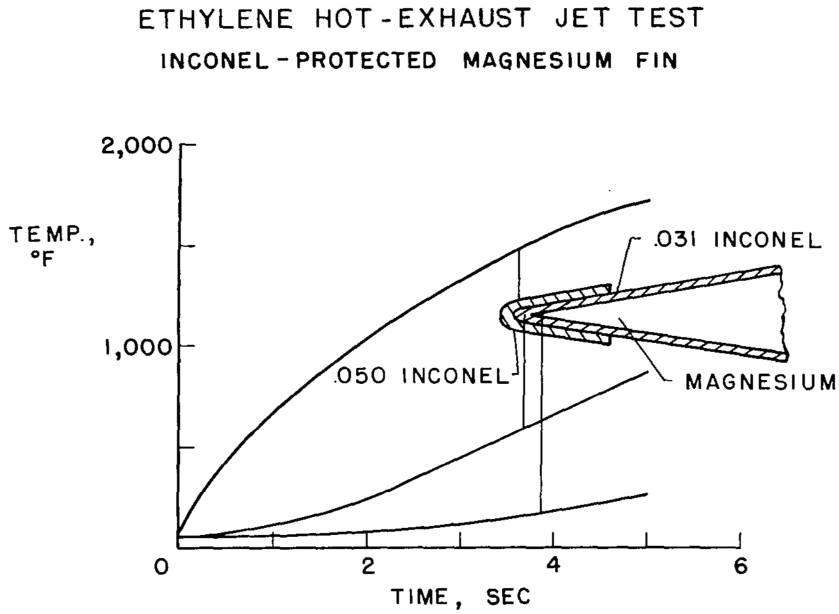

Figure 1

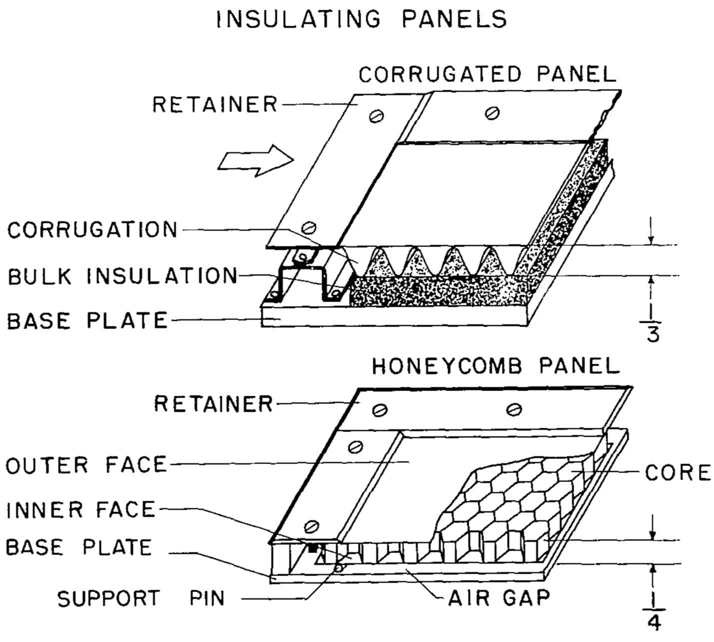

Figure 2

LABORATORY RADIANT-HEATING TEST
CORRUGATED PANEL

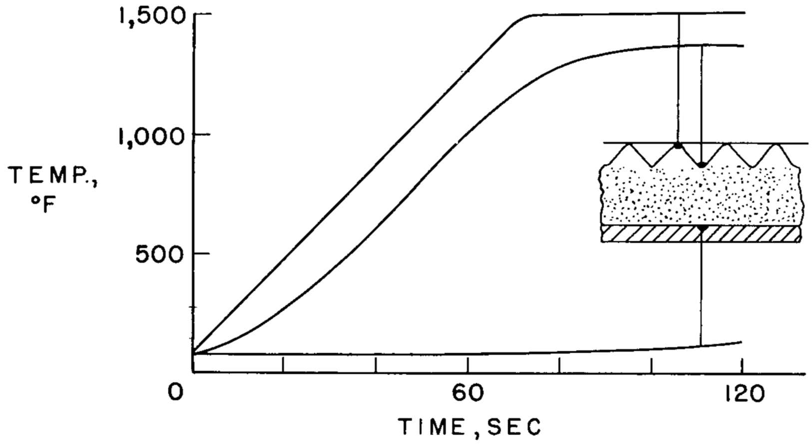

Figure 3

BLOWDOWN–JET TEST
CORRUGATED PANEL

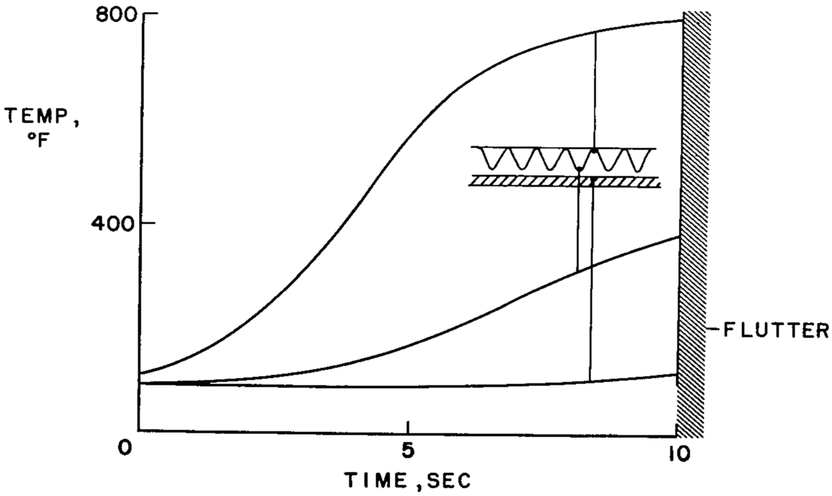

Figure 4

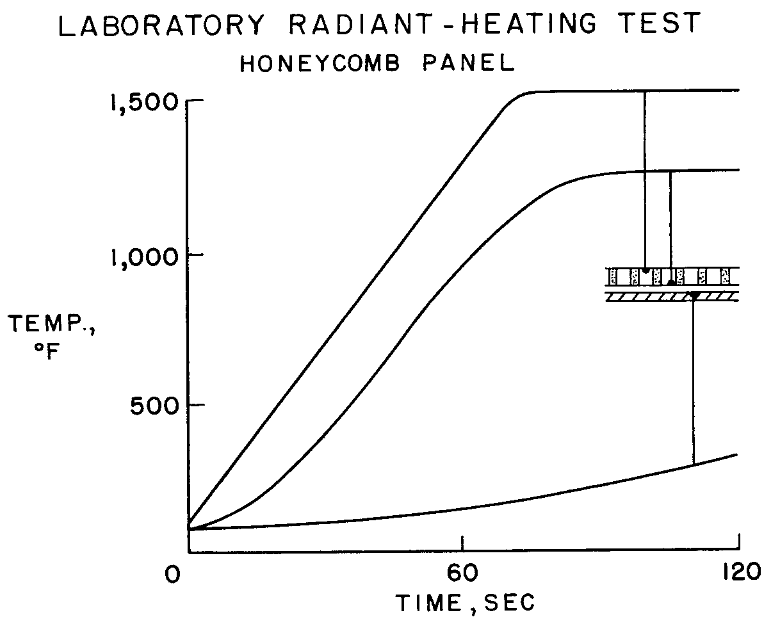

Figure 5

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