# NATIONAL BUREAU OF STANDARDS REPORT

1944

INVESTIGATION OF FIRE RESISTANCE
OF AIRCRAFT FUSELAGES



by

A. C. Hutton
and
J. V. Ryan

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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**Electromechanical Ordnance.**
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- Office of Basic Instrumentation
- Office of Weights and Measures.

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**NBS PROJECT** | **NBS REPORT**

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## INVESTIGATION OF FIRE RESISTANCE OF AIRCRAFT FUSELAGES

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## ABSTRACT

A group of fire resistance tests have been performed on small panels representative of sections of aircraft fuselages. The methods of insulating and painting of the various sections were varied in an attempt to improve the fire resistance performance of aircraft fuselages exposed to fires during crash landings. It is shown that the use of ordinary paints on the exterior of the fuselage is not desirable. The tests confirm that further work of this nature should be directed towards study of improved methods of insulating the aluminum skin from the flames, consideration of heat absorbing coatings to reduce skin temperatures, and study of possible changes in fuselage skin construction to provide a more fire retardant barrier.


## 1. INTRODUCTION

An investigation being conducted by the National Advisory Committee for Aeronautics on simulated full-scale airplane crashes of such severity that a majority of the occupants might be considered to have survived, and from actual crashes in commercial airlines, indicates that present fuselage construction provides only a relatively short period of protection to the passengers from oil and gasoline fires likely to develop from the crash.

The simulated crash fires involved full scale aircraft fuselages and during these tests control of all the variables was not possible. Therefore, the NACA requested that the National Bureau of Standards conduct small scale tests, which could be better controlled, to investigate the relative fire

resistance of the various fuselage constructions used in the larger tests, and to explore designs that offer promise of greater fire resistance than the present conventional structures. The NACA submitted for test typical sections cut from the aircrafts used in their crash tests. These specimens were supplemented by simulated fuselage sections having various combinations of coatings and insulations. Following five pilot tests, a total of fourteen sections were tested.

## 2. TEST SPECIMENS

Two distinct types of specimens were employed in these tests. The first specimens were taken from the fuselages of C82 type aircraft and were provided by the NACA. The others were simulated sections of aircraft fuselages constructed at the National Bureau of Standards by regularly employed skilled craftsmen. Nine of the latter group and five of the former were tested.

### 2.1 Specimens from Aircraft Fuselages

These test specimens, cut from fuselages of the C82 type aircraft, may be considered as typical of current aircraft, both as to materials and workmanship. They consisted of an aluminum skin, longitudinal members, and transverse or bulkhead members. They were submitted with a white paint on the outside and an olive green paint on the inside. Some of the specimens had an interior insulating protection. The specimens were approximately 30 in. square, with an essentially flat skin of .032 in. clad aluminum. The longitudinal members were spaced 7 in. o.c. and joined to the skin by 1/8-in. rivets 1-in. o.c. The two transverse members, one 3 in. and the other 8 in. high, were similarly riveted.

In preparation for tests, all four edges of some of the specimens were bent up to form a box 24 in. square, while only two opposite edges of others were so bent, forming a 24 in. wide channel. Three thermocouples were riveted to the inner side of the skin of each specimen, one at the center and the others 8 in. from the center towards opposite sides. A fourth thermocouple was mounted on one longitudinal member. The paint was removed from the exterior surface of one of the specimens in order to make a comparative evaluation.

The specimens submitted with insulation had a combination of two layers of 1-in. thick glass-fiber blanket, each of which weighed .05 - .06 lb/ft$^2$, held in place by a cover

layer weighing .12 lb/ft$^2$ and consisting of 1/4-in. glass-fiber blanket with a cotton fabric facing. This is believed to be the standard insulation in the C82 type aircraft used in the NACA crash tests. Several of the uninsulated specimens were modified by the addition of heat and flame barriers of two other types. The first was a single stainless steel layer .002-in. thick and weighing .07 lb/ft$^2$ and the second a 3/16-in. thick insulation weighing .28 lb/ft$^2$ and consisting of two layers of felted refractory fibers with a supporting glass-fiber mesh cemented between. The melting points of refractory and glass fibers, such as used in the insulations, are reported to be approximately 1700°C and 600°C respectively.

### 2.2 Simulated Construction

These specimens were in the form of a box 24-in. square and 5-in. deep with a 1-in. lip turned in to the otherwise open top. They were made by cutting the pattern from a single sheet of .032-in. 24-ST clad aluminum, bending it into shape, and securing with rivets, or by cutting the bottom piece from a separate sheet and riveting it to the sides of previously used box sections. Two longitudinal members were simulated, each consisting of a 2-in. wide strip of the same thickness aluminum sheet bent along its length to form a 1-in. angle piece, and riveted to the inner surface of the skin, each one along a line perpendicular to one side and through its third points. The 1/8-in. rivets were spaced 1-in. o.c. Three thermocouples were riveted to the skin and one to a longitudinal member in the same locations described for the C82 specimens.

The exterior surfaces of the test specimen skins were left the bright aluminum in some cases and painted in others. This protective coating consisted of a wash primer, two layers of an intumescent paint which made up the major bulk of the coating, and a weather-resistant finish coat. Two specimens were given an interior coat of a standard zinc-chromate primer. The insulation applied to the inner sides of four of the specimens consisted of a single layer of the 1-in. thick glass-fiber blanket previously described, which was held in place by a plastic leatherette material weighing .11 lb/ft$^2$. This plastic material was attached to the sides of the specimen.

The combinations of paint and insulation used on the individual test specimens are given in table 1.

## 3. TEST METHOD

The tests were conducted with a furnace in the form of a box with a 22 1/2-in. square opening in the top over which the test specimen was placed, with the outer surface of the fuselage skin down. Heat was provided by the combustion of premixed gas and air in the chamber of the furnace. The walls were of sufficient thickness and mass to make the maintenance of stable temperatures possible. Measurements were made of the temperatures in the combustion space of the furnace and at the locations previously described on the unexposed surface of the skin and the longitudinals. Measurements were made with a radiation pyrometer at a point 6-in. from the upper surface of the skin, from which the radiation intensity at that surface was determined.

In the pilot tests, the procedures described in the Standard Methods of Fire Tests of Building Construction and Materials of the American Society for Testing Materials (ASTM E119-50) were followed. As this method was not found adaptable for tests of such short duration, a modified test procedure was adopted. With a light steel sheet over the furnace opening, the flames were regulated to obtain a steady furnace temperature of approximately 860°C (arbitrarily selected); the steel sheet was removed and the test specimen immediately placed over the opening, at which time the test observations were started. Observations of temperatures and the condition of the specimen were continued as long as deemed of value and the test specimen was then removed and replaced by the steel sheet. Any flaming of the test specimen was extinguished by a stream of water from a hand-pumped fire extinguisher.

## 4. RESULTS

The particular physical changes observed and the times at which they occurred varied from test to test and were dependent on the presence or absence of the various paints and insulations. The behavior of the intumescent paint ranged from good to very poor, with a froth or foam layer as thick as 2-in. produced in some tests while in others, such as No. 1A, the paint fell off early in the test. The aluminum skin was observed to melt, gradually producing a hole-through. Eventually, flames appeared at the upper surface of many of the test specimens and considerable smoke was produced. The conditions of twelve of the specimens after test are shown in figures 1 and 2.

The times at which certain phenomena were observed are given in table 1, along with the intensity of radiation at the time when the specimen ceased to be an adequate barrier to the fire or at the end of the test, whichever was earlier. Graphs of the radiation and observed temperatures are given in figures 3 through 7. The more important observations are indicated at the appropriate times on these graphs.

## 5. DISCUSSION

The establishment of one or more criteria for failure is very difficult in tests such as these. The chief aim is the determination of the time during which the test specimen would continue as an effective safeguard to the lives of aircraft occupants. However, much is yet to be learned of the ability of the human body to withstand the types of exposure encountered. Each of the recorded phenomena -- melting and perforation of the aircraft skin, melting of the longitudinal members, the condition of the insulation, and radiation intensity - could be a criterion for failure in some cases and of little concern in others. For example, the melting of the longitudinal members is of little importance if flames have already entered the occupied space through perforated skin, but is of great importance if those longitudinal members support an interior flame barrier such as incombustible insulation. Consequently, the failure times listed in table 1 are based on different physical phenomena in different tests but always with a view to life safety.

The inconsistent behavior of the intumescent paint coatings was disappointing, and added to the difficulty of evaluating other variables in the performance of the specimens. However, the paint coatings in general appeared to cause certain effects. In tests No. 14 and No. 10, which differed only in having the exposed surface unpainted and painted respectively, the painted specimen failed earlier than the unpainted specimen. This indicated that the unpainted aluminum skin absorbed heat at a lower rate than that with a paint coating, an effect to be expected from considerations of the emissivity of the two surfaces. The effect of paint on the interior surface is shown by comparing test No. 2A (also 3A) with No. 4. Here the coating retarded failure of the skin due to the ability of the painted interior surface to more readily dissipate heat by radiation. This naturally resulted in higher radiation levels from the unexposed surface of the specimen which corresponded to the interior of a fuselage.

The various insulations increased the overall resistance in most cases, as determined by flames or radiation, but hastened the melting of the skin and longitudinal members. This latter effect could be quite important when the insulation is supported from these members, especially on the sloping sides and arched overhead of most fuselages.

Practical considerations of aircraft design, construction, and operation, place limitations on the variables which may be introduced into tests. It is necessary that occupants of aircraft be protected from the low temperatures encountered at flight altitudes by insulation. Therefore, further tests without insulation would be of questionable value. Additional work should be directed towards the development of barriers of high melting point, good reflection of radiation, and some strength. It would also appear desirable to study the possible use of energy absorbing material which would delay development of high temperatures within the aircraft. The material, or materials in a combination barrier, should be incombustible and should not give off acrid or toxic vapors or smoke.

The tests reported give evidence of the possibility of modifying the fire resistance of aircraft fuselages by changes in the finish and insulation of the aluminum skin. However, the differences achieved as yet, do not appear of sufficient value to justify adoption of any of the structures studied without further experimental work.

A research program for the purpose of studying additional insulations, heat absorbing methods, and flame or radiation barriers would seem advisable. The test method and specimen size employed in the present series is satisfactory and should be continued. In addition, a few tests with larger specimens in positions other than horizontal would be of value in determining the effect of larger failure areas, particularly on systems for attaching insulation. Such larger tests should be used for the final evaluation of promising assemblies.

Table 1 - Test Specimens and Results

| Panel No. | Source[1] | Coatings and Barriers: Outside or Exposed Surface | Coatings and Barriers: Inside or Unexposed Surface | End Points by Element: Skin Melting sec | End Points by Element: Skin Hole Through sec | End Points by Element: Longitudinals Melting sec | End Points by Element: Inner Surface Flaming[2] sec | Failure sec | Radiation at Failure Time cal/cm²/min |
|---|---|---|---|---|---|---|---|---|---|
| 14 | C82 | None[3] | Paint | 105 | 145 | <300 | - | 145 | 20 |
| 10 | C82 | Paint | do | 50 | 55 | None | - | 55 | >50 |
| 12 | C82 | do | Paint, stainless steel | 30 | <75 | 110 | - | 110 | 48 |
| 13 | C82 | do | Paint, refractory felt | 45 | 80 | <120 | 110 | 110 | 18 |
| 11 | C82 | do | Paint, $2\frac{1}{4}$-in. glass fiber and cotton cover | 35 | 35 | 65 | 130 | 65 | 0 |
| 2A | NBS | None | None | 115 | 125 | None | - | 125 | 9 |
| 3A | do | do | do | 120 | 129 | do | - | 129 | 7 |
| 4 | do | do | Primed | 150 | 175 | do | - | 175 | 18[4] at 135 sec |
| 5 | do | do | 1-in. glass fiber and plastic | 100 | 100 | <160 | 160 | 160 | >50 |

Table 1 (Contd) - Test Specimens and Results

| Panel No. | Source | Coatings and Barriers: Outside or Exposed Surface | Coatings and Barriers: Inside or Unexposed Surface | End Points by Element: Skin: Melting sec | End Points by Element: Skin: Hole Through sec | End Points by Element: Longitudinals Melting sec | End Points by Element: Inner Surface Flaming sec | Failure sec | Radiation at Failure Time cal/cm²/min |
|---|---|---|---|---|---|---|---|---|---|
| 9A | NBS | None | Primed, 1-in. glass fiber and plastic | 100 | 80 | 170 | 170 | 170 | >50 |
| 6 | do | Intumescent paint | None | 90 | 215 | None | - | 215 | 4[5] at 190 sec |
| 7 | do | do | Primed | 75 | 130 | do | - | 130 | 3 |
| 8A | do | do | 1-in. glass fiber and plastic | <120 | 120 | <141 | 141 | 141 | >50 |
| 1A | do | do | Primed, 1-in. glass fiber and plastic | 60 | - | <90 | 90 | 90 | >50 |

1 C82 indicates test panels from that type aircraft provided by NACA; NBS indicates those constructed at National Bureau of Standards.

2 Flaming of the insulation, not through hole from furnace.

3 C82 sections came with exterior white paint which was removed from specimen for test 14 only.

4 No radiation data taken past 135 sec.

5 No radiation data taken past 190 sec.

Fig. 1 Exposed surfaces of C82 specimens after tests, as numbered, and interior side of untested specimen. Not enough of specimens remained after tests 11 and 13 to photograph.

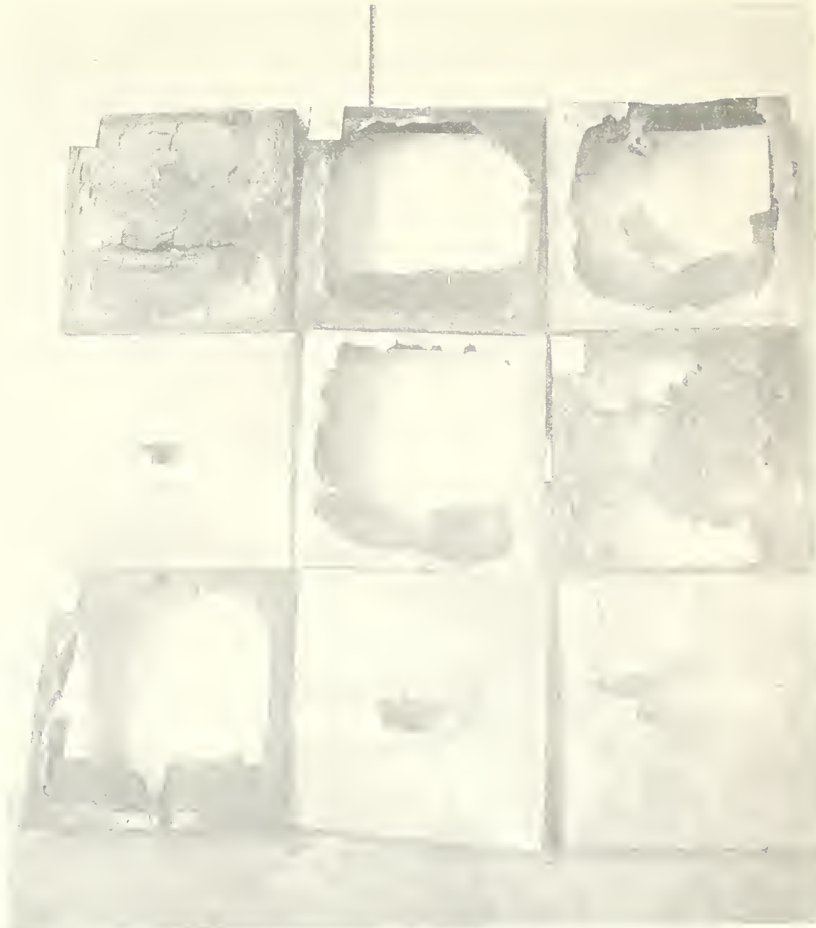
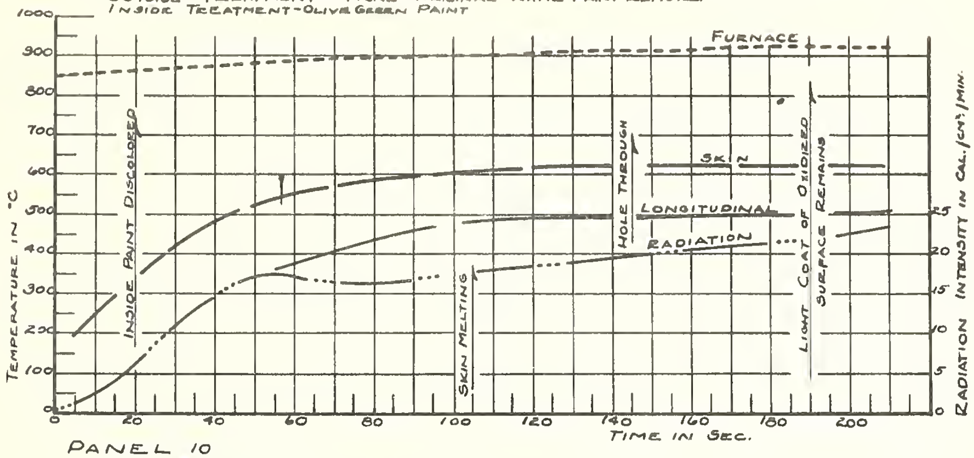
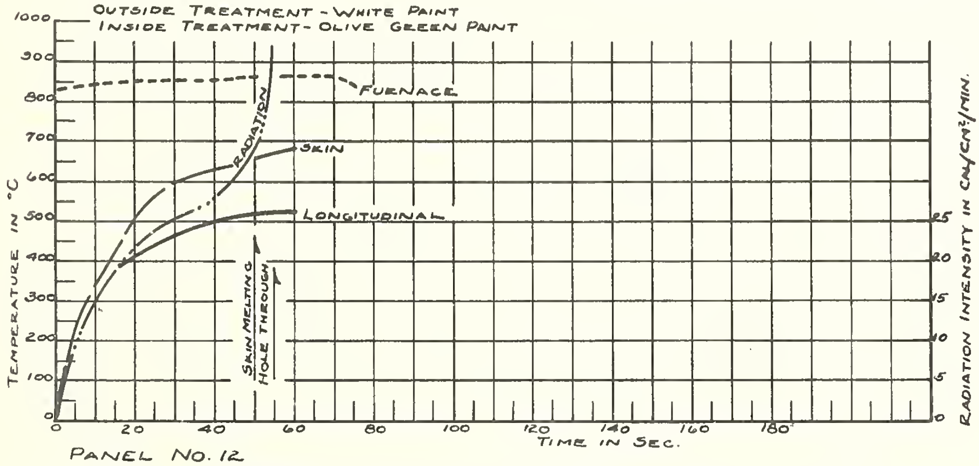


Fig. 2 Exposed surfaces of NBS specimens after tests, as numbered.

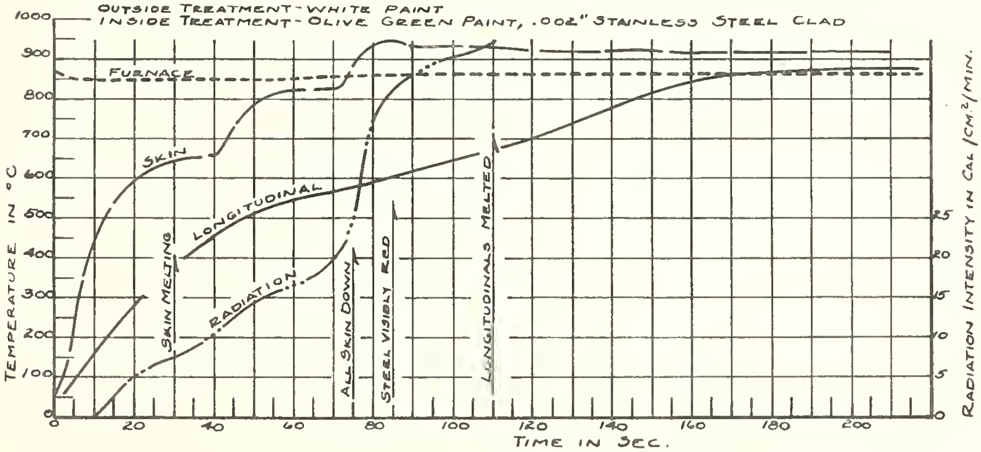
PANEL NO. 14
NACA - C82 SECTION
OUTSIDE TREATMENT - NONE (ORIGINAL WHITE PAINT REMOVED)
INSIDE TREATMENT - OLIVE GREEN PAINT

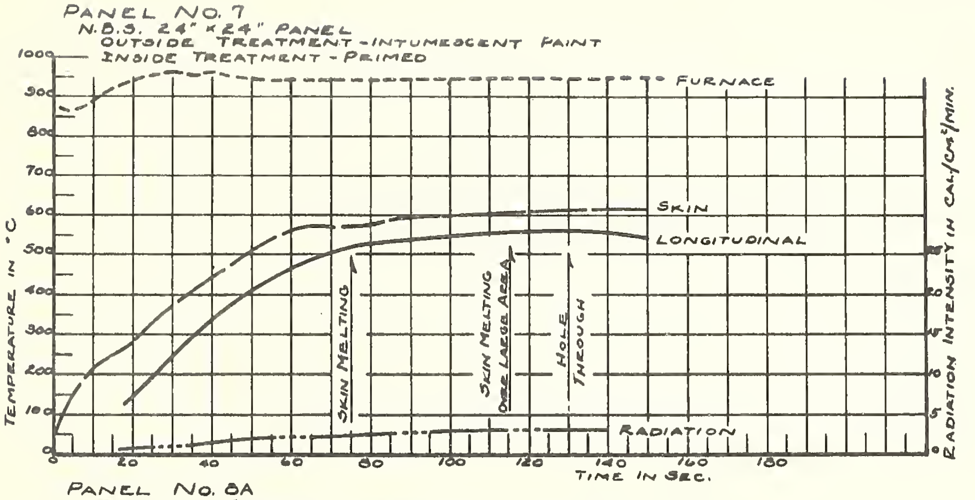


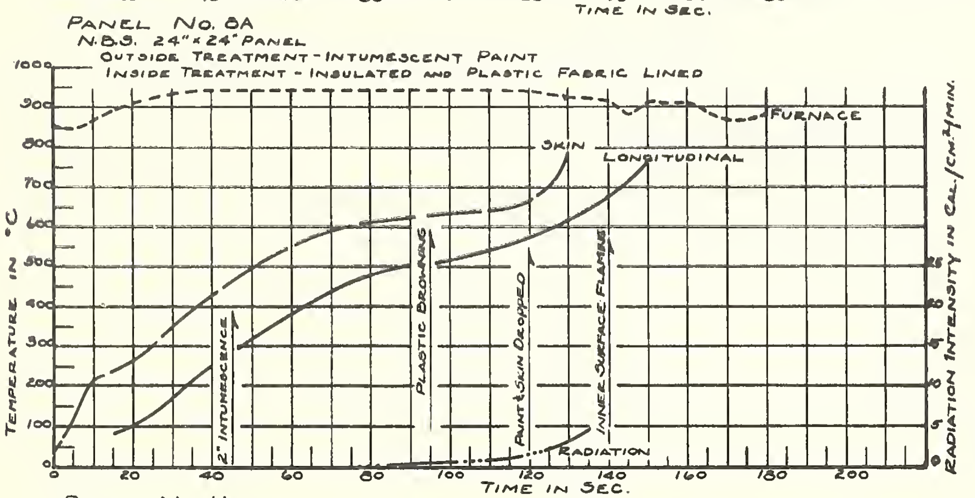

PANEL 10
NACA - C82 SECTION
OUTSIDE TREATMENT - WHITE PAINT
INSIDE TREATMENT - OLIVE GREEN PAINT

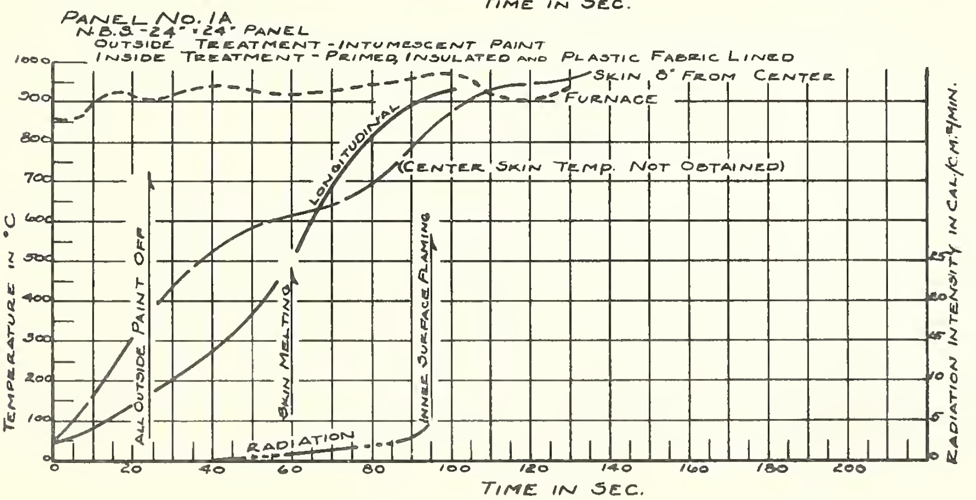


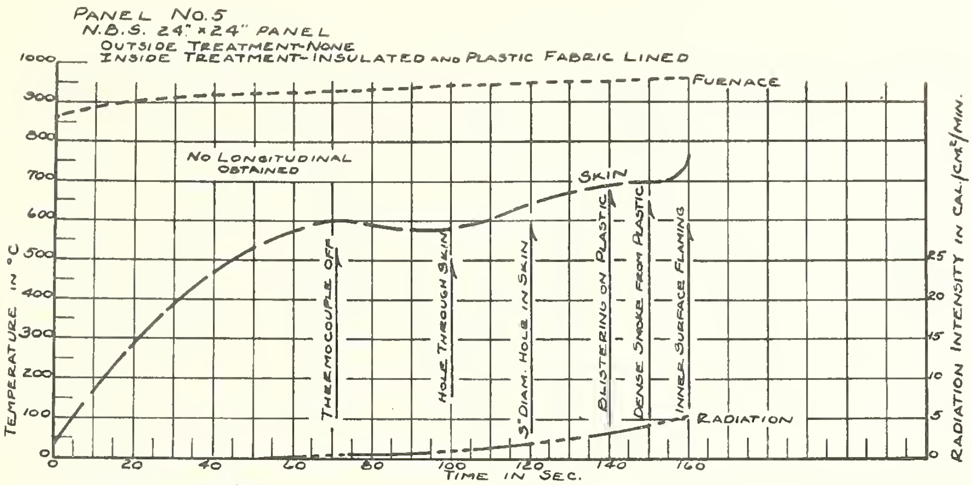

PANEL NO. 12
NACA - C82 SECTION
OUTSIDE TREATMENT - WHITE PAINT
INSIDE TREATMENT - OLIVE GREEN PAINT, .002" STAINLESS STEEL CLAD

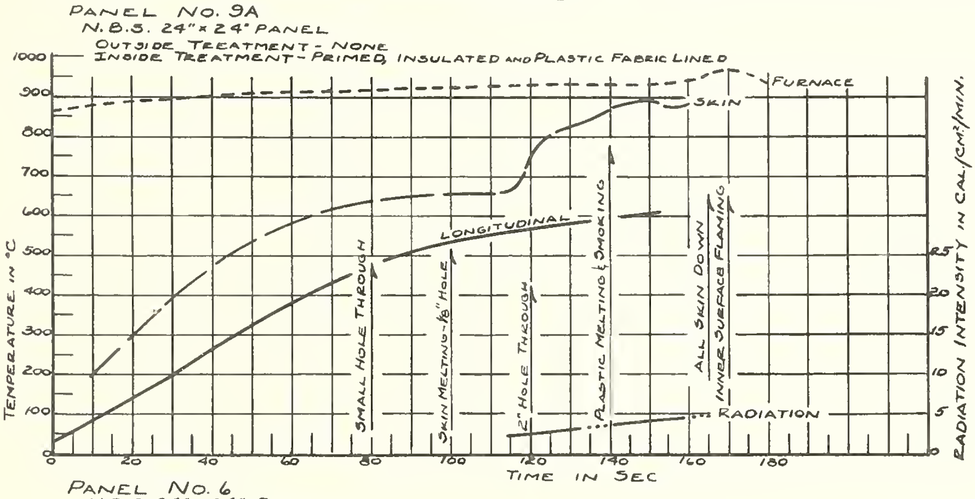


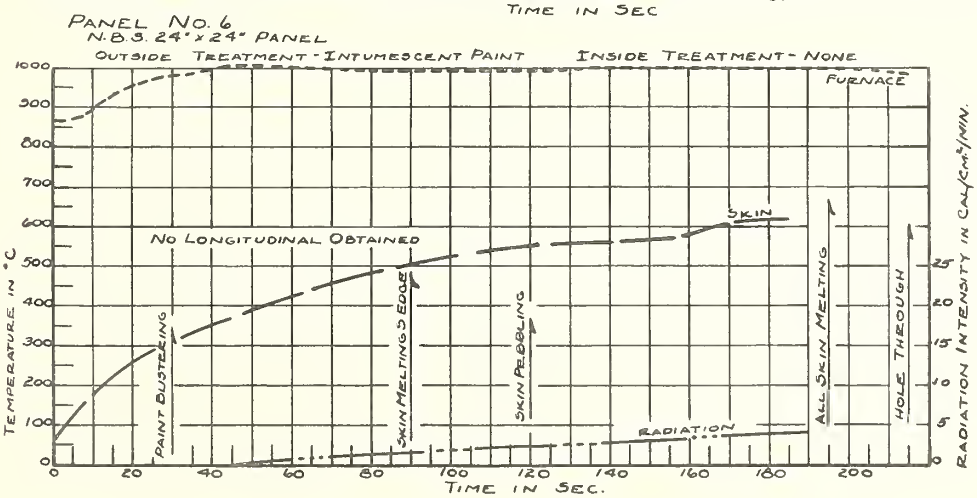

PANEL NO. 7
N.B.S. 24" × 24" PANEL
OUTSIDE TREATMENT - INTUMESCENT PAINT
INSIDE TREATMENT - PRIMED
FURNACE
SKIN
LONGITUDINAL
SKIN MELTING
SKIN MELTING OVER LARGE AREA
HOLE THROUGH
RADIATION
TEMPERATURE IN °C
RADIATION INTENSITY IN CAL./CM.²/MIN.
TIME IN SEC.


PANEL NO. 8A
N.B.S. 24" × 24" PANEL
OUTSIDE TREATMENT - INTUMESCENT PAINT
INSIDE TREATMENT - INSULATED AND PLASTIC FABRIC LINED
FURNACE
SKIN
LONGITUDINAL
2" INTUMESCENCE
PLASTIC BROWNING
PAINT & SKIN DROPPED
INNER SURFACE FLAMING
RADIATION
TEMPERATURE IN °C
RADIATION INTENSITY IN CAL./CM.²/MIN.
TIME IN SEC.

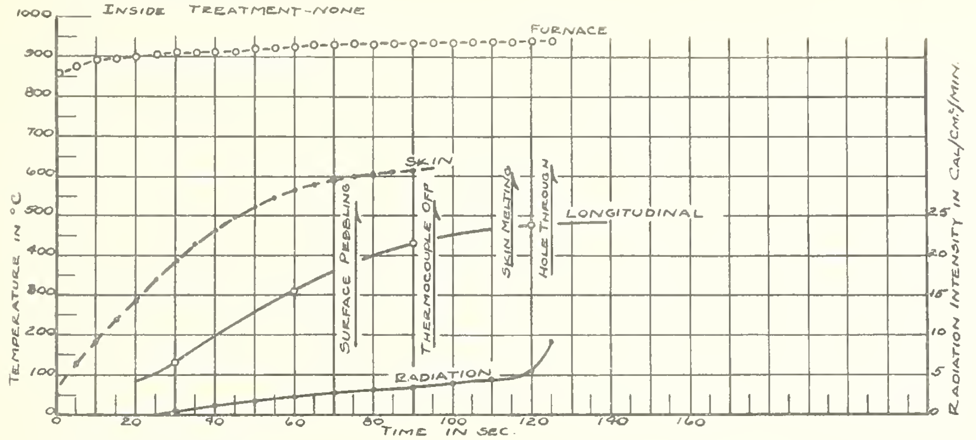

PANEL NO. 1A
N.B.S. 24" × 24" PANEL
OUTSIDE TREATMENT - INTUMESCENT PAINT
INSIDE TREATMENT - PRIMED, INSULATED AND PLASTIC FABRIC LINED
SKIN, 8" FROM CENTER
FURNACE
LONGITUDINAL
(CENTER SKIN TEMP. NOT OBTAINED)
ALL OUTSIDE PAINT OFF
SKIN MELTING
INNER SURFACE FLAMING
RADIATION
TEMPERATURE IN °C
RADIATION INTENSITY IN CAL./CM.²/MIN.
TIME IN SEC.


PANEL NO. 5
N.B.S. 24" x 24" PANEL
OUTSIDE TREATMENT-NONE
INSIDE TREATMENT-INSULATED AND PLASTIC FABRIC LINED
FURNACE
NO LONGITUDINAL OBTAINED
SKIN
THERMOCOUPLE OFF
HOLE THROUGH SKIN
3" DIAM. HOLE IN SKIN
BLISTERING ON PLASTIC
DENSE SMOKE FROM PLASTIC
INNER SURFACE FLAMING
RADIATION
TEMPERATURE IN °C
RADIATION INTENSITY IN CAL/CM²/MIN.
TIME IN SEC.

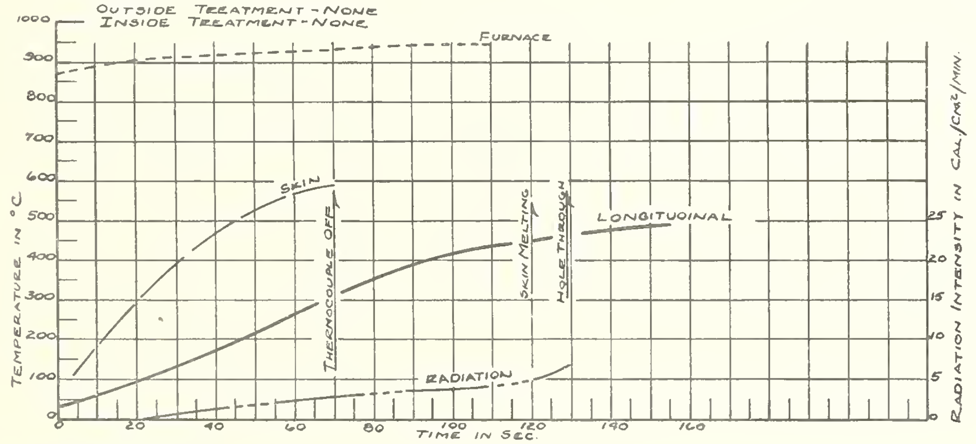

PANEL NO. 9A
N.B.S. 24" x 24" PANEL
OUTSIDE TREATMENT - NONE
INSIDE TREATMENT - PRIMED, INSULATED AND PLASTIC FABRIC LINED
FURNACE
SKIN
LONGITUDINAL
SMALL HOLE THROUGH
SKIN MELTING-1/8" HOLE
2" HOLE THROUGH
PLASTIC MELTING & SMOKING
ALL SKIN DOWN
INNER SURFACE FLAMING
RADIATION
TEMPERATURE IN °C
RADIATION INTENSITY IN CAL/CM²/MIN.
TIME IN SEC


PANEL NO. 6
N.B.S. 24" x 24" PANEL
OUTSIDE TREATMENT - INTUMESCENT PAINT
INSIDE TREATMENT - NONE
FURNACE
NO LONGITUDINAL OBTAINED
SKIN
PAINT BLISTERING
SKIN MELTING 3 EDGE
SKIN PEBBLING
ALL SKIN MELTING
HOLE THROUGH
RADIATION
TEMPERATURE IN °C
RADIATION INTENSITY IN CAL/CM²/MIN.
TIME IN SEC.

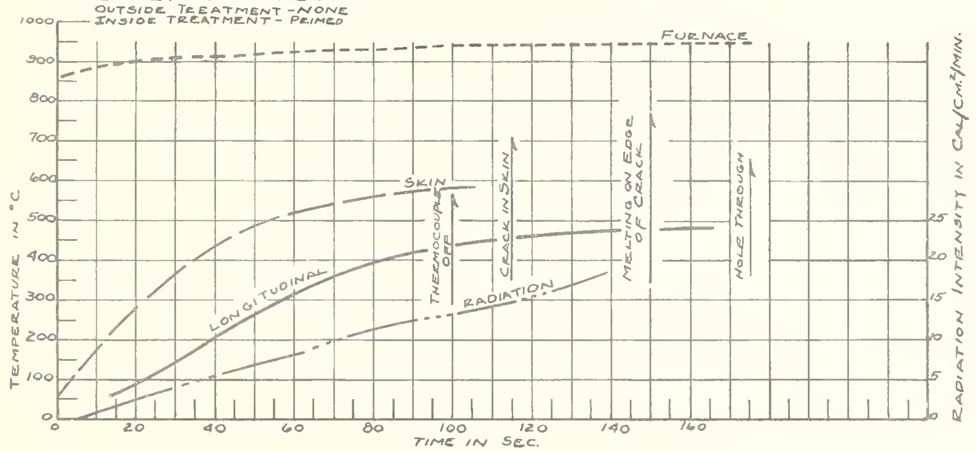
PANEL NO. 2A
N.B.S. 24" x 24" PANEL
OUTSIDE TREATMENT - NONE
INSIDE TREATMENT - NONE



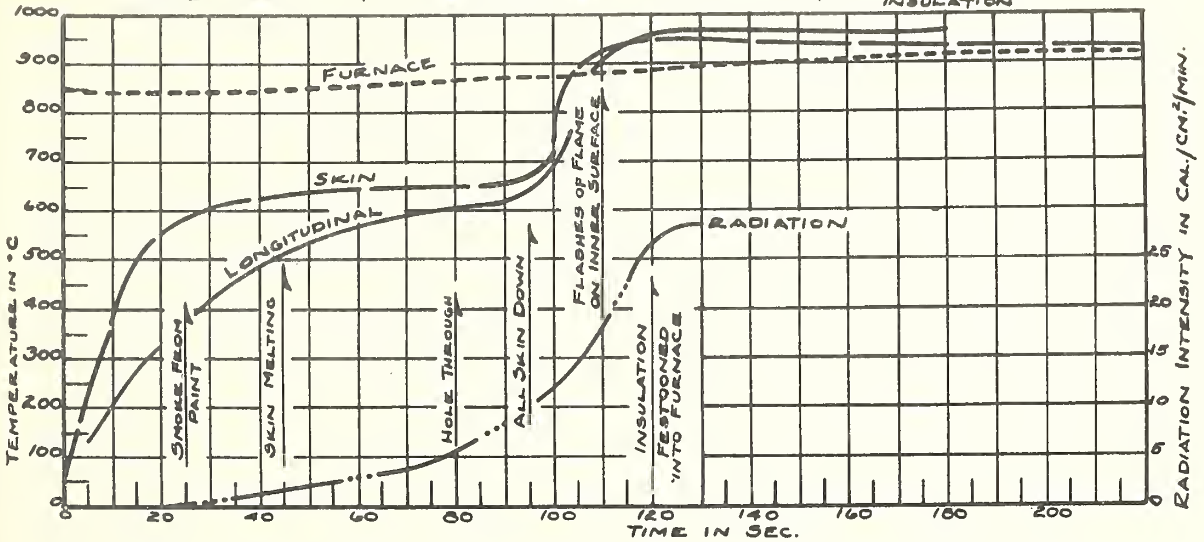

PANEL NO. 3A
N.B.S. 24" x 24" PANEL
OUTSIDE TREATMENT - NONE
INSIDE TREATMENT - NONE



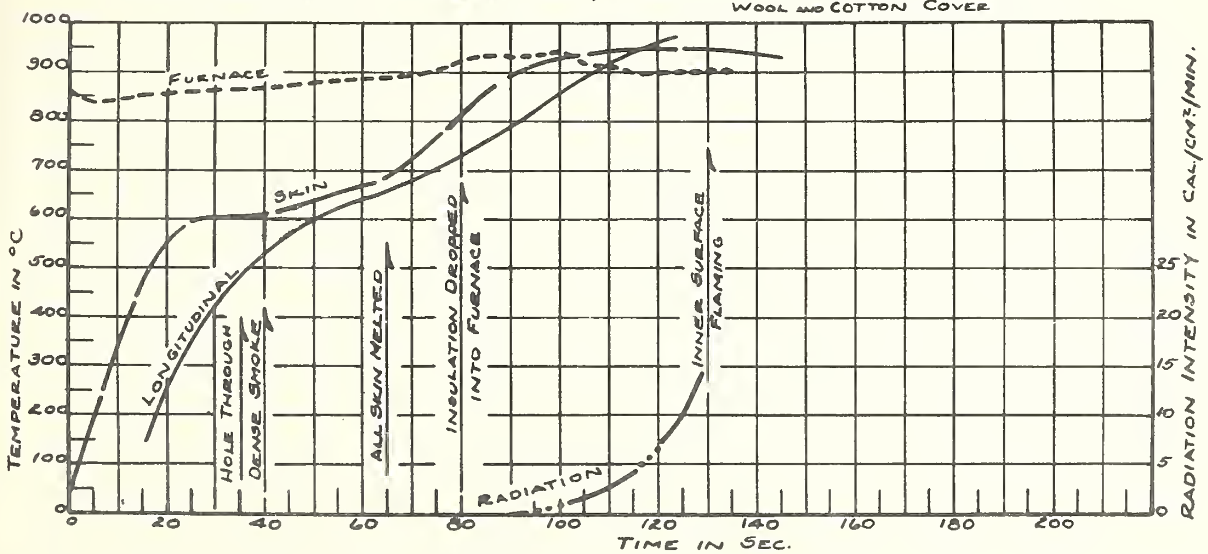

PANEL NO. 4
N.B.S. 24" x 24" PANEL
OUTSIDE TREATMENT - NONE
INSIDE TREATMENT - PRIMED



PANEL NO. 13
NACA C82 SECTION
OUTSIDE TREATMENT - WHITE PAINT
INSIDE TREATMENT - OLIVE GREEN PAINT AND 3/16" LAYER OF REFRACTORY FIBER INSULATION




PANEL NO. 11
NACA-C82 SECTION
OUTSIDE TREATMENT - WHITE PAINT
INSIDE TREATMENT - OLIVE GREEN PAINT, 2" GLASS-WOOL INSULATION AND 1/4" GLASS-WOOL AND COTTON COVER



# THE NATIONAL BUREAU OF STANDARDS

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Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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