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DATA RELATING TO THE FLAMMABILITY PROPERTIES OF MATERIALS USED IN INTERIORS OF 747 TYPE AIRCRAFT

FINAL REPORT

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1.0 INTRODUCTION

The data reported herein reflect some of the flammability properties of interior materials used in widebody transports. The data types presented are those needed to support an analytical model of a fuselage fire.

2.0 EXPERIMENTAL APPARATUS

2.1 RELEASE RATE APPARATUS

A release rate apparatus of the type developed at Ohio State University[1] (OSU) was used to determine flame spread rates, heat release rates, and smoke release rates as a function of thermal flux incident on the material tested. A schematic diagram of the instrument is shown in Figure 2-1.

Samples to be tested are mounted either vertically or horizontally and are subjected to a radiant heat flux generated from an electrically heated or gas-fired radiant panel. The thermal flux level from the electric panel ranges up to about 3.5 watts/sq cm, and from the gas-fired panel the flux goes up to about 7 watts/sq cm. A small pilot flame (12 Btu/minute) can be used to ignite the sample. The specimen is introduced into the chamber and the recorder plot is marked to show sample insertion.

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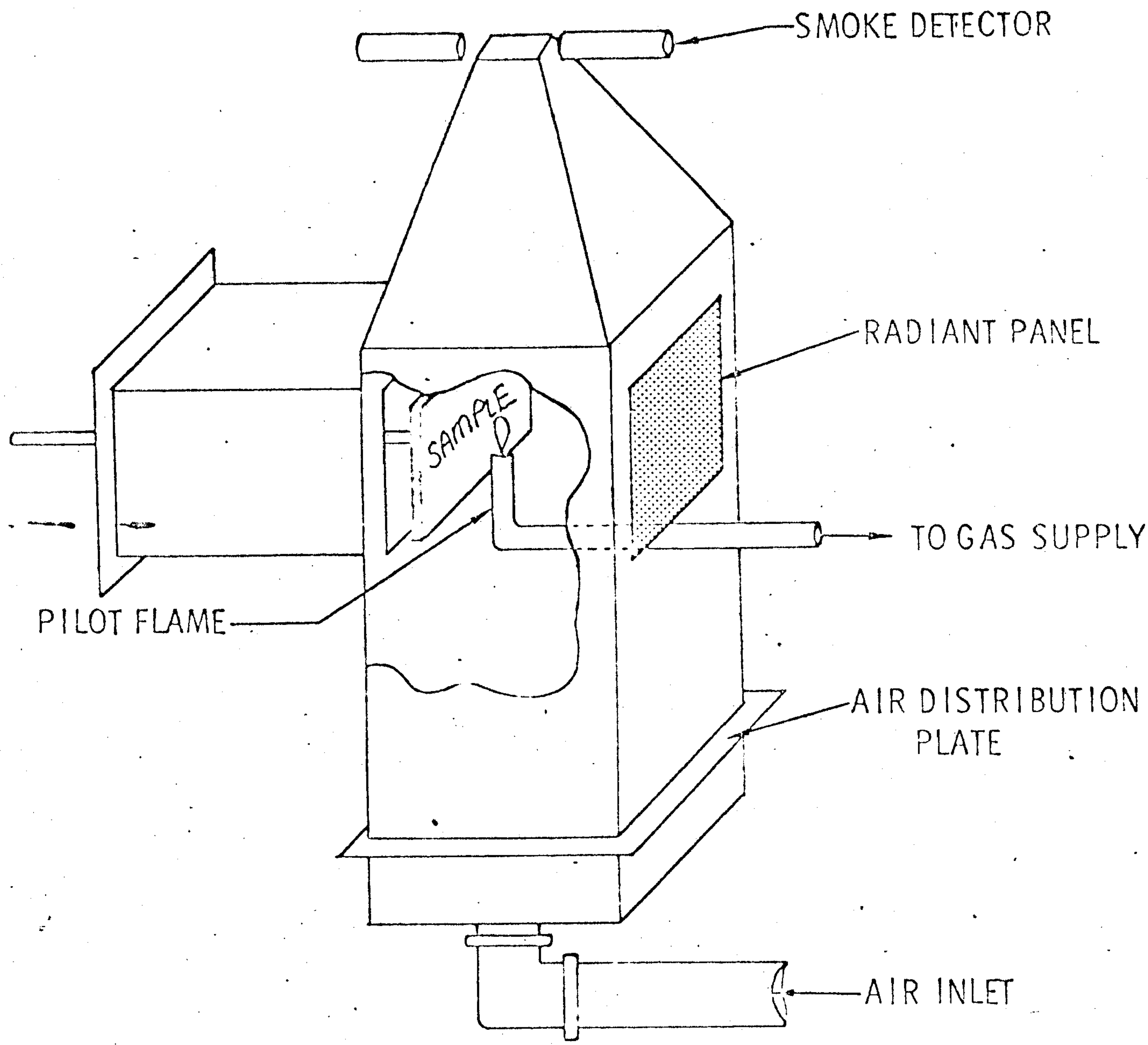
1. E. E. Smith, "Measuring Rate of Heat, Smoke, and Toxic Gas Release," Fire Technology 8, No. 3 (1972).



RELEASE RATE APPARATUS

Figure 2-1

2.1.1 Heat Release Rates

As the sample burns, heat is released that increases the stack gas temperature and induces an increase in thermopile voltage v(t) that is recorded. This is shown in Figure 2-2. This increase is proportional to <u>heat</u> <u>release</u> <u>rate</u> (proportionality constant k), so that heat release rate per unit area at time t is k v(t)/A, and total heat release is heat release rate integrated over time.

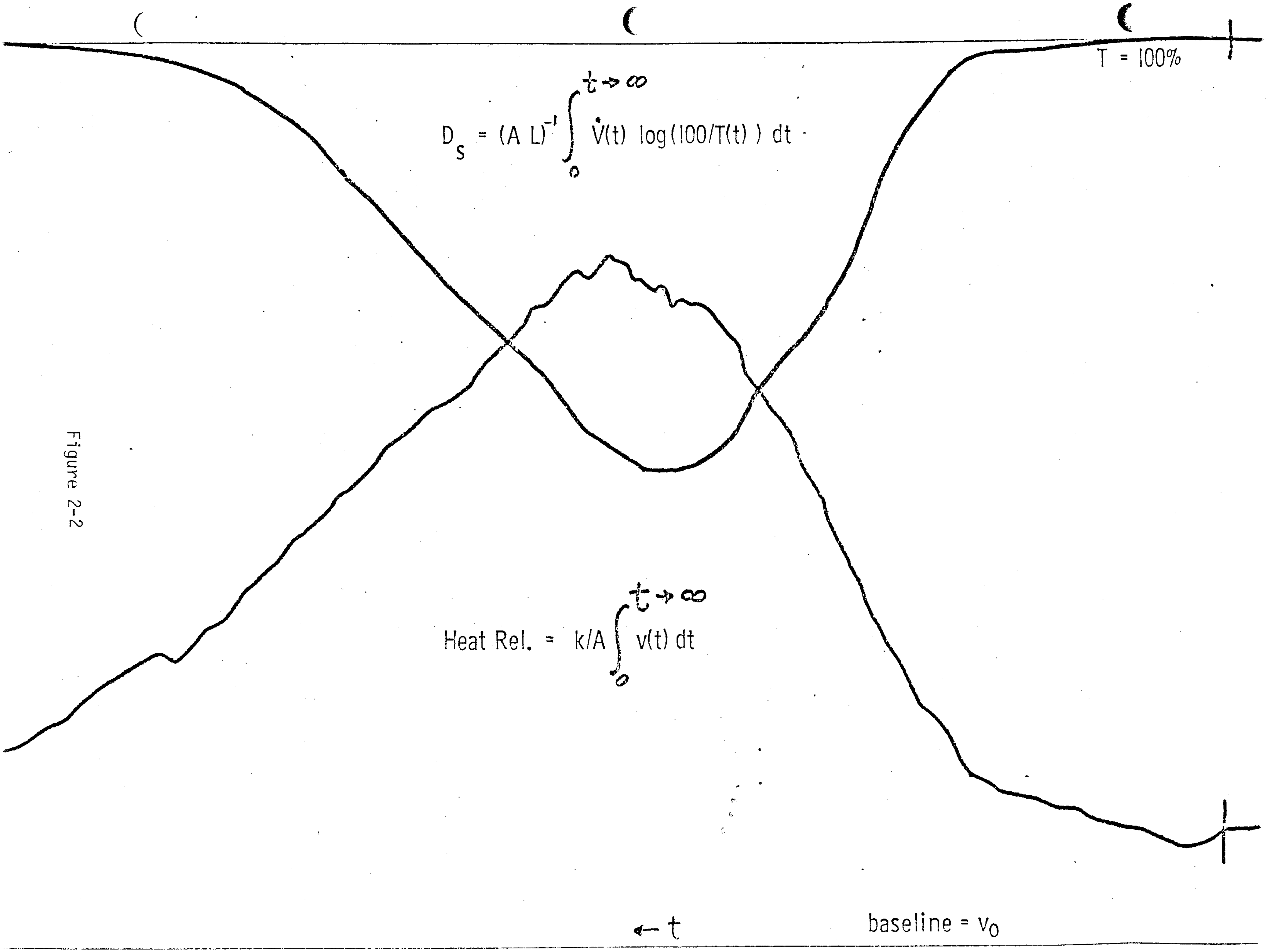
2.1.2 Smoke Release Rates

Smoke leaving the stack causes a photoelectric cell to decrease its output voltage. This is shown in Figure 2-2. This decrease is monotonically related to the light transmission T(t) (a calibration using neutral density filters is employed to determine the relationship). The volume rate of flow of exhaust gases through the stack is determined by the quantity $\dot{V}_0\, T(t)/T_0$, where $\dot{V}_0$ is the input flow rate of air, T(t) the absolute exhaust gas temperature, and T_0 the absolute input air temperature. The rate of change of specific optical density (equivalent to smoke release rate) is then:

$$\dot{D}_s(t) = (AL)^{-1}\, \dot{V}(t)\, \log\,[100/T(t)]$$

and the specific optical density is $\dot{D}_s(t)$ integrated over time:

$$D_s(t) = (AL)^{-1} \int_0^t \dot{V}(t')\, \log\,[100/T(t')]dt'$$



T = 100%
$D_s = (A\,L)^{-1} \int_0^{t \to \infty} \dot{V}(t)\,\log(100/T(t))\,dt$
Heat Rel. = $k/A \int_0^{t \to \infty} v(t)\,dt$
← t
baseline = v_0

Figure 2-2

2.2 NBS SMOKE CHAMBER

The NBS Smoke Chamber measures the increase in opacification in a chamber due to smoke accumulation from a burning sample. The light transmission through the chamber is monitored continuously by a recorder. A typical recorder plot for light transmission versus time is shown in Figure 2-3.

A specific optical density D_s is computed from the light transmission according to the formula:

$$D_s = \frac{V}{AL} \log \frac{100}{T}$$

where V is the chamber volume (18 cu ft), L the length of the light beam (3 ft), and A the sample surface area (6.55 sq in.). The D_s gives a measure of the smoke produced by a burning sample.

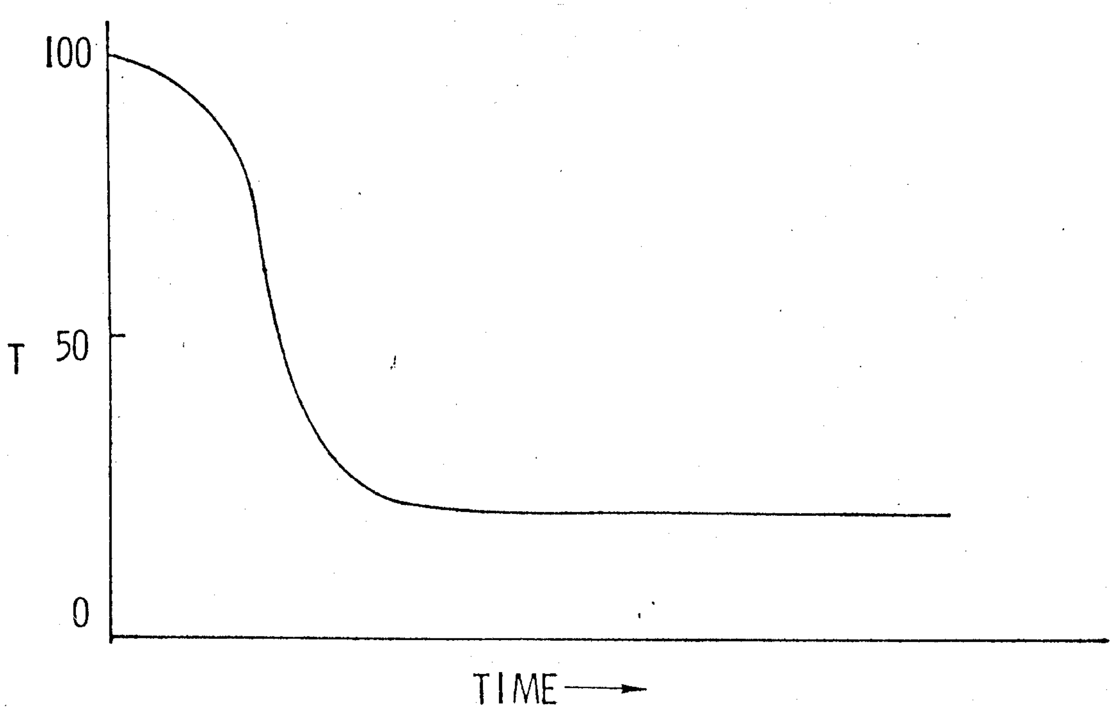


Figure 2-3 Light Transmission vs. Time Recording

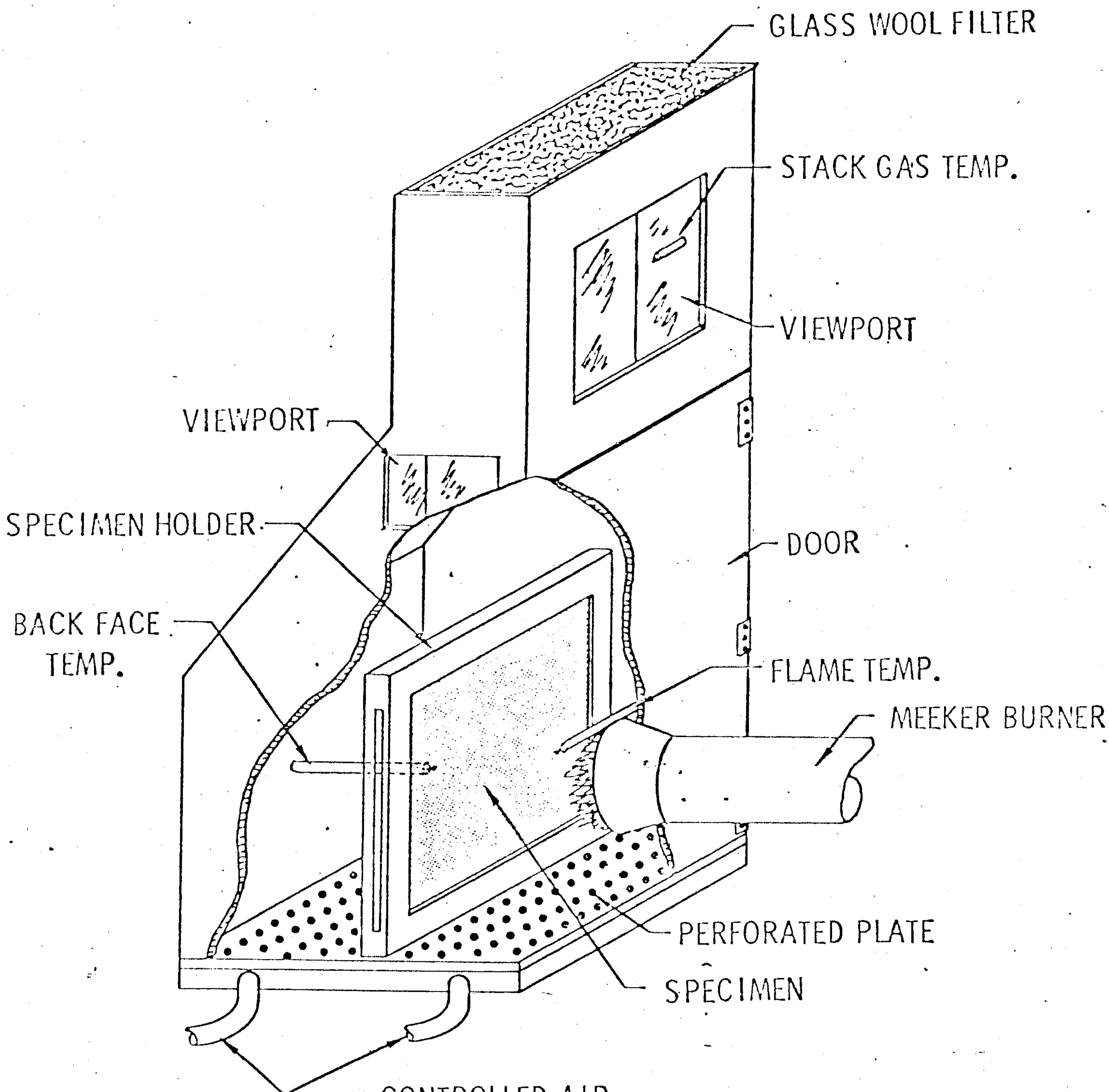


Figure 2-4

Boeing Burnthrough Apparatus

2.3 BOEING BURNTHROUGH APPARATUS

The burnthrough apparatus was developed and built at Boeing to determine the effect of high thermal fluxes, common in fires, on structures. The design of the burnthrough apparatus is shown in Figure 2-4. A sample placed in the device is subjected to heat from a Meeker burner. The conditions created by the burner have been shown to be very reproducible. The rise in temperature on the back face is monitored to give a measure of how the material stands up to the fire. A sudden, precipitous rise in back-face temperature indicates burnthrough has taken place. The temperature of the stack gases is monitored to provide a measure of the heat release rate and the total heat release.

2.4 COLORIMETRIC TUBES

Colorimetric tubes, such as Draeger tubes, are available for gas analysis. Toxic gas species produced are determined by burning test specimens in the NBS SMoke Chamber (Section 2.2) at various thermal fluxes (2.5, 5.0, and 7.5 watts/sq cm). The contents of the chamber are monitored with the colorimetric tubes. Results are expressed in parts per million, by volume.

3.0 DATA OBTAINED

3.1 DATA TYPES

The data types presented are as follows:

(a) Horizontal flame spread rates on vertical samples. These were determined in the OSU apparatus by monitoring visually the time required for the flame to spread from the center of the specimen (where the pilot flame impinged) halfway to the edge and all the way to the edge of the specimen.

(b) Horizontal flame spread rates on a horizontal sample. These were determined in the OSU apparatus for horizontal samples in the same way as was done for vertical samples. See (a) above.

(c) Vertical (up and down) flame spread rates on a vertical sample. These were determined in the same way as in (a) above, except that the impinging pilot flame was placed at the geometric center of the face of the sample, and the positions monitored on the sample were up and down rather than horizontal.

(d) Smoke release rates for flaming and pyrolyzing structures. These were determined by the procedure outlined in Section 2.1.2.

(e) Heat release rates were determined by the procedure outlined in Section 2.1.2.

(f) t_f - time to flame. This was derived by monitoring visually in the OSU apparatus when the sample began to burn, and recording the time burning commenced after sample insertion.

(g) t_{fc} - time to extinguishment after flame. This was derived by monitoring visually in the OSU apparatus the cessation of burning after flaming, and recording the time elapsed between the commencement and cessation of burning.

(h) t_p - time to pyrolyze. This was derived by monitoring visually in the OSU apparatus, in a nonpiloted experiment, the onset of pyrolysis (as indicated by a blackening of the sample surface), and recording the time elapsed between sample insertion and the onset of pyrolysis.

(i) t_{pc} - time to extinguishment after pyrolysis begins. This was determined by monitoring visually in the OSU apparatus when pyrolysis ceased, and recording the time elapsed between extinguishment of pyrolysis and the onset of pyrolysis.

(j) t_{pe} - time to extinguishment from a pyrolysis state. This was determined in the Boeing burnthrough apparatus (see Section 2.2) by monitoring visually the onset of pyrolysis after the sample is exposed to the heat of the Meeker burner, immediately thereupon extinguishing the burner, monitoring visually the cessation of pyrolysis, and recording the time elapsed between onset and extinguishment of pyrolysis.

(k) Toxic Gas Species - These are determined with colorimetric tubes in the NBS Smoke Chamber (Section 2.4). Species monitored are CO, HCl, HF, HCN, and SO_2.

3.2 STRUCTURES TESTED

The following structures were tested and data are presented:

(a) Sidewall Panels

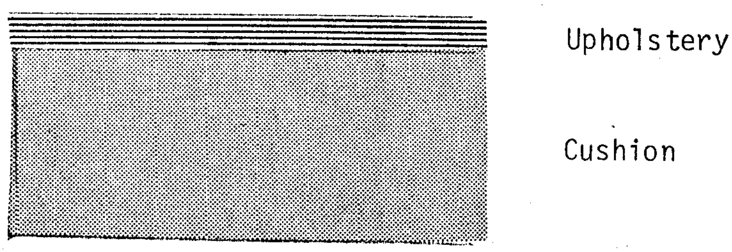
.001" Clear Tedlar
INK
.002" opaque Tedlar
1 ply type 181 fiberglas-epoxy prepreg
1 ply type 120 fiberglas-epoxy prepreg
Nomex honeycomb core; 1/8" cell, 1/4" thick, 3 #/ft^3 density
2 ply type 120 fiberglas-epoxy prepreg

(b) Ceiling Panels

- .002" opaque Tedlar
- 1 ply type 181 fiberglas-epoxy prepreg
- 1 ply type 120 fiberglas-epoxy prepreg
- Nomex honeycomb core; 1/4" cell, 1/4" thick, 1.5 #/ft^3 density
- 1 ply type 120 fiberglas-epoxy prepreg

(c) Sheet Polycarbonate. This material is used to thermoform passenger service units and window reveals.

(d) Seats (cushion plus upholstery).



(e) Carpet (pile plus backing)

(f) Stowage Bins

- .002" opaque Tedlar
- 1 ply type 181 fiberglas-epoxy prepreg
- 1 ply type 120 fiberglas-epoxy prepreg
- Nomex honeycomb core; 1/4" cell, 1/4" thick; 1.5 #/ft^3 density
- 1 ply type 181 fiberglas-epoxy prepreg
- 1 ply type 120 fiberglas-epoxy prepreg
- .001" opaque Tedlar

(g) Window transparencies (dust covers)

Flammability data necessary to support an analytical fire simulation model are presented here for 747 interior materials types. The data for the most part were generated in the Ohio State release rate apparatus which can accommodate test specimens in either a vertical or a horizontal position to simulate actual in-use orientation.

Owing to the limitations of the program, providing the required data types at times necessitated that only a small number of specimens could be tested to define individual data points. Hence, some of the data presented have statistical variations that are larger than those ultimately achievable.

VERTICAL SPECIMENS

Vertical specimens are square, six inches on a side. Data types and the way they are determined are as follows:

1. Horizontal Flame Spread Rate - inches/minute

V1A - Pilot ignition is at center of specimen at the bottom of the specimen. The time required for flame to move from the center to 1/3 the distance from the centerline to the edge (this is 1 inch) after ignition is monitored visually and the flame spread rate is computed.

V1B - Same as above except the time for the flame to move 2/3 the distance from the centerline to the edge (this is 2 inches) after ignition is monitored visually and the flame spread rate is computed.

V1C - Same as above except the time for the flame to move the full distance from the centerline to the edge (this is 3 inches) after ignition is monitored visually and the flame spread rate is computed.

V1D - Same as V1A except ignition occurs at the geometric center of the panel.

V1E - Same as V1B except ignition occurs at the geometric center of the panel.

V1F - Same as V1C except ignition occurs at the geometric center of the panel.

2. Vertical Flame Spread Rate UP - inches/minute

V2A - Ignition is at the center of the specimen at the bottom. The time required for the flame to move 1/2 the distance from the bottom of the specimen to the top (this is 3 inches) is monitored visually and the flame spread rate is computed.

V2B - Same as above except the time for the flame to move the full distance from the bottom of the specimen to the top (this is 6 inches) is monitored visually and the flame spread rate is computed.

V2C - Same as V2A except ignition occurs at the geometric center of the specimen and the time for the flame to reach 1/2 of the distance to the top (this is 1-1/2 inches) is monitored visually and the flame spread rate is computed.

V2D - Same as V2B except ignition occurs at the geometric center of the specimen and the time for the flame to reach the full distance from the panel center to the top (this is 3 inches) is monitored visually and the flame spread rate is computed.

3. Vertical Flame Spread Rate DOWN - inches/minute

V3A - Same as V2C except the direction is down rather than up.

V3B - Same as V2D except the direction is down rather than up.

4. Heat Release Rate (HRR) - Center-center ignition

V4A - The maximum heat release rate is reported in Btu/sq ft/minute.

V4A1 - bottom-center ignition

V4A2 - center-center ignition

V4A3 - no ignition

V4B - The time after sample insertion at which the maximum heat release rate occurred is reported in minutes.

V4B1 - bottom-center ignition

V4B2 - center-center ignition

V4B3 - no ignition

V5C - The total heat release is reported in BTU/Ft^2.

V5C1 - bottom-center ignition

V5C2 - center-center ignition

V5C3 - no ignition

5. Smoke Release Rate

Smoke release rate is expressed in terms of specific optical density. For the release rate apparatus, this is

$$Ds(t) = (AL)^{-1} \int_0^t V(t') \log \frac{100}{T(t')} dt'$$

where V(t) is the volumetric rate of air flow through the instrument, A the sample area, L the length of the monitoring light beam, and T(t') the transmission in percent through the light beam. V(t) is determined taking into account (perfect gas law) the thermal expansion of the input gas (at 85 cu ft/minute for all these data) as it exits the stack. The stack temperature is taken from the heat release rate curve thermopile reading. The specific optical density determined here is in principle the same as that for the NBS chamber.

V5A - D_{max} = Ds (t ∞) (no dimension)

V5A1 - bottom-center ignition

V5A2 - center-center ignition

V5A3 - no ignition

V5B - $(d\ Ds/dt)_{max}$ $(\text{minutes})^{-1}$

V5B1 - bottom-center ignition

V5B2 - center-center ignition

V5B3 - no ignition

V5C - time at maximum d Ds(t)/dt, as in V4B (minutes)

V5C1 - bottom-center ignition

V5C2 - center-center ignition

V5C3 - no ignition

6. Time to Flame - minutes

V6A - The elapsed time after the sample was inserted before ignition occurred for center-center pilot flame.

V6B - Same as above, no pilot flame.

7. Time to Extinguishment After Ignition

V7A - The time which elapses between piloted ignition at the bottom center and extinguishment, in minutes.

V7B - Same as V7A, except ignition is at center-center.

V7C - The time which elapses between auto ignition and extinguishment, in minutes.

8. Time to Pyrolyze (only exposures with no piloted ignition)

V8A - The time which elapses between sample insertion and the onset of pyrolysis monitored visually as a blackening or darkening of the sample surface, in minutes.

V8B - The time which elapses between sample insertion and the onset of pyrolysis monitored by a reduction in light transmission to 99%, in minutes.

9. Time to Extinguishment After Pyrolysis Begins (only exposures with no piloted ignition)

V9A - The time which elapses between the onset of pyrolysis and the end of pyrolysis, monitored visually, in minutes.

V9B - The time which elapses between the onset of pyrolysis and the end of pyrolysis, monitored by the time from V8B to a return to 99% light transmission, in minutes.

10. Time to Extinguishment from a Pyrolysis State

This information is determined in a special apparatus (not the OSU instrument). It utilizes a square specimen (4 inches by 4 inches). This specimen is subjected to the heat from a Meeker burner until it begins to pyrolyze. The burner is then extinguished and the time for the specimen to cease pyrolysis is monitored visually.

V10A - As above, in minutes.

HORIZONTAL SPECIMENS

Horizontal specimens are rectangular, four inches by ten inches. Data types and the way they are determined are as follows:

1. Horizontal Flame Spread Rate - inches/minute

H1A - Pilot ignition is at the geometric center of the specimen. The time required for the flame to move from the center to 1/2 the distance to the short side (this is 1 inch) is monitored visually and the flame spread rate is computed.

H1B - Same as above except the time for the flame to move the entire distance to the short side (this is 2 inches) is monitored visually and the flame spread rate is computed.

H1C - Same as above except the time for the flame to move half the distance from the center to the long side (this is 2-1/2 inches) is monitored visually and the flame spread rate is computed.

H1D - Same as above except the time for the flame to move all the way to the long side is monitored visually and the flame spread rate is computed.

2. Heat Release Rate

H2A - The maximum heat release rate is reported in Btu/sq ft/minute.

H2A1 - center-center ignition

H2A2 - no piloted ignition

H2B - The time after sample insertion at which the maximum heat release rate occurred is reported in minutes.

H2B1 - center-center ignition

H2B2 - no piloted ignition

H2C - The total heat release rate is reported in Btu/sq ft.

H2C1 - center-center ignition

H2C2 - no piloted ignition

3. Smoke Release Rate

Smoke release rate is expressed in terms of specific optical density. For the release rate apparatus, this is

$$Ds(t) = (AL)^{-1} \int_0^t V(t') \log \frac{100}{T(t')} dt'$$

where V(t) is the volumetric rate of air flow through the instrument, A the sample area, L the length of the monitoring light beam, and T(t') the transmission in percent through the light beam. V(t) is determined taking into account (perfect gas law) the thermal expansion of the input gas (at 85 cu ft/minute for all these data) as it exits the stack. The stack temperature is taken from the heat release rate curve thermopile reading. The specific optical density determined here is in principle the same as that for the NBS chamber.

H3A - $D_{max} = Ds\ (t \rightarrow \infty)$ (no dimension)

H3A1 - center-center ignition

H3A2 - no piloted ignition

H3B - $(d\ Ds/dt)_{max}$ $(\text{minutes})^{-1}$

H3B1 - center-center ignition

H3B2 - no piloted ignition

H3C - Time at maximum d Ds(t)/dt (minutes)

H3C1 - center-center ignition

H3C2 - no piloted ignition

4. Time to Flame - minutes

H4A - The time elapsed after the sample was inserted before ignition occurred for center-center pilot flame.

H4B - Same as above, no pilot flame.

5. Time to Extinguishment After Ignition

H5A - The time which elapses between piloted ignition at the bottom center and exinguishment, in minutes.

H5B - Same as H5A, except ignition is at center-center.

H5C - The time which elapses between auto ignition and extinguishment, in minutes.

6. Time to Pyrolyze (only exposures with no piloted ignition)

H6A - The time which elapses between sample insertion and the onset of pyrolysis monitored visually as a blackening or darkening of the sample surface, in minutes.

H6B - The time which elapses between sample insertion and the onset of pyrolysis monitored by a reduction in light transmission to 99%, in minutes.

7. Time to Extinguishment After Pyrolysis Begins (only exposures with no piloted ignition)

H7A - The time which elapses between the onset of pyrolysis and the end of pyrolysis, monitored visually, in minutes.

H7B - The time which elapses between the onset of pyrolysis and the end of pyrolysis, monitored by the time from H6B to a return to 99% light transmission, in minutes.

8. Time to Extinguishment from a Pyrolysis State

This information is determined in a special apparatus (not the Ohio State release rate apparatus). It utilizes a square specimen (4 inches by 4 inches). This specimen is subjected to the heat from a Meeker burner until it begins to pyrolyze. The burner is then extinguished and the time for the specimen to cease pyrolysis is monitored visually.

H8A - As above, in minutes.