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## ABSTRACT

Heat release rates of typical items in fires are needed as a prerequisite for estimating fire growth and temperatures in structural fires. That is, these burning rates are required to be specified by the user as input to single-room and multi-room structural fire computer codes like FPETool, FASTLite and HAZARD. Data are given here that permit burning items to be specified in a useful modeled way, taking a $t^2$-fire for the growth and decay periods, with a constant maximum heat release rate between these two periods. A vast range of many items are considered. Detailed tabulation and graphic display of the parameters (for each item during experimental burns) permits fire modelers to initiate calculations. Further knowledge enables the deduction of when second and subsequent items may become involved, whether flashover may occur, and when conditions may become untenable. Thus, it is clear that many important phenomena that are calculated in fires depend on the quality and accuracy of the initial burn specification.

## INTRODUCTION

Computer codes are available that permit calculations to be made of the effect of a given specified fire on the subsequent environment in a structural fire. Things like temperature of the smoke layer, its depth from the ceiling downwards, its optical density, ceiling, wall and floor temperatures, floor surface heat flux rate, etc are calculated a a function of time in all the rooms of a typical multi-room structural fire. However, the accuracy of these calculations is strongly dependent upon the correctness of the initial fire specifications.

Heat release rates of typical items in fires are needed as a prerequisite for estimating fire growth and temperatures in structural fires. That is, these burning rates are required to be specified by the user as input to single-room and multi-room structural fire computer codes like FPETool, FASTLite and HAZARD, see Bukowski et al (1989), Peacock et al (1994), and Portier et al (1996). Data are given here that permit burning items to be specified in a useful modeled way, taking a $t^2$-fire for the growth and decay periods, with a constant maximum heat release rate between these two periods.

## FUNDAMENTALS

Typically, the heat release rate (heat energy evolving on a per unit time basis) of a fire $\dot{Q}$ (kW) changes as the size of the fire changes, as a function of time t (seconds) after fire ignition. That is, the variation of " $\dot{Q}$ " versus "t" is extremely important in characterizing the rate of growth of a fire.

Data are available for heat release rate vs. time for many items, see for example Babrauskas and Grayson (1992), SFPE (1995) and the data base in Bukowski et al. (1989). Furniture calorimeter and cone calorimeter measurements are available, with data specifically for:

Pools, liquid or plastic
Cribs (regular array of sticks)
Wood pallets
Upholstered furniture
Mattresses
Pillows
Wardrobes (closets)
Television sets
Christmas trees

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Curtains (drapes)
Electric cable trays
Trash bags and containers
Industrial rack-stored commodities

Notice that although data may well be available from careful laboratory experiments, the data may not apply directly to real-world fire situations. The laboratory data does not usually take into account the enhancement of burning rates because of radiation feedback.

Full-scale furniture calorimeter tests give useful information on the burning rates of many typical household items. Peak heating values are particularly useful to know, since in some cases a triangular heat release rate vs. time representation can be utilized for simplicity. Upholstered furniture - wood frame, with fire-retardant polyurethane padding and olefin cover fabric - show peak heat release rates as follows:

| | | |
|---|---|---|
| F21 Chair | 2100 kW | at 260 s |
| F31 Loveseat | 2886 kW | at 230 s |
| F32 Sofa | 3120 kW | at 215 s |

The F number used here corresponds to the particular experiment performed, see Bukowski (1989). Other useful peak heat release rates:

| | | |
|---|---|---|
| Mattress and boxspring | 660 kW | at 910 s |
| Curtain, cotton, 1.87 kg | 240 kW | at 175 s |
| Wastepaper basket, 0.93 kg | 15 kW | at 350 s |
| Television, 39.8 kg | 290 kW | at 670 s |
| Cooking oil, corn, cottonseed, etc. 12-inch pan | 116 kW | constant |
| Christmas tree, spruce, 7 kg | 650 kW | at 350 s |

and the values help to visualize the differences between the items under burning conditions.

Of special concern in fire investigation and computer reconstruction of building fires is the use of accelerants. Liquid fuels are often preferred. They are used to accelerate the development of the fire, as indicated by temperature and spreading rates. On the practical investigative side, features often include: low burns, high temperatures at low hidden locations, rapid house fire development, and particular flame and smoke colors seen by witnesses. Burning rates of liquid pool fires are available in SFPE (1995).

## POOL FIRES

The thermal radiation hazards from hydrocarbon spill fires depend on a number of parameters, including the composition of the hydrocarbon, the size and shape of the fire, the duration of the fire, its proximity to the object at risk, and the thermal characteristics of the object exposed to the fire. The state of the art of predicting the thermal environment of hydrocarbon spill fires consists essentially of semiempirical methods, some of which are based on experimental data from small- and medium-scale tests. Needless to day, such semiempirical methods are always subject to uncertainties when experimental data from small-scale fires are extrapolated to predict the thermal properties of very large-scale fires.

A systematic study of liquid hydrocarbon pool fires over the widest range of pool diameters was conducted by Blinov and Khudiakov. Gasoline, tractor kerosene, diesel oil, and solar oil (and, to a limited extent, household kerosene and transformer oil) were burned in cylindrical pans (depth not indicated) of diameters 0.37 cm to 22.9 meters. Liquid burning rates and flame heights were measured, and visual and photographic observations of the flames were recorded. Hottel plotted these data and the results are shown in the Figure. The lower curve of this figure shows the variation of burning velocity (in meters/second of depth burning) as a function of the pan diameter. The upper curves give the ratio of flame height to flame diameter as a function of the pan diameter. The diagonal lines on the lower curves represent lines of constant Reynolds numbers, based on pan diameter.

Useful information about the rate of burning of pool fires is readily available in Tables, see SFPE (1995) for example, via the mass consumed per unit area per unit time. From the energy per unit mass values also given, one can readily compute the heat release rate $\dot{Q}$ in kW, or in Btu per hour since 100,000 Btu/hr = 29.31 kW. It may be noted that for pool diameters less than 1 meter, the burning rate expression is reduced because of a reduction in radiation feedback.

## THE $t^2$-FIRE GROWTH MODEL

Emphasis is often placed on the growth phase of the fire. Slow, medium, fast and ultra-fast fire growths may be specified by the $t^2$-fire growth model, where, after an initial incubation period,

$$\dot{Q} = \alpha_f (t - t_o)^2$$

where $\alpha_f$ is a fire-growth coefficient (kW/s$^2$) and $t_o$ is the length of the incubation period (s). The coefficient $\alpha_f$ appears to lie in the range $10^{-3}$ kW/s$^2$ for very slowly developing fires to 1 kW/s$^2$ for very fast fire growth. The incubation period ($t_o$) will depend on the nature of the ignition source and its location, but data are now becoming available (see Babrauskas) on fire growth rates on single items of furniture (upholstered chairs, beds, etc.) which may be quantified in these terms. Suggested values for the coefficient $\alpha_f$ are also given in the formula section of Makefire - a subset of the FPETool Computer Program. The specification there for the fire-growth coefficient $\alpha_f$ (kW/s$^2$) is:

| | |
|---|---|
| Slow | 0.002778 kW/s$^2$ |
| Medium | 0.011111 kW/s$^2$ |

| | |
|---|---|
| Fast | 0.044444 $kW/s^2$ |
| Ultra-fast | 0.177778 $kW/s^2$ |

and these correspond to growth times of the fire from zero size to 1 MW total heat output in

| | |
|---|---|
| Slow | 600 seconds |
| Medium | 300 seconds |
| Fast | 150 seconds |
| Ultra-fast | 75 seconds |

## BURNING RATES OF TYPICAL ITEMS

Experimental data are available for a variety of items, giving heat release rate $\dot{Q}$ (kW) vs time (seconds). Each of these graphs is in conformity with several parameters that completely characterize the situation, as given in Figure 1:

| | |
|---|---|
| $t_o$ | time to the onset of ignition |
| $t_{1\,MW}$ | time to reach 1 MW |
| $t_{\ell o}$ | level-off time |
| $t_d$ | time at which $\dot{Q}$ decay begins |
| $t_{end}$ | time at which $\dot{Q}$ equals zero |
| $t_g$ | growth time = $t_{1\,MW} - t_o$ |

Notice that both the ascent and decent are characterized by $t^2$-fire activity:

$$\dot{Q} = \alpha_g t^2 \text{ where } t = t - t_o$$
$$\dot{Q} = \alpha_d t^2 \text{ where } t = t_{end} - t$$

where $\alpha_g$ and $\alpha_d$ are the fire-growth and fire-decay coefficients ($kW/s^2$), respectively.

These heat release rates $\dot{Q}$ (in kW) vs time t (in seconds) are active only in the growth ($t_o \leq t \leq t\ t_{\ell o}$) and decay ($t_d \leq t \leq t_{end}$), respectively. The maximum heat release rate $\dot{Q}_{max}$ (kW) occurs when $t_{\ell o} \leq t \leq t_d$. The growth time to reach 1 MW = 1,000 kW of heat release rate $\dot{Q}$ is $t_{1\,MW} - t_o$ seconds, and this is related to the fire-growth parameter $\alpha_g$ ($kW/s^2$) via

$$\alpha_g = 1000 / (t_{1\,MW} - t_o)^2.$$

Simularly the fire-decay parameter $\alpha_d$ ($kW/s^2$) is found via

$$\alpha_d = \dot{Q}_{max}/(t_{end} - t_d)^2.$$

Also note that the maximum heat release rate $\dot{Q}_{max}$ (kW) is related to other parameters via:

$$\dot{Q}_{max} = 1000[(t_{\ell o} - t_o)/(t_{1\,MW} - t_o)]^2.$$

In order to characterize in the above fashion the actual experimental data of heat release rate versus time, one proceeds as follows:

1. First, one decides the values to be taken for the three key parameters $\dot{Q}_{max}$ (maximum heat release rate), $t_{\ell o}$ (time to reach $\dot{Q}_{max}$) and $t_d$ (time to start decay). Adjustments are made in order to ensure that the modeled total heat release during the time interval of from $t_o$ to $t_d$ seconds matches the experiment to within 0.1 percent.
2. Then, the time to onset of ignition $t_o$ with associated value of fire-growth parameter $\alpha_g$ is chosen so as to match the total heat release during the growth phase of from $t_o$ to $t_{\ell o}$ seconds. The correspondence of $t_o$, $t_{\ell o}$ and $\alpha_g$ is automatic since a $t^2$-fire growth is being assumed.
3. Finally, the end time $t_{end}$ with associated value of fire-decay parameter $\alpha_d$ is chosen so as to match the total heat release during the decay phase of from $t_d$ to $t_{end}$ seconds. Again, the correspondence of $t_d$, $t_{end}$ and $\alpha_d$ is automatic since a $t^2$-fire decay is being assumed.

Modeled data are given for heat release rate $\dot{Q}$ (kW) vs. time (seconds) in Tables A, B, C and D respectively as follows:

1. Furniture calorimeter data from FASTLite (see Portier et al, 1996).
2. Furniture calorimeter data from HAZARD (see Peacock et al, 1994).
3. Furniture calorimeter data from Building and Fire Research Laboratory (see BFRL Website, 1999).
4. Cone calorimeter data from HAZARD (see Peacock et al, 1994).

The data are also given in Figures as follows:

1. Table A, see Figures A1 through A34.
2. Table B, see Figures B1 through B21.
3. Table C, see Figures C1 through C10.
4. Table D, see Fgiures D1 through D25.

Careful perusal and interpretation of the figures will enable the discerning reader to deduce what the values of the defining parameters are. However, for completeness, the data are given directly in the extensive Tables A, B, C, and D in numerical form. Finally $\dot{Q}$ vs. t is given by

| | |
|---|---|
| $\dot{Q} = 0$ | $0 \leq t \leq t_o$ |
| $\dot{Q} = \alpha_g (t - t_o)^2$ | $t_o \leq t \leq t_{\ell o}$ |
| $\dot{Q} = \alpha_g (t_{\ell o} - t_o)^2$ | $t_{\ell o} \leq t \leq t_d$ |
| $\dot{Q} = \alpha_d (t_{end} - t)^2$ | $t_d \leq t \leq t_{end}$ |
| $\dot{Q} = 0$ | $t_{end} \leq t \leq$ Infinity |

with the parameters taken directly from the Tables for the particular item under consideration.

## WHAT HAPPENS NEXT?

During the course of the burning of the first item of furniture in a room, as specified from data such as that just presented in the Table, one of several things might occur. The above has provided information about the burning rate (heat release rate vs. time) of a single specified item in the burn room. What happens next? Either the item burns out without further damage to the surroundings, or one or more nearby items ignite and add fuel to the fire. This can be by direct flame contact (if the second item is judged to be sufficiently close) or, more usually, by radiant heat energy becoming sufficiently large on the surface of the second item. Direct flame contact requires time to pyrolyze the fuel and time to heat the gases produced to their ignition temperature. The radiant flux ignition problem is a very complicated issue, and depends on many factors. The radiant energy comes from the flame above the first item, the upper layer and room surfaces, but simplifying assumptions are sometimes used. As the radiant energy flux rate increases from the first item to the second, often a simple criterion for ignition of the latter is used. A good approximation is that the radiant heat flux (arriving on the surface of the second item) necessary to ignite the second item is:

| | |
|---|---|
| 10 $kW/m^2$ | easily ignitable items, such as thin curtains or loose newsprint |
| 20 $kW/m^2$ | normal items, such as upholstered furniture |
| 40 $kW/m^2$ | difficult to ignite items, such as wood of 0.5 inch or greater thickness |

In actuality, ignition is not immediate when the particular level of incident radiant heat flux reaches 10, 20 or 40 $kW/m^2$ respectively for easy, normal and difficult to ignite items. These values are used as simple rules of thumb in applied calculations, see Lilley (1995). Fundamental ignition principles, outlined for example in SFPE (1995), suggest that, for fire initiation, a material has to be heated above its critical heat flux CHF value (CHF value is related to the fire point). It was found that, as the surface is exposed to heat flux, initially most of the heat is transferred to the interior of the material. The ignition principles suggest that the rate with which heat is transferred depends on the ignition temperature $T_{ig}$, ambient temperature $T_a$, material thermal conductivity k, material specific heat $c_p$, and the material density $\rho$. The combined effects are expressed by a parameter defined at the Thermal Response Parameter (TRP) of the material

$$TRP = \Delta T_{ig} \sqrt{k \rho c_p}$$

where $\Delta T_{ig} (= T_{ig} - T_a)$ is the ignition temperature above ambient in degrees K, k is in kW/m-K, $\rho$ is in $kg/m^3$, $c_p$ is in kJ/kg-K, and TRP is in $kW\text{-}s^{1/2}/m^2$. The TRP is a very useful parameter for the engineering calculations to assess resistance of ignition and fire propagation in as-yet uninvolved items. The ignition principles suggest that, for thermally thick materials, the inverse of the square root of time to ignition is expected to be a linear function of the difference between the external heat flux and the CHF value

$$\sqrt{\frac{1}{t_{ig}}} = \frac{\sqrt{4/\pi}\left(\dot{q}''_e - CHF\right)}{TRP}$$

where $t_{ig}$ is time to ignition sec, $\dot{q}''_e$ is the external heat flux $kW/m^2$, and CHF is in $kW/m^2$. Most commonly used materials behave as thermally thick materials and satisfy this equation.

The Critical Heat Flux and the Thermal Response Parameter values for materials derived from the ignition data measured in the Flammability Apparatus and the Cone Calorimeter, by Scudamore et al (1991, are given in Lilley (1998). He also shows in Tables and Figures how the ignition time $t_{ig}$ may be determined from the heat flux $\dot{q}''$ and the Critical Heat Flux CHF and Thermal Response Parameter TRP. Complete data are given in Lilley (1998) so as to enable the ignitability question to be determined quickly. Readers are directed to that study to see fully how the size and material of a pool fire determines the total heat release $\dot{Q}$, the heat flux $\dot{q}''$ on a target fuel, and the time required for ignition to occur.

## FLASHOVER

Whether or not "flashover" occurs during the course of a fire is one of the most important outcomes of a fire calculation. Flashover is characterized by the rapid transition in fire behavior from localized burning of fuel to the involvement of all combustibles in the enclosure. High radiation heat transfer levels from the original burning item, the flame and plume directly above it, and the hot smoke layer spreading across the ceiling are all considered to be responsible for the heating of the other items in the room, leading to their ignition. Warning signs are heat build-up and "rollover" (small, sporadic flashes of flame that appear near ceiling level or at the top of open doorways or windows of smoke-filled rooms). Factors affecting flashover include room size, ceiling and wall conductivity and flammability, and heat- and smoke-producing quality of room contents. Further research studies relating to this topic include Kim and Lilley (1997 and 1999), and Lilley (1995, 1997 and 1998).

## CLOSURE

The ability to determine fire growth in terms of when the second and subsequent objects may ignite (and their burning rates) and whether or not "flashover" occurs depends strongly on the initial fire specification. The focus of this entire document was to characterize the initial item on fire (in terms of burning rate versus time) so as to more accurately be able to calculate fire growth and the possible occurrence of flashover.

Heat release rates of typical items in fires were needed as a prerequisite for estimating fire growth and temperatures in structural fires. That is, these burning rates were required to be specified by the user as input to single-room and multi-room structural fire computer codes like FPETool, FASTLife and HAZARD. Data was given here that permit burning items to be specified in a permit burning items to be specified in a useful modeled way, taking a $t^2$-fire for the growth and decay periods, with a constant maximum heat release rate between these two periods.

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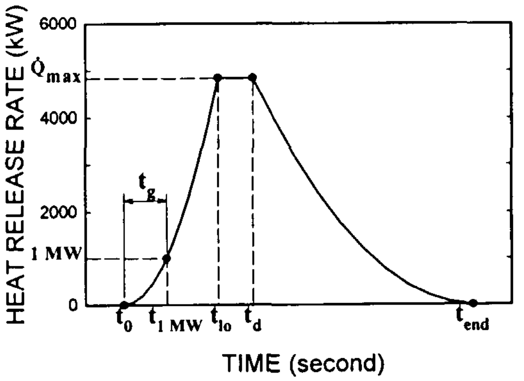


Figure 1. Heat Release Rate vs. Time in $t^2$-fire Characterization.

# TABLE A. Heat Release Rate vs Time in $t^2$-fire Characterization of FASTLite Data

| | CODE | DESCRIPTION | $t_0$ | $t_{1\,MW}$ | $t_{lo}$ | $t_d$ | $t_{end}$ | $\dot{Q}_{max}$ | $t_g$ | $\alpha_g$ | $\alpha_d$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fig. A1. | Wardrobe 1 | 1/2" Plywood wardrobe, clothing on 16 hangers | 0 | 35 | 60 | 90 | 500 | 2938.8 | 35 | 0.816327 | 0.017482 |
| Fig. A2. | Wardrobe 2 | 1/8" Plywood wardrobe, clothing on 16 hangers | 0 | 40 | 100 | 110 | 140 | 6250.0 | 40 | 0.625000 | 6.944444 |
| Fig. A3. | Wardrobe 3 | 1/8" Plywood wardrobe, FR paint, clothing on 16 hangers | 0 | 30 | 70 | 80 | 400 | 5444.4 | 30 | 1.111111 | 0.053168 |
| Fig. A4. | Wardrobe 4 | 1/8" Plywood wardrobe, FR paint, clothing on 16 hangers | 0 | 90 | 150 | 160 | 450 | 2777.8 | 90 | 0.123457 | 0.033029 |
| Fig. A5. | Wardrobe 5 | 3/4" Particle-board wardrobe, thin plastic coating | 0 | 150 | 170 | 670 | 2000 | 1284.4 | 150 | 0.044444 | 0.000726 |
| Fig. A6. | Chair 1 | Chair, one-piece wood-reinforced urethane foam | 0 | 1000 | 650 | 660 | 1900 | 422.5 | 1000 | 0.001000 | 0.000275 |
| Fig. A7. | Chair 2 | Chair, polypropylene foam frame, urethane foam, polyolefin fabric | 0 | 100 | 140 | 160 | 500 | 1960.0 | 100 | 0.100000 | 0.016955 |
| Fig. A8. | Chair 3 | Chair, thin wood frame, California foam, polyolefin fabric | 0 | 200 | 175 | 176 | 900 | 765.6 | 200 | 0.025000 | 0.001461 |
| Fig. A9. | Chair 4 | Chair, urethane foam frame, urethane foam, polyolefin fabric | 0 | 60 | 60 | 210 | 430 | 1000.0 | 60 | 0.277778 | 0.020661 |
| Fig. A10. | Chair 5 | Chair, wood frame, California foam, Haitian cotton fabric | 0 | 350 | 275 | 475 | 1000 | 617.3 | 350 | 0.008163 | 0.002240 |
| Fig. A11. | Chair 6 | Chair, wood frame, California foam, polyolefin fabric | 0 | 50 | 70 | 90 | 315 | 1960.0 | 50 | 0.400000 | 0.038716 |
| Fig. A12. | Chair 7 | Chair, wood frame, FR cotton stuffing, Haitian cotton fabric | 0 | 2000 | 210 | 310 | 1000 | 11.0 | 2000 | 0.000250 | 0.000023 |
| Fig. A13. | Chair 8 | Chair, wood frame, FR cotton stuffing, polyolefin fabric | 0 | 400 | 275 | 475 | 1000 | 472.7 | 400 | 0.006250 | 0.001715 |
| Fig. A14. | Chair 9 | Chair, wood frame, urethane foam, cotton fabric | 0 | 200 | 90 | 310 | 550 | 202.5 | 200 | 0.025000 | 0.003516 |
| Fig. A15. | Chair 10 | Chair, wood frame, urethane foam, cotton fabric | 0 | 75 | 50 | 250 | 1250 | 444.4 | 75 | 0.177778 | 0.000444 |
| Fig. A16. | Chair 11 | Chair, wood frame, urethane foam, cotton fabric, polyester batting | 0 | 425 | 347 | 367 | 1000 | 666.6 | 425 | 0.005536 | 0.001664 |
| Fig. A17. | Chair 12 | Chair, wood frame, urethane foam, polyolefin fabric | 0 | 80 | 160 | 170 | 420 | 4000.0 | 80 | 0.156250 | 0.064000 |
| Fig. A18. | Chair 13 | Chair, wood frame, urethane foam, quilted cotton/polyolefin, polyester batting | 0 | 200 | 187 | 200 | 500 | 874.2 | 200 | 0.025000 | 0.009714 |
| Fig. A19. | Bed | Innerspring mattress and boxspring, cotton felt/urethane/sisal spring cover | 0 | 1100 | 680 | 1080 | 1300 | 382.1 | 1100 | 0.000826 | 0.007896 |
| Fig. A20. | Lounge chair 1 | Lounge chair, metal frame, urethane foam, plastic-coated fabric | 0 | 350 | 170 | 220 | 350 | 235.9 | 350 | 0.008163 | 0.013960 |
| Fig. A21. | Lounge chair 2 | Lounge chair, one-piece molded glass fiber, metal legs | 0 | 120 | 20 | 21 | 150 | 27.8 | 120 | 0.069444 | 0.001669 |
| Fig. A22. | Lounge chair 3 | Lounge chair, one-piece molded thermoplastic | 0 | 275 | 230 | 430 | 900 | 699.5 | 275 | 0.013223 | 0.003167 |
| Fig. A23. | Lounge chair 4 | Lounge chair, wood frame, latex foam/cotton stuffing, plastic-coated fabric | 0 | 500 | 130 | 140 | 300 | 67.6 | 500 | 0.004000 | 0.002641 |
| Fig. A24. | Loveseat 1 | Loveseat, mixed foam and cotton batting stuffing, cotton fabric | 0 | 400 | 350 | 400 | 2000 | 765.6 | 400 | 0.006250 | 0.000299 |
| Fig. A25. | Loveseat 2 | Loveseat, wood frame, California foam, polyolefin fabric | 0 | 80 | 130 | 160 | 400 | 2640.6 | 80 | 0.156250 | 0.045844 |
| Fig. A26. | Loveseat 3 | Loveseat, Wood frame, urethane foam, plastic-coated fabric | 0 | 350 | 330 | 430 | 1500 | 889.0 | 350 | 0.008163 | 0.000776 |
| Fig. A27. | Metal wardrobe 1 | Metal wardrobe, clothing on 16 hangers | 0 | 250 | 125 | 150 | 500 | 250.0 | 250 | 0.016000 | 0.002041 |
| Fig. A28. | Metal wardrobe 2 | Metal wardrobe, clothing on 8 hangers | 0 | 50 | 40 | 47 | 200 | 640.0 | 50 | 0.400000 | 0.027340 |
| Fig. A29. | Patient lounge chair | Patient lounge chair, metal frame, urethane foam cushion | 0 | 170 | 80 | 90 | 150 | 221.5 | 170 | 0.034602 | 0.061515 |
| Fig. A30. | Sofa 1 | Sofa, metal frame, urethane foam, plastic-coated fabric | 0 | 500 | 260 | 460 | 800 | 270.4 | 500 | 0.004000 | 0.002339 |
| Fig. A31. | Sofa 2 | Sofa, wood frame, California foam, polyolefin fabric | 0 | 100 | 170 | 250 | 430 | 2890.0 | 100 | 0.100000 | 0.089198 |
| Fig. A32. | F21 Chair | F21 Chair, wood frame, polyurethane foam, olefin fabric | 140 | 215 | 250 | 250 | 360 | 2151.1 | 75 | 0.177778 | 0.177778 |
| Fig. A33. | F31 Loveseat | F31 Loveseat, wood frame, polyurethane foam, olefin fabric | 90 | 165 | 215 | 265 | 390 | 2777.8 | 75 | 0.177778 | 0.177778 |
| Fig. A34. | F32 Sofa | F32 Sofa, wood frame, polyurethane foam, olefin fabric | 75 | 150 | 205 | 270 | 400 | 3004.4 | 75 | 0.177778 | 0.177778 |

**TABLE B. Heat Release Rate vs Time in $t^2$-fire Characterization of HAZARD Data (Furniture Calorimeter)**

| | CODE | | DESCRIPTION | IGNITION SOURCE | $t_0$ | $t_{1\,MW}$ | $t_{lo}$ | $t_d$ | $t_{end}$ | $\dot{Q}_{max}$ | $t_g$ | $\alpha_g$ | $\alpha_d$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fig. B1. | Bed 1 | BED001 | Double bed,bedding,night table;gyp bd walls;test R1 (85-2998) | Wastebasket&trash,0.75 kg | 169 | 211 | 230 | 230 | 936 | 2109.4 | 42 | 0.566893 | 0.004232 |
| Fig. B2. | Bed 2 | BED002 | Double bed,bedding,night table;plywood walls;test R5 (85-2998) | Wastebasket&trash,0.75 kg | 164 | 239 | 360 | 430 | 998 | 6829.5 | 75 | 0.177778 | 0.021169 |
| Fig. B3. | Chair 1 (F21) | UPC001 | Upholstered chair,F21,wood frame,pu foam-fr,olefin | Gas burner,50kw,200s | 126 | 218 | 260 | 260 | 607 | 2121.5 | 92 | 0.118147 | 0.017619 |
| Fig. B4. | Chair 2 (F23) | UPC002 | Chair,F23,wood frame,fr cotton batting,olefin test 24 (82-2604) | Gas burner,50kw,200s | 0 | 538 | 450 | 450 | 1932 | 699.6 | 538 | 0.003455 | 0.000319 |
| Fig. B5. | Chair 3 (F25) | UPC003 | Upholstered chair,F25,wood frame,pu foam,olefin,test 29 | Gas burner,50kw,200sec | 106 | 215 | 260 | 260 | 679 | 1996.1 | 109 | 0.084168 | 0.011370 |
| Fig. B6. | Chair 4 (F28) | UPC004 | Uphols.chair,F28,wood frame,pu/pe/ctn bedding,cotton test 28 | Gas burner,50kw,200sec | 82 | 478 | 420 | 420 | 1184 | 728.5 | 396 | 0.006377 | 0.001248 |
| Fig. B7. | Chair 5 (F30) | UPC005 | Uphols.chair,F30,pu frame,pu foam,olefin,test 30 (82-2604) | Gas burner,50kw,200sec | 40 | 140 | 130 | 263 | 1017 | 810.0 | 100 | 0.100000 | 0.001425 |
| Fig. B8. | Chair 6 | CHR001 | Bean bag chair,vinyl/ps foam beads,c05 nbs tn 1103 | Newspaper,396g | 88 | 748 | 545 | 718 | 1228 | 479.5 | 660 | 0.002296 | 0.001843 |
| Fig. B9. | Chair 7 | CHR002 | Chair,molded flexible pu frame,pu cover test 64 (83-2787) | Gas burner,50kw,200s | 644 | 1662 | 1330 | 1330 | 2685 | 454.1 | 1018 | 0.000965 | 0.000247 |
| Fig. B10. | Chair 8 | CHR003 | Easy chair,molded ps foam frame,pu pad&cover,c07,test 48 | Gas burner,50kw,200s | 38 | 245 | 240 | 240 | 883 | 952.3 | 207 | 0.023338 | 0.002303 |
| Fig. B11. | Christmas Tree | CTR001 | Christmas tree,spruce,dry, vtt 285,no.17 | 200 ml isopropanol | 290 | 327 | 320 | 350 | 478 | 657.4 | 37 | 0.730460 | 0.040125 |
| Fig. B12. | Cooking Oil | CKG001 | Cooking Oil,Corn;Cottonseed;Etc In 12in.Pan | | 0 | 15 | 5 | 1000 | 1000 | 111.1 | 15 | 4.444444 | |
| Fig. B13. | Curtain | CUR001 | Curtain,Cotton,0.31kg/M2,Item 9 | 5ml isopropanol | 123 | 229 | 175 | 175 | 411 | 240.7 | 106 | 0.089000 | 0.004321 |
| Fig. B14. | Loveseat (F31) | UPS002 | Loveseat,F31,wood frame,pu foam(fr),olefin test 37 (82-2604) | Gas burner,50kw,200s | 71 | 165 | 229 | 249 | 701 | 2825.3 | 94 | 0.113173 | 0.013829 |
| Fig. B15. | Mattress 1 | MAT001 | Mattress,m05,pu foam,rayon ticking,bedding | Wastebasket+0.72kg cont | 269 | 437 | 480 | 480 | 933 | 1577.4 | 168 | 0.035431 | 0.007687 |
| Fig. B16. | Mattress 2 | MAT002 | Mattress+boxspring(westchase hilton) test 67 (83-2787) | Cigarette lighter | 144 | 858 | 606 | 980 | 2233 | 418.7 | 714 | 0.001962 | 0.000267 |
| Fig. B17. | Sofa (F32) | UPS001 | Upholstered\sofa,F32,wood\frame,pu foam-fr,olefin test 38 | Gas burner,50kw,200s | 74 | 154 | 211 | 283 | 651 | 2932.7 | 80 | 0.156250 | 0.021655 |
| Fig. B18. | Trash Bags | TRB001 | Trash bags (3),paper | | 0 | 100 | 58 | 111 | 517 | 336.4 | 100 | 0.100000 | 0.002041 |
| Fig. B19. | TV Set | TLV001 | Television set,b/w,wood cabinet,exp.3 | 100ml isopropanol | 304 | 984 | 670 | 670 | 1872 | 289.7 | 680 | 0.002163 | 0.000201 |
| Fig. B20. | Wardrobe | CLT001 | Wardrobe closet,plywood,fr paint nbsir83-2787 test 42 | Cardboard box/paper 0.9kg | 70 | 113 | 170 | 170 | 358 | 5408.3 | 43 | 0.540833 | 0.153020 |
| Fig. B21. | Waste Basket | WPB001 | Wastepaper basket,polyethylene,milk cartons,exp.7 | 10ml isopropanol | 115 | 2034 | 350 | 350 | 1264 | 15.0 | 1919 | 0.000272 | 0.000018 |

# TABLE C. Heat Release Rate vs Time in $t^2$-fire Characterization of Building and Fire Research Laboratory Data

| | CODE | DESCRIPTION | $t_0$ | $t_{1\,MW}$ | $t_{lo}$ | $t_d$ | $t_{end}$ | $\dot{Q}_{max}$ | $t_g$ | $\alpha_g$ | $\alpha_d$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fig. C1. | Bunk Bed | BFRL* in February 1996. | 186 | 211 | 240 | 240 | 445 | 4665.6 | 25 | 1.600000 | 0.111020 |
| Fig. C2. | Koisk | Western Fire Center in the summer of 1995. | 817 | 1129 | 1230 | 1230 | 3300 | 1752.2 | 312 | 0.010273 | 0.000409 |
| Fig. C3. | Loveseat | | 48 | 222 | 350 | 371 | 866 | 3012.4 | 174 | 0.033029 | 0.012294 |
| Fig. C4. | Mattress (Center) | BFRL in February 1996. | 9 | 173 | 145 | 219 | 959 | 687.7 | 164 | 0.037180 | 0.001256 |
| Fig. C5. | Mattress (Corner) | BFRL in February 1996. | 85 | 294 | 295 | 321 | 484 | 1009.6 | 209 | 0.022893 | 0.037999 |
| Fig. C6. | Small Dresser | BFRL in February 1996. | 112 | 346 | 423 | 423 | 870 | 1766.4 | 234 | 0.018263 | 0.008840 |
| Fig. C7. | Sofa | | 26 | 222 | 390 | 399 | 931 | 3449.0 | 196 | 0.026031 | 0.012186 |
| Fig. C8. | Wooden Pallet | BFRL in February 1996. | 0 | 467 | 634 | 664 | 1616 | 1843.1 | 467 | 0.004585 | 0.002034 |
| Fig. C9. | Workstation (2 panels) | Sponsored by GSA** and performed at BFRL in 1991. | 132 | 244 | 280 | 280 | 3276 | 1746.2 | 112 | 0.079719 | 0.000195 |
| Fig. C10. | Workstation (3 panels) | Sponsored by GSA and performed at BFRL in 1991. | 283 | 386 | 550 | 550 | 1142 | 6719.7 | 103 | 0.094260 | 0.019174 |

* BFRL – Building and Fire Research Laboratory
** GSA – General Services Administration

## TABLE D. Heat Release Rate vs Time in $t^2$-fire Characterization of HAZARD Data (Cone Calorimeter)

| | CODE | | DESCRIPTION | | $t_0$ | $t_{1MW}$* | $t_{lo}$ | $t_d$ | $t_{end}$ | $\dot{Q}''_{max}$** | $t_g$ | $\alpha_g$ | $\alpha_d$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fig. D1. | Cotton Fabric | CTN002 | Cotton fabric,fr (test 803a) | Fabric | 29 | 89 | 45 | 45 | 206 | 71.1 | 60 | 0.277778 | 0.002743 |
| Fig. D2. | Fir Board | DFR003 | Douglas fir (828) | Board | 2 | 32 | 15 | 15 | 1502 | 187.8 | 30 | 1.111111 | 0.000085 |
| Fig. D3. | Fir Plywood Board 1 | DFP002 | Douglas fir plywood,1/2in.thick (435) | Board | 74 | 124 | 92 | 604 | 1193 | 129.6 | 50 | 0.400000 | 0.000374 |
| Fig. D4. | Fir Plywood Board 2 | DFP002 | Douglas fir plywood,1/2in.thick (446) | Board | 0 | 28 | 13 | 309 | 1829 | 215.6 | 28 | 1.275510 | 0.000093 |
| Fig. D5. | Gypsum Board 1 | GBD002 | Gypsum board,1/2in.thick (434) | | 228 | 280 | 243 | 246 | 274 | 83.2 | 52 | 0.369822 | 0.106135 |
| Fig. D6. | Gypsum Board 2 | GBD002 | Gypsum board,1/2in.thick (448) | | 6 | 66 | 30 | 30 | 102 | 160.0 | 60 | 0.277778 | 0.030864 |
| Fig. D7. | Mattress Composite | MAT001 | Mattress ass'y m05,pu foam,rayon ticking (test 296) | Composite | 8 | 44 | 28 | 111 | 164 | 308.6 | 36 | 0.771605 | 0.109876 |
| Fig. D8. | Oak Board 1 | RDO002 | Red oak,7/8in.thick (1454) | | 156 | 191 | 166 | 1684 | 2310 | 81.6 | 35 | 0.816327 | 0.000208 |
| Fig. D9. | Oak Board 2 | RDO002 | Red oak,7/8in.thick (1456) | Board | 0 | 26 | 11 | 707 | 1802 | 179.0 | 26 | 1.479290 | 0.000149 |
| Fig. D10. | Oak Board 3 | RDO002 | Red oak,7/8 in.thick (1468) | Board | 0 | 28 | 13 | 806 | 1354 | 215.6 | 28 | 1.275510 | 0.000718 |
| Fig. D11. | Pine Board 1 | PIN002 | Pine (838) | Board | 14 | 19 | 16 | 637 | 940 | 160.0 | 5 | 40.000000 | 0.001743 |
| Fig. D12. | Pine Board 2 | PIN002 | Pine (842) | Board | 111 | 198 | 137 | 834 | 1511 | 89.3 | 87 | 0.132118 | 0.000195 |
| Fig. D13. | Pine Board 3 | PIN002 | White pine (wood),0.75 in (test 487) | Board | 0 | 8 | 3 | 587 | 4048 | 140.6 | 8 | 15.625000 | 0.000012 |
| Fig. D14. | Pine Board 4 | PIN002 | White pine (wood),0.75 in (test 493) | Board | 40 | 67 | 47 | 1097 | 4176 | 67.2 | 27 | 1.371742 | 0.000007 |
| Fig. D15. | PMMA Sheet 1 | MMA001 | PMMA 1" black (cb) w/frame (test 1461) | Sheet | 0 | 123 | 115 | 804 | 1032 | 874.1 | 123 | 0.066098 | 0.016816 |
| Fig. D16. | PMMA Sheet 2 | MMA001 | PMMA 1" black (cb) w/frame (test 1470) | Sheet | 148 | 218 | 197 | 1689 | 2240 | 490.0 | 70 | 0.204082 | 0.001614 |
| Fig. D17. | Polyisocyanurate Foam 1 | RPI002 | Rigid polyisocyanurate foam,2 in (test 438) | Foam | 0 | 40 | 9 | 9 | 61 | 50.6 | 40 | 0.625000 | 0.018722 |
| Fig. D18. | Polyisocyanurate Foam 2 | RPI002 | Rigid polyisocyanurate foam,2 in (test 449) | Foam | 0 | 15 | 6 | 6 | 1127 | 160.0 | 15 | 4.444444 | 0.000127 |
| Fig. D19. | Polystyrene Foam | PSF004 | Polystyrene foam,2 in (test 437) | Foam | 84 | 268 | 201 | 201 | 417 | 404.3 | 184 | 0.029537 | 0.008666 |
| Fig. D20. | Polyurethane Foam 1 | FPU007 | Flexible polyurethane foam,fr,2 in (test 725) | Foam | 15 | 112 | 80 | 80 | 158 | 449.0 | 97 | 0.106281 | 0.073806 |
| Fig. D21. | Polyurethane Foam 2 | RPU001 | Rigid polyurethane foam,gm-29/gm-30 (test 257) | Foam | 0 | 33 | 15 | 15 | 260 | 206.6 | 33 | 0.918274 | 0.003442 |
| Fig. D22. | Polyurethane Foam 3 | RPU002 | Rigid polyurethane foam,fr,gm-31 (test 258) | Foam | 0 | 36 | 12 | 12 | 115 | 111.1 | 36 | 0.771605 | 0.010473 |
| Fig. D23. | Polyvinyl Sheet | PVC002 | Polyvinyl chloride,0.5 in thick (test 333) | Sheet | 12 | 102 | 37 | 703 | 768 | 77.2 | 90 | 0.123457 | 0.018263 |
| Fig. D24. | Rayon Fabric | RYN001 | Rayon fabric (test 804a) | Fabric | 26 | 73 | 40 | 40 | 71 | 88.7 | 47 | 0.452694 | 0.092329 |
| Fig. D25. | Wool Fabric | WNE001 | Wool fabric/neoprene padding (test 722) | Composite | 23 | 62 | 45 | 45 | 167 | 318.2 | 39 | 0.657462 | 0.021379 |

* In this table, $t_{1MW}$ refers to the time to reach 1 $MW/m^2$.

** In this table, $\dot{Q}_{max}$ refers to the maximum heat release rate in $kW/m^2$.

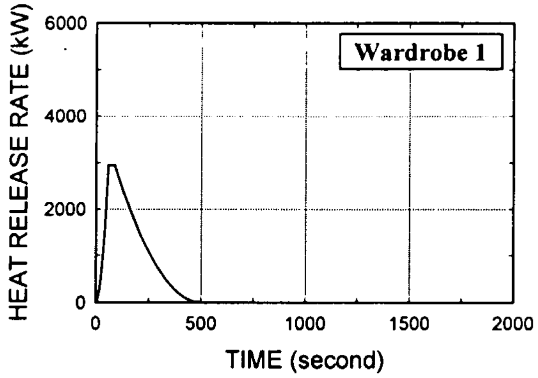


Fig. A1. 1/2" Plywood wardrobe, clothing on 16 hangers

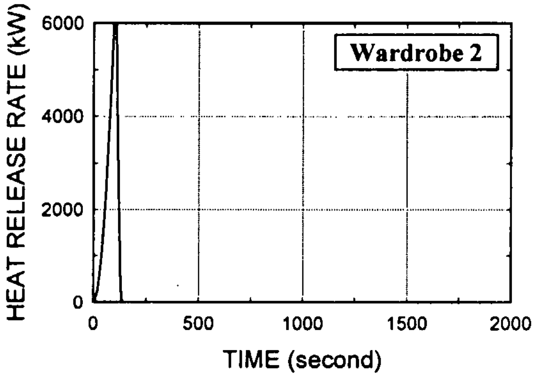


Fig. A2. 1/8" Plywood wardrobe, clothing on 16 hangers

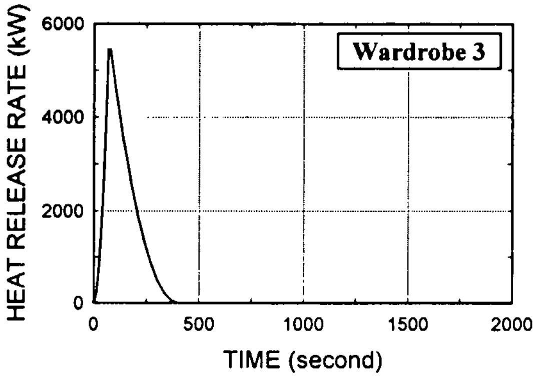


Fig. A3. 1/8" Plywood wardrobe, FR paint, clothing on 16 hangers

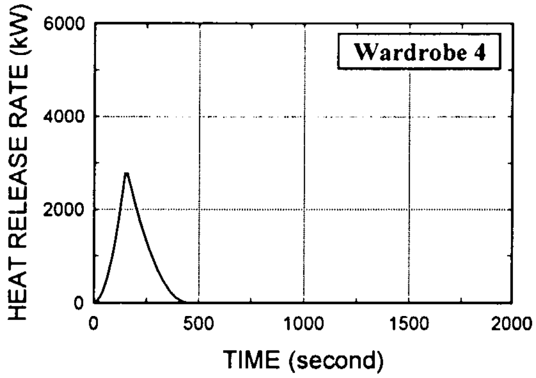


Fig. A4. 1/8" Plywood wardrobe, FR paint, clothing on 16 hangers

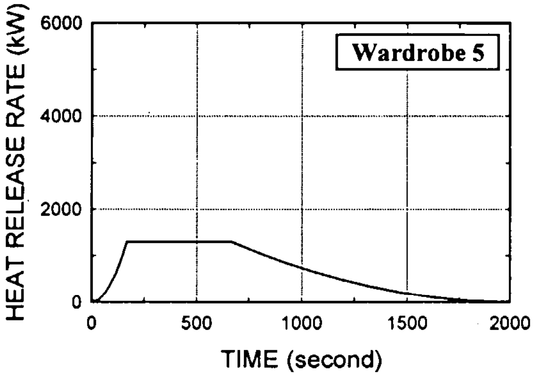


Fig. A5. 3/4" Particle-board wardrobe, thin plastic coating

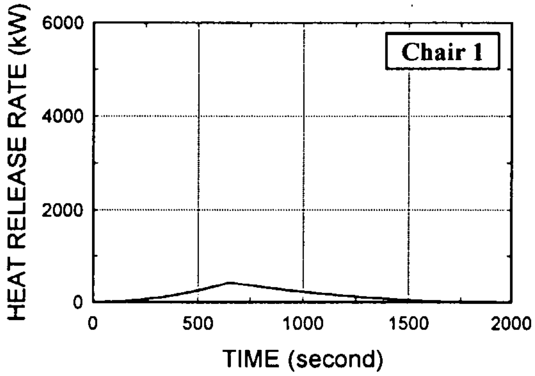


Fig. A6. Chair, one-piece wood-reinforced urethane foam

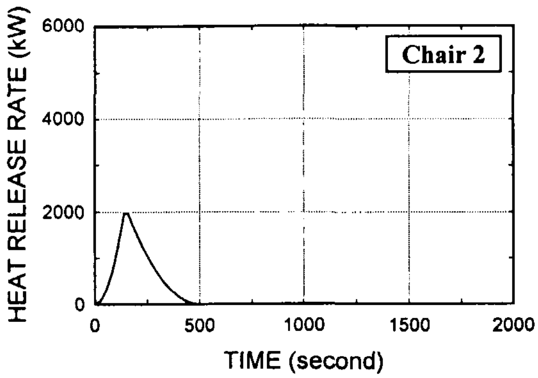


Fig. A7. Chair, polypropylene foam frame, urethane foam, polyolefin fabric

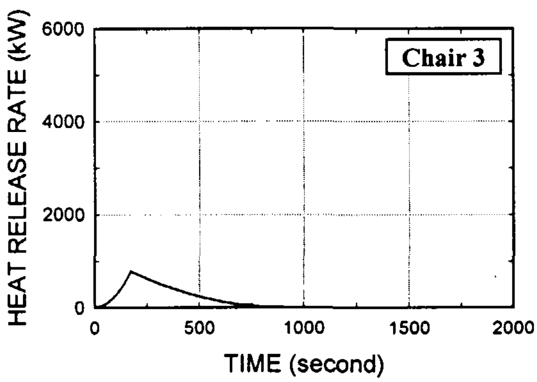


Fig. A8. Chair, thin wood frame, California foam, polyolefin fabric

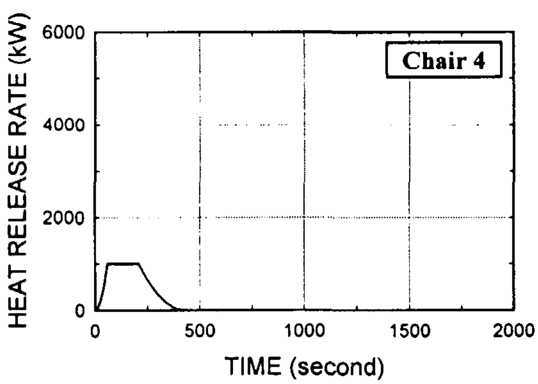


Fig. A9. Chair, urethane foam frame, urethane foam, polyolefin fabric

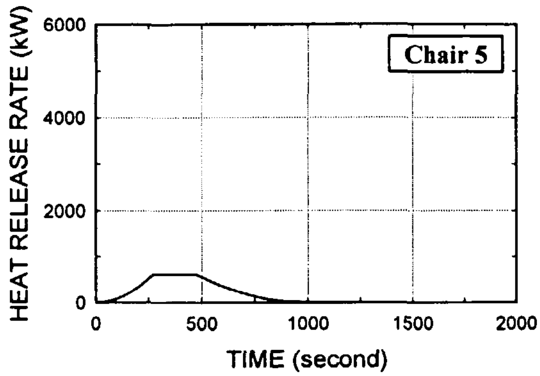


Fig. A10. Chair, wood frame, California foam, Haitian cotton fabric

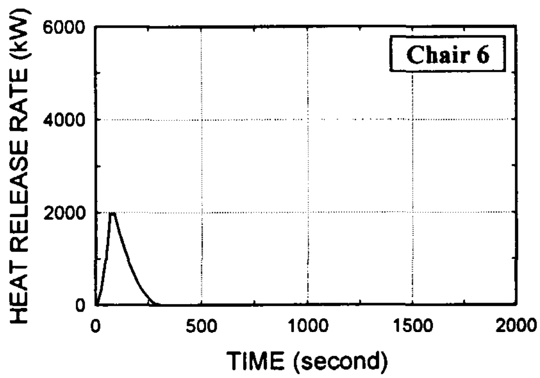


Fig. A11. Chair, wood frame, California foam, polyolefin fabric

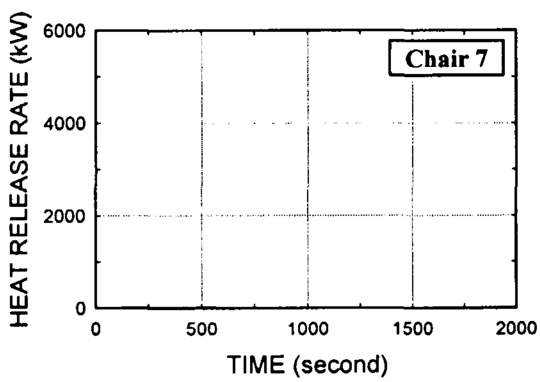


Fig. A12. Chair, wood frame, FR cotton stuffing, Haitian cotton fabric

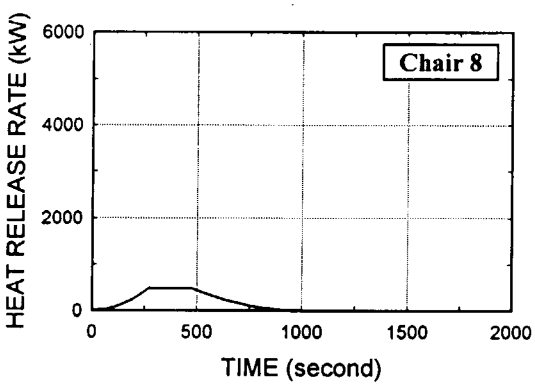


Fig. A13. Chair, wood frame, FR cotton stuffing, polyolefin fabric

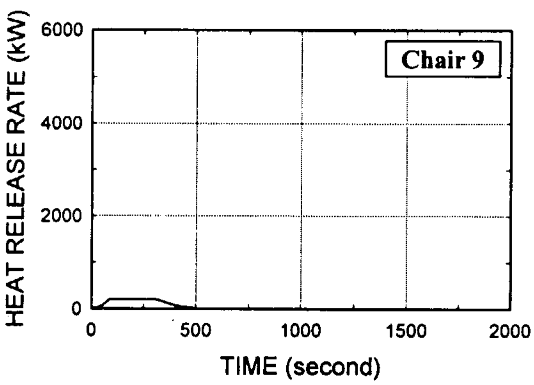


Fig. A14. Chair, wood frame, urethane foam, cotton fabric

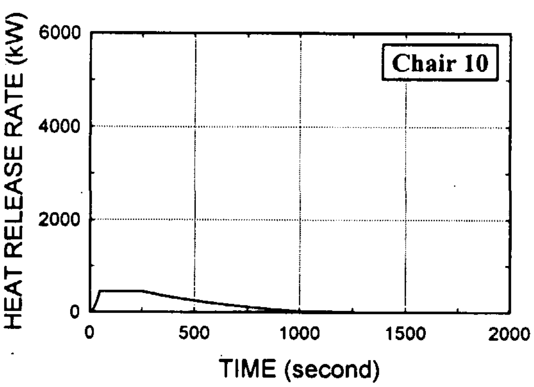


Fig. A15. Chair, wood frame, urethane foam, cotton fabric

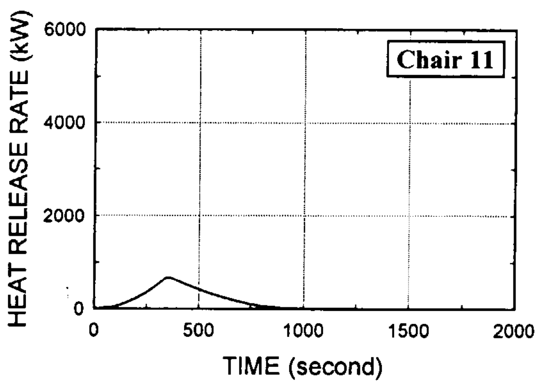


Fig. A16. Chair, wood frame, urethane foam, cotton fabric, polyester batting

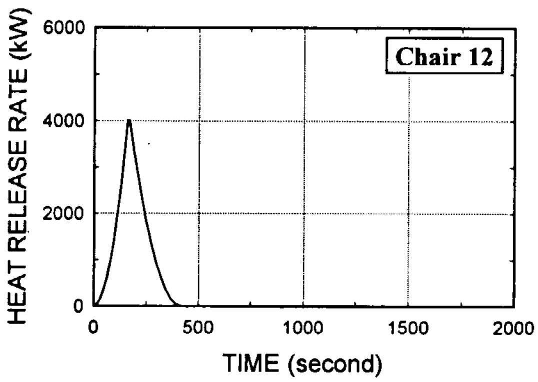


Fig. A17. Chair, wood frame, urethane foam, polyolefin fabric

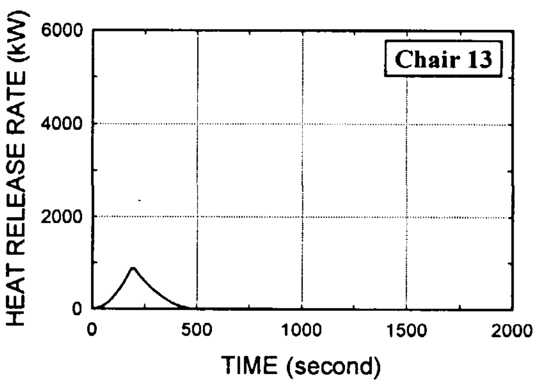


Fig. A18. Chair, wood frame, urethane foam, quilted cotton/polyolefin, polyester batting

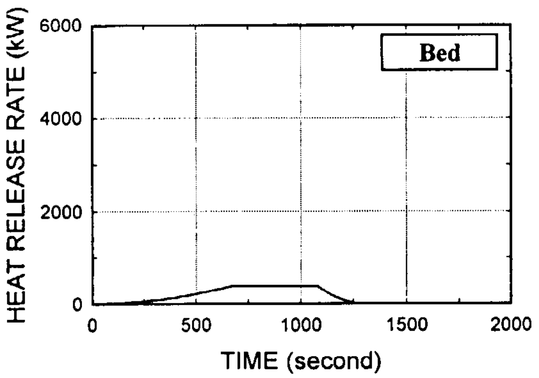


Fig. A19. Innerspring mattress and boxspring, cotton felt/urethane/sisal spring cover

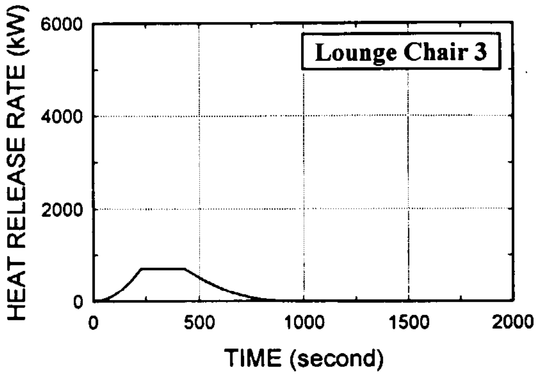


Fig. A22. Lounge chair, one-piece molded thermoplastic

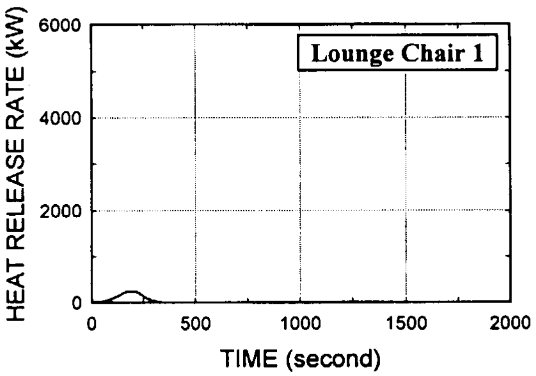


Fig. A20. Lounge chair, metal frame, urethane foam, plastic-coated fabric

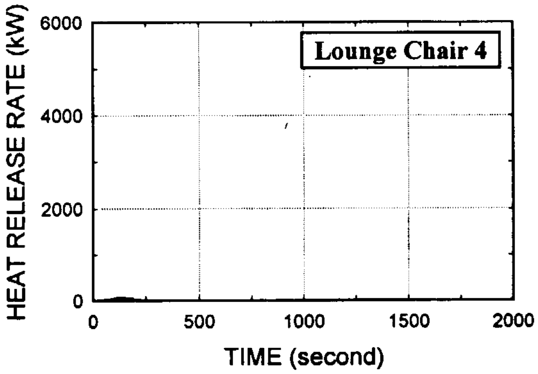


Fig. A23. Lounge chair, wood frame, latex foam/cotton stuffing, plastic-coated fabric

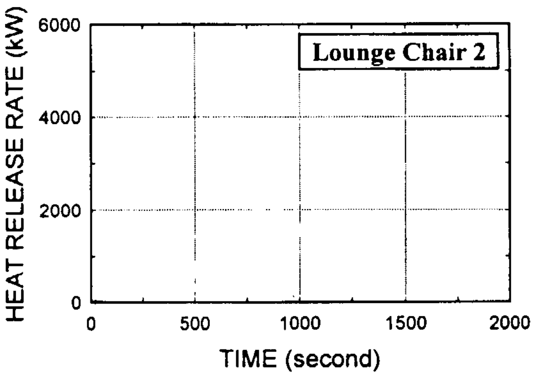


Fig. A21. Lounge chair, one-piece molded glass fiber, metal legs

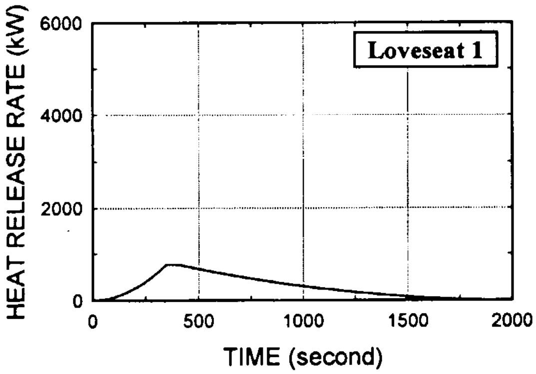


Fig. A24. Loveseat, mixed foam and cotton batting stuffing, cotton fabric

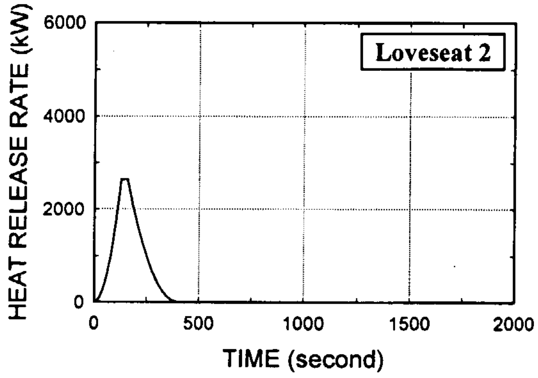


Fig. A25. Loveseat, wood frame, California foam, polyolefin fabric

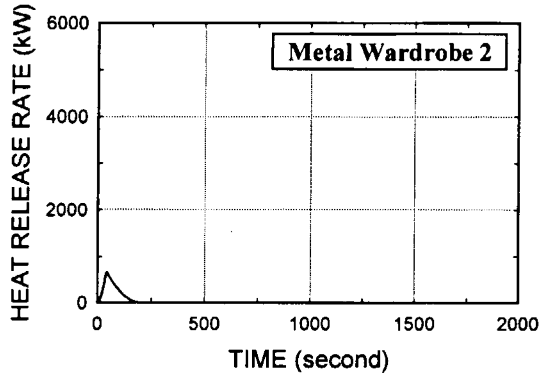


Fig. A28. Metal wardrobe, clothing on 8 hangers

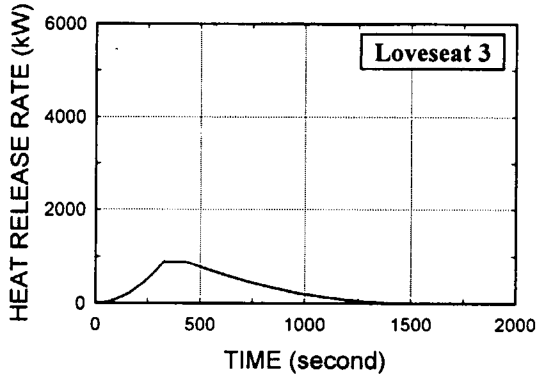


Fig. A26. Loveseat, wood frame, urethane foam, plastic-coated fabric

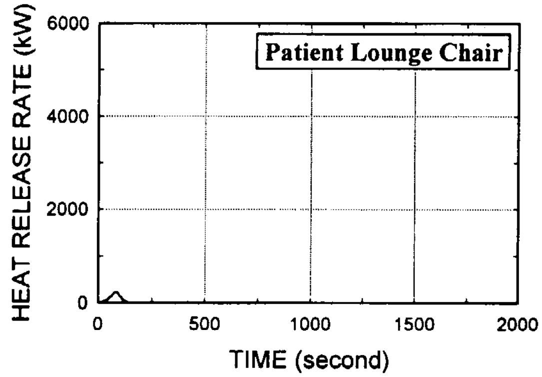


Fig. A29. Patient lounge chair, metal frame, urethane foam cushion

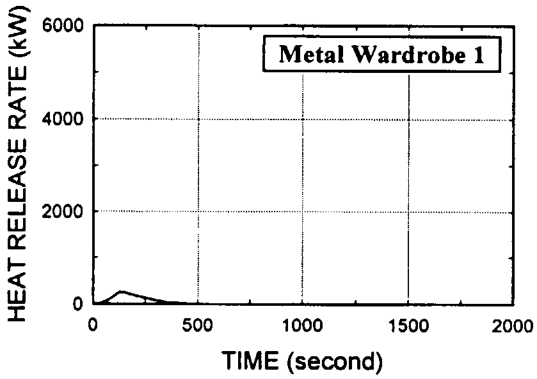


Fig. A27. Metal wardrobe, clothing on 16 hangers

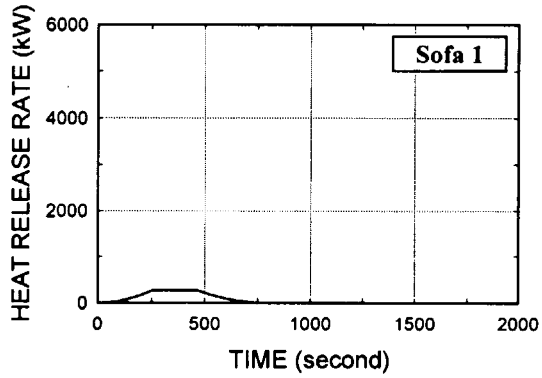


Fig. A30. Sofa, metal frame, urethane foam, plastic-coated fabric

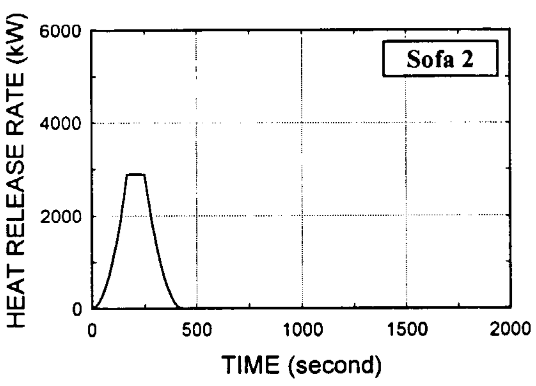


Fig. A31. Sofa, wood frame, California foam, polyolefin fabric

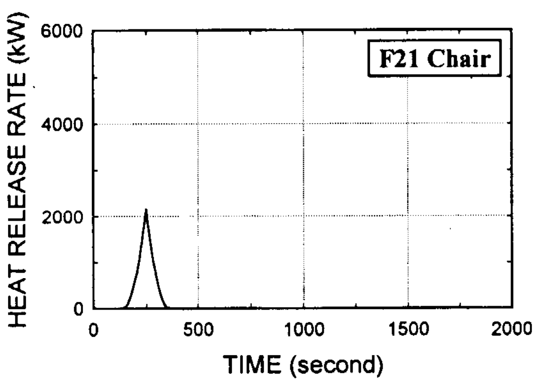


Fig. A32. F21 Chair, wood frame, polyurethane foam, olefin fabric

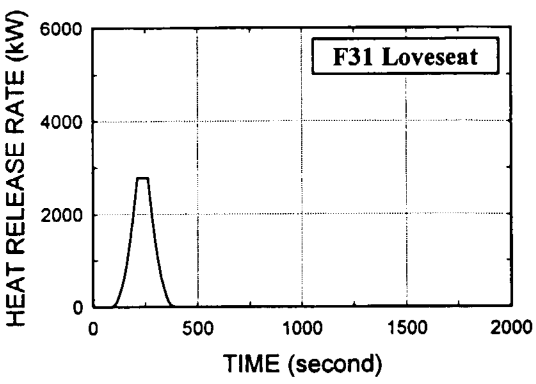


Fig. A33. F31 Loveseat, wood frame, polyurethane foam, olefin fabric

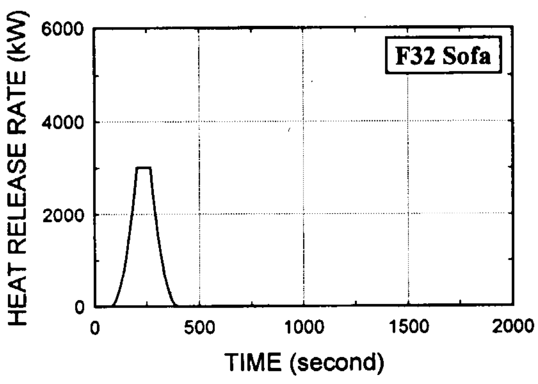


Fig. A34. F32 Sofa, wood frame, polyurethane foam, olefin fabric

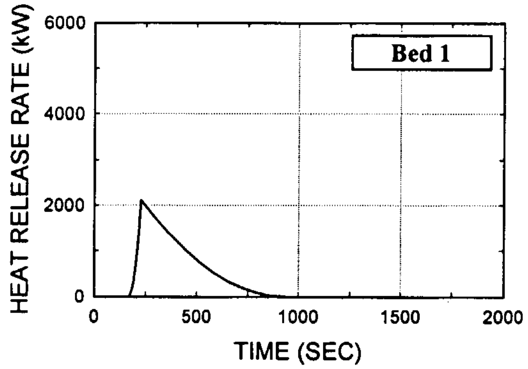


Fig. B1. Double bed, bedding, night table; gyp bd walls; test R1 (85-2998)

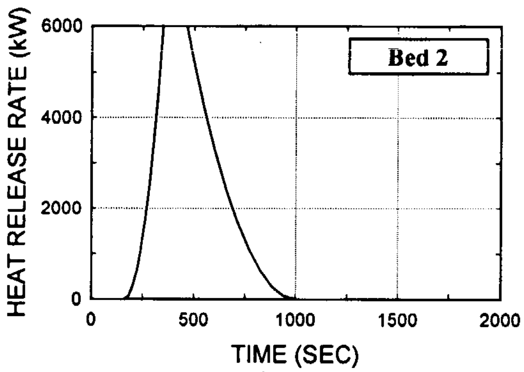


Fig. B2. Double bed, bedding, night table; plywood walls; test R5 (85-2998)

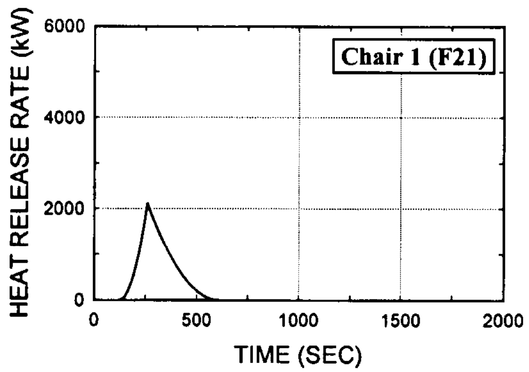


Fig. B3. Upholstered chair, F21, wood frame, pu foam-fr, olefin

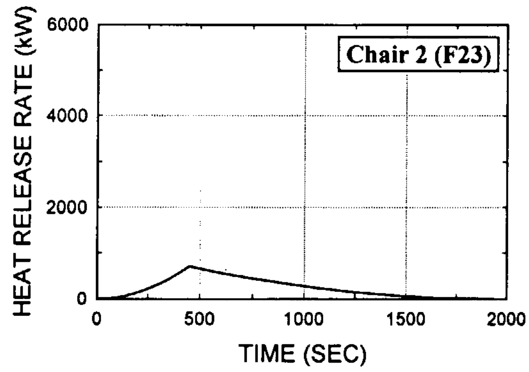


Fig. B4. Chair, F23, wood frame, fr cotton batting, olefin test 24(82-2604)

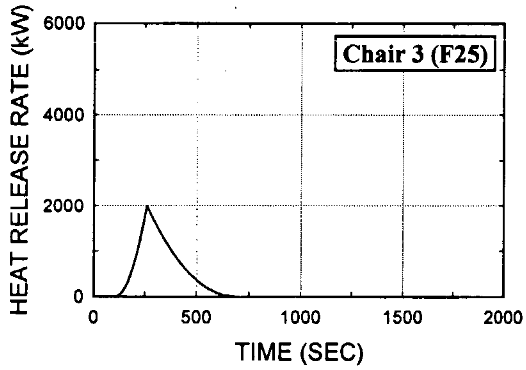


Fig. B5. Upholstered chair, F25, wood frame, pu foam, olefin, test 29

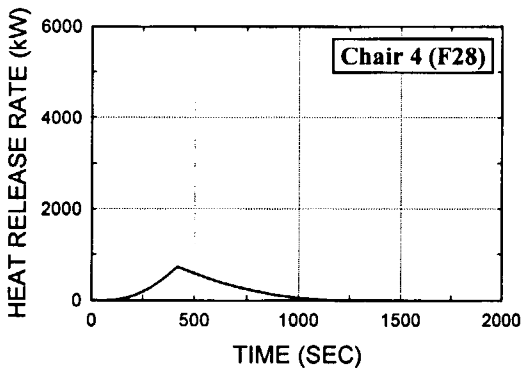


Fig. B6. Uphols.chair, F28, wood frame, pu/pe/ctn bedding, cotton test 28

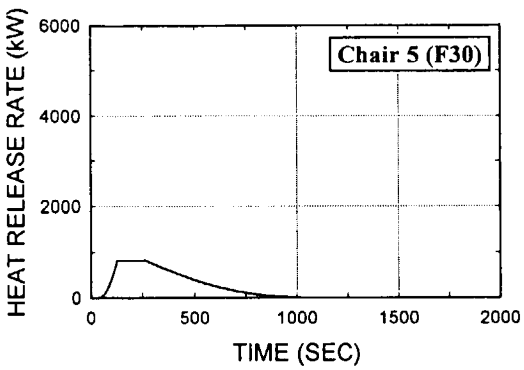


Fig. B7. Uphols.chair, F30,pu frame, pu foam, olefin, test 30 (82-2604)

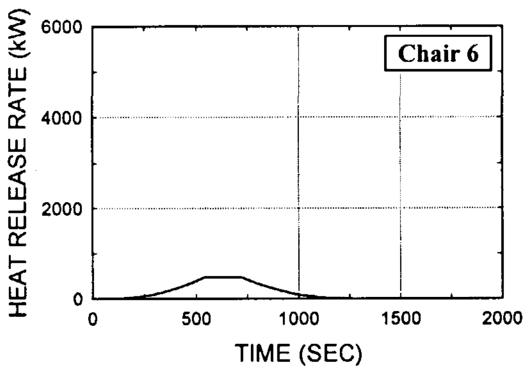


Fig. B8. Bean bag chair, vinyl/ps foam beads, c05 nbs tn 1103

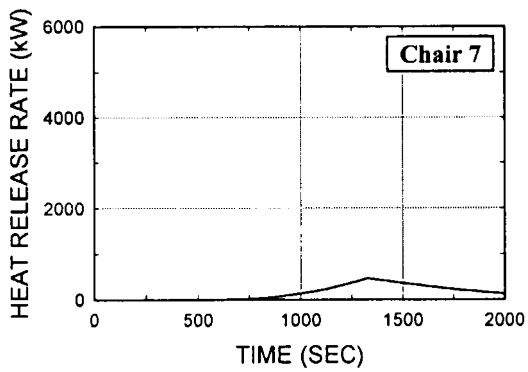


Fig. B9. Chair, molded flexible pu frame, pu cover test 64 (83-2787)

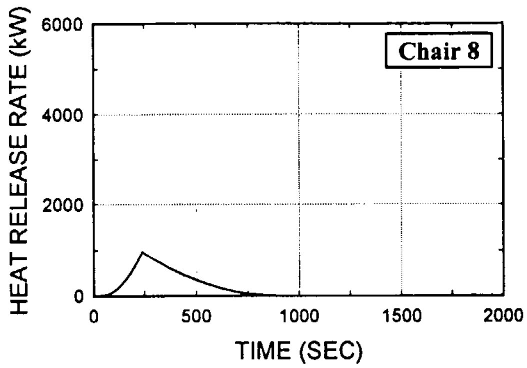


Fig. B10. Easy chair, molded ps foam frame, pu pad & cover, c07, test 48

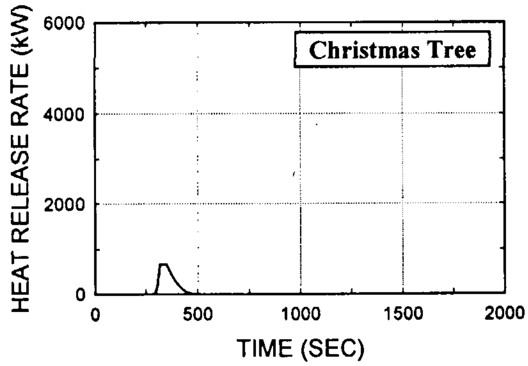


Fig. B11. Christmas tree, spruce, dry, vtt 285, no.17

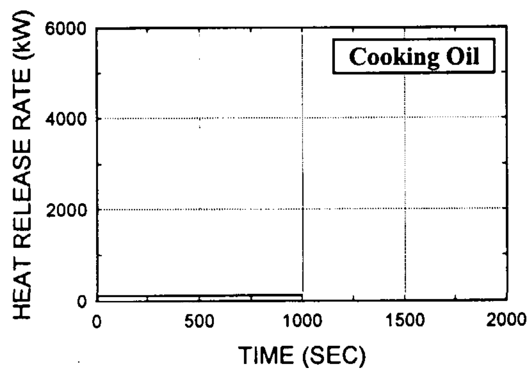


Fig. B12. Cooking Oil, Corn; Cottonseed; Etc In 12in.Pan

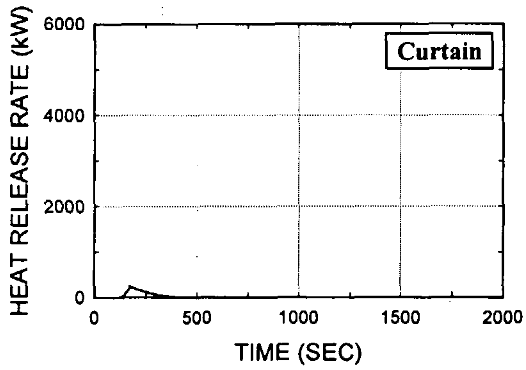


Fig. B13. Curtain, Cotton, 0.31kg/M2, Item 9

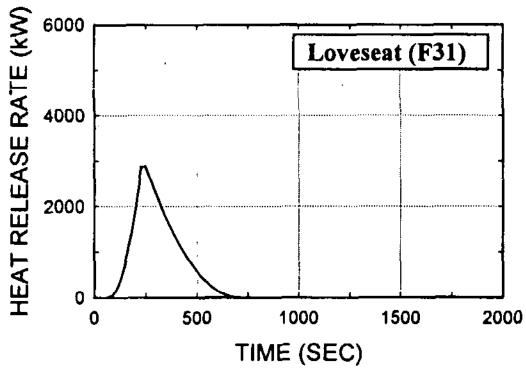


Fig. B14. Loveseat, F31, wood frame, pu foam (fr), olefin test 37 (82-2604)

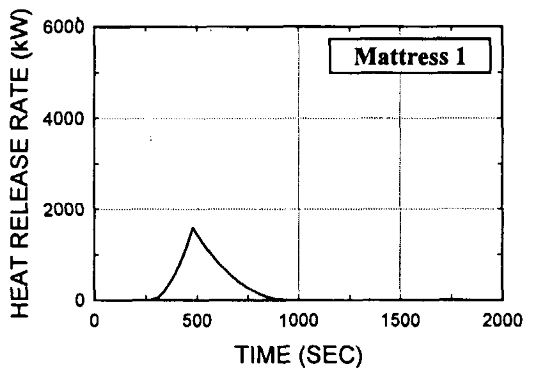


Fig. B15. Mattress, m05, pu foam, rayon ticking, bedding

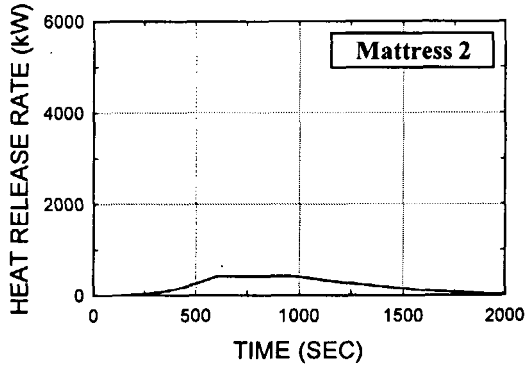


Fig. B16. Mattress + boxspring (west chase hilton) test 67 (83-2787)

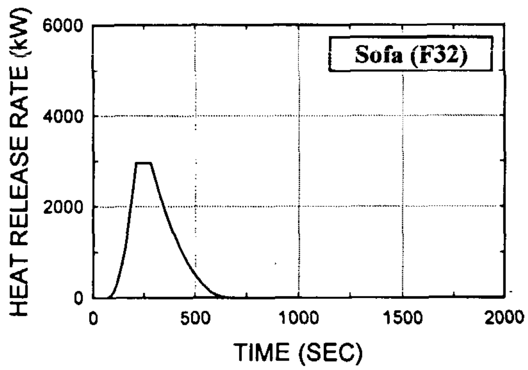


Fig. B17. Upholstered\sofa, F32, wood\frame, pu foam-fr, olefin test 38

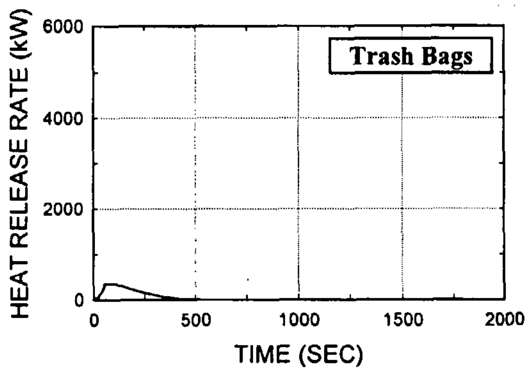


Fig. B18. Trash bags (3), paper

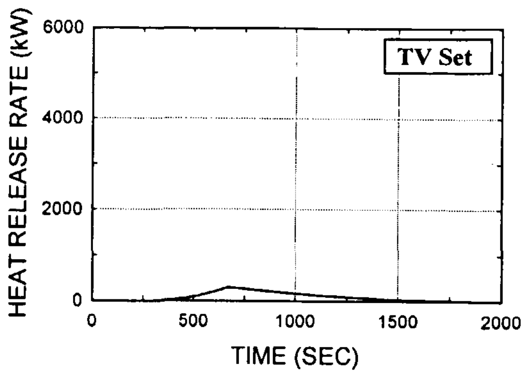


Fig. B19. Television set, b/w, wood cabinet, exp.3

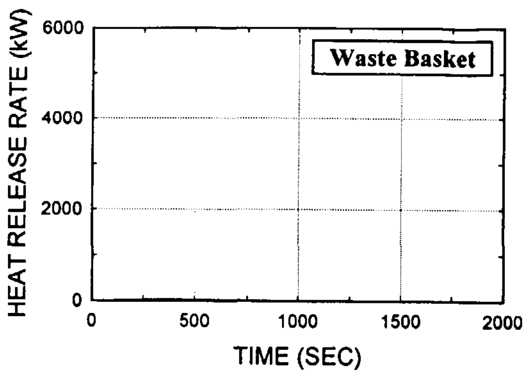


Fig. B21. Wastepaper basket, polyethylene, milk cartons, exp.7

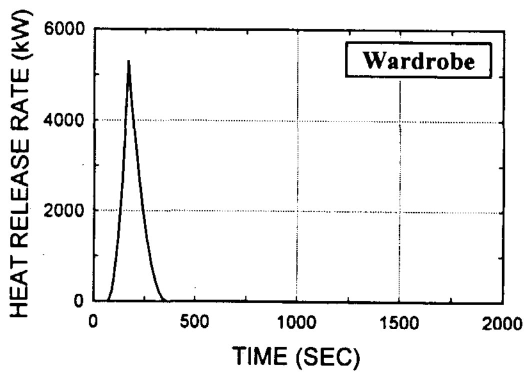


Fig. B20. Wardrobe closet, plywood, fr paint nbsir 83-2787 test 42

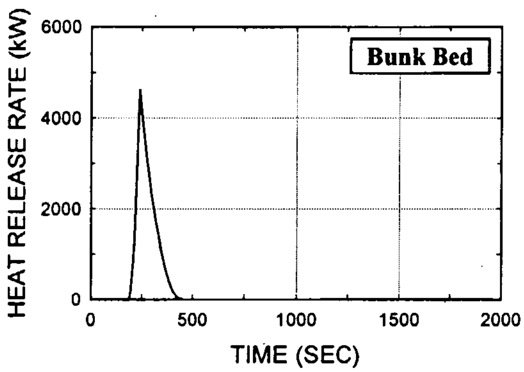


Fig. C1. Bunk Bed, BFRL in February 1996

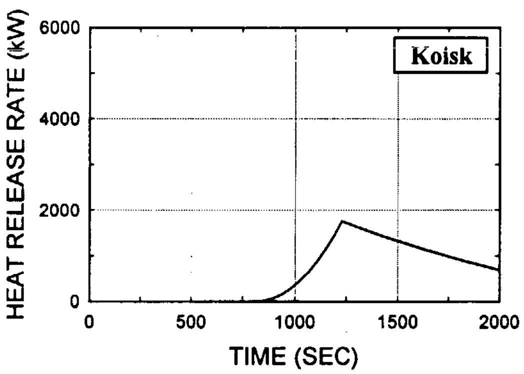


Fig. C2. Koisk, Western Fire Center in the summer of 1995

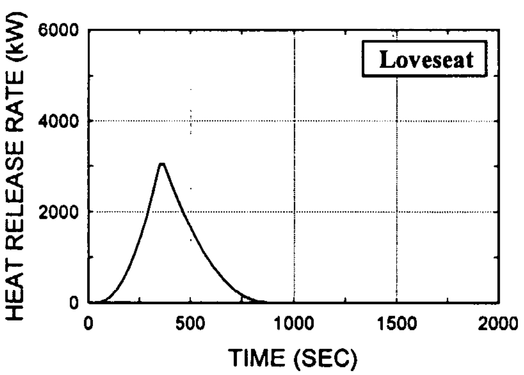


Fig. C3. Loveseat

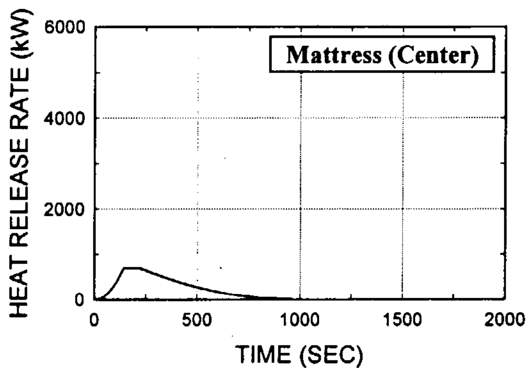


Fig. C4. Mattress (Center), BFRL in February 1996

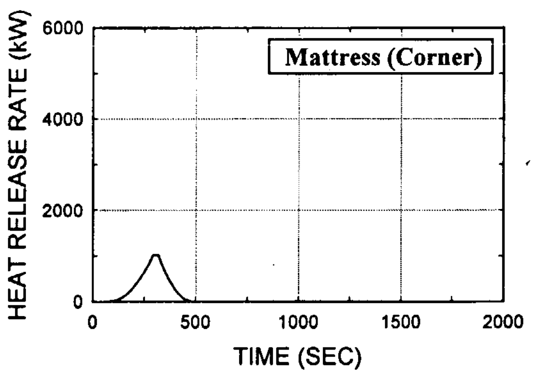


Fig. C5. Mattress (Corner), BFRL in February 1996

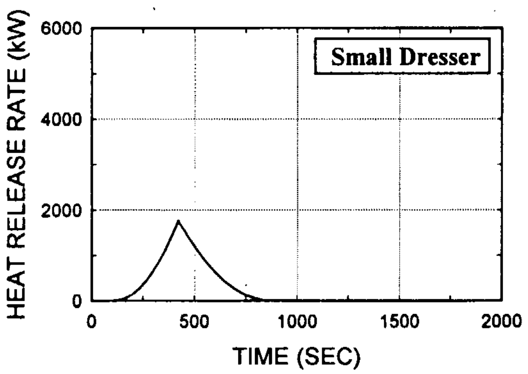


Fig. C6. Small Dresser, BFRL in February 1996

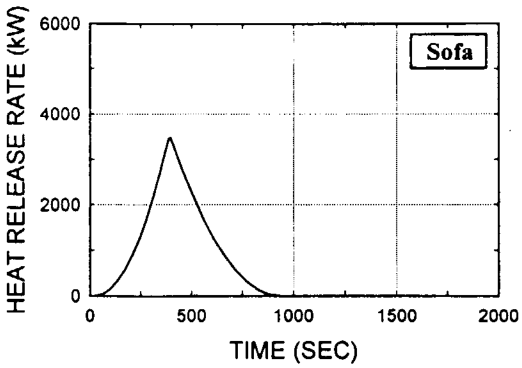


Fig. C7. Sofa

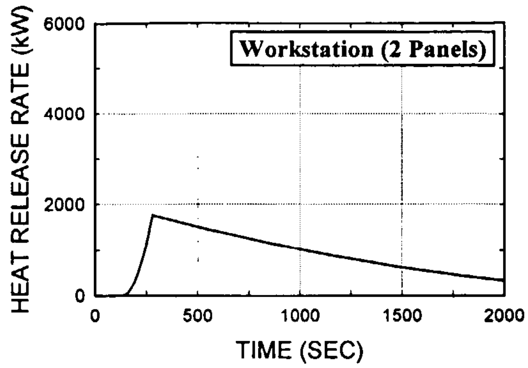


Fig. C9. Workstation (2 panels), Sponsored by GSA and performed at BFRL in 1991

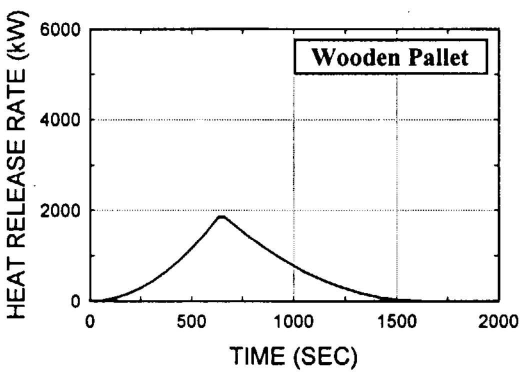


Fig. C8. Wooden Pallet, BFRL in February 1996

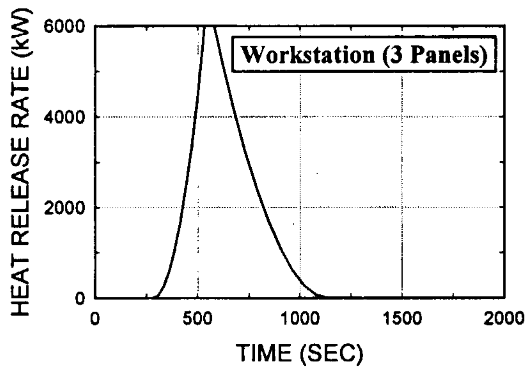


Fig. C10. Workstation (3 panels), Sponsored by GSA and performed at BFRL in 1991

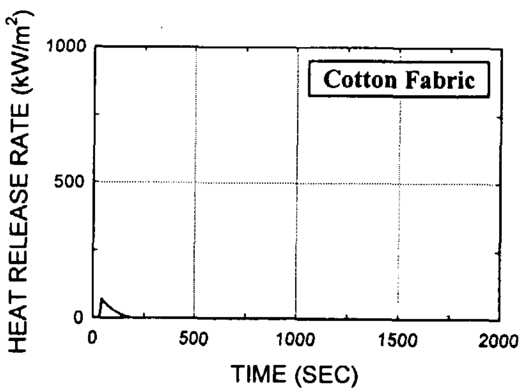


Fig. D1. Cotton fabric, fr (test 803a), Fabric

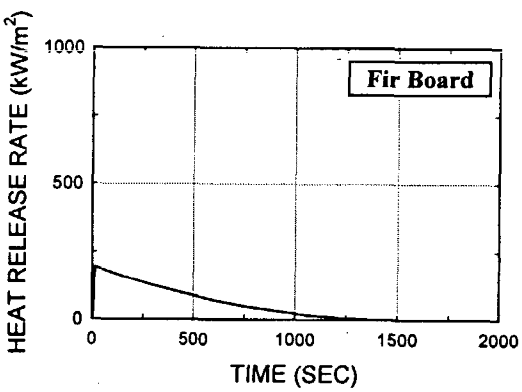


Fig. D2. Douglas fir (828), Board

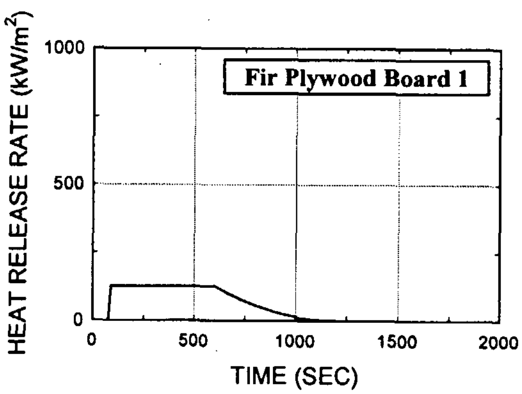


Fig. D3. Douglas fir plywood, 1/2 in. thick (435), Board

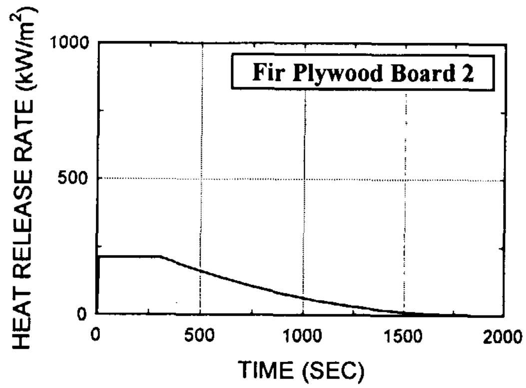


Fig. D4. Douglas fir plywood, 1/2 in. thick (446), Board

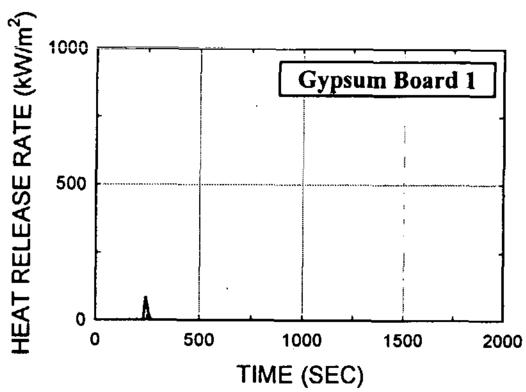


Fig. D5. Gypsum board, 1/2 in. thick (434)

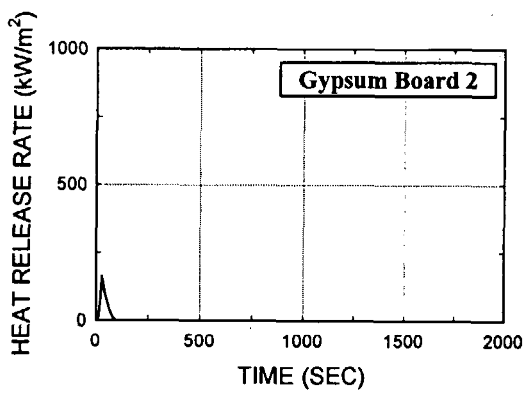


Fig. D6. Gypsum board, 1/2 in. thick (448)

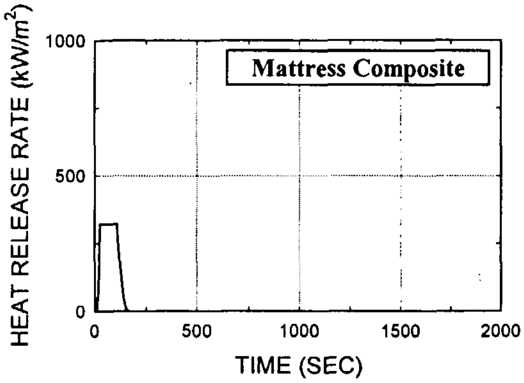


Fig. D7. Mattress ass'y m05, pu foam, rayon ticking (test 296), Composite

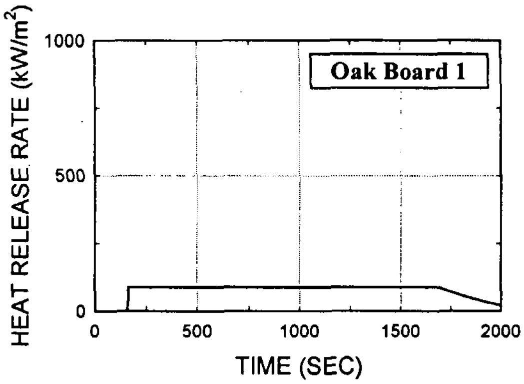


Fig. D8. Red oak, 7/8 in. thick (1454)

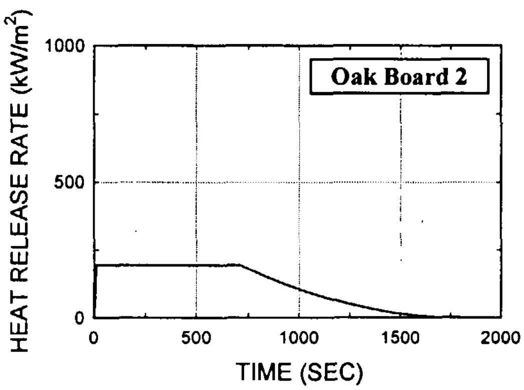


Fig. D9. Red oak, 7/8 in. thick (1456), Board

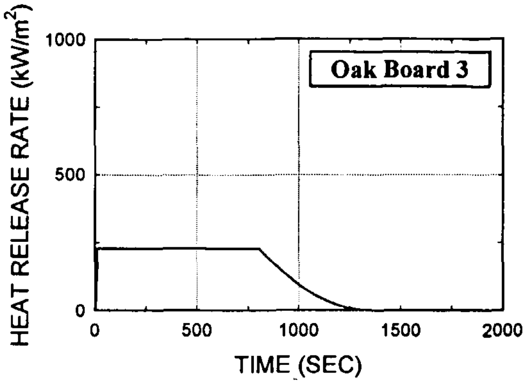


Fig. D10. Red oak, 7/8 in. thick (1468), Board

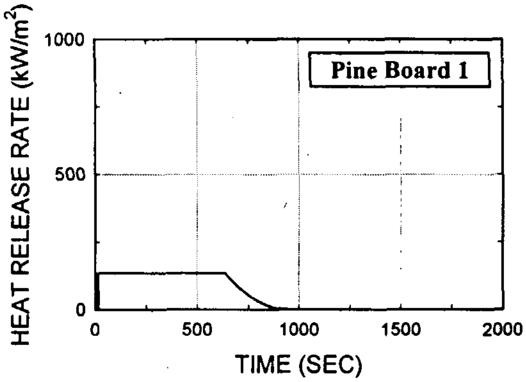


Fig. D11. Pine (838), Board

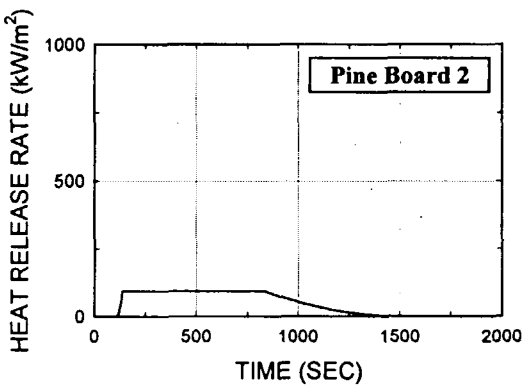


Fig. D12. Pine (842), Board

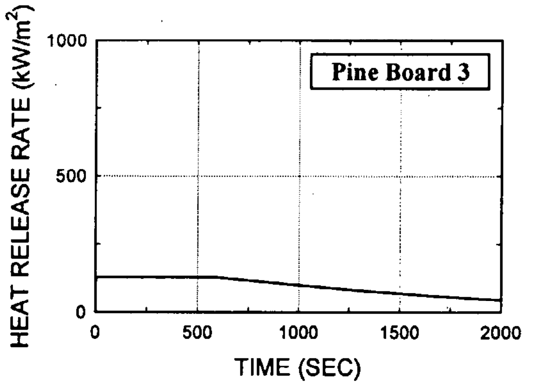


Fig. D13. White pine (wood), 0.75 in (test 487), Board

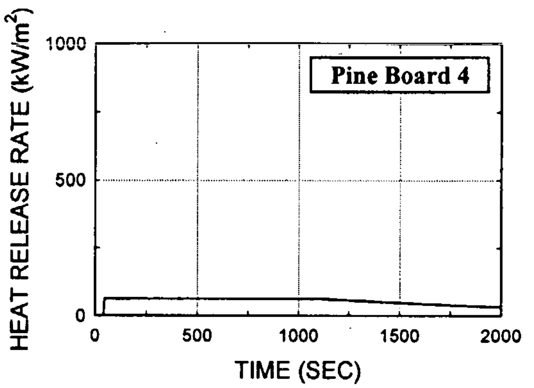


Fig. D14. White pine (wood), 0.75 in (test 493), Board

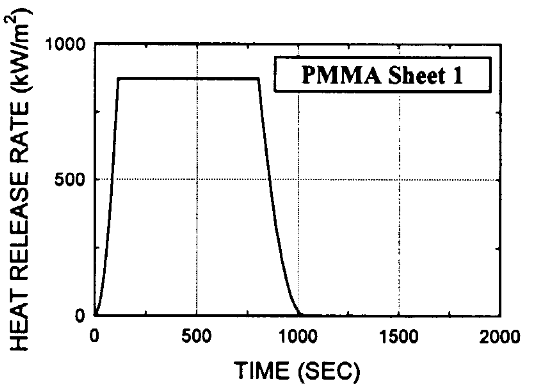


Fig. D15. PMMA 1" black (cb) w/frame (test 1461), Sheet

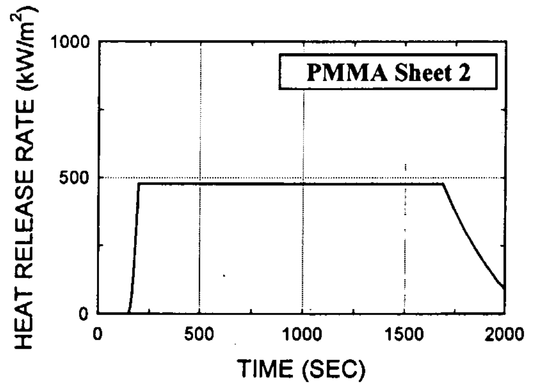


Fig. D16. PMMA 1" black (cb) w/frame (test 1470), Sheet

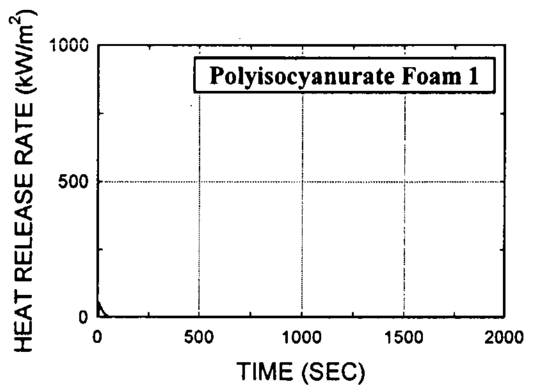


Fig. D17. Rigid polyisocyanurate foam, 2 in (test 438), Foam

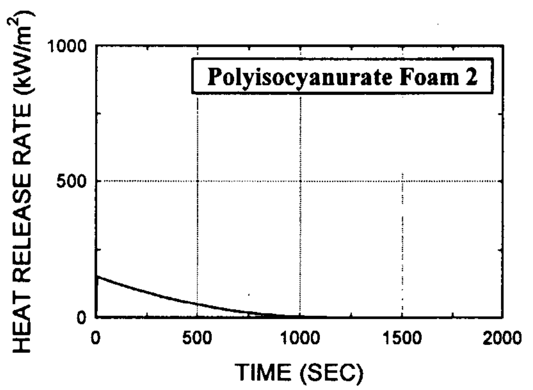


Fig. D18. Rigid polyisocyanurate foam, 2 in (test 449), Foam

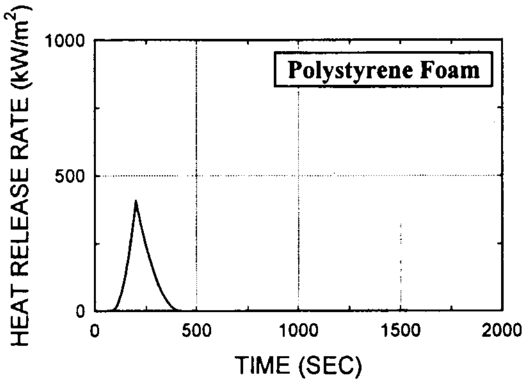


Fig. D19. Polystyrene foam, 2 in (test 437), Foam

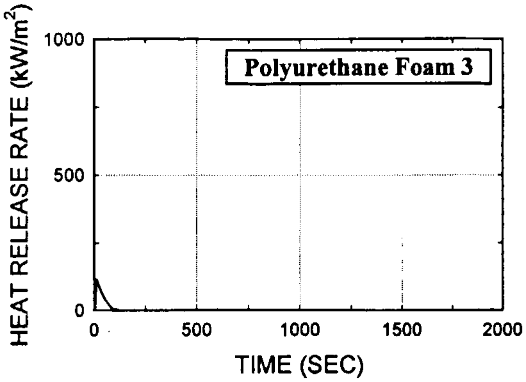


Fig. D22. Rigid polyurethane foam, fr, gm-31 (test 258), Foam

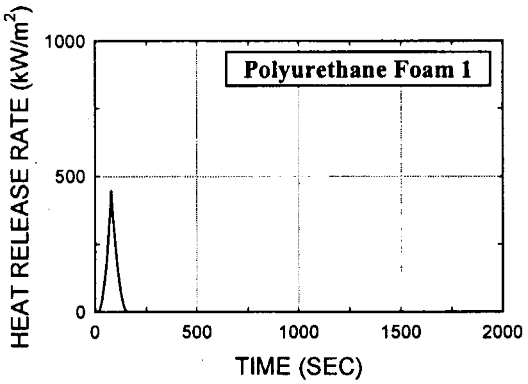


Fig. D20. Flexible polyurethane foam, fr, 2 in (test 725), Foam

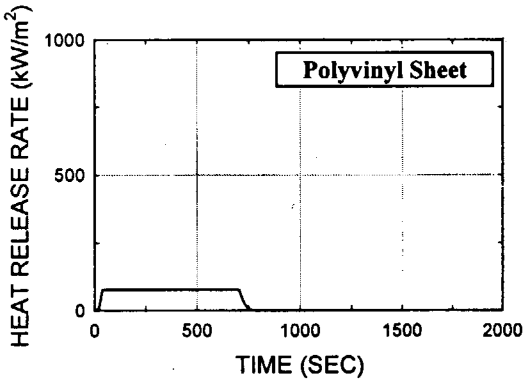


Fig. D23. Polyvinyl chloride, 0.5 in thick (test 333), Sheet

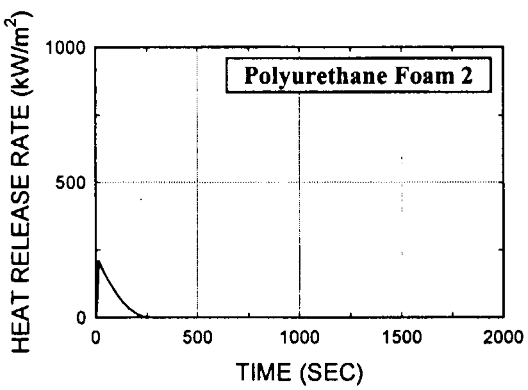


Fig. D21. Rigid polyurethane foam, gm-29/gm-30 (test 257), Foam

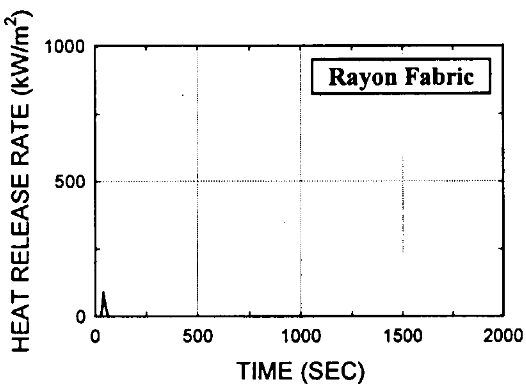


Fig. D24. Rayon fabric (test 804a), Fabric

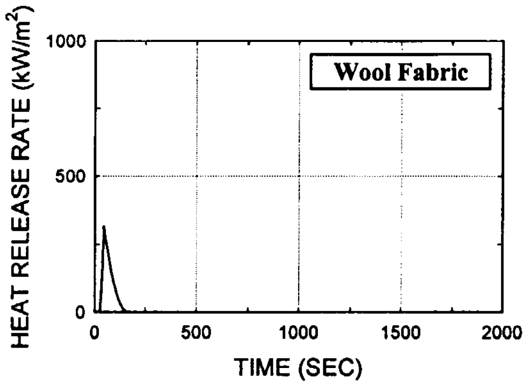


Fig. D25. Wool fabric/neoprene padding (test 722), Composite