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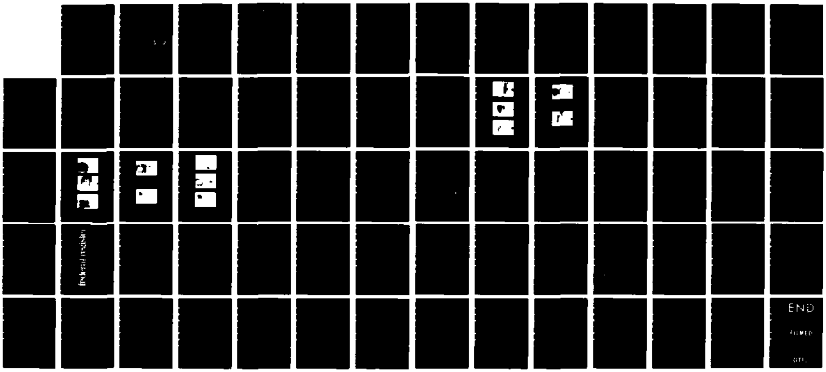

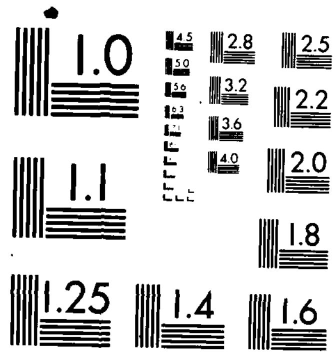

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Aircraft Interior Panel Test Criteria Derived from Full-Scale Fire Tests

AD-A161 637

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September 1985

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16. Abstract

Full-scale cabin fire tests were conducted to determine potential increases in passenger survivability associated with different interior honeycomb panel constructions. The test fuselage was a C-133 with a simulated wide-body door opening exposed to an 8-foot by 10-foot fuel fire. In the first series, the interior near the door was lined with the honeycomb panels to determine whether earlier studies performed with small-scale enclosures were consistent with the full-scale counterpart. These earlier studies resulted in the selection of the Ohio State University (OSU) Rate of Heat Release Apparatus as the most appropriate type test to evaluate aircraft panels. The first series was followed by tests that included fire-blocked seats and carpeting as well as the panels to determine the type survivability increases that could be attained from low heat release materials. The scenario employed generally resulted with flashover within 2 minutes for panels considered typical in performance. A low heat release phenolic/fiberglass panel demonstrated a flashover delay until about 4 minutes into the test. An incombustible panel prevented flashover altogether. The performance of the various panels was evaluated to develop recommended flammability criteria for a modified OSU Rate of Heat Release Apparatus.

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EXECUTIVE SUMMARY

This report describes the derivation of improved small-scale fire test requirements for cabin interior panel materials from an analysis of full-scale postcrash cabin fire tests. The improved requirements are based on measurements made in a modified Ohio State University (OSU) heat release apparatus. The development of the OSU apparatus and the full-scale fire test conditions were recommendations of the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee. This work has resulted in the issuance of Notice of Proposed Rulemaking (NPRM) 85-10.

The full-scale fire scenario consisted of an intact fuselage with an open door adjacent to a large external fuel fire. Six types of interior honeycomb panels installed in a wide-body test article in a representative arrangement at sidewall, ceiling, stowage bin, and partition locations were evaluated. Two series of full-scale tests were conducted. In the first test series, each type of panel was evaluated without any other materials installed in the test article. The results of these tests demonstrated that the composition of the resin and cloth used in the panel facings had a significant effect on fire performance. This indicated that improvements in fire performance could be achieved by relatively minor modifications in panel design using state-of-the-art materials. Results from the first series of tests also indicated that the temperature increase inside the test article closely tracked the smoke and toxic gas concentration measurements. Since temperature rise is dependent, along with other factors, on the heat release rate characteristics of interior materials, this finding reinforced the selection of the OSU heat release apparatus by the SAFER committee for fire hazard assessment. In the second test series, the panels were evaluated in a more realistic cabin environment that included rows of aircraft seats protected with fire-blocking layers, as required by recent Federal Aviation Administration (FAA) rulemaking, and carpeting. The results from the second test series demonstrated that significant improvements in safety, or, more specifically, a delay in the onset of flashover, could be achieved through the utilization of aircraft panels with lower heat release rate characteristics. It was noteworthy that the fire safety benefits provided by improved panel design were in addition to the benefits provided by fire-blocking layer protection of aircraft seat cushions.

The full-scale cabin fire tests were analyzed in order to select for the OSU apparatus relevent test exposure conditions and measurements, as well as criteria for improved safety, to be utilized in conjunction with NPRM 85-10. It was determined that a radiant heat exposure of 3.5 watts per square centimeter and measurements of peak heat release rate and total heat release at 2 minutes correlated well with full-scale data. Using as a benchmark the performance of a phenolic/fiberglass panel, which is a state-of-the-art composite used in certain applications in cabin interiors, criteria was set at 65 kw/m^2 for peak heat release rate and 65 $kw\text{-}min/m^2$ for total heat release at 2 minutes. For the open door fire scenario studied, the phenolic/fiberglass panel added approximately 2 minutes to survivability when compared against other panels (e.g., phenolic/kevlar and epoxy/fiberglass). Thus, selection of interior panels based on the OSU apparatus test requirements set forth on the basis of full-scale tests could result in major safety gains during certain postcrash fire scenarios.

INTRODUCTION

PURPOSE.

The purpose of this work was to determine what safety improvements were achievable for aircraft interior cabin panels to enhance survivability in the event of a postcrash fire.

BACKGROUND.

Transport aircraft employ a wide variety of polymeric materials in their interiors. The collective performance of these materials under a given fire scenario can determine the time available for passenger escape during a postcrash fire. Prior to recent Federal Aviation Administration (FAA) rulemaking requiring seat blocking layers, the minimum fire safety requirements for the cabin interior were based on a 1972 rule that required carpets and seats as well as interior panels to be subjected to a Bunsen burner test. Because this test ensures that materials will resist ignition from relatively small ignition sources, the validity of the test is self-evident. In contrast, a postcrash fire can involve thousands of gallons of burning aviation kerosene from ruptured fuel tanks. Upgrading flammability requirements in the face of this type fire threat requires full-scale testing to determine the manner in which interior materials get involved.

In the mid 1970's the FAA issued an advance notice of proposed rulemaking (NPRM) on toxicity, an NPRM on smoke, and an additional NPRM on flammability relating to commercial fleet retrofit. In public hearings in 1977, the withdrawal of these initiatives was recommended because of their piecemeal approach and the lack of adequate full-scale supporting data. The former criticism led to an attempt to develop a combined hazard index (reference 1). The formation of an advisory committee was recommended as well at the 1977 hearings, and this led to the establishment of the Special Aviation Fire and Explosion Reduction (SAFER) committee whose findings were published in 1980 (reference 2). Although the SAFER committee made numerous recommendations relating to both fuel fire hazards and aircraft material flammability, smoke, and toxicity; three specific recommendations are noteworthy with regard to the direction they gave to subsequent FAA research and development. The SAFER committee recommended the specific fire scenario for the FAA to use in full-scale C133 tests. The committee recommended expedited development and evaluation of the Ohio State University (OSU) Rate of Heat Release Apparatus as the potential standardized test for materials. Additionally, the committee recommended for technology development purposes that a 5-minute evacuation time be considered to represent the majority of cases (reference 2). In response to these and other recommendations of the SAFER committee, the FAA developed a formal program plan (reference 3) that would guide its research to achieve the goals set by the SAFER committee. The initial major step involved the implementation of the broad committee full-scale test goals into an actual operational test article with a workable and repeatable test method. This early work resulted in characterization of the full-scale fire environment as well as identification of flashover as the dominant event marking the end of survivable conditions in the cabin (reference 4). Further work involving the full-scale evaluation of seat blocking layers (references 5 and 6) continued to show flashover of the cabin interior as the time at which survivable conditions ended. In fact, the benefits in survivability attached to seat blocking layers have been quantitatively tied to the time to flashover (reference 7). The importance of flashover in the

SAFER recommended scenario cannot be overstated, as these full-scale test results provided a technical basis for the FAA to concentrate on material flammability as the driving factor in cabin survivability. For the most part, the tests showed that smoke and toxic gases became a survivability threat only when enough cabin materials were burning to cause flashover conditions.

The seat-blocking layers delayed flashover by slowing down the heat release rate of burning seat materials. This was accomplised by delaying ignition of the seats and by shielding the urethane foam from nearby fire sources. To determine potential flashover delays available from improved cabin lining materials, full-scale comparative tests were performed with epoxy type panels and advanced fireproof panels provided by National Aeronautics and Space Administration (NASA) (reference 8). These tests showed a 140-second flashover delay when the severe rupture scenario was employed (wherein a seat row is directly exposed to an external fuel fire) and prevention of flashover when the cabin was exposed to a fuel fire through an open fuselage doorway. This finding was significant because it showed that further improvements in survivability were possible through lessened panel flammability.

The approach to this effort on panels involved subjecting prototype panels of various constitution (epoxy, phenolic, fiberglass, graphite, kevlar™, etc.) to a battery of standard laboratory scale fire tests and to one-quarter scale flashover tests in a controlled enclosure. Correlation of the results led to a preliminary recommendation that the OSU device be targeted as the most promising test method for determining panel flammability (reference 9). The culmination of the effort on flammability of the interior panels was a series of full-scale fire tests on the prototype panels along with extensive OSU tests involving various operational modes and many additional materials.

OBJECTIVES.

This work had two primary objectives. The first was the determination through full-scale fuselage fire tests, whether the OSU Rate of Heat Release Apparatus was an acceptable indicator of the fire performance of interior panels. The second objective was the determination of the relationship between panel fire performance and enhanced survivability in a specific postcrash fire scenario.

TEST MATERIALS

Although many different panel materials have been evaluated as part of the overall test effort, five panels were used most extensively in the development of the correlation between full-scale and small-scale tests. These were honeycomb panels constructed for the Federal Aviation Administration (FAA) by General Veneer Manufacturing Company in South Gate, California. The physical overall description of each panel is given in table 1. All the test panels had a phenolic-dipped Nomex™ core and a 2-mil Tedlar™ decorative surface on one exterior surface. The facesheets that actually sandwiched the core were the only constituent of the panel assembly that varied among the five panels. The facesheets are composed of a fabric impregnated with a resin. The fabrics tested included fiberglass, kevlar, and graphite while the resins included epoxy and phenolic. These various components are representative of the components used in state-of-the-art aircraft interiors. The epoxy facesheets (panel 1 and 3) were purchased as prepregnated sheets by General Veneer. The epoxy/glass was procured from Ciba-Geigyic. and the epoxy/kevlar from Fiberite. General Veneer assembled the constituent parts of

TABLE 1. DESCRIPTION OF TEST PANELS

No.	Designation	Description
1	EP/FG	Epoxy glass facings, face and back 1-ply 7781 fiberglass impregnated with resin, fire retardant, and co-cured 1/8 cell, 1.8 lb, 1/4-inch thick Nomex™ honeycomb. Outer surface covered with 2-mil white Tedlar™ Wt. = 0.36 lbs/sq. ft.
2	PH/FG	Phenolic glass facings, face and back 1-ply 7781 style woven fiberglass impregnated with a modified phenolic resin, and co-cured to 1/8 cell, 1.8 lb, 1/4-inch thick Nomex™ honeycomb. Outer surface covered with 2-mil white Tedlar™ Wt. = 0.42 lbs/sq. ft.
3	EP/KE	Epoxy Kevlar tm facings, face and back 1-ply 285 style woven Kevlar impregnated with epoxy resin, fire retardant, and co-cured to 1/8 cell, 1.8 lb, 1/4-inch thick Nomex™ honeycomb. Outer surface covered with 2-mil white Tedlar™ Wt. = 0.38 lbs per sq. ft.
4	PH/KE	Phenolic Kevlar facings, face and back 1-ply 285 style woven Kevlar impregnated with a modified phenolic resin and co-cured to 1/8 cell, 1.8 lb, 1/4-inch thick Nomex™ honeycomb. Outer surface covered with 2-mil white Tedlar™ Wt. = 0.38 lbs per sq. ft.
5	PH/GR	Phenolic graphite facings, 1-ply 8 harness satin, 3K fiber T-300 woven graphite impregnated with a modified phenolic resin, and co-cured to 1/8 cell, 1.8 lb, 1/4-inch thick Nomex™ honeycomb. Outer surface covered with 2-mil white Tedlar™ Wt. = 0.36 lbs/sq. ft.

Note: Weight is based on nominal weight of the components.

the epoxy facesheets into panels by curing them at 265° F for 1 hour. The phenolic facesheets employed a benzyl phenolic from Weyerhauser. The fabrics in this case were not bought by General Veneer as prepregs. The cure time for the phenolic panels was approximately 2 hours. The panel assemblies were heated in a press to 275° F. The press was opened to relieve any solvent gases. The panel was then raised under pressure to 320° F where it was cured for one hour. These times and temperatures may be slightly higher than those used by the airframe manufacturers, but they are certainly comparable. This is in contrast to the advanced polyimide panel used to find the upper limit to delay of flashover. That panel consisted of a polyimide dipped nomex core, an American Cyanamid polyimide resin on the fiberglass facesheets, and a polyetheretherketone (peek) decorative surface. Assembly of this panel involved a 16-hour cure at 500° F.

Performance of these panels under various fire test methods has been previously documented (references 9 and 10). Procurement of these panels provided a range of performance adequate for correlation purposes and ensured test specimen uniformity in the testing done at various laboratories. Among the laboratories participating in the early part of this effort were the FAA Technical Center, the National Bureau of Standards, the Jet Propulsion Laboratory, and Factory Mutual Research Corporation (references 9, 10, and 11).

FULL-SCALE FIRE TESTS

TEST CONFIGURATIONS.

The C-133 test fuselage was configured in these tests with an open doorway exposed to an external fuel fire as previously done for seat blocking layers and advanced panel work (references 5, 6, and 8). Figure 1 shows a schematic of the fuselage. The panels described earlier were tested in two modes — the panels alone and panels with a complement of seats and carpeting. Additionally, the peek/polyimide panels tested previously (reference 8) were included in these tests for comparative purposes. The panels were tested alone as well as in conjunction with other materials to ensure that findings on cabin hazards were due to changes in panel performance rather than interactions with other furnishings. Figure 2 shows the configurations used for panels alone. The interior surfaces around the C-133 doorway nad panels configured as sidewalls, ceiling, overhead stowage bins, and a simulated galley wall. The tests involving other materials were configured as shown in figure 3 and involved four sets of double seats with Norfab blocking layers and wool/nylon aircraft carpet in the vicinity of the doorway.

The tests of panels without seats and carpet showed the propensity of the various panels to be ignited and release heat. There was not enough fuel load in the fuselage to attain flashover type conditions throughout the fuselage. Thus, in these tests the fuselage interior temperature rise represents the most significant quantitative data. In tests with panels, seats, and carpets, the fuel load is more realistic and large enough to create the kind of flashover conditions found previously for this type scenario (references 6 and 8). Thus, in addition to the temperature versus time data, the time to flashover is significant. With flashover as the survivability endpoint, the time of escape can be estimated from this information.

The tests described here are considered representative tests. Other panels and other scenarios were tested and some repeat tests were performed. For instance, a series of in-flight fire scenarios were performed with the test panels. However, the main purpose was to evaluate the relation of full-scale fire performance of honeycomb panels to their performance in the OSU device within the context of a post-crash fire scenario.

PANELS WITHOUT SEATS.

The type panel performance under exposure to a pool fire outside a doorway can be represented by photographic documentation. Figure 4 shows an interior view at 5 minutes into the test with peek/polyimide as the test specimen. At no time did these panels evidence any fire involvement. An intermediate case is represented by the phenolic/graphite panel (No. 5) in figure 5 which shows the decorative Tedlar burning off at 1 minute into the test but with the panels relatively uninvolved at 1 minute and 40 seconds. A poor performance by the phenolic/kevlar panel (No. 4) is shown in figure 6. At 1 minute, the decorative Tedlar is burning off, but at 1 minute and 55 seconds, the panel facesheet is undergoing sustained burning.

Figure 7 shows temperature versus time curves for the panels. The least temperature rise is associated with the peek/polyimide which demonstrated no apparent fire involvement. The most significant temperature increases are associated with epoxy/fiberglass (No. 1) and phenolic/kevlar (No. 4), although the temperature curve for epoxy/kevlar (No. 3) eventually surpasses the epoxy/fiberglass. Intermediate temperature rises are shown by phenolic/fiberglass (No. 2) and phenolic/graphite (No. 5), although early in the test phenolic/fiberglass results in substantially lower temperature rise than phenolic/graphite.

Figure 8 shows a comparison of smoke production in the C-133 during these tests. Epoxy/fiberglass, phenolic/kevlar, and epoxy/kevlar all show significant smoke production during the test. The phenolic/fiberglass and the phenolic/graphite along with peek/polyimide show negligible smoke production.

Figure 9 shows comparative data for the measurement of carbon monoxide in these tests. These data are similar to the smoke production data in that phenolic/fiberglass and phenolic/graphite perform near the peek/polyimide while the epoxy/fiberglass, the phenolic/kevlar, and the epoxy/kevlar are noticeably higher. Comparative data on hydrogen fluoride is shown in figure 10. Except for the phenolic/kevlar which showed unexpectedly high readings, the levels provided by the panels are comparable and are traceable to the Tedlar surfaces which were the same for all the panels except peek/polyimide.

The overall fire performance of the panels in this test series was similar to that found in the small-scale enclosure tests used for preliminary correlation work (reference 9). These tests demonstrated that the earlier 1/4-scale model work was an adequate surrogate for the full-scale testing of panels by themselves. Subsequent full-scale tests with seats and carpets were needed to determine if the relative panel performance remained the same under a more representative interior configuration.

PANELS WITH SEATS.

With the addition of seats and carpet, enough fireload was located near the fuselage doorway so that flashover could occur. Figure 11 shows combined temperature, smoke, and gas data taken during the test with phenolic/kevlar panels. As found in previous studies of similar scenarios (references 4 and 8), at the time of flashover there is a sudden deterioration of the cabin environment from thermal, smoke, and toxicity parameters.

As with the fire tests of panels themselves, the photographic documentation provides a clear picture of the relative performance of the materials. Figure 12 shows the degree of fire involvement for five different panels at 1 minute and 30 seconds into the test. For interiors made of either phenolic/fiberglass or peek/polyimide, the cabin environment is still stable as the fire has not spread into the interior. For the phenolic/graphite interior, the fire in the cabin is in a growth stage with localized burning of the seats and carpet near the doorway. The worst situation is evidenced by the epoxy/fiberglass and phenolic/kevlar linings where the furnishings and linings near the door are totally involved in fire. These photographs are particularly significant with regard to the phenolic/graphite panels. When previously tested without seats, this panel demonstrated early, but unsustained flammability, which resulted in its performance appearing similar to phenolic/fiberglass. However, when configured with seats and carpet, this early flammability can sustain itself through interaction with the seats and carpet.

Figure 13 shows the cabin interior for three materials at 3 minutes and 40 seconds into the test. With peek/polyimide interior, there is still no fire involvement of the cabin materials. For the phenolic/graphite panels, the cabin is completely enveloped in flames. For the phenolic/fiberglass, the fire is in a growth stage with burning seat backs and panels in evidence.

Figures 14 through 18 show the temperature profiles at 1-foot vertical intervals at station 270 in the fuselage for the tests with panels and seats. The profile at the ceiling for each panel tested is shown in figure 19. The epoxy/fiberglass and phenolic/kevlar interiors show an early temperature growth reflective of early flashover. The phenolic/graphite shows a relatively early rise to moderate temperatures (approximately 570° F) where the temperature remains until flashover is indicated, approximately 2 minutes later. Phenolic/fiberglass performs like the peek/polyimide until flashover develops approximately 4 minutes into the test. There was no flashover with the peek/polyimide panels.

The smoke profiles in figure 20 are consistent with the comparative temperature profiles. The hydrogen fluoride profiles in figure 21 are further reflective of the phenomena occuring in the C-133. The epoxy/fiberglass and the phenolic/kevlar, which reached flashover early, evidence an early release of hydrogen fluoride. The phenolic/graphite panel, which showed early fire involvement, shows an early peak in hydrogen fluoride with a later smaller peak when the interior reaches flashover.

The phenolic/fiberglass panel has virtually no hydrogen fluoride for the first several minutes, and this is consistent with the lack of interior fire growth over the first 3 minutes. The phenolic/fiberglass test shows a peak in hydrogen/fluoride when fire growth near the doorway occurs. This peak is at the same time as the corresponding photograph in figure 13.

The times to flashover in these tests are shown in figure 22. Flashover was determined from photographic coverage and time temperature profiles. The peek/polyimide interior did not reach flashover at all. The phenolic/graphite reached flashover a little earlier than the phenolic/fiberglass, although the phenolic/graphite interior had sustained fire growth into the interior approximately 2 minutes prior to flashover. Both epoxy/fiberglass and phenolic/kevlar reach flashover conditions a little more than a minute into their respective tests.

CRITERIA DEVELOPMENT

The notice of proposed rulemaking on interior materials issued on April 16, 1985 (appendix A), was based on preliminary evaluation of a variety of test methods in conjunction with panel performance in small-scale enclosure fires (reference 9). Fine tuning the test methodology involved further correlation of OSU results with the full-scale test results reported here, along with a government-industry round-robin testing effort to establish improved laboratory repeatability with the OSU device. These efforts resulted in recommended changes to the OSU methodology (appendix B).

Table 2 shows the performance of the test panels as tested by the OSU methodology described in appendix B. These data were taken from the OSU apparatus at the FAA Technical Center. More detailed documentation of the development of this methodology is in progress (references 12 and 13). One salient result from this methodology development was the finding that heat release determined from thermopile correlated against heat release found from oxygen depletion with a high degree of confidence for a range of materials. Thus, the data in table 2 are all derived from thermopile measurements with a sample exposure of 3.5 watts per centimeter squared.

TABLE 2. OSU DATA FOR PANELS USED IN THE C-133

Panel Type	Peak* (KW/M2)	2-Min. Total*(KW-Min/M2)
EP/FG	92.6	82.4
PH/FG	58.3	53.4
EP/KV	76.8	86.1
PH/KV	84.4	92.8
PH/GR	69.4	78.7
PEEK/PI	7.5	3.4

*AVERAGE OF 3 TESTS

Selection of pass-fail criteria for materials can be based on evaluation of the full-scale test data. Phenolic/kevlar shows a peak heat release rate of 84 and a 2-minute integrated heat release of 93 in the OSU device. This material sustained an early flashover in the C-133 tests. This indicates that criteria definitely should be set below these numbers. Epoxy/fiberglass shows OSU data of 93 for peak and 82 for 2-minute integrated heat release. Phenolic/graphite shows a peak of 69 and a 79 total for 2 minutes. Concentrating on the 2-minute total, the epoxy/fiberglass and the phenolic/graphite are indistinguishable. Nevertheless, the flashover for phenolic/graphite occurred nearly 2 minutes after the flashover for epoxy/fiberglass which occurred very early. This indicates that the overall region between 69 and 93 for peak heat release and in the vicinity of 80 for 2-minute integrated heat represents an area of transition from high flammability to low flammability for the materials in the full-scale scenario used. This transition means that materials may or may not contribute to early flashover, depending on the chain of events within the cabin, once materials get involved. This can be shown in figures 19 and 21 if the phenolic/graphite graphs are evaluated. The phenolic/graphite demonstrates an early release of hydrogen fluoride and an early temperature rise at about 80 seconds into the test. Whether this early release of heat leads to a flashover quickly is somewhat probabilistic. The epoxy/fiberglass curve also shows involvement through the evolution of hydrogen fluoride from the Tedlar surface. In this case flashover occurs quickly.

Setting criteria near the OSU numbers evidenced by phenolic/graphite and epoxy/fiberglass would certainly not assure improved safety. In fact, the full-scale testing did not include the many small thermoplastic parts associated with an aircraft interior as well as various carry-on type items. With the added flammability of these items, flashover early would be likely with materials of the heat release potential of epoxy/fiberglass and phenolic/graphite.

The best material shown in these tests was peek/polyimide which showed a peak of 8 and a 2-minute integrated value of 3 in the OSU. With this material, there was no flashover in the C-133. Quite definitely this represents a safety improvement.

Figures 19 and 21 indicate that the phenolic/fiberglass behaves similar to the peek/polyimide right up to the time of flashover at 4 minutes. There is no early heat release and no early development of hydrogen fluoride indicative of a burning Tedlar surface. The OSU peak and total values for phenolic/fiberglass are 58 and 53, respectively. These values seem to assure some measure of improved safety. The rationale for setting limits at 65 kw/m^2 for the peak and 65 $kw\text{-}min/m^2$ for the 2-minute OSU total is to encompass this phenolic/fiberglass material and to stay below the transition region demonstrated by the epoxy/fiberglass and the phenolic/graphite. Further testing would be needed to determine if these recommended limits should be lowered to 60 to more tightly bracket the phenolic/fiberglass performance.

Figure 23 shows comparative fractional effective doses for the materials from the C-133 tests. These allow survivability type estimates to be done in a quantitative manner as with the seat blocking layers (reference 5). Taking 2 minutes as the time to flashover for existing in-service panels (e.g., epoxy/fiberglass) from previous work, movement to an interior of phenolic/fiberglass panels like the one tested in the C-133 would appear to add approximately 2 minutes to survivability.

SUMMARY DISCUSSION

Although a number of different type laboratory-scale fire tests were evaluated in this program, the successful correlation of full-scale fire tests and rate of heat release test devices can be explained. The specific full-scale fire scenarios employed by the FAA have been useful in finding the time to flashover with a wide variety of interior furnishings. The rationale for employing fire blocking layers on aircraft seats was the additional escape time available due to delayed onset of flashover. Nevertheless, flashover is an enclosure phenomenon that generally occurs when a fire within the enclosure generates heat at some critical rate that is affected by heat transfer and ventilation effects. Flashover is to a large degree caused by the heat release rate of burning materials within the fuselage.

In an analysis of the contributing factors to flashover in the C-133 (reference 10), the flashover event corresponded to a heat release rate of approximately 1000 kilowatts by burning carpet, seats, and wall lining materials. The role of the external pool fire in these tests is primarily to radiatively heat the interior materials to a temperature where they can sustain flame spread. The flashover itself results from the combined rate of heat release from these burning materials. Thus, a rate of heat release test device, that can irradiate materials by flux levels similar to those found in the full-scale test article, by its very design will yield the contributory potential of a given material to the flashover event. The correlation results cited in this report (reference 12 and 13) are most important in the development of the test device heat flux that best reflects the array of heat fluxes that exist in the full-scale test article at various distances from and angles to the fuel fire covered doorway.

Probably any of the heat release rate tests used in this program could be adequately correlated with full-scale tests so that they could be used to establish the flashover yielding potential of various materials. The decision to select the OSU device was based on recommendations of the SAFER committee, the use of the OSU in the development of the Combined Hazard Index, the availability of the device in the aircraft industry, and the fact that the OSU is an ASTM designated test.

The actual criteria for material selection are driven by the level of fire safety desired as evidenced in full-scale testing. Clearly, the ultimate in fire safety would be lining materials that were virtually non-combustible. The effectiveness of such an approach is documented with full-scale testing of peek/polyimide panels (reference 8) which showed a flashover delay in excess of 2 minutes in the fuselage rupture scenario. Nevertheless, these advanced panels are beyond the state-of-the-art in processing and totally unsuitable for use in an aircraft. This performance really demonstrates the ultimate benefit attainable, much as non-combustible seat cushions were used as a yardstick in the seat fire blocking layer test program (reference 5). Another option would be to set test criteria at the performance level of epoxy-type in-service panels which were tested along with the peek/polyimide panels for comparison. However, such a performance level would lead to no new safety benefit on newly manufactured aircraft. The one material that tested well under virtually any test condition was the phenolic/fiberglass panel designated as panel No. 2. The performance of this panel was similar to the best in-use panels in the OSU device. Thus, the improved survivability documented in full-scale tests of panel No. 2 are achievable with state-of-the-art manufacturing processes. Thus, panel No. 2 was used as a benchmark to select the recommended performance criteria for OSU testing of aircraft materials. Both the peak OSU heat release and the 2-minute total heat release, when established at 65 kw/m^2 and 65 kw-min/m^2, respectively, encompass this material. Besides the good performance of this panel in the full-scale tests, the full-scale tests indicate that an increase in OSU 2-minute heat release of approximately 30 percent (panel No. 1 versus panel No. 2) results in dramatic erosion of fire safety. The full-scale tests demonstrate that the flammability performance of the interior is very sensitive to relatively small changes in material heat release potential.

CONCLUSIONS

1. Aircraft interior panels with low heat release rate characteristics improve survivability for certain types of postcrash cabin fire scenarios.

2. OSU apparatus heat release rate measurements on aircraft interior panels correlate with full-scale cabin fire test results.

3. OSU apparatus acceptance criteria for aircraft interior panels based on the performance of a phenolic/fiberglass panel evaluated during this study will improve survivability for certain types of postcrash cabin fire scenarios.

4. The increase in cabin air temperature from heat released by aircraft interior panels during full-scale fire tests tracked the smoke and toxic gas concentrations.

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3. Engineering and Development Program Plan, Aircraft Cabin Fire Safety, Federal Aviation Administration, FAA Technical Center, Report No. FAA-ED-18-7, June 1980.

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8. Sarkos, C. P., and Hill, R. G., Evaluation of Aircraft Interior Panels Under Full-Scale Cabin Fire Test Conditions, AIAA Paper 85-0393, AIAA 23rd Aerospace Sciences Meeting, Reno, Nevada, January 14-17, 1985.

9. Sarkos, C. P., Filipczak, R. A., and Abramowitz, A., Prelimi ary Evaluation of an Improved Flammability Test Method for Aircraft Materials, Federal Aviation Administration, Report DOT/FAA/CT-84/22, December 1984.

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12. Filipczak, R., et al, Correlation of Small-Scale Tests with Performance during Full-Scale Cabin Fire Tests, FAA report in preparation.

13. Fitzgerald, L., Interlaboratory Comparison of Heat Release Data from Aircraft Panels, FAA report in preparation.

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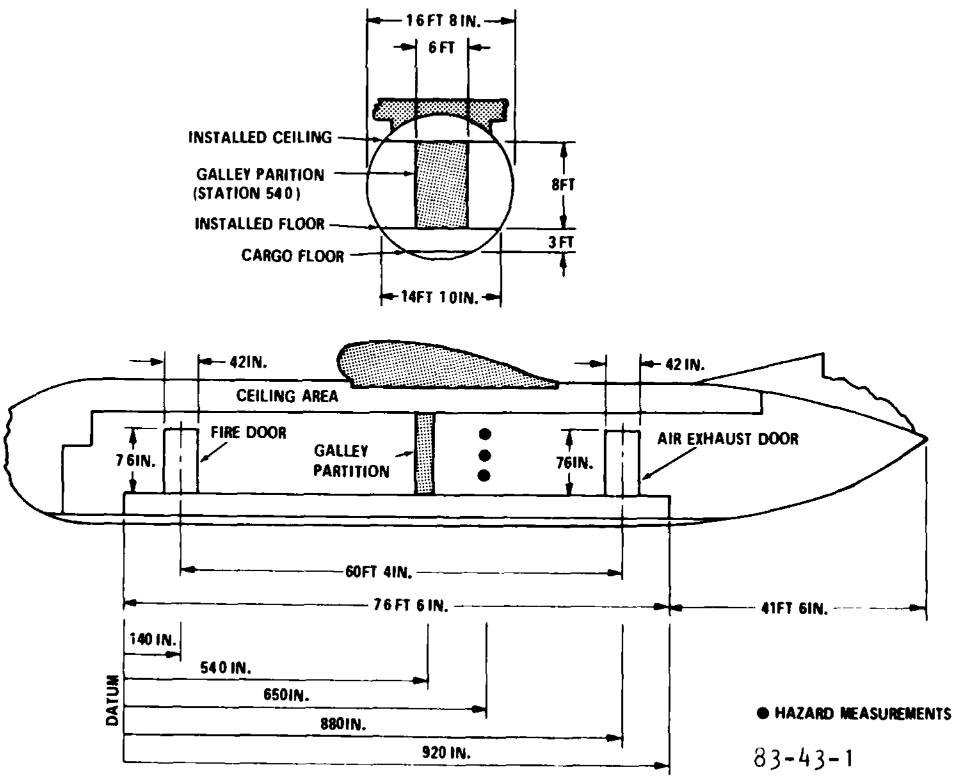


FIGURE 1. SCHEMATIC OF C-133

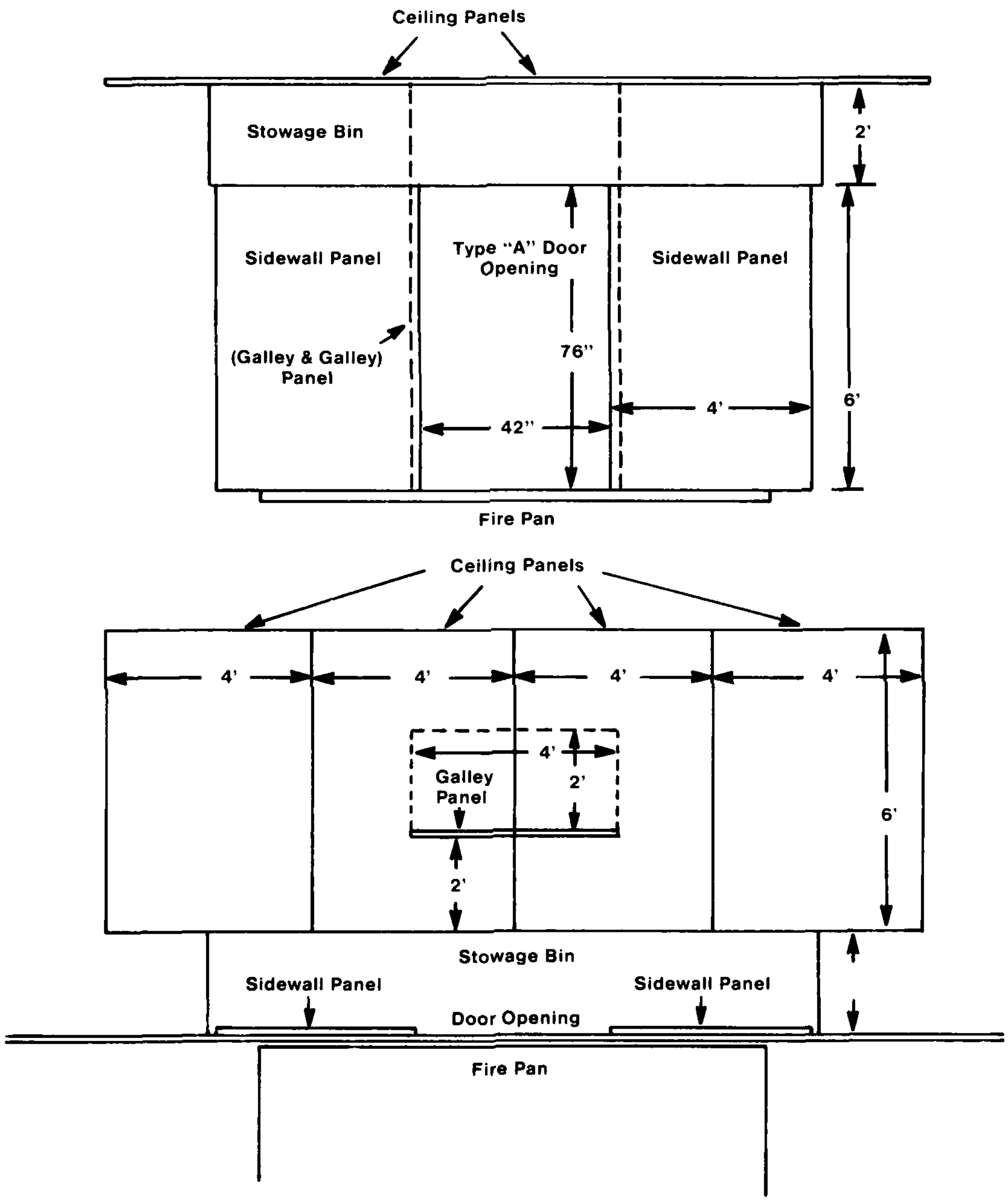


FIGURE 2. MATERIAL CONFIGURATION (PANELS WITHOUT SEATS)

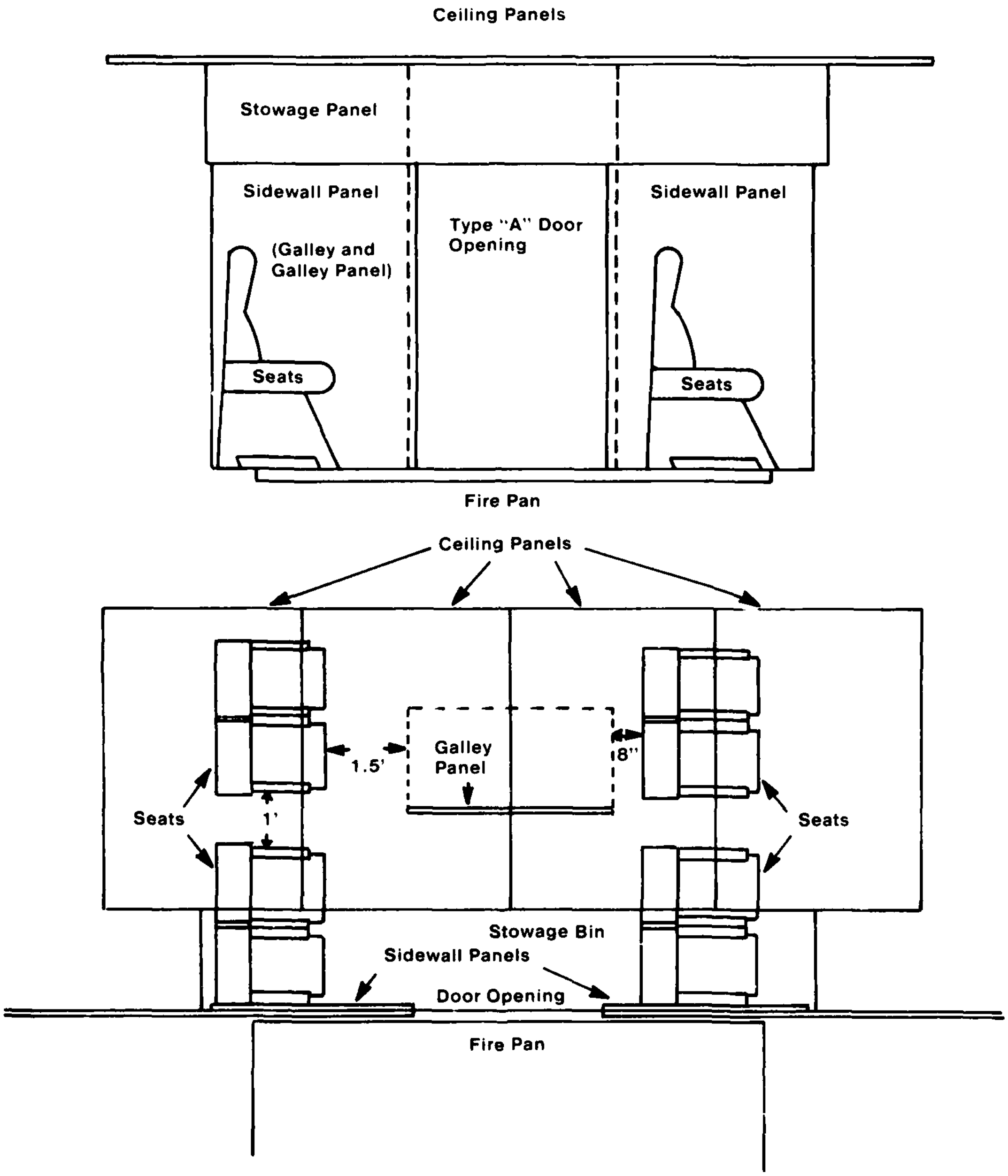
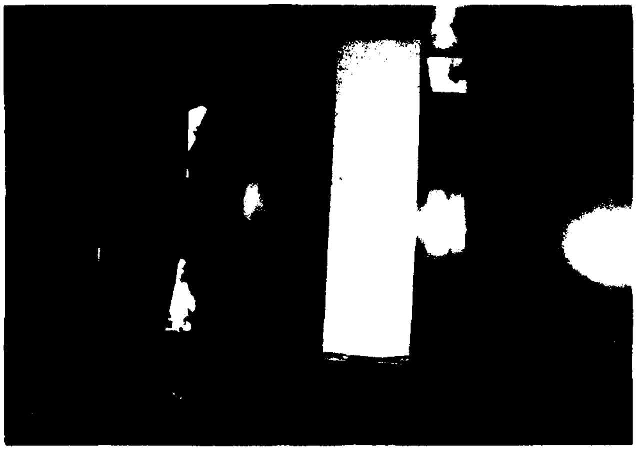


FIGURE 3. MATERIAL CONFIGURATION (PANELS WITH SEATS)



5 Minutes Into Test

FIGURE 4. PEEK/POLYIMIDE PANELS

1 Minute Into Test

1 Minute 40 Seconds Into Test

FIGURE 5. PHENOLIC/GRAPHITE PANELS

1 Minute Into Test

1 Minute 55 Seconds Into Test

FIGURE 6. PHENOLIC/KEVLAR PANELS

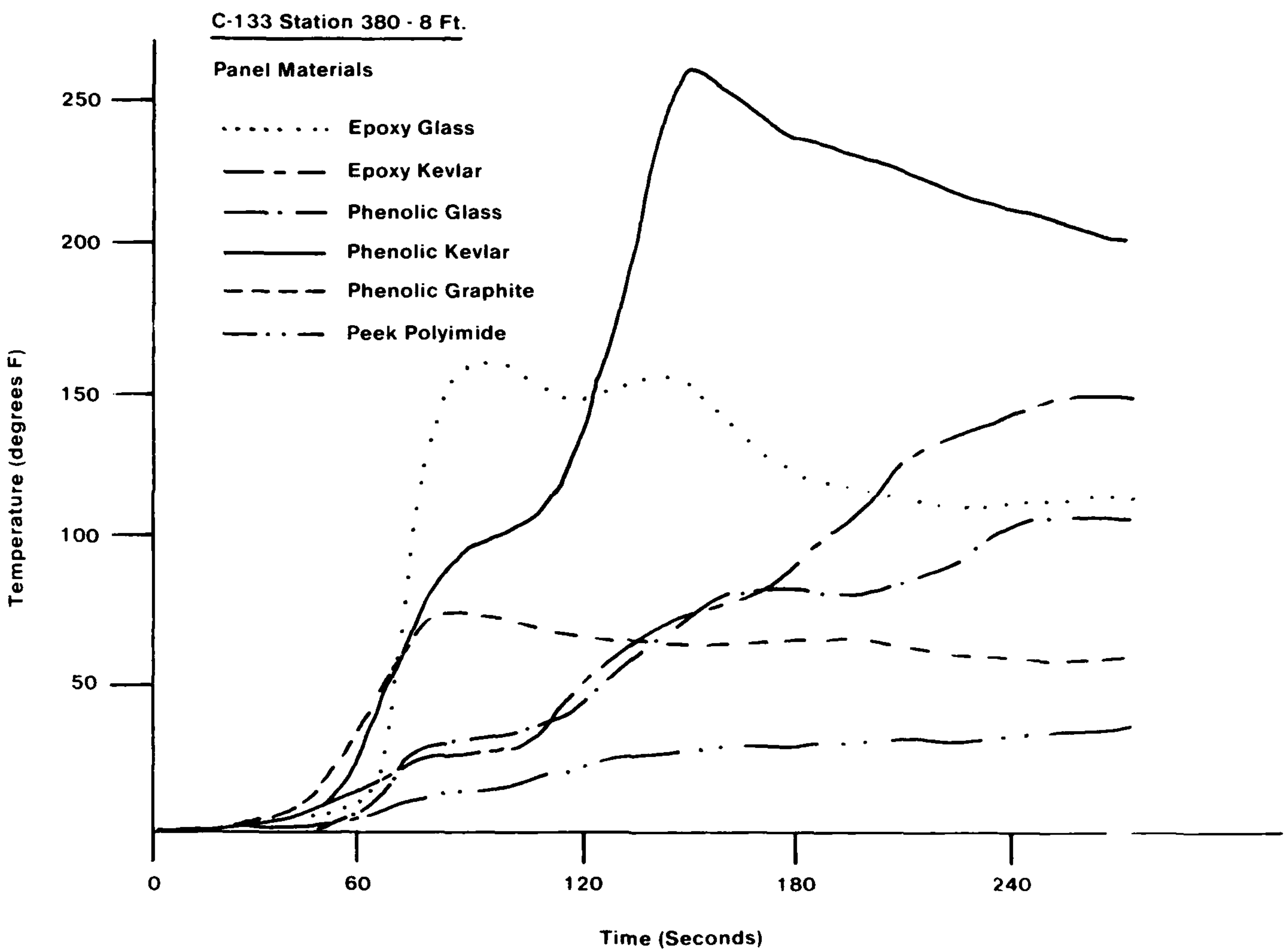


FIGURE 7. COMPARATIVE TEMPERATURE INCREASE (PANELS WITHOUT SEATS)

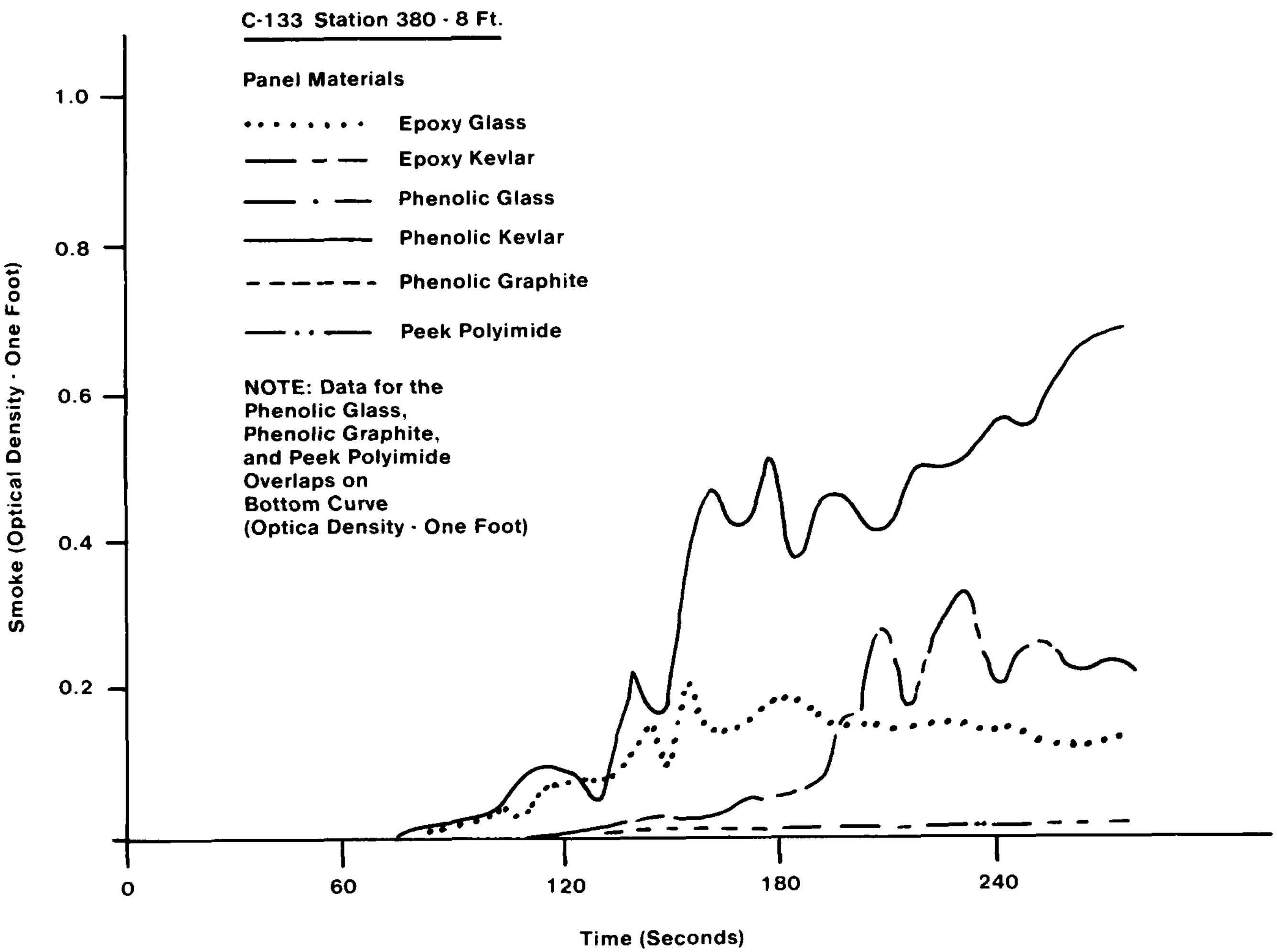


FIGURE 8. COMPARATIVE SMOKE LEVELS (PANELS WITHOUT SEATS)

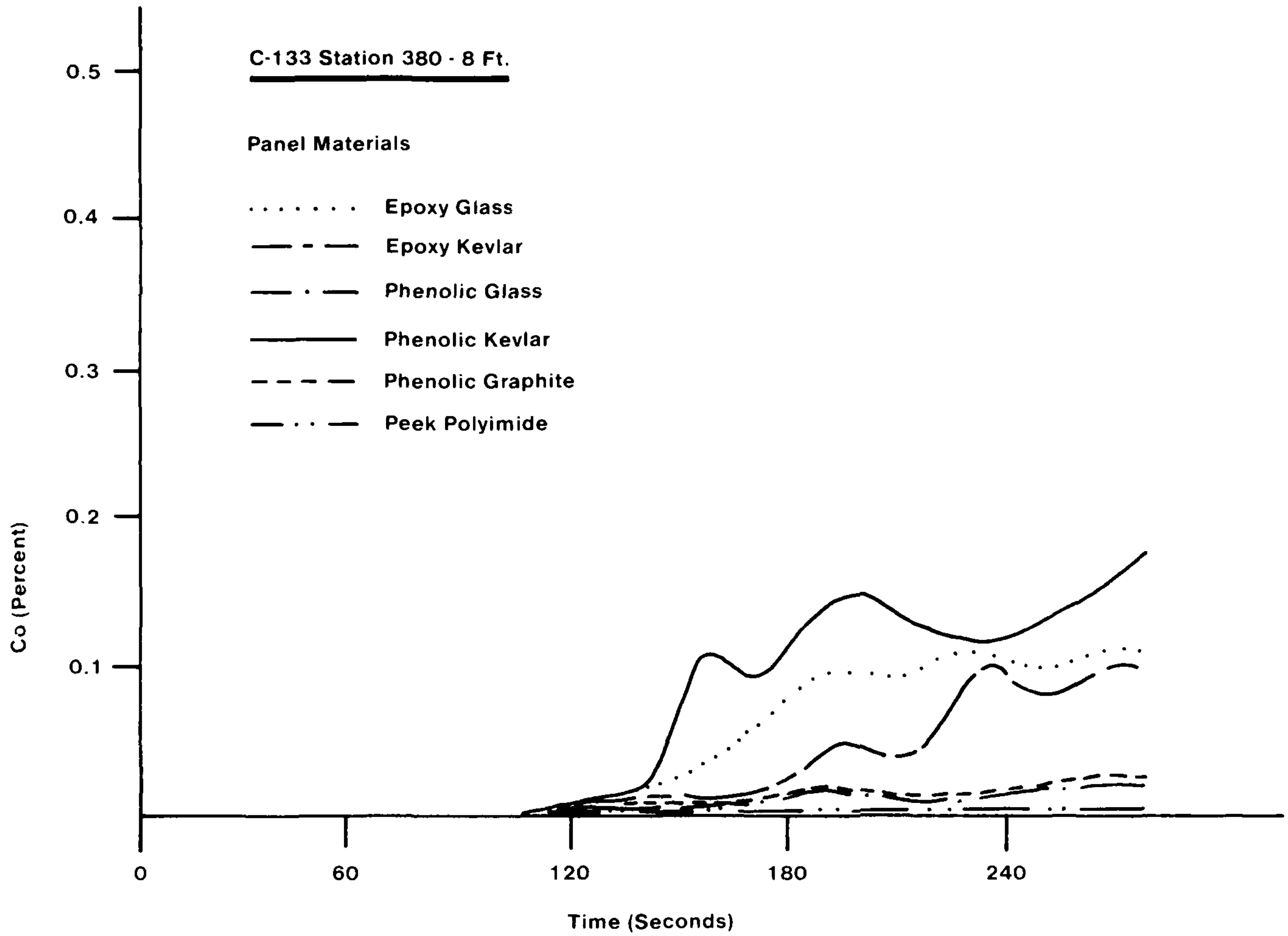


FIGURE 9. COMPARATIVE CARBON MONOXIDE (PANELS WITHOUT SEATS)

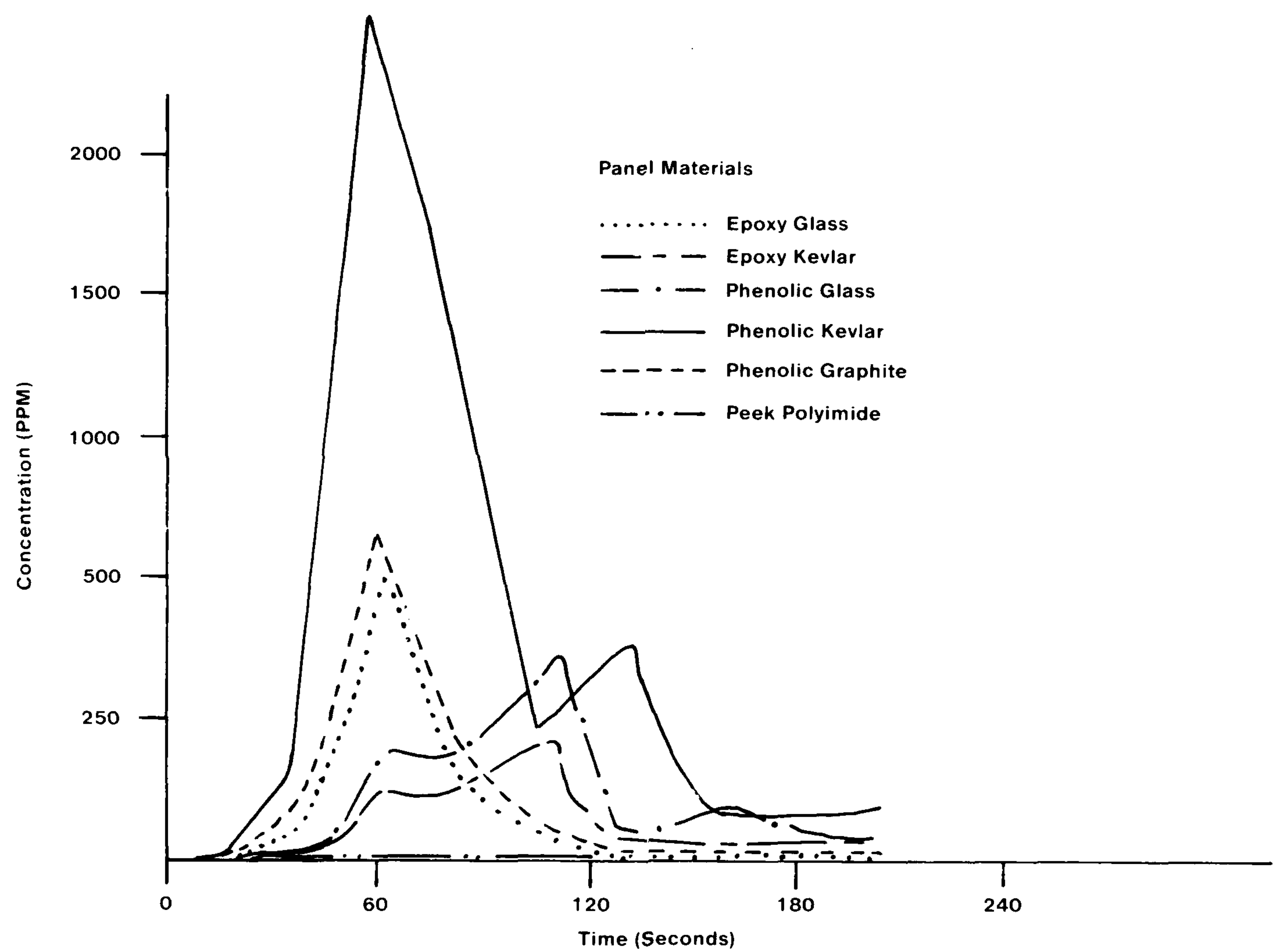


FIGURE 10. COMPARATIVE HYDROGEN FLUORIDE (PANELS WITHOUT SEATS)

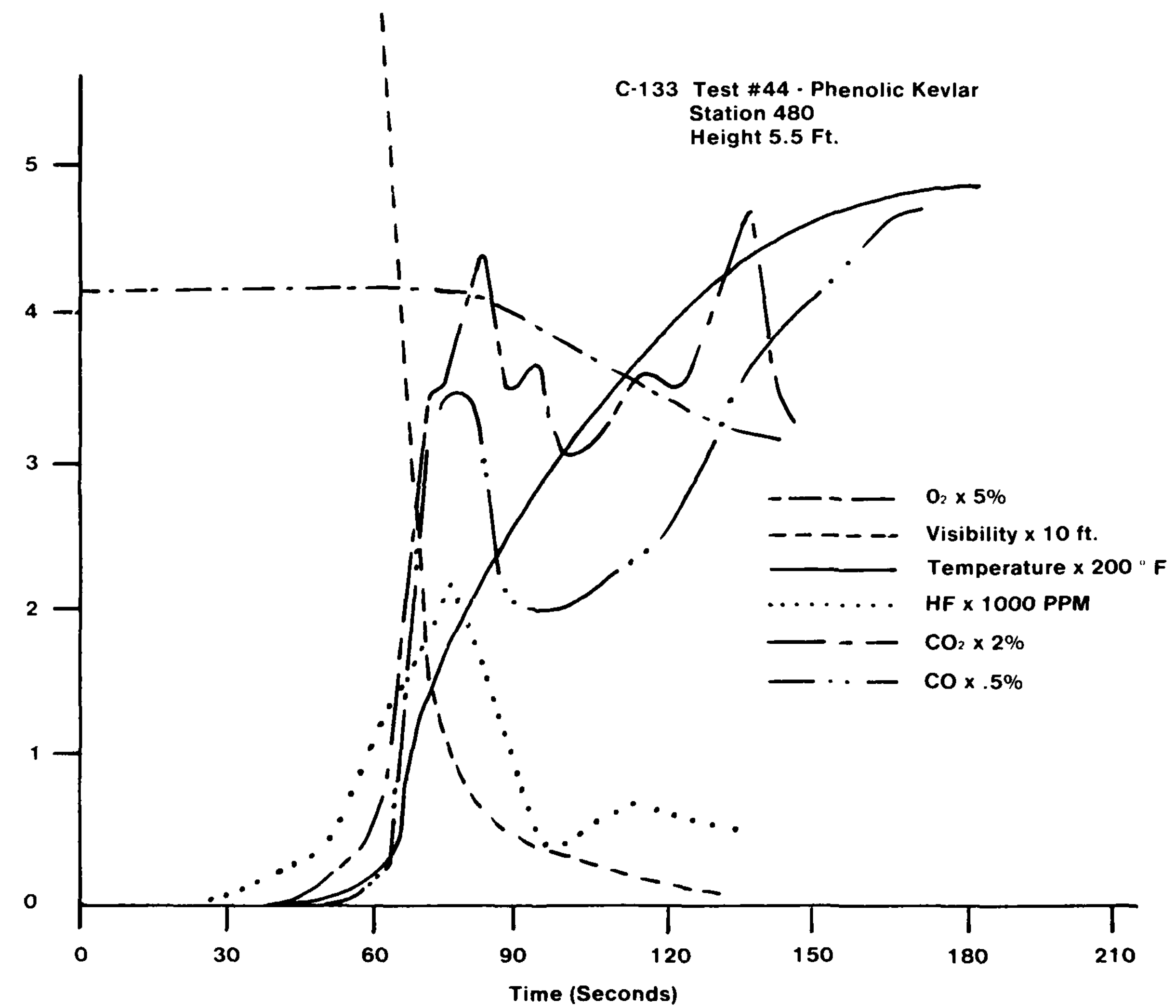
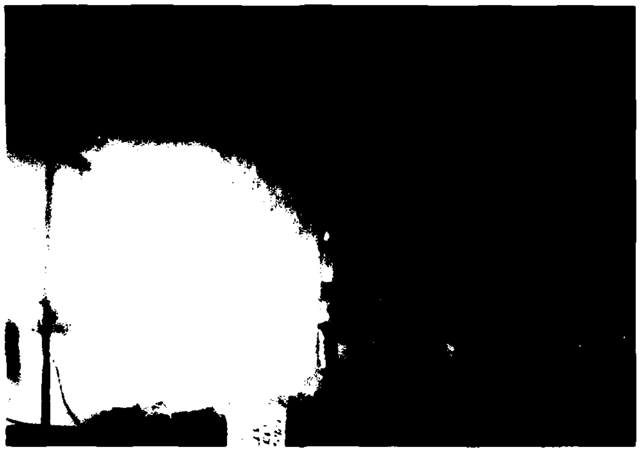


FIGURE 11. HAZARD-TIME PROFILES



Epoxy/Fiberglass

Phenolic/Fiberglass

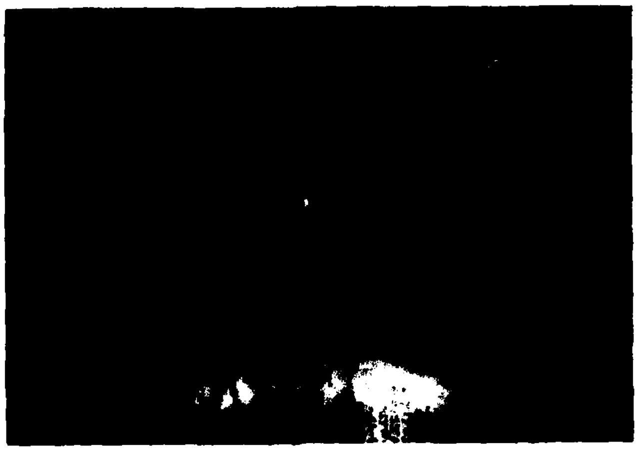
Phenolic/Kevlar

FIGURE 12. PANEL COMPARISON AT 1 MINUTE 30 SECONDS (1 of 2 pages)

Phenolic/Graphite

Peek/Polyimide

FIGURE 12. PANEL COMPARISON AT 1 MINUTE 30 SECONDS (2 of 2 pages)



Phenolic/Graphite

Phenolic/Fiberglass

Peek/Polyimide

FIGURE 13. PANEL COMPARISON AT 3 MINUTES 40 SECONDS

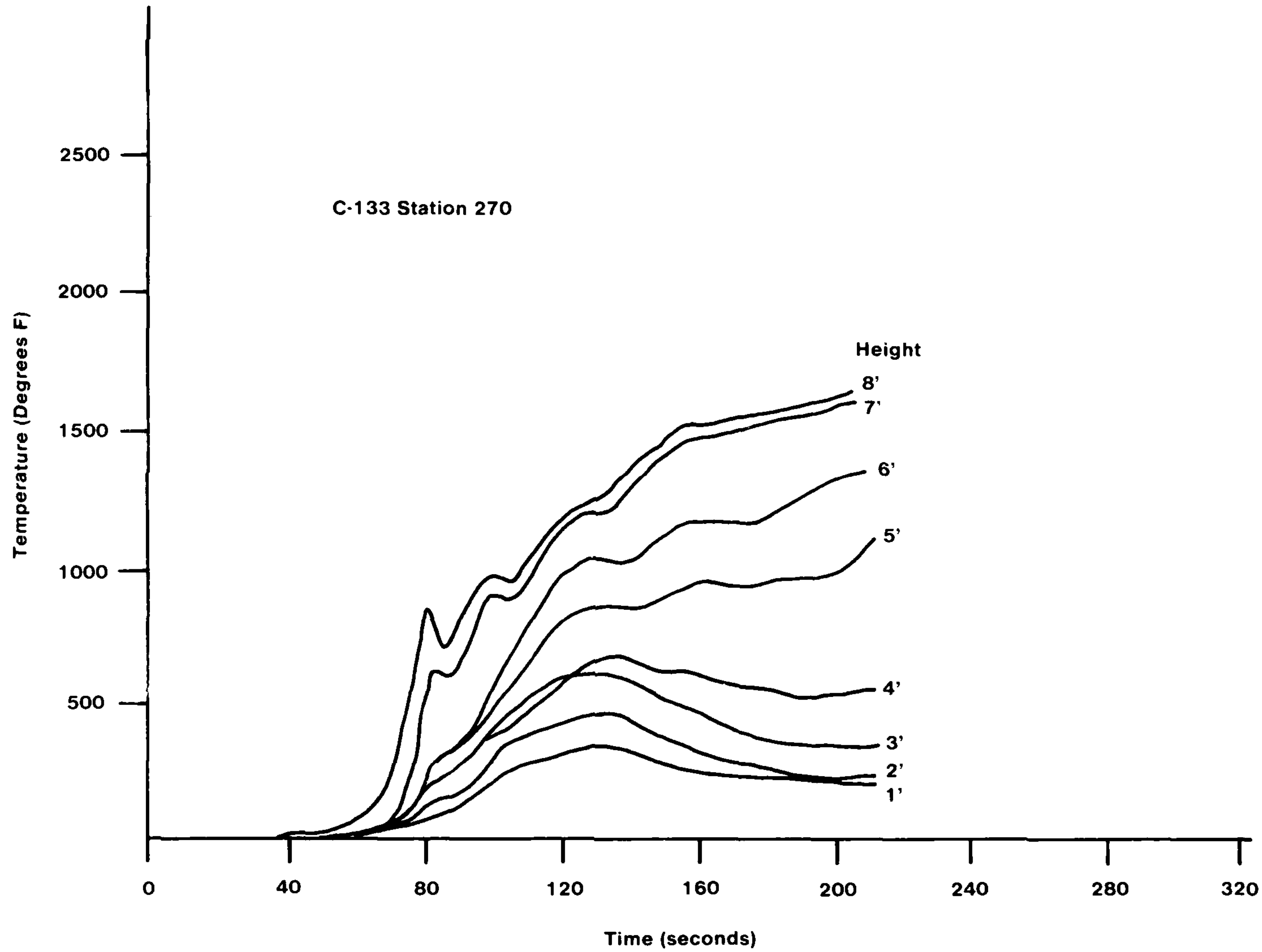


FIGURE 14. TEMPERATURE PROFILES FOR EPOXY/FIBERGLASS PANELS

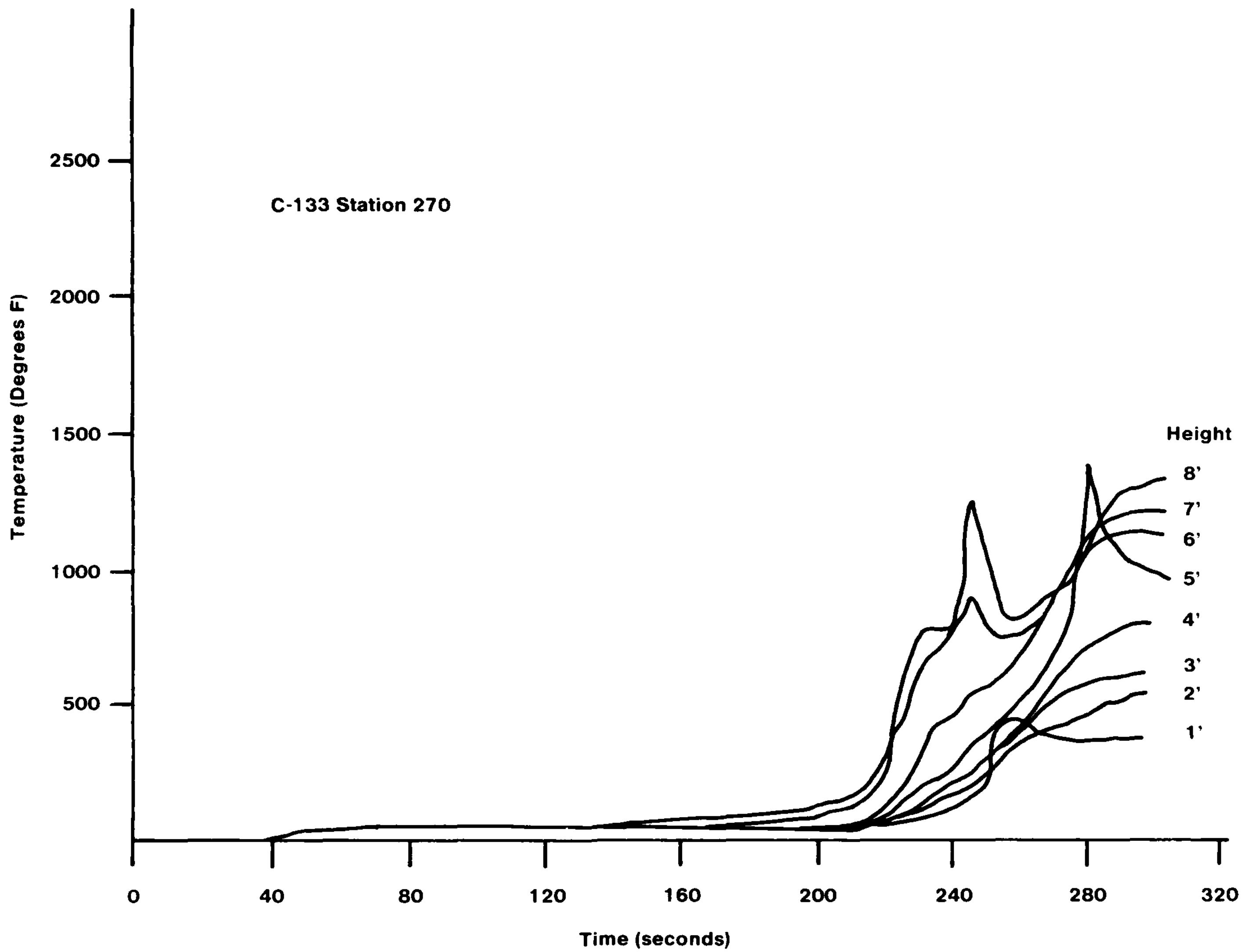


FIGURE 15. TEMPERATURE PROFILES FOR PHENOLIC/FIBERGLASS PANELS

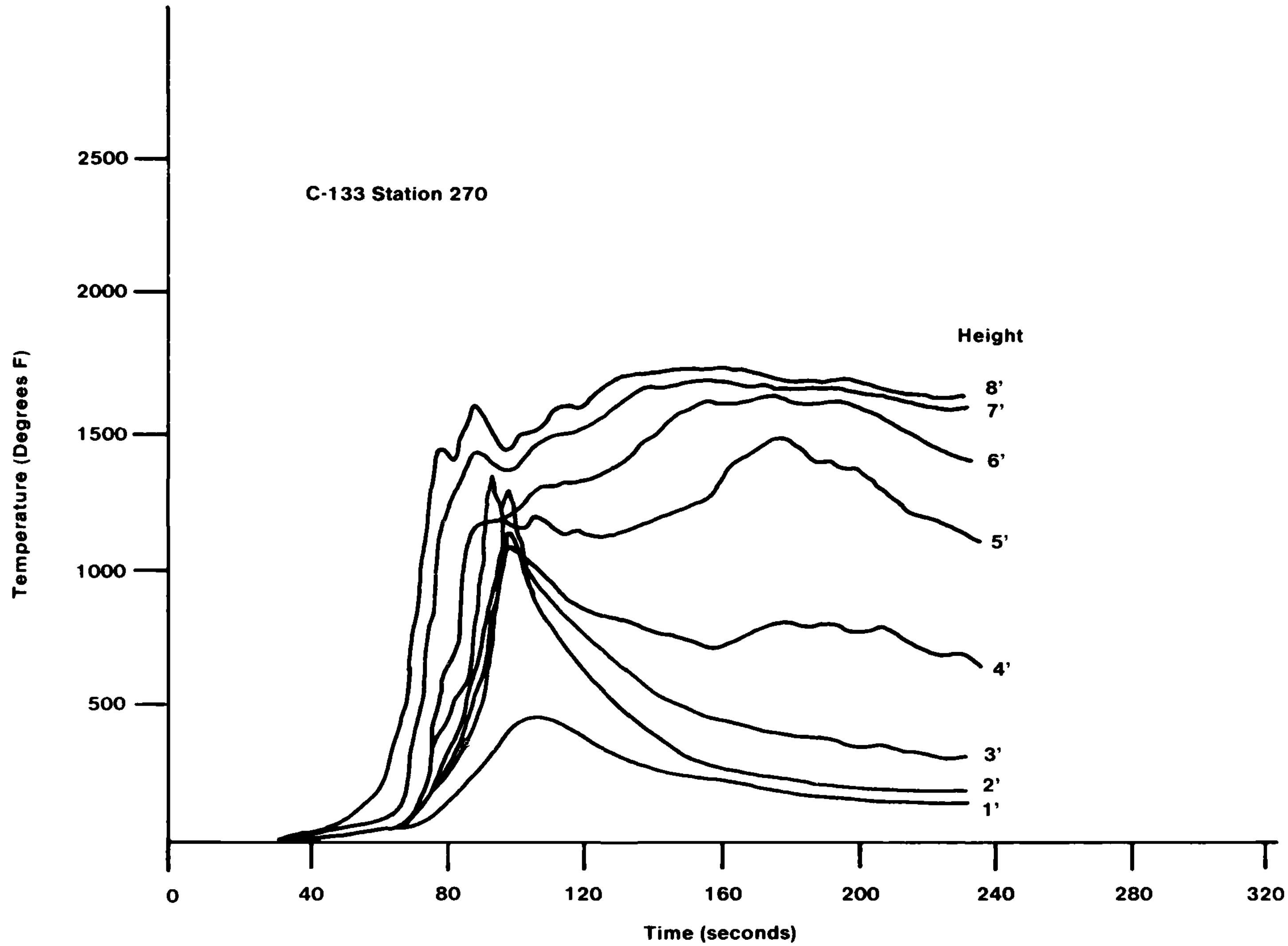


FIGURE 16. TEMPERATURE PROFILES FOR PHENOLIC/KEVLAR PANELS

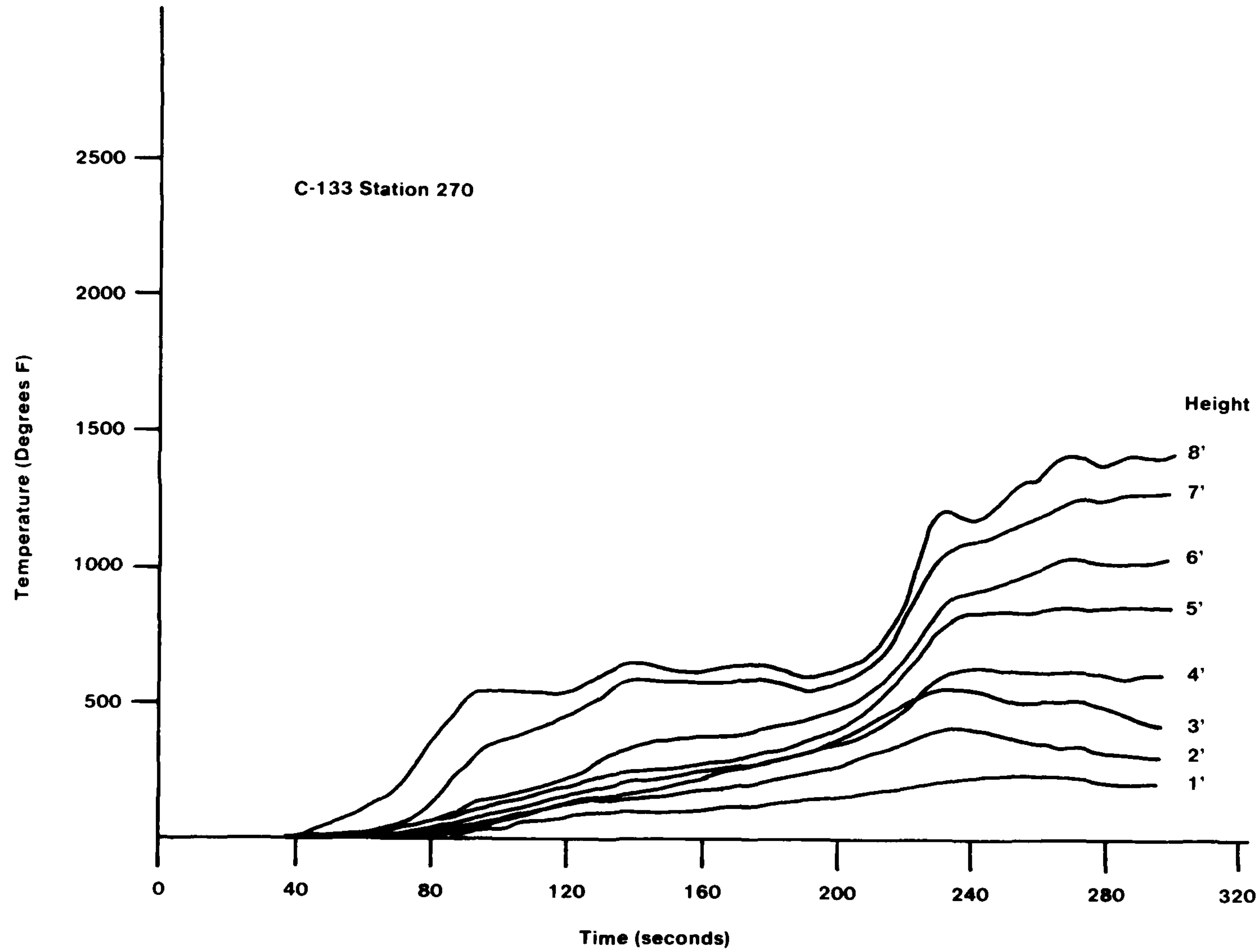


FIGURE 17. TEMPERATURE PROFILES FOR PHENOLIC/GRAPHITE PANELS

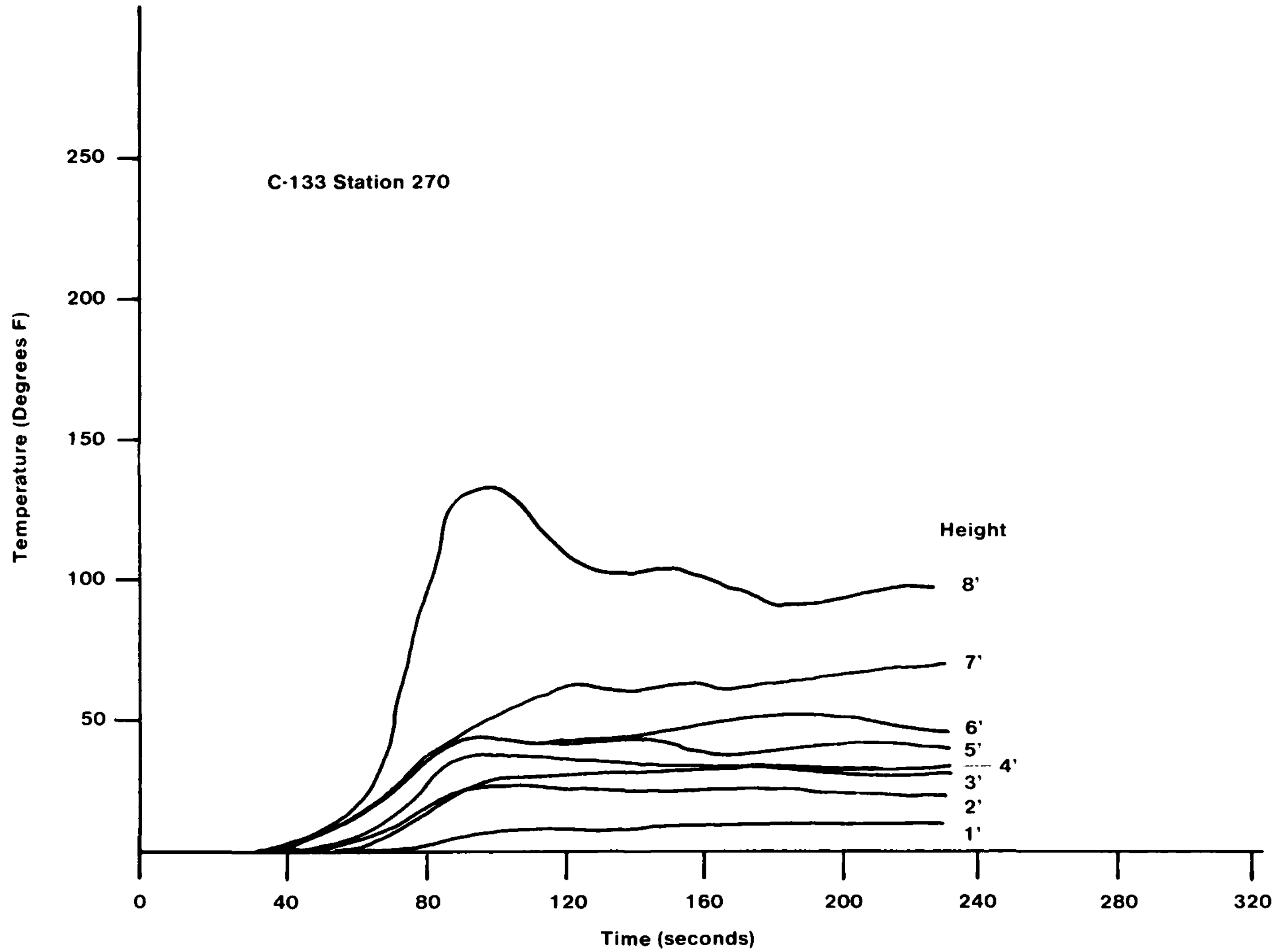


FIGURE 18. TEMPERATURE PROFILES FOR PEEK/POLYIMIDE PANELS

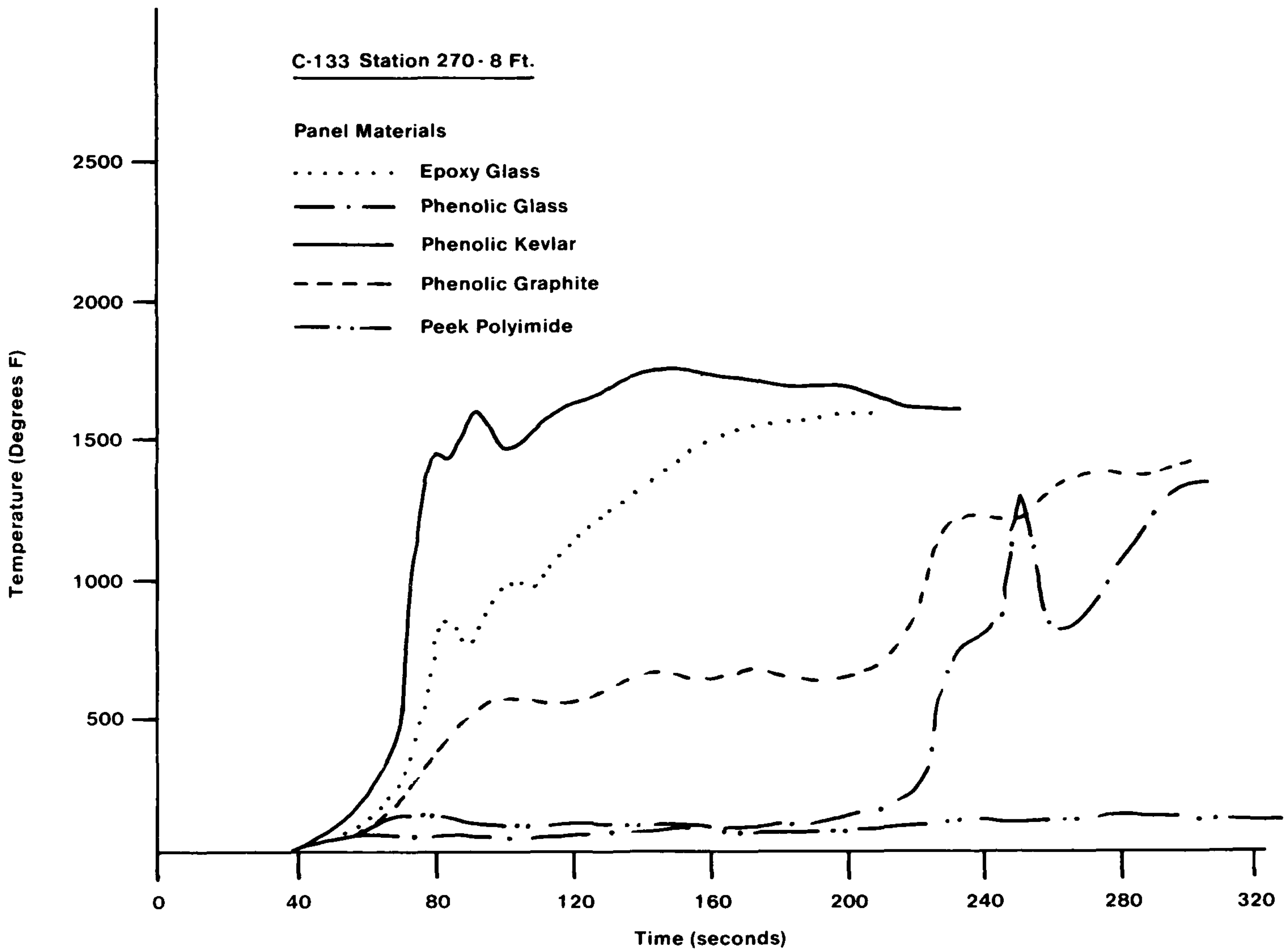


FIGURE 19. COMPARATIVE TEMPERATURE PROFILES

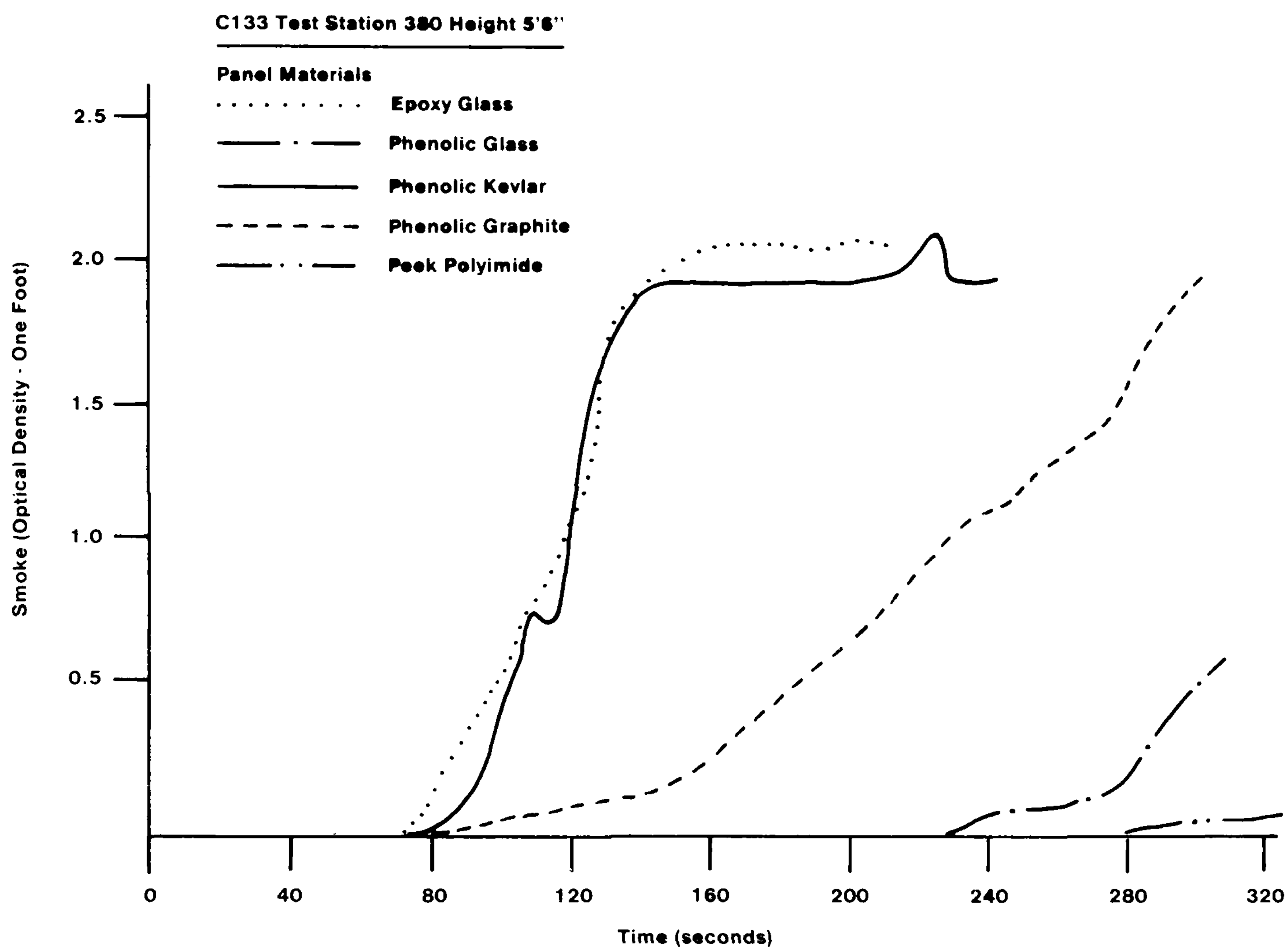


FIGURE 20. COMPARATIVE SMOKE PROFILES

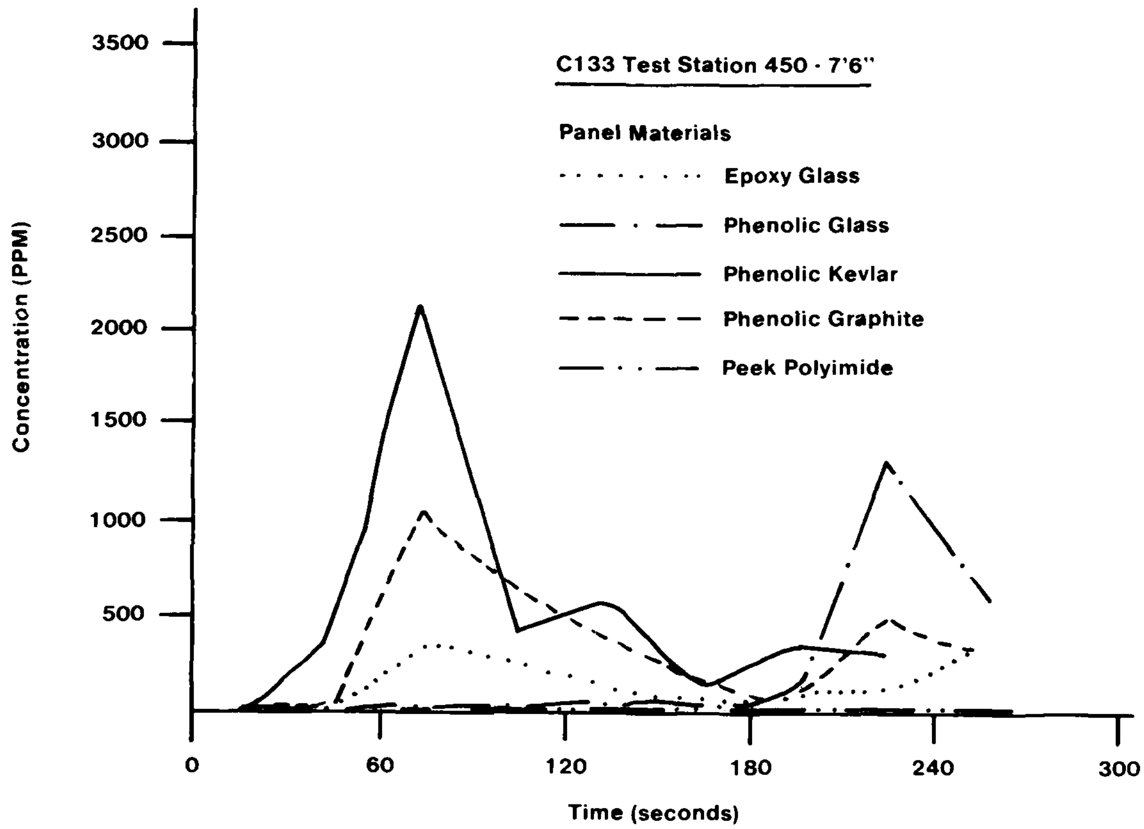


FIGURE 21. COMPARATIVE HYDROGEN FLUORIDE PROFILES

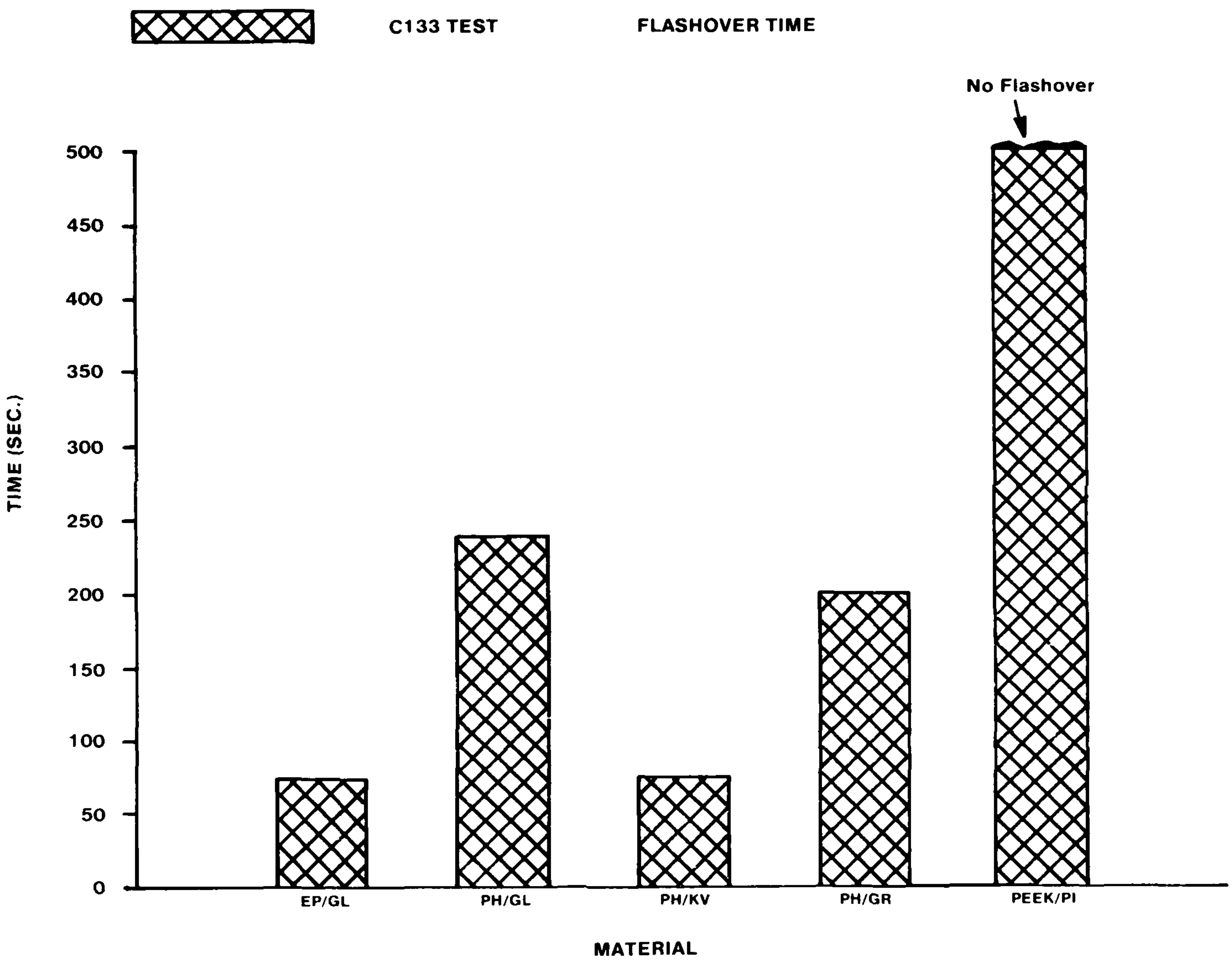


FIGURE 22. FLASHOVER BAR GRAPH

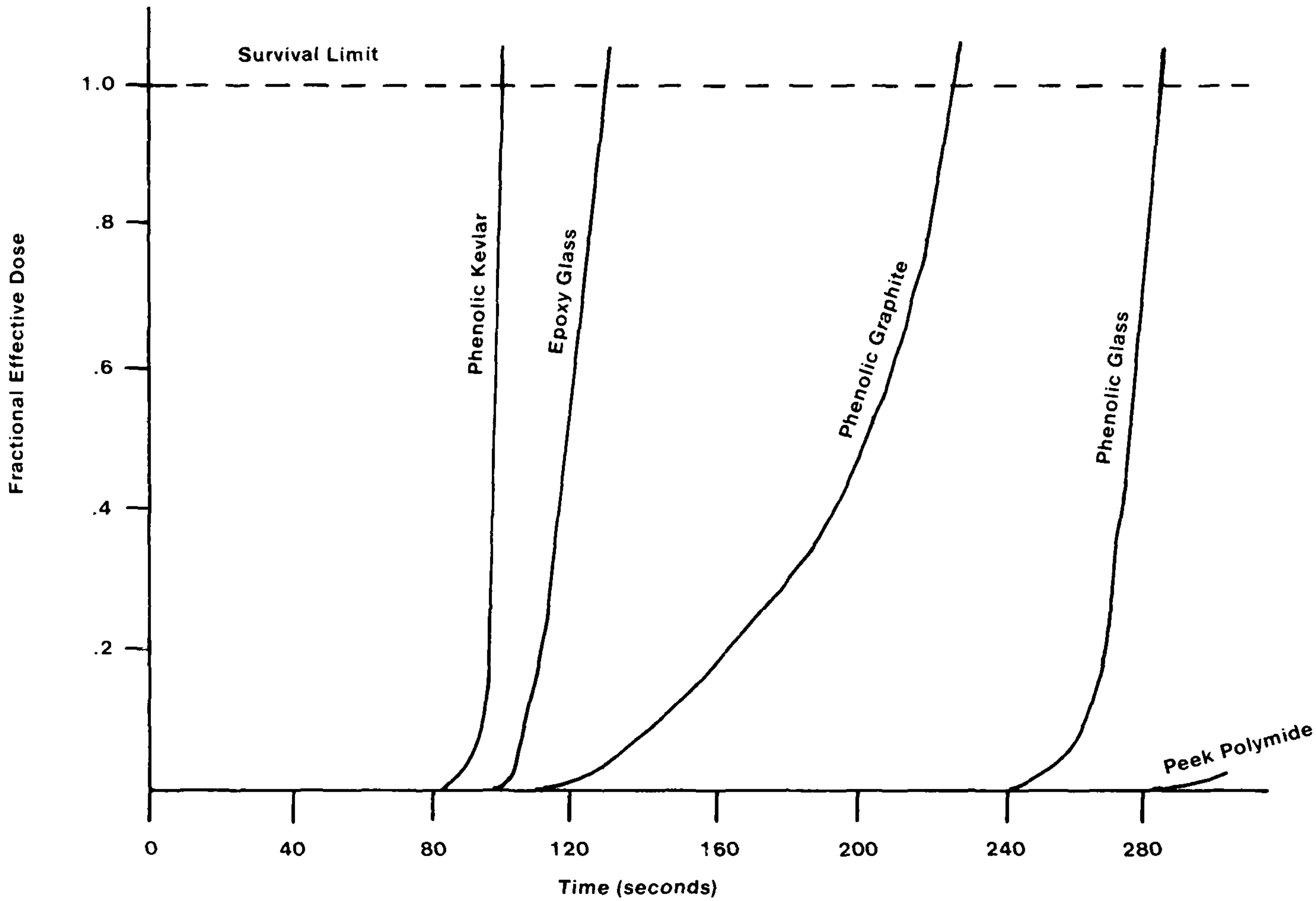


FIGURE 23. FRACTIONAL EFFECTIVE DOSE COMPARISON

APPENDIX A

NPNM 85-10

federal register

Tuesday
April 16, 1985

Part II

Department of Transportation

Federal Aviation Administration

14 CFR Parts 25 and 121

Improved Flammability Standards for Materials Used in the Interiors of Transport Category Airplane Cabins: Notice of Proposed Rulemaking

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Parts 25 and 121

[Docket No. 24594; Notice No. 85-10]

Improved Flammability Standards for Materials Used in the Interiors of Transport Category Airplane Cabins

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This notice proposes to upgrade the fire safety standards for cabin interior materials in transport category airplanes by: (1) Establishing new fire test criteria for type certification; (2) requiring that the cabin interiors of airplanes manufactured after a specified date and used in air carrier service comply with these new criteria; and (3) requiring that the cabin interiors of all other airplanes type certificated after January 1, 1958, and used in air carrier service comply with these new criteria upon the first replacement of the cabin interior. These proposals are the result of fire testing and are intended to increase airplane fire safety.

DATES: Comments must be received on or before July 15, 1985.

ADDRESSES: Comments on this proposal may be mailed in duplicate to: Federal Aviation Administration, Office of the Chief Counsel, Attention: Rules Docket (AGC-204), Docket No. 24594, 800 Independence Avenue SW., Washington, D.C. 20591, or delivered in duplicate to: Room 916, 800 Independence Avenue SW., Washington D.C. 20591. Comments delivered must be marked: Docket No. 24594. Comments may be inspected in Room 916 weekdays, except Federal holidays, between 8:30 a.m. and 5:00 p.m. In addition, the FAA is maintaining an information docket of comments in the Office of the Regional Counsel (ANM-7), FAA, Northwest Mountain Region, 17900 Pacific Highway South, C-68966, Seattle, Washington 98168. Comments in the information docket may be inspected in the Office of the Regional Counsel weekdays, except Federal holidays, between 7:30 a.m. and 4:00 p.m..

FOR FURTHER INFORMATION CONTACT: Richard Nelson, Regulations Branch (ANM-112), Regulations and Policy Office, Aircarft Certification Division, FAA, Norhwest Mountain Region, 17900 Pacific Highway South, C-68966, Seattle, Washingtion 98168; telephone (206) 431-2121.

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested persons are invited to participate in the proposed rulemaking by sumitting such written data, views, or arguments as they may desire. Comments relating to the environomental, energy, or economic impact that might result from adoption of proposals contained in this notice are invited. Substantive comments should be accompanied by cost estimates. Commenters should identify the regulatory docket or notice number and submit comments, in duplicate, to the Rules Docket address specified above. All comments will be considered by the Administrator before taking action on the proposed rulemaking. The proposals contained in this notice may be changed in light of comments received. All comments will be available in the Rules Docket, both before and after the closing date for comments, for examination by interested persons. A report summarizing each substantive public contact with FAA personnel concerning this rulemaking will be filed in the docket. Commenters wishing the FAA to acknowledge receipt of their comments must submit with those comments a self-addressed, stamped postcard on which the following statement is made: "Comments to Docket No., 24594." The postcard will be date/time stamped and returned to the commenter.

Availability of NPRM

Any person may obtain a copy of this NPRM by submitting a request to the Federal Aviation Administration, Office of Public Affairs, Attention: Public Information Center, APA-430, 800 Independence Avenue SW., Washington, D.C. 20591; or by calling (202) 426-8058. Communications must identify the notice number of this NPRM. Persons interested in being placed on a mailing list for future NPRMs should also request a copy of Advisory Circular No. 11-2A, Notice of Proposed Rulemaking Distribution System, which describes the application procedures.

Background

During the nearly post-World War II period, a number of regulatory steps were taken to improve transport category airplanes from a fire safety standpoint. Among the areas of concern was flammability of the various materials used in the interiors of the pasenger cabins. Accordingly, Part 4b of the former Civil Air Regulations (CAR) was amended in 1947 to provide a test standard for such materials. The standard adopted at that time consisted of a requirement to show that the material was slow burning while in a horizontal orientation. This standard was upgraded periodically as the state-of-the-art in interior materials improved. The current standard, which was adopted in May of 1972 and is contained in § 25.853 of the Federal Aviation Regulations (FAR), specifies that all large-usage material must be self-extinguishing in a vertical orientation when subjected to a small flame. The test method used to show compliance with this standard is often referred to as the "vertical Bunsen burner test". The use of materials which meet this standard reduces the probability of ignition by a small flame, and the rate of flame propagation beyond the ignition source.

Which the current standard provides protection from small flames, it does not ensure that interior materials will not ignite and burn when subjected to a larger, external fire. The materials used in nonstructural applications in cabin interiors are almost exclusively organic in nature and, when ignited by an intense external fire, emit heat, smoke, combustibles and toxic gases. Although these emissions affect the survivability of the occupants of the airplane, the extent depends on a number of factors, such as fuselage integrity, fire locations and involvement, ambient wind conditions, exit locations and airplane configurations.

Because the standard adopted in 1972 considered only the flammability of interior materials, the FAA made two regulatory proposals pertaining to toxicity and smoke: Advance Notice of Proposed Rulemaking (ANPRM) No. 74-38 (39 FR 45044; December 30, 1974) and NPRM No. 75-3 (40 FR 6505; February 12, 1975), respectively. Advance Notice of Proposed Rulemaking No. 74-38 was issued to invite public participation in developing standards governing the toxic gas emission characteristics of compartment interior materials when subjected to fire. Notice of Proposed Rulemaking No. 75-3 was issued to solicit comments on proposed amendments of Parts 25 and 121 of the FAR concering standards for the smoke emission characteristics of compartment interior materials. The rules proposed in NPRM No. 75-3 would have required that certain material used in each compartment occupied by the crew or passengers meet certain test criteria pertaining to smoke emission. The materials that would have had to be tested would have been specified either in terms of their use in a compartment or in terms of the processes involved in their manufacture. In addition to type certification requirements, NPRM No.

75–3 proposed retrofit provisions to ensure that cabin interiors of airplanes already in service were upgraded with respect to the smoke emission characteristics of the compartment interior materials. Also, in 1975, the FAA proposed in NPRM No. 75–31 (40 FR 29410; July 11, 1975) to require the retrofit of certain transport category airplanes already in service with cabin materials meeting the flammability standard adopted in 1972. The public response to these proposals was negative. Commenters cited inadequate development of test methodology and the high cost of compliance coupled with questionable safety benefit. Of particular concern was an inadequate understanding of the interrelationship of flammability, smoke and toxicity. Following evaluation of the public comments, these proposals were withdrawn for further study.

As part of this study, public hearings on aircraft fire safety were held, and, in June of 1978, the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee was established by the FAA. This Committee was directed to "examine the factors affecting the ability of the aircraft cabin occupant to survive in the post-crash environment and the range of solutions available." The Commitee consisted of 24 representatives of a wide range of aviation and general public interests. Technical support groups included approximately 150 of the world's top experts in fire research, accident investigation, materials development, and related fields. At the conclusion of its investigation into cabin materials technology, the Committee issued findings and formal recommendations pertaining to long-range research, design, testing, and the problems of smoke and toxic gas emission. The SAFER Advisory Committee recommended that further research and development be undertaken in regard to cabin materials, and that a test method using radiant heat for screening cabin materials be evaluated and implemented as soon as available. The FAA concurred with these recommendations and initiated the necessary reserach and development. See Report No. FAA-ASF-80-4, Final Report of the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee, dated June 26, 1980. A copy of this report has been included in the Rules Docket and is available for public inspection. This document is available for purchase from the National Technical Information Service (NTIS) in Springfield, Virginia 22161.

The reseach and development program, managed and conducted primarily at the FAA Technical Center in Atlantic City, New Jersey, was designed to study aircraft fire characteristics, develop practical test methods and investigate the feasibility of the various new standards being considered at that time. Further study concerning toxicity was conducted at the FAA Civil Aeromedical Institute (CAMI) in Oklahoma City, Oklahoma. This program encompassed a number of other areas related to aircraft fire safety in addition to the flammability of interior materials. As a result, new standards have been adopted for floor proximity emergency escape path markings and flammability of seat cushions in Amendments Nos. 25–58 and 121–183 (49 FR 43182; October 26, 1984), and 25–59, 29–23 and 121–184 (49 FR 43188; October 26, 1984), respectively; and new standards have been proposed for cargo or baggage compartments in NPRM No. 84–11 (49 FR 31830; August 8, 1984) and for smoke detector and hand held fire extinguishers in NPRM No. 84-5 (49 FR 21010; May 17, 1984). Also, Technical Standard Order (TSO) C69 has been amended to improve the fire resistance of evacuation slides.

Among the tests conducted at the Technical Center were full-scale fire tests using the fuselage of a military C-133, configured to represent a wide-body jet transport airplane. The test conditions simulated typical post-crash, external fuel-fed fires. Among other aspects of cabin fires, the phenomenon known as "flashover" was investigated. ("Flashover" is a condition in which certain gases and other products emitted during the combustion process and trapped in the upper portions of the cabin reach their auto-ignition temperature and are ignited spontaneously. Due to the almost total involvement of the cabin atomosphere, survival after flashover is virtually impossible.) Numerous laboratory tests were also conducted to correlate possible material qualification test methods with the full-scale tests. As a result of these tests, the Ohio State University (OSU) rate of heat release apparatus standardized by the American Society of Testing and Materials (ASTM), ASTM-E-906, as modified with an oxygen analyzer for heat release measurement, was determined to be the most suitable for material quaification. This is a test method employing radiant heat, as recommended by the SAFER Advisory Committee. The feasibility of this test method and the proposed standards was then verified by testing a number of representative materials. The overall approach is outlined in Report No. FAA-ED-18-7, Engineering and Development, Program Plan, Aircraft Cabin Fire Safety, dated June 1980, revised February 1983. A copy of this report has been placed in the Rules Docket and is available for public inspection. It is available for purchase from the NTIS at the address given earlier.

Discussion

As noted, testing with the modified OSU test apparatus was found to be the most suitable means of assuring that prospective interior materials meet acceptable standards for flammability. Consideration was also given to establishing separate test methods and standards for such materials with respect to smoke and toxicity.

The full-scale fire tests demonstrated a correlation between flammability and smoke emission characteristics in the materials tested. Material flammability, as represented by an increase in air temperature, was also reflected in increased smoke emission in a growing fire enironment. Because of this correlation between flammability and smoke emissions, and the fact that fire growth is a more significant survivability factor than smoke alone, it is not considered ncessary to establish a separate test method and standards for measurieng smoke emission characteristics. For a further discussion of these tests and their results, see Report No. DOT/FAA/CT-83/43, entitled, "Aircraft Seat Fire Blocking Layers: Effectiveness and Benefits Under Various Scenarios" (available for purchase from the NTIS at the address stated earlier), and Draft Report No. 85-0393, "Evaluation of Aircraft Interior Panels Under Full-Scale Cabin Fire Test Conditions," which has been prepared for presentation at the American Institute of Aeronautics and Astronautics 23rd Aerospace Sciences Meeting, January 14–17, 1985. These document have been placed in the Rules Docket and are available for public inspection.

With respect to toxic emissions, the test program, including testing of individual panels in the C-133 airplane, showed that: (1) There is a correlation between flammability characteristics and toxic emissions; and (2) the severe hazard from toxic emissions occurs as a result of flashover in fires involving interior materials. The levels of toxic gases measured before flashover, or when flashover did not occur, were below levels estimated to prevent occupant survival. After flashover, occupant survival is virtually impossible, regardless of the level of toxic emissions.

The proposed flammability standards address the toxicity problem in two ways. First, they require the use of cabin interior materials with higher ignition temperatures, reducted heat release rates, and lower content of thermally unstable components, thereby reducing toxic emission levels as well as smoke levels before flashover. Second, they delay or prevent the onset of flashover, where high levels of toxic emissions occur.

In view of the demonstrated improvements in toxicity characteristics which these standards will represent, and the fact that a satisfactory separate test for toxicity is not available, it is not considered practical or necessary to establish an entirely separate test method or standard for toxicity. For additional information concerning toxic emissions see Report No. DOT/FAA/CT-83-43, and draft Report No. 85-0393, referenced earlier in this document.

As proposed in this notice, all larger interior surface materials used from the floor up in compartments occupied by the crew or passengers would have to be qualified to the new flammability standards. This would include sidewalls, ceilings, bins and partitions, galley structures, and any coverings on these surfaces, but would not include smaller items, such as windows, window shades, or curtains. Floor coverings and floor structure would not have to meet these standards because the full-scale tests showed very little involvement of flooring until after flashover had occurred. Seats would not be tested because the recently-adopted standards for flammability of seat cushions will greatly inhibit involvement of the seats. In addition to the testing required to meet the new flammability standards, interior materials would still have to meet the current vertical Bunsen burner test. This test would be retained because it is possible that an extremely thin material might not release enough heat to exceed the proposed standards, yet be highly flammable. The vertical Bunsen burner is a relatively simple and inexpensive test to perform, and its retention should cause little or no additional burden.

Service items, such as pillows or blankets, magazines, food, and alcoholic beverages, are not part of the certification process and would not have to meet the new flammability standards. While these items are flammable, it is not considered practical or feasible to establish flammability standards for them at this time. Similarly, passenger carry-on items and even the clothing worn by passengers represent a significant quantity of flammable material; however, it is considered that it would be impracticable to establish and enforce flammability standards for such items.

Many of the fatalities in crashes involving transport category airplanes have been attributed to the effects of post-crash fire rather than from trauma at impact, and there have been at least three major accidents, world wide, with fatalities due to in-flight cabin fires since 1973. The recently-adopted standards for seat cushions will eliminate or delay involvement of a large quantity of flammable material during a cabin fire; however, the other interior materials also represent a significant quantity of flammable material. The FAA research and development program has shown that interior materials with improved flammability characteristics are feasible and would further reduce the number of fatalities from both post-crash and in-flight cabin fires. It is, therefore, considered essential that cabin interior materials meeting the proposed standards, based on the modified Ohio State University test method, be introduced into service—particularly air carrier service—as early as economically and technologically feasible. Accordingly, it is proposed to amend Part 25 to require the use of cabin interior materials meeting the new flammability standards for all transport category airplanes for which application for type certification is made after the effective date of the amendment. Concurrently, Part 121 is proposed to be amended to require such materials in all airplanes newly manufactured two years or more after the effective date of the amendment and operated under the provisions of Part 121 or 135, regardless of the basis for type certification. (Section 135.169(a) incorporates the provisions of § 121.312 by reference, insofar as operations with large airplanes are concerned.) The two year compliance period for newly manufactured airplanes is intended to allow the airplane manufacturers time to select and qualify prospective cabin interior materials and incorporate them with a minimum of disruption to the assembly line. In addition, all other large airplanes type certificated after January 1, 1958, and operated under the provisions of Part 121 or 135 would have to be modified to use such materials the first time the cabin interior is replaced after a date two years from the effective date of this proposed amendment. ("Replaced", as used in this context, means an essential complete replacement of the cabin interior. Replacement of individual panels on a piece-meal basis would not significantly increase the level of safety and might result in parts incompatibility.) Unlike the coverings on seat cushions which must be replaced frequently due to wear, the interior materials addressed by this notice are more durable and, at the same time, more costly to replace. It is, therefore, not considered economically feasible to require these materials to be replaced with materials that meet the new flammability standards within the same time frame as required for seat cushion materials meeting the new seat cushions flammability standards.

A general retrofit requirement is not being proposed at this time because of a number of practical and cost-benefit considerations. By relating introduction of new materials to normal interior replacement cycles, the financial burden and the resultant cost to the traveling public would be reduced. Based on FAA testing of a number of representative materials, many airplanes in service presently incorporate materials that would meet the proposed new standards; and many more have interior materials that come very close to meeting these standards. For these airplanes, the increase in safety resulting from a retrofit requirement would be negligible. Many other airplanes will be retired from air carrier service in the near future due to obsolescence. The interiors of most of the remaining airplanes will be replaced for other reasons, such as wear or modernization. It is impossible to predict exactly how rapidly new materials would be phased into these airplanes under the proposed rules, because the service life of an interior depends on a number of factors. Recently, interiors have typically been replaced after seven to ten years of service. This may, however, have been accelerated somewhat due to the introduction of the "wide-body look" in narrow-body airplanes. Nevertheless, it appears that there would be few, if any, airplanes in which the interiors are not replaced for other reasons within a reasonable period of time. If materials not meeting the proposed new standards do remain in service in a significant number of air carrier airplanes because routine interior replacements are not accomplished as anticipated, and a substantial increase in overall safety could be realized, the FAA would consider proposing a mandatory retrofit requirement in a subsequent rulemaking action.

Airplanes type certificated on or before January 1, 1958, are not included because their advanced age and very limited numbers in Part 121 or 135 operation would make compliance impractical from an economic standpoint. That date was selected because it would include the Boeing 707 and Douglas DC-8 vintage and later airplanes and exclude older models, such as the Douglas DC-6/7 and Convair 340/440. It should be noted that the replacement provisions of this notice do not apply to airplanes that are not operated under the provisions of Part 121 or 135, such as executive airplanes.

The term "replacement" would be substituted for the terms "major overhaul" and "refurbishing" currently used in § 121.312 because the latter terms have been found to be technically inappropriate. Interiors are not "overhauled" in the sense of Part 43 of this subpart, and "refurbishing" implies renovation or refinishing, rather than replacement of components. As noted earlier, "replacement", as used in this context, means an essentially complete replacement of the interior rather than replacement of individual components on a piecemeal basis.

Regulatory Evaluation

I. Cost Benefit Analysis

The proposals contained in this notice would upgrade the fire safety standards for cabins in transport category airplanes. Such airplanes would have to comply with new fire test criteria if application for type certificate is made after the effective date of the proposed rule, or, for airplanes used in air carrier service only, if they are manufactured after a specified date or if substantial sections of their interiors are replaced after that date.

The proposals result from FAA research efforts recommended by the FAA sponsored SAFER Advisory Committee. The proposals address flammability, smoke and toxicity considerations of cabin materials by an improved flammability test. Compliance with the proposals is possible utilizing the current state-of-the-art in cabin materials. The cabin components covered will be all high volume usage, surface materials above the floor of the airplane cabin, including sidewalls, ceiling, bins, and partitions.

There are minimal costs in complying with the proposed tests. The test procedure is a relatively simple one, and tests already conducted indicate that a number of materials presently used comply with the proposed standards. Further, the materials which meet the standards are basically the same cost as other materials used today, which might not pass the test. Also, there is no apparent problem in substituting these materials for components which fail to meet the standards. For new certification programs, there should be no increased design engineering or material costs, and only a small cost for the required testing. To introduce the materials into the production of airplanes which have already been certificated, the costs are expected to total about $2.3 million for design, engineering and certification testing to assure compliance for a specific group of panel materials. Of this total, approximately $600,000 is expected to be required for initial testing, engineering and certification. This is based on the FAA estimate that such activities will require the equivalent of approximately 12,000 engineer-hours, at $26 per hour, plus an additional $300,000 for materials, test equipment, consultants, and other nondirect labor costs. These are not recurring costs, and future costs are expected to be negligible. Data indicate that the materials used in specific components do not change frequently over the production life of an airplane, so that any future testing cost is incurred infrequently. There is no cost associated with switching over manufacturing processes to use only materials which comply with the proposed tests.

The balance, approximately $1.7 million, involves redesign of components in current production airplanes to comply with the new standards. It is estimated approximately half of the components, as presently constructed, will pass the proposed tests. While the number of engineering hours required to redesign each of the remaining components will vary considerably, it is estimated that the total for all of these remaining components will approximate 33,000 engineer-hours. Again, a cost of $26 per engineer-hour is used. An equivalent amount can also be expected for other resources, including inventory adjustment costs and similar costs.

The benefits from these proposals result from the increased likelihood of surviving an in-flight cabin fire or a crash which involves a post-crash fire. The improved flammability standards proposed in this notice would provide an additonal increment of time for passengers trapped in a burning airplane to escape. This, in turn, would allow more passengers to survive in a given situation. The benefits of these proposals are in addition to those resulting from the improved seat cushion standards contained in Amendments 25-59 and 121-184 because of the additional survival time increment gained and resultant additonal lives saved. Unlike the costs, which would be incurred largely over the first two years, the benefits would not start until a year later and would increase gradually thereafter as airplanes with new materials are phased into service.

The National Bureau of Standards (NBA), on FAA's behalf, recently conducted an extensive review of all commercial accidents worldwide in which fire was a factor in fatalities. While the NBS study dealt primarily with standards for seat cushions, the conclusion reached with respect to escape time versus survivability are equally applicable to these proposals. A copy of the NBS study, Report No. DOT/FAA/CT-84/8, entitled "Decision Analysis Model for Passenger-Aircraft Fire Safety with Application to Fire-Blocking of Seats" and dated April 1984, has been placed in the Rules Docket and is available for public inspection. Based on the results of the NBS study and a monetized value of $650,000 per life, the FAA estimates that the cumulative difference in lives saved and damage reduced by the year 2000 would amount to a benefit of approximately $8.8 million dollars. These benefits are discounted to a present value using a ten percent discount rate. The benefit to cost ratio is, therefore, approximately four to one.

The complete economic analysis for these proposals has been placed in the Rules Docket and is available for public inspection.

II. Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 (RFA) was enacted by Congress in order to ensure, among othe things, that small entities are not disproportionately affected by government regulations. The RFA requires agencies to review rules which may have "a significant economic impact on a substantial number of small entities." The entities potentially affected by these proposals are airplane manufacturers and, assuming that airplane costs go up moderately, the operators of large airplanes. The FAA has issued guidance on the meaning of small entities and significant economic impact for both of these entity types. (Order 2100.14, *Regulatory Flexibility Criteria and Guidance*, FAA, July 1983.)

With respect to airplane manufacturers, the FAA has determined that airplane and airplane parts manufacturers are small if they have 75 or fewer employees. The airplane manufacturers subject to the terms of this proposal are all large firms. Only five current U.S. firms have certificated airplanes under Part 25, and the smallest, Gates Lear Jet, has an estimated 6,500 employees. (*Million*

Dollar Directory—1983. Dunn and Bradstreet Inc.)

Since the proposal may add a small amount to the price of new airplanes, there may be an impact on small entities which are operators of airplanes. The FAA has determined that for operators of airplanes for hire, small entities are those which own nine or fewer airplanes. The significant cost thresholds for "operators of airplanes for hire" are $85,070 for scheduled operators with airplanes having 60 or more seats, $47,506 for other scheduled operators and $3,315 for unscheduled operators (1983 values). The cost increase for new airplanes manufactured under the standards of this proposal is expected to be under $10,000 per airplane. The typical small entity operator of large airplanes would have to buy so many airplanes per year to reach this level of impact, that the operator would cease to be a small entity. There are thousands of small entities who are unscheduled operators, but only a few which operate large airplanes. In this type of entity, the cost increase could seemingly reach a level of significant economic impact because of the low annual cost threshold. However, the overwhelming majority of unscheduled operators are on demand air taxis, which operate small airplanes that are not subject to the requirements of this proposal.

In view of the above, FAA finds that compliance with these proposals would not result in a significant economic impact for a substantial number of small entities.

III. International Trade Assessment

This proposal, if adopted, would have little or no impact on trade opportunities for both U.S. firms doing business overseas and foreign firms doing business in the U.S. The proposal affects the rules for certificating new airplanes. Also, newly manufactured airplanes for the U.S. market, whether made by U.S. or foreign manufacturers, would have to comply with the rule. Any cost of compliance is negligible, however, when compared to the cost of a new airplane.

Conclusion

For the reasons given earlier in the preamble, the FAA has determined that this is not a major regulation as defined in Executive Order 122[illegible]. The FAA has determined that this action is significant as defined in Department of Transportation Regulatory Policies and Procedures (44 FR 11034; February 26, 1979). In addition, it has been determined under the criteria of the Regulatory Flexibility Act that this regulation, at promulgation, will not have a significant economic impact on a substantial number of small entities.

List of Subjects

14 CFR Part 25

Air transportation, Aircraft, Aviation safety, Safety.

14 CFR Part 121

Aviation safety, Safety, Air carriers, Air transportation, Aircraft, Airplanes, Airworthiness directives and standards, Flammable materials, Transportation, Common carriers.

The Proposed Amendment

Accordingly, the FAA proposes to amend Parts 25 and 121 of the Federal Aviation Regulations (FAR) 14 CFR Parts 25 and 121, as follows:

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

1. By amending § 25.853, be adding a new paragraph (a–1).

§ 25.853 Compartment interiors.

* * * * *

(a–1) In addition to the flammability requirements prescribed in paragraph (a) of this section, interior ceiling panels, interior wall panels, partitions, galley structure, large cabinet walls and materials used in the construction of stowage compartments (other than underseat stowage compartments and compartments for stowing small items, such as magazines and maps) must also meet the test requirments of Part III of Appendix F of this part or other approved equivalent method.

* * * * *

2. By amending Appendix F by adding a new Part III to read as follows:

Appendix F

* * * * *

Part III—Test Method to Determine the Heat Release Rate From Cabin Materials Exposed to Radiant Heat

(a) *Summary of Method.* The specimen to be tested is injected into an environmental chamber through which a constant flow of air passes. The specimen's exposure is determined by a radiant heat source adjusted to produce the desired total heat flux on the specimen of 5.0 W/cm². The specimen is tested so that the exposed surface is vertical. Combustion is initiated by piloted ignition. The combustion products leaving the chamber are monitored in order to calculate the release rate of heat.

(b) *Apparatus.* The Ohio State University (OSU) rate of heat release apparatus standarized by the American Society of Testing and Materials (ASTM), ASTM E-906, as modified with an oxygen analyzer for heat release measurement, is used.

(1) This apparatus is shown in Figure 1. All exterior surfaces of the apparatus, except the holding chamber, shall be insulated with 25 mm thick, low density, high-temperature fiberglass board insulation. A gasketed door through which the sample injection rod slides forms an airtight closure on the specimen hold chamber.

(2) *Oxygen Depletion Measurement.* (i) A sample probe for measuring the oxygen concentration in the calorimeter is located 50 mm below the point of innner and outer pyramidal sections flow convergence in the middle of and perpendicular to the long axis of the inner section. The probe is constructed of 6.3 mm outside diameter, 0.8 mm wall thickness stainless steel tubing with three #20 holes drilled such that one hole is in the geometric center of the inner pyramidal section and the other two holes are one-third the distance from the wall of the inner section to the middle hole. The holes are oriented up, away from the sample.

(ii) The oxygen analyzer is protected with a heated fiberglass filter located upstream of the sample pump, which is upstream of the analyzer. A 120 ml cartridge of indicator drierite and ascarite shall be in between the pump and the analyzer to remove water and CO_2 (This cartridge must be replaced whenever the drierite is exhausted.) The pump shall be a positive displacement type made of stainless steel construction. The pressure and flow to the analyzer shall remain constant during the test. A mercury-filled, open-end manometer shall be between the pump and filter to assure that the filter and probe remain obstructed. The maximum pressure drop from clogging of the filter and probe may not exceed 5 mm Hg. A calibration check of the oxygen depletion method for heat release rate measurement shall be made simultaneously with the calibration of the thermopile (see paragraph (c)), but shall be only for comparison between methods to verify the system is functioning properly.

(3) *Thermopile.* The temperature difference between the air entering the environmental chamber and that leaving is monitored by a thermopile having three hot and three cold, 24 gauge Chromel-Alumel junctions. The hot junctions are spaced across the top of the exhaust stack. Two hot junctions are located 25 mm from each side on diagonally opposite corners, and the third in the center of the chimney's cross-section 10 mm below the top of the chimney. The cold junctions are located in the pan below the lower air distribution plate (see paragraph (b)(5)).

(i) *Thermal Inertia Compensator.* A compensator tab is made from 0.55 mm stainless steel sheet, 10 by 20 mm. An 800 mm length of 24 gauge Chromel-Alumel glass insulated duplex thermocouple wire shall be welded or silver soldered to the tab as shown in Figure 2, and the wire bent back so that is is flush against the metal surface.

(ii) The compensator tab shall be mounted on the exhaust stack as shown in Figure 3 using a 6-32 round head machine screw, 12 mm long. Add small (approximately 4.5 mm O.D., 9 mm O.D.) washers between the head of the machine screw and the compensator tab to give the best response to a square wave input. (One or two washers should be adequate.) The "sharpness" of the square wave can be increased by changing the ratio of the output from the thermopile and compensator thermocouple which is fed to the recorder. The ratio is changed by adjusting the 1–K ohm variable resistor (R_1) of the thermopile bleeder shown in Figure 4. When adjusting compensation, Keep R_1 as small as possible. Adjustment of compensator shall be made during calibration (see paragraph (c)(1)) at a heat release rate of 7.0 plus or minus 0.5 kW.

(iii) Adjust washers and variable resistor (R_1) so that 90 percent full scale response is obtained in 8 to 10 seconds. There shall be no overshoot as shown in Figure 5A. If an insufficient number of washers is added, or R_1 is too small, the output with square wave input will look like Figure 5B; if too many washers are added and R_1 is too large, the output will look like Figure 5A.

(iv) Subtract the output of the compensator from the thermopile. The junctions enclosed in the dotted circle of Figure 4 are kept at the same constant temperature by electrically insulating the junctions and placing them on the pipe carrying air to the manifold, then covering them and the pipe with thermal insulation.

(v) Thermopile hot junctions shall be cleared of soot deposits daily.

(4) *Radiation Source.* A radiant heat source for generating a flux up to 100 kW/m², using four silicon elements, Type LL 20×12×5/8; nominal resistance 1.4 ohms, is shown in Figures 6A and 6B. The silicon carbide elements are mounted in the stainless steel panel box by inserting them through 15.9 mm holes in 0.8 mm thick ceramic fiber board. Location of the holes in the pads and stainless steel cover plates are shown in Figure 6B. The diamond shaped mask of 24 gauge stainless steel is added to provide uniform heat flux over the area occupied by the 150 by 150 mm vertical sample. A power supply of 12.5 kVA, adjustable from 0 to 270 volts is required. (If a heat flux of up to 100 kW/m² is desired, a separate power supply for each pair of elements can be used where maximum voltage is less than 270 volts.)

(5) *Air Distribution System.* The air entering the environmental chamber is distributed by a 6.3 mm thick aluminum plate having 8, No. 4 drill holes, 51 mm from sides on 102 mm centers, mounted at the base of the environmental chamber. A second plate of 18 gauge steel having 120, evenly spaced, No. 28 drill holes is mounted 150 mm above the aluminum plate. A well-regulated air supply is required. The air supply manifold at the base of the pyramidal section has 48, evenly spaced, No. 26 drill holes 10 mm from the inner edge of the manifold so that 0.03 m³/second of air flows between the pyramidal sections and 0.01 m³/second flows through the environmental chamber when total air flow to apparatus is controlled at 0.04 m³/second.

(6) *Exhaust Stack.* An exhaust stack, 133 by 70 mm in cross section, and 254 mm long, fabricated from 28 gauge stainless steel, is mounted on the outlet of the pyramidal section. A 25 by 76 mm plate of 31 gauge stainless steel is centered inside the stack, perpendicular to the air flow, 75 mm above the base of the stack.

(7) *Specimen Holders.* A vertical specimen holder shall be attached to the injection rod using the vertical support shown in Figure 7. The 150 mm by 150 mm specimen is tested in a vertical orientation (Figure 8). The holder is provided with a "V" shaped spring pressure plate and 12.7 mm backing plate of rigid insulation board having a density of 320 plus or minus 80 kg/m³ and thermal conductivity of 0.06 plus or minus 0.01 W/m. K. ("Kaowool" M-Board, Surface, Rigidized, Babcock/Wilcox Refractories, Augusta, Georgia, or its equivalent, is satisfactory.) The position of the spring pressure plate may be changed to accommodate different specimen thickness for inserting a retaining rod in different holes of the specimen holder frame. The adjustable radiation shield (Figure 1) on the vertical specimen holder, which covers the opening made when the radiation doors are in their open position and the specimen is inserted, is adjusted to position the front surface of the specimen 100 mm from the entrance to the environmental chamber.

(8) *Radiometers.* Total-flux meters (calorimeters) shall be used to measure the total heat flux at the point where the center of the specimen's surface is located at the start of the test. The total-flux meters shall have view angles of 180 degrees and be calibrated for incident flux. When positioned to measure flux, the sensing surface of the flux meter for vertical specimens shall extend beyond any solid supporting device so that air heated by such a support does not contact the sensing surface of the flux meter.

(9) *Pilot-Flame Positions.* Pilot ignition of the specimen shall be accomplished by simultaneously exposing the specimen to a lower pilot burner and an upper pilot burner, as described in paragraphs (b)(9)(i) and (b)(9)(ii) respectively.

(i) *Lower Pilot Burner.* Pilot-flame tubing shall be 6.3 mm O.D., 0.8 mm wall, stainless steel tubing. Fuel shall be methane or natural gas having 90 percent or more methane. A methane-air mixture, 120 cm³/min gas and 850 cm³/min air shall be the fuel mixture fed to the lower pilot flame burner. Normal position of the end of the pilot burner tubing is 10 mm from and perpendicular to the exposed vertical surface of the specimen. The centerline at the outlet of the burner tubing shall intersect the vertical centerline of the sample, 5 mm above the lower edge of the specimen.

(ii) *Upper Pilot Burner.* The pilot burner shall be a straight length of 6.3 mm O.D., 0.8 mm wall, stainless steel tubing 360 mm long. One end of the tubing shall be closed, and three No. 40 drill holes, 60 mm apart, drilled into the tubing for gas ports, all radiating in the same direction. The first hole shall be 5 mm from the closed end of the tubing. The tube is inserted into the environmental chamber through a 6.6 mm hole drilled 10 mm above the upper edge of the window frame. The tube is supported and positioned by an adjustable "Z" shaped support mounted outside the environmental chamber, above the viewing window. The tube is positioned above and 20 mm behind the exposed upper edge of the specimen. The middle hole shall be in the vertical plane perpendicular to the exposed surface of the specimen which passes through its vertical centerline and shall be pointed toward the radiation source. Fuel gas to the burner shall be methane or natural gas with at least 90 percent methane, adjusted to produce flame lengths of 25 mm.

(c) *Calibration of Equipment*—(1) *Heat Release Rate.* A burner as shown in Figure 9 shall be placed over the end of the pilot flame tubing using a gas tight connection. The gas to the pilot flame shall be accurately metered, e.g., by a wet test meter, and set at a low flow rate. The gas shall be at least 0 percent methane and have an accurately known net heating value. The output of the recorder is "zeroed". Then the gas flow to the burner shall be increased to a higher, preset value and allowed to burn for 4.0 minutes, after which the gas flow is again returned to its low flow rate. The sequence is repeated until a constant increase and consistent return to the "zero" base line is achieved. The difference in flow between the low and high settings for gas flow, multiplied by its net heating value, shall be used as the rate of heat release. The output of the differential temperature recorder, after reaching a steady state value, is the output corresponding to that heat release rate. At least three levels of heat release shall be used. The heat release rate shall not exceed 7.75 kW, nor be less than 1.5 kW when calibrating.

(2) *Flux Uniformity.* Uniformity of flux over the specimen shall be periodically checked and checked after each heating element change to determine if it is within acceptable limits of plus or minus 5 percent.

(d) *Sample Preparation.* (1) The standard size for vertically mounted specimens is 150 by 150 mm exposed surface with thickness up to 100 mm.

(2) *Conditioning.* Specimens shall be conditioned as described by Part 1 of this appendix (70° F. plus or minus 5° F. and 50 percent plus or minus 5 percent relative humidity).

(3) *Mounting.* Only one surface of a specimen shall be exposed during a test. Specimens having a slab geometry shall be insulated on five sides. A double layer of 0.025 mm aluminum foil wrapped tightly on sides and back is satisfactory. For products whose exposed surface is not a plane, the mounting and method of calculating surface area exposed must be described when reporting results.

(e) *Procedure.* (1) The pilot flames are lighted and their position as described in paragraph (b)(9) is checked.

(2) The power supply to the radiant panel is set to produce a radiant flux of 5.0 W/cm². The flux is measured at the point the center of the specimen surface will occupy when positioned for test. The radiant flux is measured with the lower pilot flame displaced to the side of the environmental chamber and after air flow through the equipment is adjusted to the desired rate. The sample should be tested in its end use thickness.

(3) The air flow to the equipment is set at 0.04 plus or minus 0.001 m³/s atmospheric pressure and 70° F. plus or minus 5° F.). The stop on the vertical specimen holder rod is adjusted so that the exposed surface of the specimen shall be positioned 100 mm from the entrance when injected into the environmental chamber.

(4) Steady state conditions, such that the radiant flux does not change more than 0.5 kW/m^2 over a ten minute period, shall be maintained before the specimen is injected.

(5) The specimen is placed in the hold chamber with the radiation shield doors closed. The airtight outer door is secured, recording devices started, and output oxygen analyzer set to "zero" on the recorder. "Zero" conditions are those existing at the time immediately before the specimen is injected. The specimen shall be retained in the hold chamber 60 seconds plus or minus 10 seconds before injection.

(6) When the specimen is to be injected, the radiation doors are opened, and specimen is injected into the environmental chamber.

(7) Unless immediate ignition occurs, a negative heat release will occur at elevated exposures due to heat absorption by the cold specimen holder. Data-acquistion devices shall have the capability of following these negative outputs, and correcting the sample burn with a "blank" test result.

(8) Injection of the specimen marks time zero. A continuous record of the output from the oxygen analyzer shall be made during the time the specimen is in the environmental chamber.

(9) Test duration time is five minutes.

(10) A minimum of three replicate tests shall be made.

(f) *Calculations*—(1) *Heat Release Rate by Oxygen Depletion.* Heat release rate is calculated by the oxygen depletion method by multiplying the change in oxygen mole fraction by the OSU flow rate (0.1m^3/sec) by the heat of combustion (16.7 MJ/m^3) to CO_2. The final result is the heat release rate in kilowatts. This number shall then be standardized per unit sample area as appropriate.

Heat Release = $Q = 1.67 \times 10^4 (.01\ m^3/sec)$ $(X_o - X_s)\ A\ (m^2)$

Heat Release = 7.189 $(X_o - X_s)$ (Kilowatts/m^2)

Where the sample area is .0232 m^2, and X_o is the initial mole fraction of oxygen and X_s is the measured mole fraction of oxygen.

(2) *Heat Release Rate by Thermopile Measurement.* Heat release rates may also be calculated from the reading of the thermopile output, the exposed surface area of the specimen and the constant "k_H". "k_H" is obtained from calibration runs:

$$k_H = \frac{\textit{Heat Release Rate (kW)}}{\text{Chart Reading}}$$

Then: Heat Release Rate (kW/m^2) = kH (Chart Rdg.)/A

where:

A = exposed surface area of specimen (m^2).

Chart Reading = millivolts above the baseline thermopile output minus the "blank" test result.

(i) Heat release rates are determined from chart reading as a function of time.

(g) *Criteria.* The total heat release over the first two minutes of sample exposure shall not exceed 40 kilowatt-minutes per square meter if measurement is by thermopile or, alternatively, 70 kilowatt-minutes per square meter if measurement is by oxygen depletion.

(h) *Report.* The test report shall include the following:

(1) *Description of specimen.*

(2) Radiant heat flux to specimen, expressed in kW/m^2.

(3) Data giving release rates of heat (in kW/m^2) as a function of time, either graphically or tabulated at intervals no greater than 10 seconds. The data shall be integrated to give total heat release as a function of time for the five-minute test, as well as for the first two minutes of sample exposure.

(4) The time which total fire involvement is reached shall be noted.

(5) If melting, sagging delaminating, or other behavior that affects exposed surface area or mode of burning occur, these behaviors shall be reported, together with the time as which such behaviors were observed.

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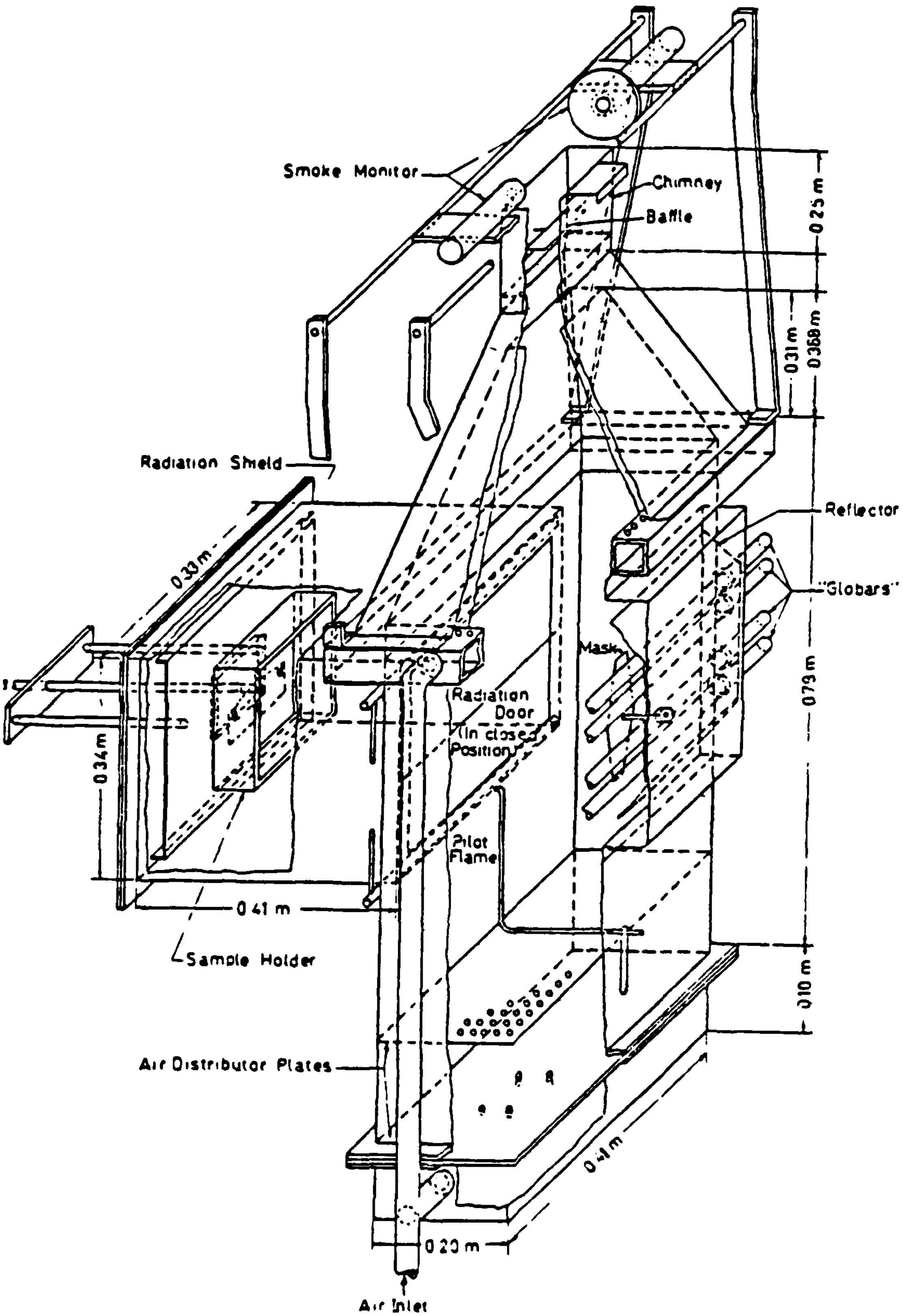
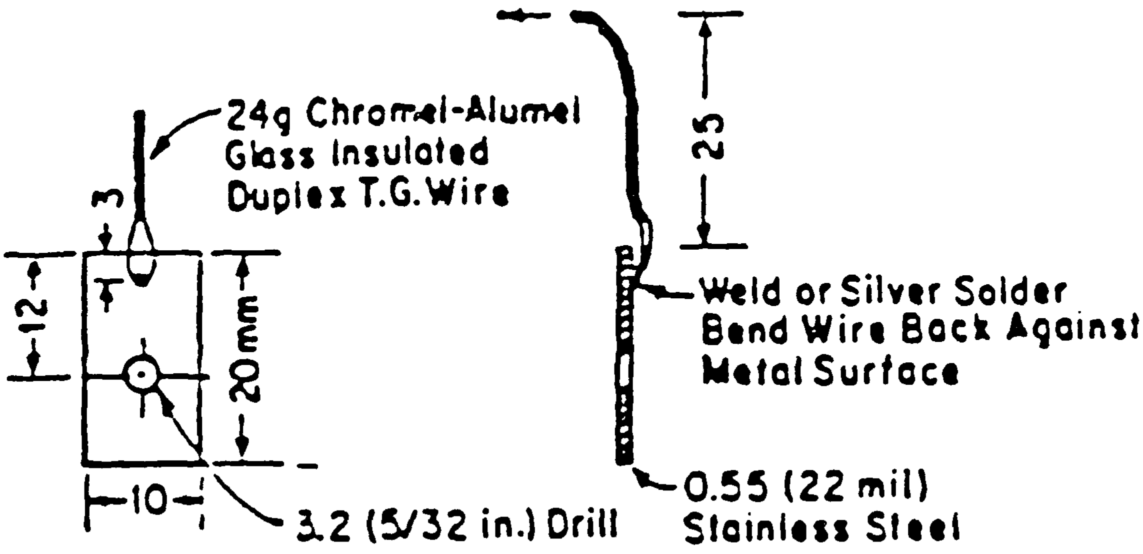


Figure 1. Release Rate Apparatus



(Unless denoted otherwise, all dimensions are in millimeters.)

Figure 2. Compensator Tab

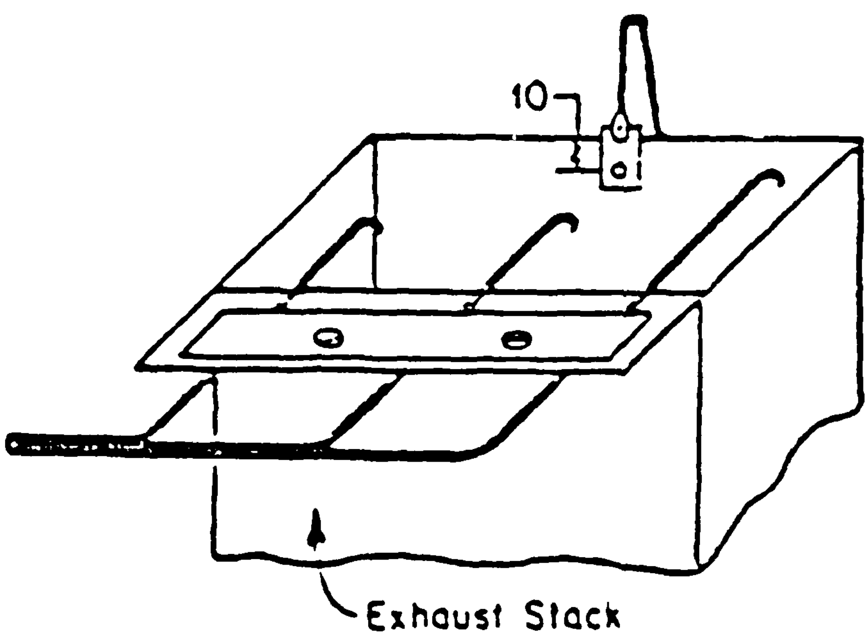


Figure 3. Compensator Tab Mount

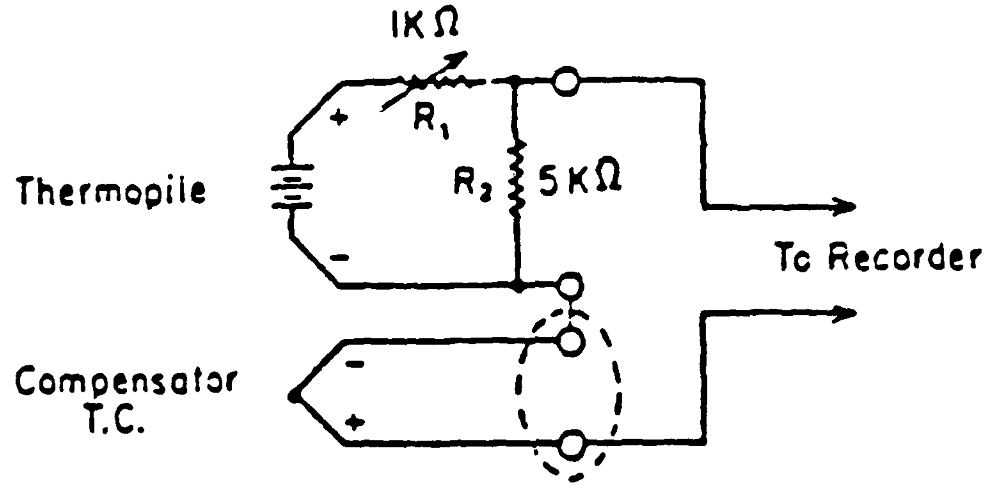


Figure 4. Wiring Diagram

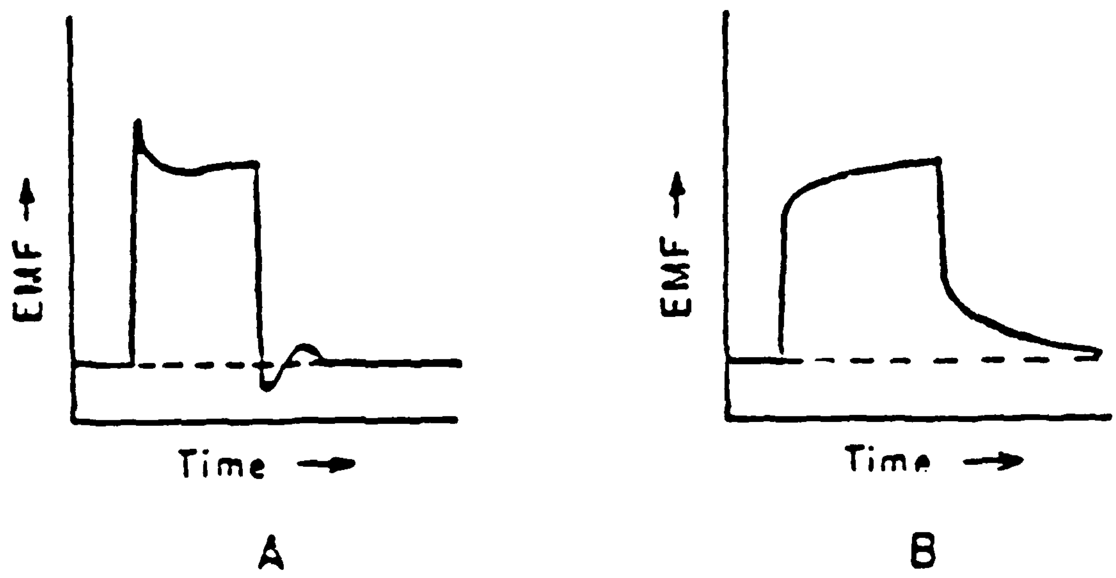
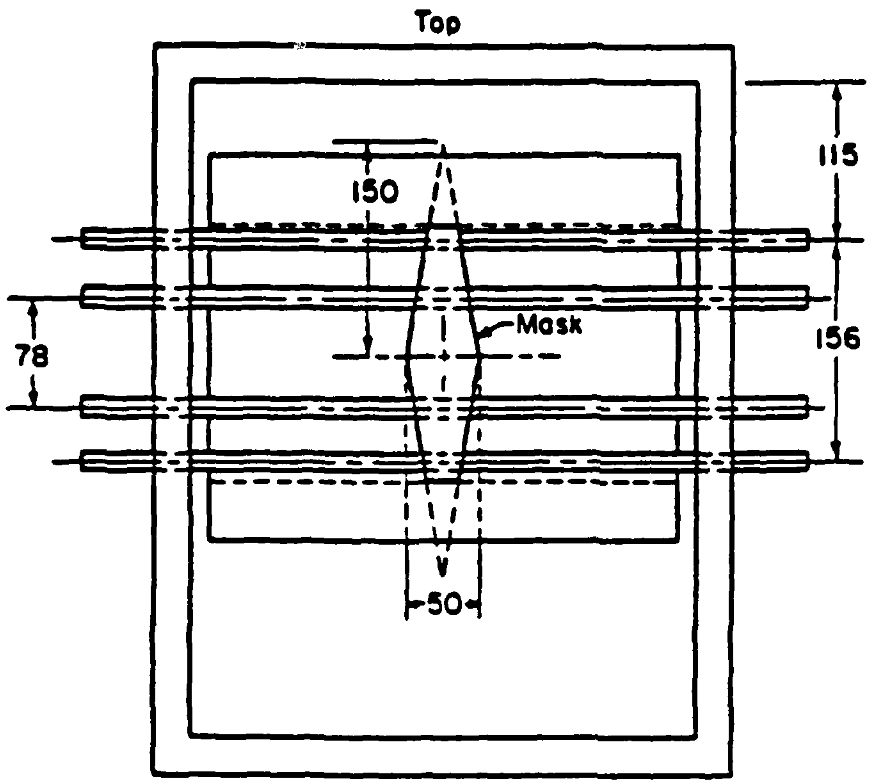
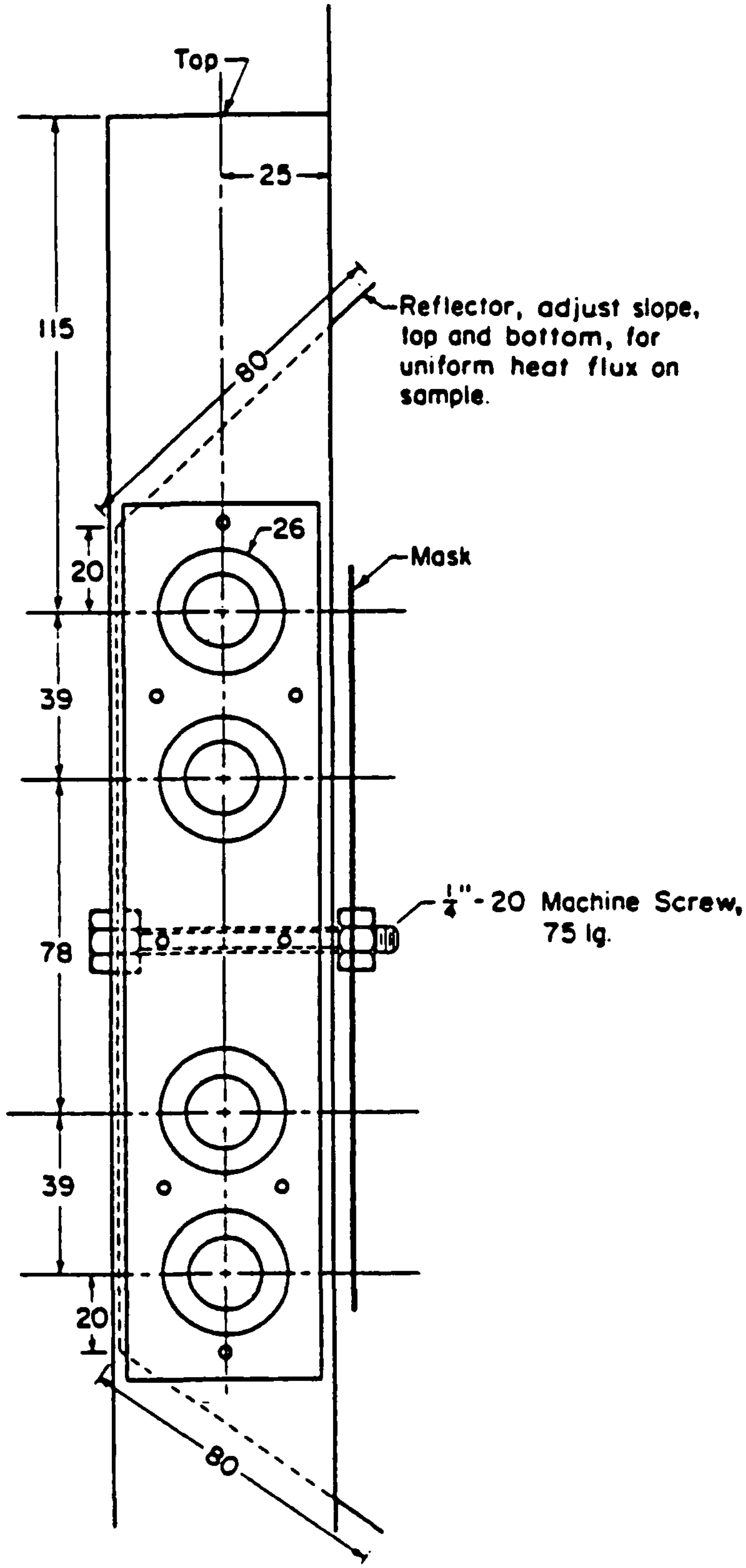


Figure 5. Square Wave Response



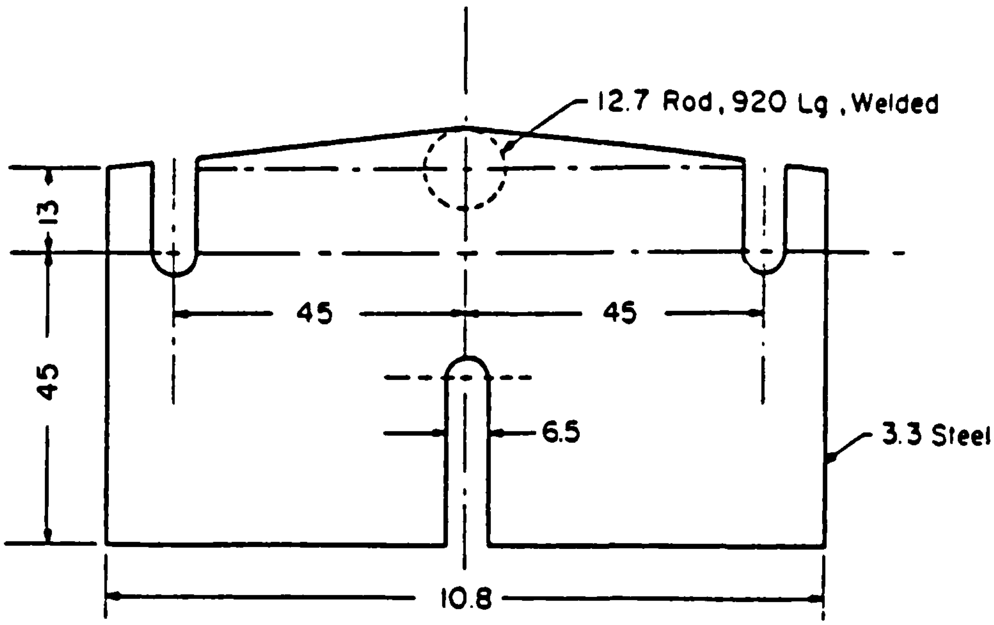
(Unless denoted otherwise, all dimensions are in millimeters.)

Figure 6A. "Globar" Radiant Panel



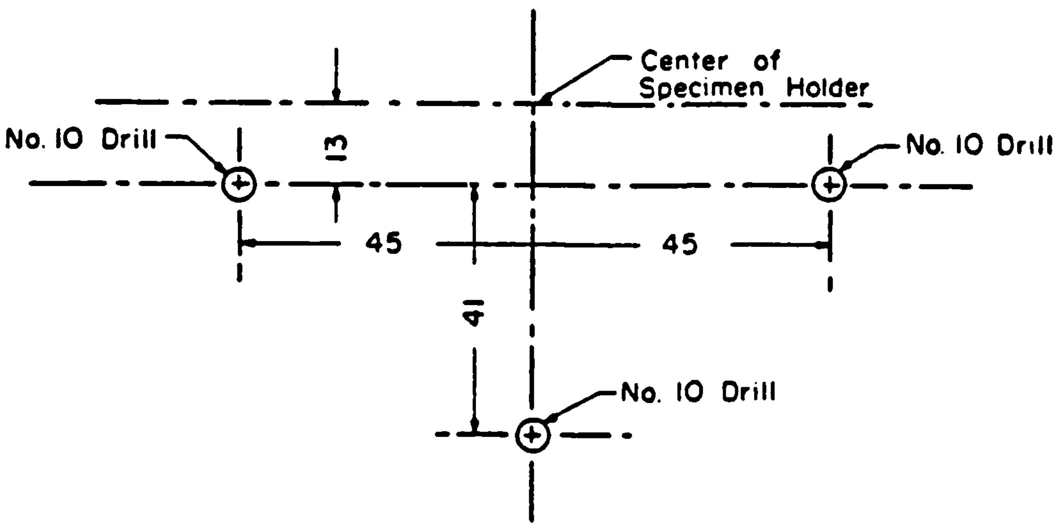
(Unless demonted otherwise, all dimensions are in millimeters.)

Figure 68. "Globar" Radiant Panel



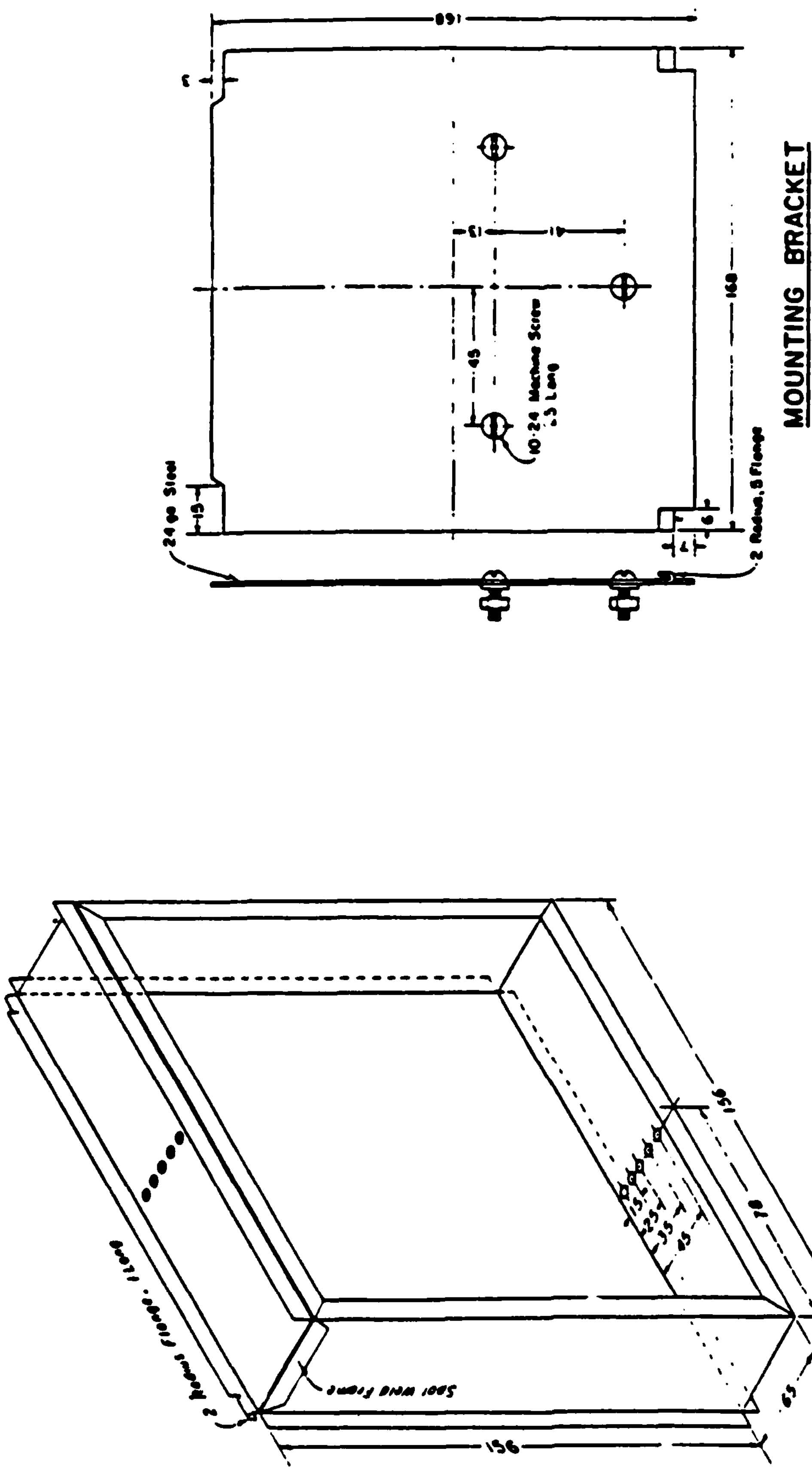
VERTICAL SUPPORT

(Unless denoted otherwise, all dimensions are in millimeters.)



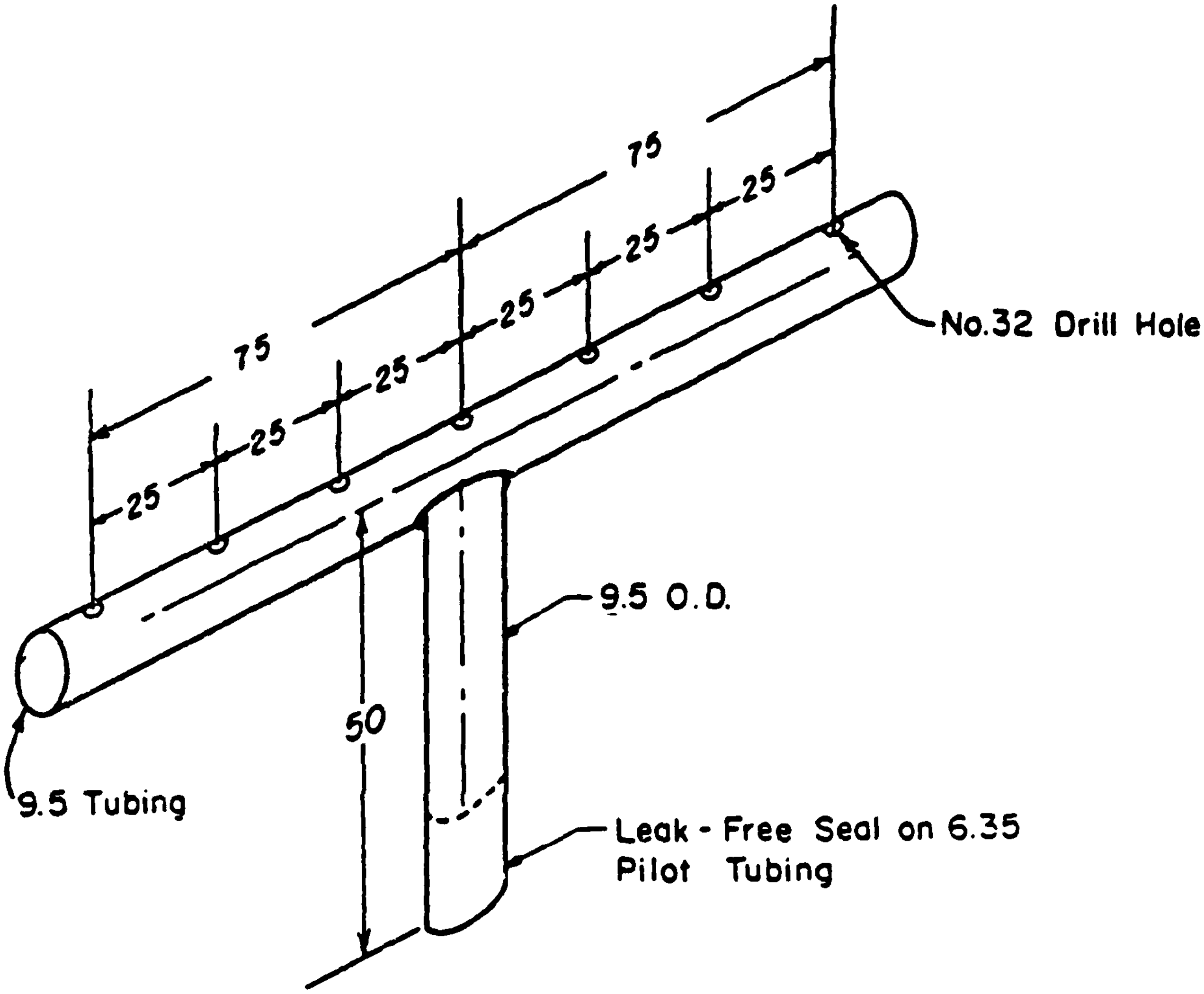
TEMPLATE FOR MOUNTING BOLTS
VERTICAL MOUNT

Figure 7. Vertical Holder Mount



(Unless denoted otherwise, all dimensions are in millimeters.)

Figure 8. Vertical Specimen Holder



(Unless denoted otherwise, all dimensions are in millimeters.)

Figure 9. Calibration Burner

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APPENDIX B

REVISED TEST METHOD TO DETERMINE THE HEAT RELEASE RATE FROM CABIN MATERIALS EXPOSED TO RADIANT HEAT

(a) Summary of Method. The specimen to be tested is injected into an environmental chamber through which a constant flow of air passes. The specimen's exposure is determined by a radiant heat source adjusted to produce the desired total heat flux on the specimen of 3.5 W/cm^2 using a calibrated calorimeter. The specimen is tested so that the exposed surface is vertical. Combustion is initiated by piloted ignition. The combustion products leaving the chamber are monitored in order to calculate the release rate of heat.

(b) Apparatus. The Ohio State University (OSU) rate of heat release apparatus, as described below, is used. This is a modified version of ASTM E-906.

(1) This apparatus is shown in figure 1. All exterior surfaces of the apparatus, except the holding chamber, shall be insulated with 25 mm thick, low-density, high-temperature, fiberglass board insulation. A gasketed door through which the sample injection rod slides forms an airtight closure on the specimen hold chamber.

(2) Thermopile. The temperature difference between the air entering the environmental chamber and that leaving is monitored by a thermopile having three hot and three cold, 32-gauge Chromel-Alumel junctions. The hot junctions are spaced across the top of the exhaust stack. Two hot junctions are located 25 mm from each side on diagonally opposite corners, and the third in the center of the chimney's cross-section 10 mm below the top of the chimney. The cold junctions are located in the pan below the lower air distribution plate (see paragraph (b)(4)).

(i) Thermal Inertia Compensator. A compensator tab is made from 0.55 mm stainless steel sheet, 10 by 20 mm. An 800 mm length of 24-gauge Chromel-Alumel glass insulated duplex thermocouple wire shall be welded or silver soldered to the tab as shown in figure 2, and the wire bent back so that it is flush against the metal surface.

(ii) The compensator tab shall be mounted on the exhaust stack as shown in figure 3, using a 6-32 round head machine screw 12 mm long. Add small (approximately 4.5 mm I.D., 9 mm O.D.) washers between the head of the machine screw and the compensator tab to give the best response to a square wave input. (One or two washers should be adequate.) The "sharpness" of the square wave can be increased by changing the ratio of the output from the thermopile and compensator thermocouple which is fed to the recorder. The ratio is changed by adjusting the 1-K ohm variable resistor (R1) of the thermopile bleeder shown in figure 4. When adjusting compensation keep R1 as small as possible. Adjustment of compensator shall be made during calibration (see paragraph (c)(1)) at a heat release rate of 7.0 plus or minus 0.5 kw.

(iii) Adjust washers and variable resistor (R1) so that 90 percent full-scale response is obtained in 8 to 10 seconds. There shall be no overshoot as shown in figure 5A. If an insufficient number of washes is added, or if Rl is too small, the output with square wave input will look like figure 5B; if too many washers are added or if Rl is too large the output will look like figure 5A.

(iv) Subtract the output of the compensator from the thermopile. The junctions enclosed in the dotted circle of figure 4 are kept at the same constant temperature by electrically insulating the junctions and placing them on the pipe carrying air to the manifold, then covering them and the pipe with thermal insulation.

(v) Thermopile hot junctions shall be cleared of soot deposits daily.

(3) Radiation Source. A radiant heat source for generating a flux up to 100 kw/m^2 using four silicon carbide elements, Type LL, 20" long by 5/8 O.D.; nominal resistance 1.4 ohms is shown in figures 6A and 6B. The silicon carbide elements are mounted in the stainless steel panel box by inserting them through 15.9 mm holes in 0.8 mm thick ceramic fiberboard. Location of the holes in the pads and stainless steel cover plates are shown in figure 6B. The diamond shaped mask of 24-gauge stainless steel is added to provide uniform heat flux over the area occupied by the 150 by 150 mm vertical sample. A power supply of 12.5 kVA adjustable from 0 to 270 volts is required.

(4) Air Distribution System. The air entering the enviromental chamber is distributed by a 6.3 mm thick aluminum plate having 8 No. 4 drill holes, 51 mm from sides on 102 mm centers, mounted at the base of the environmental chamber. A second plate of 18-gauge steel having 120 evenly spaced No. 28 drill holes is mounted 150 mm above the aluminum plate. A well regulated air supply is required. The air supply manifold at the base of the pyramidal section has 48 evenly spaced No.26 drill holes 10 mm from the inner edge of the manifold so that 0.03 m^3/second of airflows between the pyramidal sections and 0.01 m^3/second flows through the environmental chamber when total airflow to apparatus is controlled at 0.04 m^3/second.

(5) Exhaust Stack. An exhaust stack 133 by 70 mm in cross section and 254 mm long fabricated from 28-gauge stainless steel is mounted on the outlet of the pyramidal section. A 25 by 76 mm plate of 31-gauge stainless steel section is centered inside the stack, perpendicular to the airflow, 75 mm above the base of the stack.

(6) Specimen Holders. The 150 mm X 150 mm specimen is tested in a vertical orientation. The holder (figure 7) is provided with a specimen holder frame, which touches the aluminum foil wrapped (d)(3) specimen along only the 10 mm perimeter, and a "V" shaped spring to hold the assembly together. A detachable 12 mm X 12 mm X 150 mm drip pan is also provided for testing of materials prone to exhibit that behavior. The positioning of the spring and frame may be changed to accommodate different specimen thicknesses by inserting the retaining rod in different holes on the specimen holder.

Since the radiation shield described in ASTM E-906 has been eliminated, a guide pin is added to the injection mechanism. This fits into a slotted metal plate on the injection mechanism outside of the holding chamber and can be used to provide accurate positioning of the specimen face after injection. The front surface of the specimen shall be 100 mm from the closed radiation doors after injection.

The specimen holder clips onto the mounting bracket (figure 7). The mounting bracket is attached to the injection rod by 3 screws which pass through a wide area washer welded onto a 1/2" nut. The end of the injection rod is threaded to screw into the nut and a .020 in. thick wide area washer is held between two 1/2 in. nuts which are adjusted to tightly cover the hole in the radiation doors through which the injection rod or calibration calorimeter pass.

(7) Radiometers. A total-flux flush calorimeter mounted in the center of a 1/2 in. kaowool m board inserted in the sample holder shall be used to measure the total heat flux. The total flux calorimeter shall have view angle of 180 degrees and be calibrated for incident flux. Calorimeter calibration shall be traceable to NBS.

(8) Pilot-Flame Positions. Pilot ignition of the specimen shall be accomplished by simultaneously exposing the specimen to a lower pilot burner and an upper pilot burner as described in paragraphs (b)(8)(i) and (b)(8)(ii), respectively.

(i) Lower Pilot Burner. Pilot-flame tubing shall be 6.3 mm O.D., 0.8 mm wall, stainless steel tubing. Fuel shall be methane. A mixture 120 cm^3/min methane and 850 cm^3/min air shall be the fuel fed to the lower pilot burner flame burner. Normal position of the end of the pilot burner tubing is 10 mm from and perpendicular to the exposed vertical surface of the specimen. The centerline at the outlet of the burner tubing shall intersect the vertical centerline of the sample 5mm above the lower exposed edge of the specimen.

(ii) Upper Pilot Burner. The pilot burner shall be a straight length of 6.3 mm O.D., 0.8 mm wall, stainless steel tubing, 360 mm long. One end of the tubing shall be closed, and three No. 40 drill holes, 60 mm apart, drilled into the tubing for gas ports, all radiating in the same direction. The first hole shall be 5 mm from the closed end of the tubing. The tube is inserted into the environmental chamber through a 6.6 mm hole drilled 10 mm above the upper edge of the window frame. The tube is supported and positioned by an adjustable "Z" shaped support mounted outside the environmental chamber above the viewing window. The tube is positioned above and 20 mm behind the exposed upper edge of the specimen. The middle hole shall be in the vertical plane perpendicular to the exposed surface of the specimen which passes through its vertical centerline and shall be pointed toward the radiation source. Fuel gas to the burner shall be methane adjusted to produce flame lengths of 25 mm.

(c) Calibration of Equipment.

(1) Heat Release Rate. A burner as shown in figure 8 shall be placed over the end of the lower pilot burner tubing using a gas tight connection. The gas flow to the pilot flame shall be accurately measured by a wet test meter. Prior to usage, the wet test meter is properly leveled and filled with distilled water to the tip of the internal pointer while no gas is flowing. Ambient temperature and pressure are recorded and the vapor pressure of water, based on the internal wet test meter temperature, determined from the literature. The gas shall be at least 99% methane. A baseline flow rate of approximately 1 liter/min is set and increased to higher preset flows of 2, 4, 6, and 8 liters/min. The rate is determined by using a stopwatch to time a complete revolution of the wet test meter for both the baseline and higher flow, with the flow returned to baseline before changing to the next higher flow. The thermopile baseline voltage is measured.

The gas flow to the burner shall be increased to the higher preset flow and allowed to burn for 4.0 minutes and the thermopile voltage measured. The sequence is repeated until all four values have been determined. The average of the four values shall be used as the calibration factor, but the procedure must be repeated if the percent relative standard deviation is greater than 5%. Calculations are shown in (10)(f).

(2) Flux Uniformity. Uniformity of flux over the specimen shall be periodically checked and also after each heating element change to determine if it is within acceptable limits of plus or minus 5 percent.

(d) Sample Preparation.

(1) The standard size for vertically mounted specimens is 150 by 150 mm exposed surface with thickness up to 100 mm.

(2) Conditioning. Specimens shall be conditioned as described by part 1 of appendix F of NPRM 85-10.

(3) Mounting. Only one surface of a specimen shall be exposed during a test. A single layer of 0.025 mm aluminum foil will be wrapped tightly on sides and back.

(e) Procedure.

(1) The power supply to the radiant panel is set to produce a radiant flux of 3.5 W/cm^2. The flux is measured at the point the center of the specimen surface will ocuppy when positioned for test. The radiant flux is measured after airflow through the equipment is adjusted to the desired rate. The sample should be tested in its end use thickness.

(2) The pilot flames are lighted and their position as described in paragraph (b)(9) is checked.

(3) The airflow to the equipment is set at 0.04 plus or minus 0.001 m^3/s at atmospheric pressure. Proper airflow may be set and monitored by either (1) an orifice meter designed to produce a pressure drop of at least 200 mm of the manometric fluid, or by (2) a rotometer (variable orifice meter) with a scale capable of being read to ± 0.0004 m^3/s. The stop on the vertical specimen holder rod is adjusted so that the exposed surface of the specimen shall be positioned 100 mm from the entrance when injected into the environmental chamber.

(4) Steady-state conditions, such that the radiant flux does not change more than 0.5 kW/m^2 over a 10-minute period, shall be maintained before the specimen is injected.

(5) The specimen is placed in the hold chamber with the radiation doors closed. The airtight outer door is secured and recording devices started. The specimen shall be retained in the hold chamber for 60 seconds plus or minus 10 seconds before injection. The thermopile "zero" value is determined during the last 20 seconds of the hold period.

(6) When the specimen is to be injected, the radiation doors are opened and specimen is injected into the environmental chamber and radiation doors closed behind the specimen.

(7) A negative heat release will occur due to heat absorption by the cold specimen holder. Data acquisition devices shall have the capability of following these negative outputs and correcting the sample burn with a "blank" test.

(8) Injection of the specimen marks time zero. A continuous record of the thermopile output shall be made during the time the specimen is in the environmental chamber.

(9) Test duration time is five minutes.

(10) A minimum of three replica[illegible] tests shall be made.

(f) Calculations. Heat release measurement.

(1) The calibration factor is calculated as follows

$$Kh=\frac{(F1-F0)}{(V1-V0)} \times \frac{(210,8-22)kcal}{mole} \times \frac{273}{Ta} \times \frac{P-Pv}{760} \times \frac{mole\ CH4STP}{22.41} \times \frac{WATT.min}{.01433kcal} \times \frac{kw}{1000w}$$

F0=flow of methane at baseline (lpm)

F1=higher preset flow of methane (lpm)

V0=thermopile voltage at baseline (mv)

V1=thermopile voltage at higher flow (mv)

Ta=Ambient temperature (°K)

P =Ambient pressure (mm Hg)

Pv=Water vapor pressure (mm Hg)

(2) Heat release rates may be calculated from the reading of the thermopile output voltage at any instant of time as

$$HRR=\frac{(Vm-Vb) \times Kh}{.02323\ m2}$$

Where HRR=Heat release Rate kw/m2
Vm=measured thermopile voltage (mv)
Vb="Blank" thermopile voltage
Kh=Calibration factor (Kw/mv)

Vb is the "blank" test (7) obtained by a run conducted with an empty sample holder assembly.

(3) The integral of the heat release rate is the total heat release as a function of time and is calculated by multiplying the rate by the data sampling frequency in minutes and summing the time zero to two minutes. This is quite time consuming if not done via computerized data aquisition.

(g) Criteria. The total heat release over the first two minutes of sample exposure shall not exceed 65 kilowatt-minutes per square meter, and the peak heat release rate shall not exceed 65 kilowatts per square meter.

(h) Report. The test report shall include the following:

(1) Description of specimen.

(2) Radiant heat flux to specimen expressed in W/cm^2

(3) Data giving release rates of heat (in kW/m^2) as a function of time either graphically or tabulated at intervals no greater than 10 seconds. Calibration factor (kh) shall be recorded.

(4) If melting, sagging delaminating, or other behavior that affects exposed surface area or mode of burning occur these behaviors shall be reported together with the time at which such behaviors were observed.

(5) Peak heat release rate and 2—minute integrated heat release shall be reported.

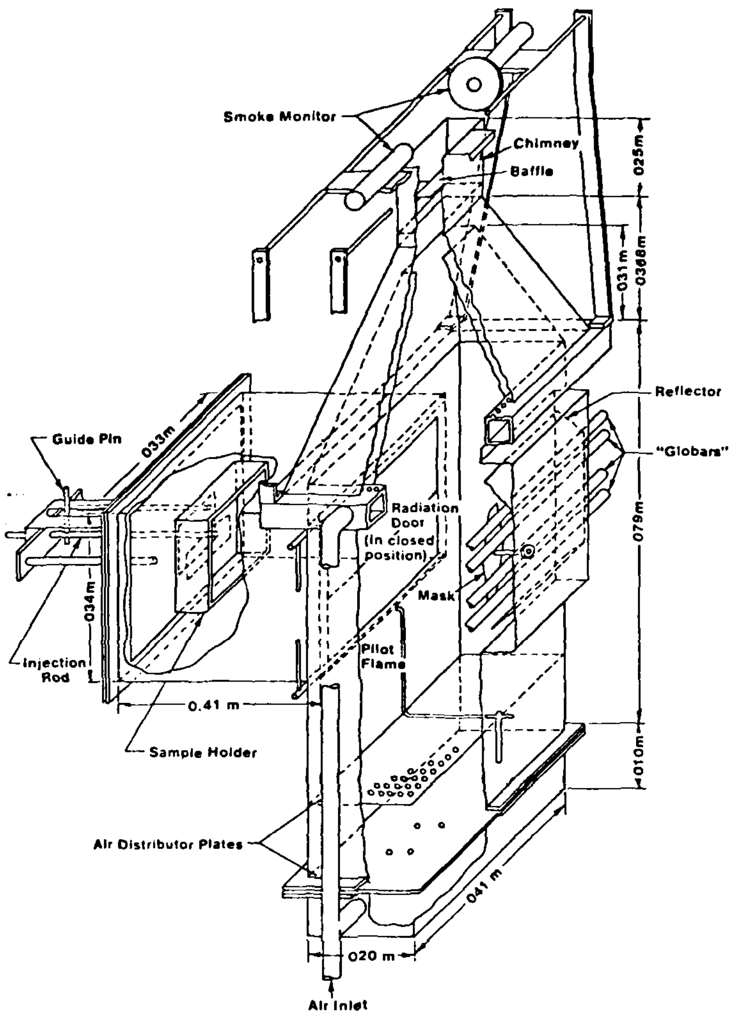
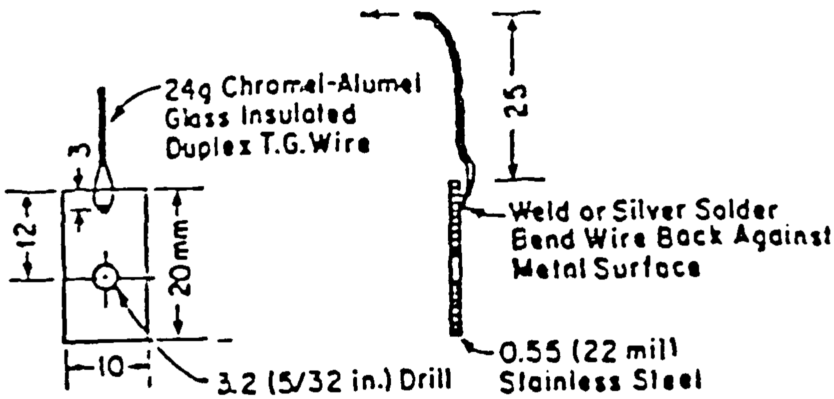


Figure 1. Release Rate Apparatus



(Unless denoted otherwise, all dimensions are in millimeters.)

Figure 2. Compensator Tab

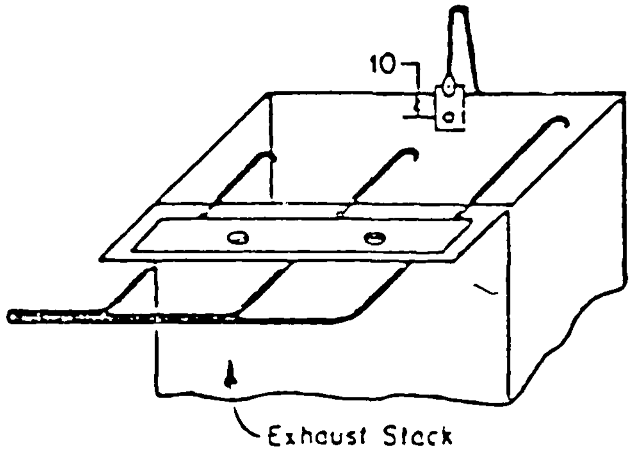


Figure 3. Compensator Tab Mount

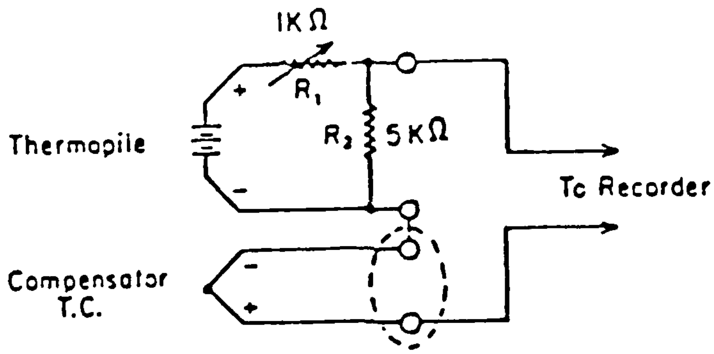


Figure 4. Wiring Diagram

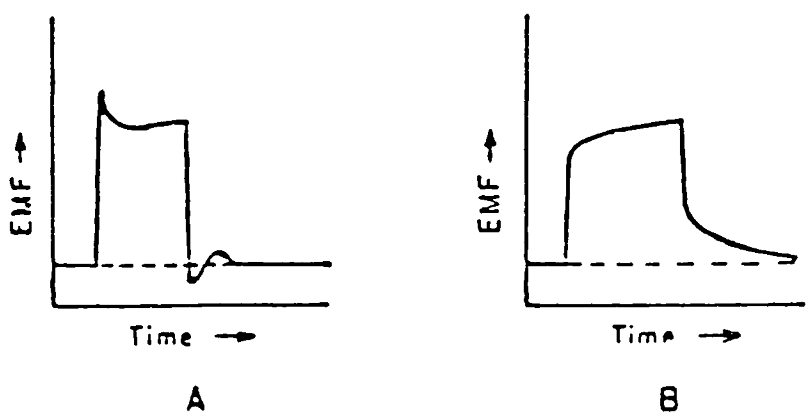
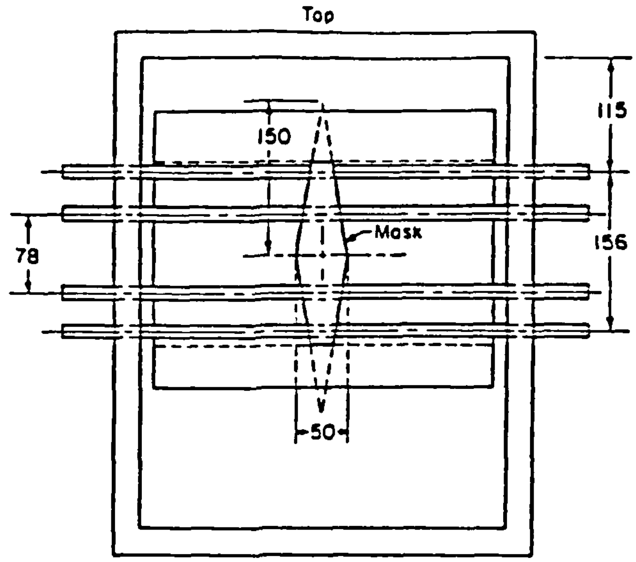
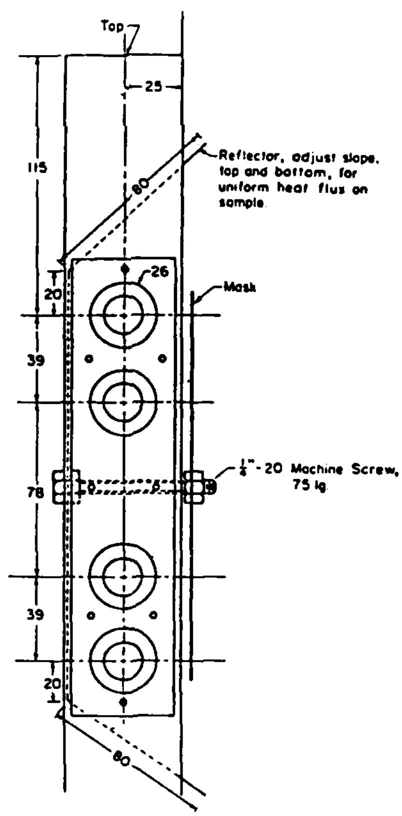


Figure 5. Square Wave Response



(Unless denoted otherwise, all dimensions are in millimeters.)

Figure 6A. "Globar" Radiant Panel



(Unless demonted otherwise, all dimensions are in millimeters.)

Figure 6B. "Globar" Radiant Panel

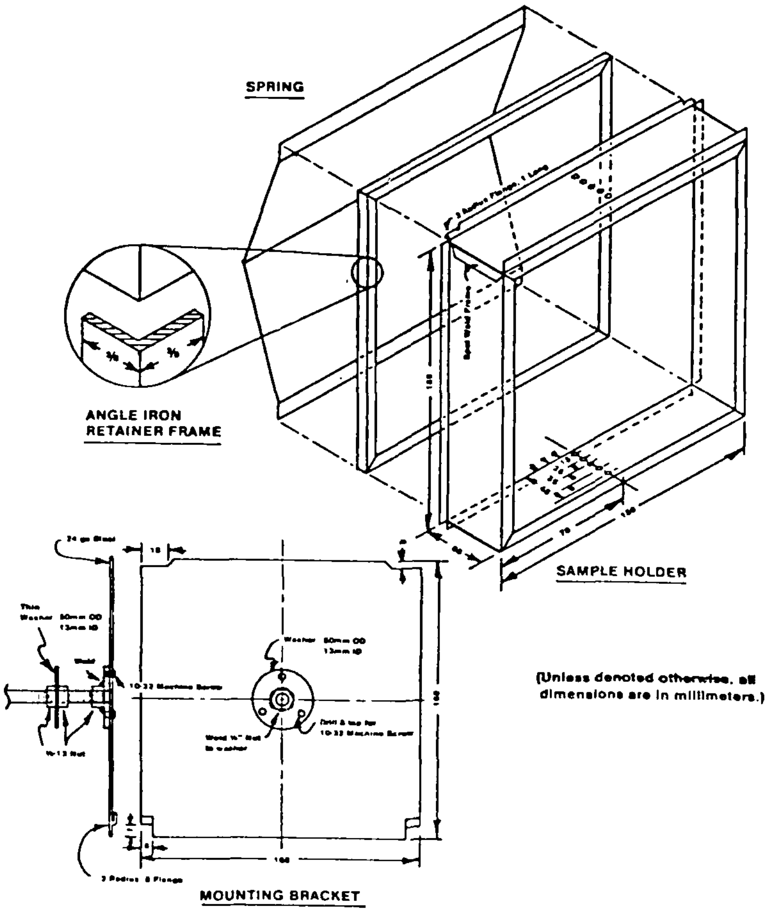
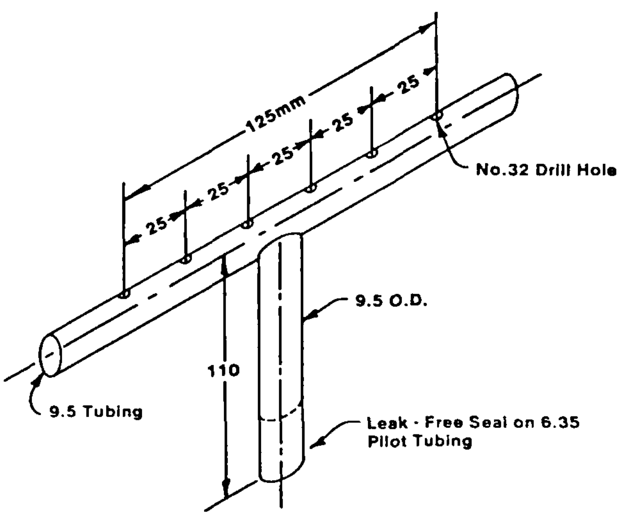


FIGURE 7



(Unless denoted otherwise, all dimensions are in millimeters.)

FIGURE 8

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