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Interlaboratory Comparison of Heat Release Data from Aircraft Panels

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March 1986

DOT/FAA/CT-TN86/3

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U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City Airport, N.J. 08405

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-TN86/3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle INTERLABORATORY COMPARISON OF HEAT RELEASE DATA FROM AIRCRAFT PANELS		5. Report Date March 1986
		6. Performing Organization Code
7. Author(s) Richard G. Hill and Lawrence T. Fitzgerald		8. Performing Organization Report No. DOT/FAA/CT-TN86/3
9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A computer program was developed to correlate and statistically analyze laboratory and full-scale fire test data. The program and its usage is presented in this report. Also, the results of a roundrobin test program utilizing the Ohio State University Rate of Heat Release (OSU) test apparatus are described. Data from the roundrobin was used to show the capabilities of the newly developed computer program. The results of the roundrobin indicated that reproducibility between laboratories had increased and that a further increase could be expected with greater standardization of equipment and procedures.

17. Key Words Correlation, Roundrobin, Rank Correlation, Heat Release, Reproducibility		18. Distribution Statement Document is on file at the Technical Center Library, Atlantic City Airport, New Jersey 08405	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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EXECUTIVE SUMMARY

This report contains the results of a roundrobin test program between the Federal Aviation Administration (FAA) Technical Center and three members of Aerospace Industries Association (AIA) (Boeing, Douglas and Heath Tecna, the latter represented by Ohio State University), utilizing the Ohio State University rate of heat release apparatus. The results of the testing are presented and analyzed utilizing a newly developed computer program to correlate and statistically analyze test data. The results show a large improvement in test data reproducibility between laboratories due to increased standardization of equipment and procedures. As an example, the percent relative standard deviation for the 2-minute integrated heat release from a 5-watt per square centimeter exposure, using the thermopile measurement method, was reduced from 25.16 percent to 5.44 percent. Analysis of the data indicates that further improvements in reproducibility (lower than 10 percent) could be gained by greater standardization of equipment and procedures.

INTRODUCTION

PURPOSE.

The purpose of this report is twofold:

1. To compare and analyze data obtained by different laboratories during roundrobin testing with the Ohio State University Rate of Heat Release Apparatus.

2. Describe and illustrate the use of a computer program for the storage and statistical analysis of laboratory test data.

BACKGROUND.

In order to determine the reproducibility of the Ohio State University (OSU) apparatus, the Federal Aviation Administration (FAA) Technical Center and the Aerospace Industries Association of America, Inc. (AIA) conducted a series of tests, utilizing the same aircraft interior materials at three different laboratories (FAA Technical Center, Boeing, and Douglas). The results of that series showed a lack of consistent test results between laboratories. The FAA and AIA subsequently agreed to various modifications to the equipment and test methodology aimed at improving its between-laboratory reproducibility. A second roundrobin was then conducted using the same materials and laboratory participants, and joined by Ohio State University, representing Heath Tecna, an AIA member.

DISCUSSION

TEST EQUIPMENT.

The OSU Rate of Heat Release Apparatus and test format, as outlined in ASTM E-906, was utilized initially, with various modifications later agreed to by the test participants. The first series of tests was conducted as outlined in appendix A, of reference 1 and the second in appendix B, of reference 1. There were still some slight remaining variations in test equipment and/or procedures between laboratories, in spite of attempts to completely standardize.

COMPUTER HARDWARE.

MAINCORR is currently operating on a Data General Model 10/SP Desktop computer and utilizes the folowing peripherals:

- all hardcopy printed output is performed on an NEC Spinwriter Model #7710 Letter Quality printer.

- all hardcopy graphic output is plotted on a Hewlett Packard Model #755 8-pen Plotter with automatic sheet feed.

- all CRT plotting is performed on a Data General Model 10/SP Color System Console.

The Model 10/SP Desktop computer is equipped with one fifteen (15) megabyte disk drive used for database storage and 512 kilobytes of internal memory (RAM).

COMPUTER SOFTWARE.

MAINCORR is a statistics program, written in the programming language, Fortran IV, for the purpose of comparing various fire test data for aircraft cabin materials that will determine the validity and consistency of these test data.

Table 1 is a list of statistics the user is currently able to obtain from the program MAINCORR.

MAINCORR is also capable of producing X-Y coordinate plots which show the relationship between two tests for each material. The relationship is compared by a one-to-one correspondence line and the least square best fit line of the data values. A bargraph compares the data of each material for up to four tests.

Operation, selection, and data selection is accomplished by MAINCORR through a series of screen queries (tables 2 through 5). Each operation leads the user through its own set of screens.

The data base setup to handle the material information consists of four separate files. Each file holds a laboratory title and a pointer to the next file. Only the last file contains the data that is processed. This file structure reduces the number of input-output seeks to a maximum of four before the required data are accessed.

Currently, the data base is set up to accept up to 20 tests. Each test is capable of accepting 20 apparatuses, and each apparatus is capable of accepting 20 data variables. Under each data variable is the material test result. As of this printing, 25 materials are included. The total number of data points allowed in the file is 10,000, expandable to 64,000.

This program consists of 12 modules, one main program and 11 subroutines. Figures 1 through 3 illustrate the program flow. Two subroutines are utilized for input to the data base, one subroutine for output from the data base, three subroutines for graphical output of data, three subroutines for statistical purposes and two subroutines for editing purposes. Figure 4 is a brief program description.

TEST MATERIALS.

In-service aircraft interior materials were supplied by AIA for use in the round-robin test series. These materials included ceiling panels, sidewalls, stowage bins, and partitions. In this report the materials will only be referred to by a reference number. Three thermoplastic materials were also supplied by the FAA, (ABS, polycarbonate, and Ultem™). A description of the materials is contained in reference 2, appendix A. In addition, five types of composite panels used by the FAA in full-scale testing were supplied and included in some of the testing. Those panels are listed as epoxy/fiberglass, epoxy/Kevlar™, phenolic/fiberglass, phenolic/Kevlar, and phenolic/graphite, which is a general description of the facings, and are described in more detail in reference 2.

TEST RESULTS.

Table 6 lists the various parameters reported by each laboratory for both roundrobins. For the first roundrobin three laboratories participated (FAA, Boeing, and Douglas). The Ohio State University was an additional participant (using the thermopile only) in the second roundrobin.

For each of the materials tested, three samples were run, with the average of those three runs being reported. This report does not deal with internal laboratory repeatability, therefore, only the average values were utilized.

Because of the vast amount of data it was necessary to limit the scope of comparison. Since the main reason for the testing was to develop the OSU apparatus into a more reproducible laboratory test for use in regulating the usage of aircraft interior panels, and since the FAA released an Notice of Proposed Rule Making (NPRM) specifying the OSU apparatus and stating acceptance criteria, the criteria outlined in that NPRM were utilized to limit the number of parameters for comparison. Therefore, the parameters used for the first roundrobin were the thermopile measured 2-minute integrated heat release, at a sample exposure of 5 watts per square centimeter (hereinafter referred to as just watts) and the oxygen depletion measured 2-minute integrated heat release at 5 watts. For the second roundrobin the important parameters were the thermopile 2-minute integrated heat release and the thermopile peak heat release rate, both measured at a sample exposure of 3.5 watts.

A summary of the derivation of those parameters is as follows:

Initially, it was determined that the 5 watt 2-minute integrated heat release data gave the best correlation with full-scale test results. At first it was not determined which method of measuring heat release worked best, so either thermopile or oxygen depletion could be used. The first roundrobin also indicated a major problem in reproducibility. The percent standard deviation between laboratories for the 2-minute integrated heat release at 5 watts was 40.0 for oxygen depletion and 25.2 for thermopile.

Modifications were made in the OSU equipment and procedures by FAA and AIA in order to improve reproducibility. During those changes it was discovered that the heat flux transducer used in calibrating the FAA's equipment was in error. The 5-watt data from the first roundrobin was in reality taken at approximately 3.8 watts. When the test data with the modified OSU equipment was analyzed, the 3.5-watt data correlated better with full-scale test results. Figure 5 shows the correlation between the FAA's data before and after the modifications to the OSU equipment. The recommended pass/fail criteria for NPRM 85-10 was adjusted accordingly (reference 3).

Although there was a large difference in the absolute values of heat release measured by the two vintages of the OSU equipment, figure 5 indicates a reasonably good correlation. Perhaps more surprising was the excellent correlation between the thermopile and oxygen depletion methods for measuring heat release. Figures 6 and 7 and tables 7 through 10 show that relationship utilizing the FAA data. Figures 8 through 11 show that the relationship was almost as true for the other laboratories. Because of this extremely good correlation and the higher cost and complexity of the oxygen measurements, it was recommended that the thermopile measurement method only be required. The peak thermopile reading requirement that