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An Evaluation of Precision for the ASTM E648-91A Standard Test Method for Critical Radiant Flux of Floor-Covering Systems

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AN EVALUATION OF PRECISION FOR THE ASTM E 648-91a STANDARD TEST METHOD FOR CRITICAL RADIANT FLUX OF FLOOR-COVERING SYSTEMS

by

J. Randall Lawson

ABSTRACT

The primary goal of this project was to develop data to be used in writing a precision statement for the newly revised ASTM E 648 test procedure. Revisions to the standard included the use of a new line pilot burner, improved control over air flow through the test chamber and an extended chamber equilibration time before the apparatus is calibrated. An interlaboratory test program was conducted to develop the precision data. In this study, seven laboratories performed tests on seven sets of flooring materials. Six carpets and one resilient flooring material were selected for the evaluation. The interlaboratory study was designed and carried out using procedures recommended in ASTM E 691 standard on interlaboratory studies. Results from the program show that precision for the revised ASTM E 648 method is generally well within the range expected for standard fire test procedures. Coefficients of variation for repeatability ranged from 2.2 to 19.7 percent, and coefficients of variation for reproducibility ranged from 3.6 to 25.2 percent. In addition to these findings, a carpet variability problem appears to have been identified. A large variation in test results for two carpet products appears to be associated with carpet non-uniformity. Recommendations are made for research to develop an understanding of the variations associated with the specific style of carpeting. Recommendations are also made for studies to further improve the test standard.

Keywords: ASTM E 648, carpets, critical radiant flux, fire tests, flammability, floor coverings; interlaboratory evaluation; precision.

1. INTRODUCTION AND BACKGROUND

This research project is an extension of a previous study performed by the National Institute of Standards and Technology (NIST) and the Carpet and Rug Institute (CRI). Results from the earlier study are reported in NISTIR 89-4191, "Examination of the Variability of the ASTM E 648 Standard with Respect to Carpets"[1].[1] The current interlaboratory study (ILS) involved NIST, CRI and the American Society for Testing and Materials (ASTM). Results from this study will be used to improve the data base associated with the revised ASTM E 648-91 standard [2] and to prepare a precision and bias statement for the standard. In addition, the National Voluntary Laboratory Accreditation Program (NVLAP) is conducting an independent laboratory accreditation round using the same materials as used in this study. This report does not address the work being done by NVLAP.

It is known that tests performed on materials considered to be identical under presumed identical test conditions do not, in general, produce identical results [3]. All test procedures have some unavoidable random errors that can not be controlled easily, even with today's technology. This random behavior can generally be attributed to: the operator, equipment used, calibration of the equipment, and environmental changes. Precision, as defined by ASTM, is a concept related to the closeness of agreement between test results obtained under prescribed like conditions from a measurement process being evaluated [4]. Bias is a concept related to a consistent or systematic difference between a set of test results from a test method, and an accepted reference value of the property being measured. Bias is not being addressed in this study, since there is no currently accepted absolute reference value for the property of Critical Radiant Flux (CRF) measured in the ASTM E 648 test method.

[1] Numbers in brackets refer to the literature references.

Precision estimates in this study are based on the comparison of test results within a laboratory and the comparison of results, on the same materials, between laboratories. It is important to have an understanding of precision with test methods, especially when one is concerned with safety of life and property. In fire testing, it is not uncommon for precision statements to indicate variations ranging from 10 to 30 percent. With some procedures this value may even be higher. However, it is in the interest of the standard's maker and user to insure that a test procedure is well controlled and meets the requirements and technology of the time. Therefore, the history of standard test methods shows that one of the most significant factors addressed over the years is precision.

1.1 A Brief History of Test Precision

Precision of the flooring radiant panel test procedure has been of interest since the method was developed in the early 1970's. Several formal interlaboratory programs and a number of proficiency rounds were conducted on this test method over the years. The following provides a brief summary of the test method's precision since it first came into use.

<u>1975</u>

In 1975, Irwin Benjamin and Howard Adams published a report containing the first interlaboratory test data for the flooring radiant panel test method [5]. This test program included 13 laboratories and measurements on 3 replicates of 8 flooring materials. The following precision statements were made in their report:

Repeatability - about 20 percent (sic)

Reproducibility - on the order of 35 percent (sic)

Their report defined repeatability and reproducibility in the following ways:

> Repeatability - is a quantity that will be exceeded only about 5 percent of the time by the difference, taken in absolute value, of randomly selected results obtained in the same laboratory on a given material.
>
> Reproducibility - is a quantity that will be exceeded only about 5 percent of the time by the difference, taken in absolute value, of two single test results made on the same material in two different randomly selected laboratories.

Although stated differently, these definitions produce substantially the same results as the definitions used to analyze results of this study, seen in section 3. In their study, it should be noted that Benjamin and Adams dropped one complete set of materials from the program when it did not ignite (DNI) or show flame propagation away from the pilot burner. This carpet was a 0.95 kg/m^2 (28 oz/yd^2) Nylon 6,6; level loop; tufted; jute backed carpet.[2]

1979 to 1987

During this time period, NVLAP ran a series of proficiency rounds to aid in accreditation of the participating laboratories. The coefficient of variation for reproducibility, $S_R CV$, (see definition in section 3) in these rounds ranged from 22 to 36 percent. The 30 percent range values obtained

[2] Products are specified in this report using the identical terminology as provided to NIST by the industry. These product style identifications are used in the report to provide insight for the reader into the behavior of these various product classes with exposure to the Flooring Radiant Panel test procedure.

from these measures of laboratory proficiency resulted in NVLAP giving notice that it intended to remove the test procedure from its accreditation program. A more detailed discussion of these proficiency rounds is found in reference 1. Also during this time period, a special proficiency round was conducted by NVLAP using Standard Reference Material 1012, which was developed by NIST. This material consists of corrugated box board and exhibited a within laboratory coefficient of variation (CV) of 10.9 percent from testing 31 randomly selected specimens from the manufactured lot. Coefficient of variation (CV) in this case is defined as the standard deviation divided by the mean average ($\bar{x}$) times 100. The original mean value for the SRM from these 31 tests was 0.36 W/cm^2. The CV from this special NVLAP proficiency round for 10 of the 11 laboratories participating was 6.4 percent. In this round, one of the eleven laboratories was considered to be an outlier [1].

1987

An interlaboratory test program was run by CRI on a single carpet product, a 1.08 kg/m^2 (32 oz/yd^2); Nylon 6,6; cut pile; staple fiber carpet, which did not produce the expected results. This project experienced a problem with significant materials variability in its selected carpet. With some of the specimens, there was no flame propagation (NFP) away from the ignition point, and much of the data was not usable. Statistics for the carpet specimens which did propagate flames showed a coefficient of variation of 23.8 percent [1].

1989

In 1989, during the NIST/CRI research project a single type of carpet was selected and tested in a proficiency round to evaluate changes proposed for the test procedure. These changes included using a new line pilot burner. Results from this study showed an interlaboratory coefficient of variation of 11.5 percent, and some variations in CRF were found to be associated with conditioning time after glue down [1].

2. EXPERIMENTAL PROCEDURES

2.1 Laboratory Selection

ASTM E 691 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method was used as a guide for designing and operating this test program. Work on the ILS was carried out with participation of the Carpet and Rug Institute; ASTM Subcommittee E 05.22 on Surface Burning and its assigned task group for the E 648 test procedure; and the National Institute of Standards and Technology, Building and Fire Research Laboratory. Of prime importance to this interlaboratory study was accuracy and simplicity. It was decided to use eight qualified laboratories for the project. This would allow for the loss of two labs and still be able to maintain the minimum of six as required by E 691. The laboratories which participated in this project operate as: independent testing laboratories, industry laboratories and government laboratories. All of these laboratories were considered to be qualified for participation in the project because they had been actively using the test method and some had helped to develop it over the years. Following several months of project preparation, one of the laboratories found that it would not be able to continue in the study. This left seven laboratories which completed the work.

2.2 Instructions to Laboratories

Several weeks before testing was to start, each laboratory was sent a copy of the modified standard for review and familiarization. This was basically the same standard test procedure used in the NIST/CRI proficiency round conducted in 1989 and discussed in reference 1. A detailed drawing of the new line pilot burner was sent to allow each laboratory to construct a burner and prepare for the test program. Each laboratory was asked to submit its data in the standard ASTM E 648 test procedure format. In addition, a special project information packet was sent to each laboratory. This information was provided for additional knowledge on changes to the standard and explained what was expected from the participants when preparing, conditioning, and testing the materials during the interlaboratory program. A copy of this information and instructions is presented in the Appendix of this report.

2.3 Laboratory Visits

Each of the volunteer laboratories was visited prior to beginning testing to ensure that it was physically ready and understood the new test protocol. During these visits it was found that all participants were well prepared for the program. Each laboratory had properly installed its new pilot burners and tested them prior to the visit. Air flow through the test chambers was checked with a newly calibrated air flow anemometer, and all laboratories were found to be within standard tolerances. While visiting the labs, it was discovered that two laboratories were experiencing problems with the radiant panel flame-out detectors. In one of the labs, radiant panel flame-outs resulted in the loss of data on one material; a new set of specimens was shipped to complete the test work. In addition, a check on heat flux gauge calibrations at the laboratories found that one new gauge, which was held as a spare by the laboratory, had an error of slightly more than 25 percent. All other laboratory gauges showed calibration variations of less than 3 percent.

2.4 Materials Selection

2.4.1 Carpets and Resilient Flooring

Seven products were selected for the ILS, six carpets and one resilient flooring material. The carpets were generally of the design used in commercial and institutional buildings. There was an attempt to select carpets which would represent the current types in use with critical radiant flux values in the Class I and Class II ranges. A Class I carpet has a minimum critical radiant flux (CRF) of 0.45 W/cm^2, and a Class II carpet has a minimum CRF of 0.22 W/cm^2. The resilient flooring was to be a Class I material. Table 1 provides details on the materials tested. For the carpets, 56 specimens were cut for each material. Each specimen was given a materials code letter and location number based on where it was cut from the carpet. A representative example of a typical sampling map is shown in Figure 1. The resilient flooring was sampled in a similar manner. Adhesives for the carpets and the resilient flooring were shipped with the flooring materials to each of the testing laboratories. Special instructions, as shown in the

Appendix, were sent to each laboratory. These outlined details for preparing, gluing and conditioning the test specimens.

2.4.2 Adhesives

Each laboratory was shipped a 3.8 L (1 gal) container of PARABOND M-433 Premium Commercial Floor Covering Adhesive.[3] This is a high solids, water based, synthetic latex based, carpet adhesive. The adhesive for attaching the resilient flooring to the board was Armstrong S-280. This adhesive is an alkali- and moisture-resistant troweling adhesive manufactured especially for installation of resilient flooring. A 0.95 L (1 qt) container of the adhesive was shipped to each laboratory, and each laboratory received a metal trowel for spreading the resilient flooring adhesive. Directions for use of the adhesives were provided with the special instructions list shown in the Appendix. These directions allowed for the products to be glued to the test substrate in a fashion that would normally be used by a flooring contractor and followed by the testing laboratories. The limit on days of conditioning after glue down resulted from the finding in the 1989 study [1] that variations in conditioning time after glue down can alter the test results. The four to ten day window allowed a reasonable period of time for the laboratories to test their specimens without causing significant variations resulting from adhesive curing. This matter should be addressed in the next draft of the standard test method.

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[3] Certain commercial products are identified in this report in order to adequately specify the materials used. Such identification does not imply recommendation by the National Institute of Standards and Technology, nor does it imply that these materials identified are the best available for the purpose.

3. RESULTS

All of the participating laboratories were able to complete their tests and submit the results promptly for analysis. Upon receiving the data from each participant, it was entered into a computer file for analysis. After all data were entered, they were processed using ASTM E 691 data reduction software [6]. Test results from the seven laboratories are shown in Tables 2 and 3. Table 2 provides the data as received from each of the laboratories on each of the seven materials. Table 3 provides the computed statistics for repeatability (within laboratory) and reproducibility (between laboratories). The following equations define the statistical values listed in Table 3 where:

x = individual test result,

Cell average:

$$\bar{x} = \sum_{1}^{n} \frac{x}{n} \tag{1}$$

where n = number of test results per cell

Average of cell averages:

$$\tilde{x} = \sum_{1}^{p} \frac{\bar{x}}{p} \tag{2}$$

where p = number of laboratories

Cell standard deviation:

$$S = \sqrt{\sum_{1}^{n} (x-\bar{x})^2/(n-1)} \tag{3}$$

Cell deviation:

$$d = \bar{\bar{x}} - \tilde{x} \tag{4}$$

Standard deviation of cell averages:

$$S_{\bar{x}} = \sqrt{\sum_{1}^{p} \frac{d^2}{p-1}} \tag{5}$$

Repeatability standard deviation:

$$S_r = \sqrt{\sum_{1}^{p} \frac{S^2}{p}} \tag{6}$$

Reproducibility standard deviation:

$$S_R = \sqrt{(S_{\bar{x}})^2 + (S_r)^2\ (n-1)/n} \tag{7}$$

Percent coefficient of variation of repeatability:

$$S_r CV = \frac{S_r}{\tilde{x}} 100 \tag{8}$$

Percent coefficient of variation of reproducibility:

$$S_R CV = \frac{S_R}{\bar{x}} 100 \tag{9}$$

Table 3, also provides the repeatability limit, r, and the reproducibility limit, R, which are defined below:

r = the value below which the absolute difference between two single test results obtained under repeatability conditions may be expected to lie with a probability of approximately 95 %.

R = the value below which the absolute difference between two single test results obtained under reproducibility conditions may be expected to lie with a probability of approximately 95 %.

Note: The repeatability limit is defined as 2.8 x S_r the repeatability standard deviation, and the reproducibility limit is defined as 2.8 x S_R the reproducibility standard deviation. The multiplier for both values is independent of the size of the interlaboratory study [4].

Results for the repeatability statistic (r) and reproducibility statistic (R) are plotted in Figure 2.

In addition to calculating the above statistics, the ASTM software also produces two values known as consistency statistics, h and k. The k-value is used to examine consistency of the within-laboratory precision from laboratory to laboratory. The h-value is used to examine consistency of the test results between laboratories. These values provide information that help to identify possible outliers in the study. For the h and k values generated in this study, there was no significant indication of inconsistency that would imply any outlier laboratories.

4. DISCUSSION

There are two themes in this section. The first is the quantitative reproducibility of the test method. The second concerns the erratic behavior of some of the tested products. During this discussion, products are presented as described to NIST by the suppliers. No attempt is being made to attribute the cause of the observed behavior to any particular component of the products.

Four carpet products, A,D,E and F, exhibited relatively uniform results. There had been early concern regarding product E. All of the samples of carpet E melted and drew away from the hot end of the test chamber. The sample would split through to its backing, buckle up as it melted, and recede from the radiant panel and burner. With the new five-minute preheat, it appeared that the specimens would completely pull away from the hot end before the pilot could be put into position. However, despite this concern, each of the samples tested by all labs *was* ignited by the pilot burner.

As shown in Table 3, all four of these carpets (A,D,E and F) had S_r values less than 0.08 and S_R values of less than 0.12. The S_rCV values were all less than 20 percent and the S_RCV values were all less than 26 percent. Based on the precision statistics shown in Table 3, it is apparent that the test procedure can do a reasonable job of reproducing test values on the same material within a laboratory and between laboratories.

The non-carpet material, G, also showed low variability. As noted in Table 2, all of the test values were greater than 1.0 W/cm^2, with 6 laboratories reporting results in the narrow range between 1.04 and 1.14. The seventh laboratory reported its values as >1.00, as permitted by the standard. These numbers are not statistically usable since they do not provide specific values, and they were not used for calculating the results presented in Table 3. This reporting of test results as "greater than 1.00" has caused substantial difficulties with the test procedure for many years. These values have often been called, "Did Not Ignite" (DNI), a designation that is not correct. In all cases observed by the writer where a combustible material has been subjected to the pilot flame, the material *has* ignited and burned in the pilot flame area. However, the test procedure does not have a flux calibration point closer than 10 cm from the hot end of the specimen, and some flames do not propagate to or beyond that location. Thus, it would be useful for the test procedure to add a flux profile measurement at about the 2 cm mark. This would allow for a more complete profile on the hot end and would virtually eliminate the need to report values as >1.00. A similar experience has been noted when testing thermal insulation materials with the ASTM E-970 Attic Flooring Radiant Panel Test [7], but on the cool end of the specimen. Recently, an additional flux measurement point was added at 98 cm to complete the profile on the cool end.

The differences in coefficient of variation between laboratories, $S_R CV$, and within a laboratory, $S_r CV$, for materials A, D, E, F, and G are all less than 6 percent. These small differences indicate that the test procedure is displaying control over its variables, and it is coming close to its maximum potential for reproducibility. Reproducibility precision can not be less than repeatability precision. The test is expected to provide reproducible results between laboratories for materials possessing relatively uniform critical radiant flux properties. This is also shown by the values of r and R in the precision vs. property level plot in Figure 2. It should also be noted that precision remains relatively constant over the range of critical radiant flux for these five products.

Products B and C showed behavior quite different from these five, with $S_R CV$ values above 30 percent (Table 3 and Figure 2). As described by the industry, these two products were identical except for the backing construction. In earlier interlaboratory studies, other products of this style also exhibited high variation in repeatability. In the 1987 CRI program using the earlier version of the test method and original pilot burner, specimens from a single roll of this type carpet (Nylon 6,6, 1.08 kg/m^2 (32 oz/yd^2)) showed no flame propagation, while other specimens had values as low as 0.46 W/cm^2 [1].

> [Note: after several months, NIST and other laboratories re-tested some 51 specimens from the same roll to determine the variability problem. The same test procedure and pilot burner were used. Only one specimen failed to propagate flame, and the remaining 50 values produced an average critical radiant flux of 0.44 W/cm^2 with a

standard deviation of 0.093 and range of 0.33 to 0.84 W/cm^2 [1]. These results led to a recommendation in reference 1:

> "Determine the effect of specimen location on the carpet to assess variation in the product and determine the effect of carpet aging on critical radiant flux. This will address the unanswered question of why the results of the CRI program carried out in 1987 were so different from the NIST results and those from several of the laboratories on the same carpet tested in 1988."]

Similar variability was found with one example of this type of product in the NIST/CRI study of 1989. At that time, NIST evaluated six carpets in order to select one for use in the test method parametric study [1]. One of these (Nylon 6,6 fiber, loop pile, 0.95 kg/m^2 (28 oz/yd^2)) exhibited excess variability. Two similar products exhibited no flame propagation. The fourth had a higher density (1.70 kg/m^2 (50 oz/yd^2)) and a cut pile. It had a coefficient of variation of repeatability of 11.8 percent.

The variability in the performance of products B and C does not appear to be related to the critical radiant flux measurement method but appears to be related to non-uniform product characteristics. Data from this study indicate that some variability may be dependent upon location of samples in the carpet roll. Figures 3 and 4 map test results to sample position. For example, laboratory 2 obtained a value of 1.04 W/cm^2 from specimen B32, while for adjacent specimen B33, laboratory 6 determined a value of 1.19 W/cm^2. Laboratory 7 obtained values of 0.92 W/cm^2 for specimen C40 and 1.15 W/cm^2 for specimen C41. Specimen C28 is also near this cluster of high values. Similar multi-laboratory clusters of low values can also be observed.

This style of carpet has also shown a positive feature. It has been involved in all of the major cases where there was no propagation of flame away from the ignition point. For example, it was reported by Benjamin and Adams [5] that a Nylon 6,6 carpet of 0.95 kg/m^2 (28 oz/yd^2) did not propagate flame away from the point of ignition. This is one of the goals that fire safety professionals are striving to encourage.

5. CONCLUSIONS AND RECOMMENDATIONS

1. Test results for five of the seven products in this study show that the new procedure can provide repeatability and reproducibility values well within the norm expected for fire test methods.

2. The small differences in coefficient of variation between laboratories, $S_R CV$, and within laboratories, $S_r CV$, for five of the materials show that reproducibility is approaching the level of repeatability within laboratories.

3. Data from this study and earlier studies indicate that products of a construction represented by carpets B and C can be excessively variable. Products displaying inconsistent behavior may be of more concern than materials that are consistently poor performers. Enough historical data are now available which show an inordinate amount of variability that an effort should be launched to define and correct the problem. In particular, a study should be carried out on the remaining carpet specimens of B and C to further quantify the variability with those carpets.

4. For products that exhibit high values of variability, procedures should be added to the standard to increase confidence in results from such products. Highly variable products can not be seen as being equal to products with much lower variability. Three replicates on a highly variable product will

not enable a prediction of average performance. As an example, benefits of increasing the number of replicates for these products should be examined.

5. As found in this study, a potential exists for increases in variability resulting from specimens shrinking away from the hot end of the test chamber. In light of this, an effort should be made to develop a standard procedure for insuring the ignition of flooring products which shrink and pull away from the radiant panel and pilot burner.

6. Comments should be added to the standard discussing the influence that conditioning time, after carpet glue down, has on critical radiant flux values. Limits should be set on this variable in the standard [1].

7. Bias could not be determined in this study for lack of an absolute measure of critical radiant flux. Steps should be taken to develop this measure so that bias can be addressed.

6. REFERENCES

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7. ACKNOWLEDGEMENTS

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Table 1. Flooring Materials Tested

Material Identification	Material Description
A	Nylon 6, staple cut pile 1.02 kg/m^2 (30 oz/yd^2)
B	Nylon 6,6 BCF, loop pile 0.95 kg/m^2 (28 oz/yd^2)
C	Nylon 6,6 BCF, loop pile with unitary backing 0.95 kg/m^2 (28 oz/yd^2)
D	Polyester staple, cut pile 1.08 kg/m^2 (32 oz/yd^2)
E	Polypropylene (Olefin) BCF, loop pile 0.88 kg/m^2 (26 oz/yd^2)
F	Wool, loop pile 1.36 kg/m^2 (40 oz/yd^2)
G	Vinyl Resilient Flooring

Note: All carpets except C had a polypropylene primary backing with SBR latex and a polypropylene secondary backing. The unitary backing of C was also constructed of polypropylene.

Table 2. ASTM E648-91 Flooring Radiant Panel Interlaboratory Data 1991

CRITICAL RADIANT FLUX FOR MATERIALS (W/cm^2)

Lab.	A	B	C	D	E	F	G
1	0.50	0.35	0.55	0.24	0.31	0.72	1.08
	0.43	0.39	0.60	0.27	0.34	0.86	1.08
	0.41	0.36	1.07	0.24	0.29	0.73	1.08
2	0.46	0.64	1.04	0.38	0.43	0.88	1.04
	0.44	0.60	0.61	0.44	0.32	0.86	1.04
	0.40	1.04	0.67	0.37	0.33	0.86	1.04
3	0.45	0.61	0.58	0.16	0.27	0.95	1.04
	0.40	0.37	0.58	0.34	0.24	0.82	1.04
	0.42	0.44	0.45	0.36	0.25	0.87	1.12
4	0.37	0.55	0.82	0.28	0.31	0.75	1.09
	0.43	0.47	1.15	0.26	0.31	0.60	1.15
	0.58	0.67	1.15	0.16	0.42	0.63	1.14
5	0.44	0.35	0.59	0.36	0.31	0.86	>1.00
	0.36	0.35	0.90	0.28	0.27	0.60	>1.00
	0.43	0.43	1.10	0.32	0.41	0.63	>1.00
6	0.50	1.15	0.52	0.39	0.31	0.91	1.10
	0.42	1.19	0.61	0.32	0.33	0.85	1.08
	0.41	0.43	0.60	0.41	0.23	0.89	1.08
7	0.35	0.35	0.77	0.24	0.22	0.77	1.14
	0.31	0.32	0.92	0.37	0.21	0.87	1.12
	0.37	0.42	1.15	0.33	0.24	0.87	1.12

Table 3. ASTM E-648 Flooring Radiant Panel Precision Statistics Summary 1991

Material Code	Type	Average* W/cm^2	S_r	S_rCV %	S_R	S_RCV %	$r=2.8xS_r$	$R=2.8xS_R$
G	Vinyl Resilient Flooring	1.09	0.024	2.2	0.039	3.6	0.067	0.110
F	Wool Loop Pile 1.36 kg/m^2 (40 oz/yd^2)	0.80	0.077	9.6	0.111	13.9	0.215	0.311
A	Nylon 6 Staple 1.02 kg/m^2 (30 oz/yd^2)	0.42	0.054	12.8	0.059	13.9	0.153	0.165
D	Polyester Staple 1.08 kg/m^2 (32 oz/yd^2)	0.31	0.061	19.7	0.078	25.2	0.172	0.219
E	Polypropylene BCF Loop 0.88 kg/m^2 (26 oz/yd^2)	0.30	0.049	16.2	0.064	21.2	0.137	0.179
	====================							
C	Nylon 6,6 BCF Loop Double Back 0.95 kg/m^2 (28 oz/yd^2)	0.78	0.201	25.7	0.247	31.6	0.564	0.692
B	Nylon 6,6 BCF Loop Unitary Back 0.95 kg/m^2 (28 oz/yd^2)	0.55	0.197	36.0	0.272	49.7	0.552	0.761

* This value is the average of cell averages. The standard specifies that results are to be reported in units of W/cm^2.

Figure 1. Example of a typical flooring sampling map

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
A15	A19	A17	A18	A19	A20	A24	A22	A23	A24	A26	A26	A27	A28
A29	A30	A31	A38	A33	A34	A35	A36	A37	A38	A39	A19	A41	A42
A43	A48	A48	A46	A47	A48	A49	A50	A51	A52	A53	A54	A55	A56

Note: The above represents a piece of carpet taken from the machine which is 12 ft. wide.
Tufting or machine direction progresses from the top to the bottom of the sample.

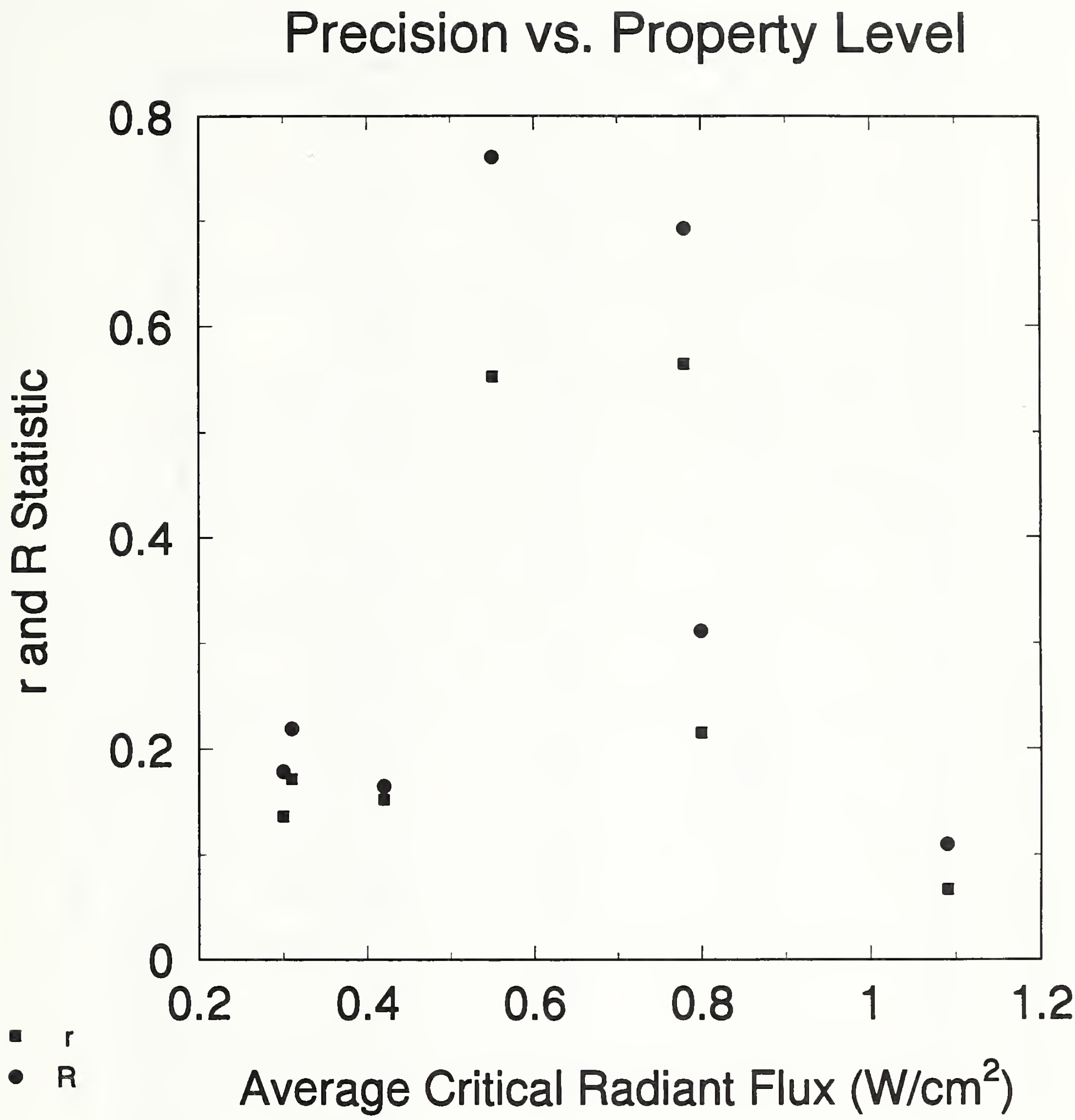

Figure 2. Plot of Repeatability (r) and Reproducibility (R) Statistics

Figure 3. Map of critical radiant flux values for carpet B

B1	B2	B3 L6* 1.15	B4 L3 0.61	B5	B6	B7	B8 L5 0.35	B9	B10 L2 0.64	B11 L4 0.55	B12	B13 L2 0.60	B14 L7 0.35
B15	B16 L4 0.47	B17	B18 L1 0.36	B19	B20	B21 L7 0.32	B22	B23 L3 0.37	B24 L7 0.42	B25	B26	B27	B28
B29	B30 L4 0.67	B31	B32 L2 1.04	B33 L6 1.19	B34 L1 0.35	B35 L5 0.35	B36	B37 L3 0.44	B38 L6 0.43	B39 L5 0.43	B40 L1 0.39	B41	B42
B43	B44	B45	B46	B47	B48	B49	B50	B51	B52	B53	B54	B55	B56

* The letter L and number identifies the laboratory for that data point.

Figure 4. Map of critical radiant flux values for carpet C

C1 L1 1.07	C2	C3 L4 1.15	C4	C5 L4 0.82	C6	C7 L3 0.58	C8	C9 L3 0.58	C10	C11	C12	C13 L2 1.04	C14 L6 0.52
C15	C16	C17	C18	C19 L6 0.61	C20	C21 L5 0.59	C22	C23	C24 L4 1.15	C25	C26 L6 0.60	C27	C28 L5 0.90
C29	C30	C31 L5 1.10	C32 L2 0.61	C33 L2 0.67	C34 L1 0.55	C35 L3 0.45	C36 L1 0.60	C37 L7 0.77	C38	C39	C40 L7 0.92	C41 L7 1.15	C42
C43	C44	C45	C46	C47	C48	C49	C50	C54	C52	C53	C54	C55	C56

APPENDIX

ASTM E 648 INTERLABORATORY TEST PROGRAM
1991
PROJECT INFORMATION SHEET

Standard Revisions:

NEW PILOT BURNER: Section 6.4 describes the new pilot burner. Note the gas flow rate and pilot flame height as described. Sections 12.3 and 12.4 define the pilot burners use during testing. Note the change in specimen preheating before applying the pilot burner and the new specifications for specimen/pilot burner exposure times.

Experience has shown that the new pilot will require some cleaning. After extended use, it is suggested that the burner be lightly brushed to remove carbon deposits and pilot holes may need to be picked clean. A fine rigid wire is suitable for cleaning the holes.

Please keep your new pilot burner working at peak performance throughout this test program.

AIR FLOW THROUGH THE CHAMBER: Section 6.6 has new specifications related to air flow through the test chamber. It has been found that these specifications are significant to proper chamber operation and test results.

CHAMBER PREHEAT TIME FOR CALIBRATION: Section 10.3 adds an additional 30 minutes to the chamber stabilization time since research has shown that test chambers can still be in transition at the one hour point.

SPECIMEN CONDITIONING: Section 11.0 has changed to increase time for conditioning flooring specimens after glue down. See addition request below.

Special Considerations For This Project:

SPECIMEN PREPARATION:

For the specimen substrate, use the fiber reinforced cement board as specified in section 9.2.1 and note 10.

Be sure to follow directions of the adhesive manufacturer for gluing down specimens.

For carpets, be sure to roll them as described in Section X 2.2.2.

SPECIMEN CONDITIONING:

After the specimens have been glued and rolled, allow them to condition for a minimum of 96 hours (4 days). For this project, all carpets shall be tested no later than 10 days after being glued down.

Be sure to note on your test data sheets, sent to NIST, the total conditioning time for each specimen before it was tested.

CALIBRATION AND TESTING:

Check the operation of your heat flux transducer which is used to develop the flux profile to insure that it is operating properly.

With your test results, please send a copy of your flux profile and all supporting data.

With your test data, provide the air flow rate through your chamber as measured under Section 6.6.

Take pictures of each of your test specimens showing their burn patterns and submit to NIST with your test data.

Note any unusual problems experienced while conducting the tests on your test sheets.

Submit all test data to NIST by November 1, 1991.

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Dalton, GA 30722

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The primary goal of this project was to develop data to be used in writing a precision statement for the newly revised ASTM E 648 test procedure. Revisions to the standard included the use of a new line pilot burner, improved control over air flow through the test chamber and an extended chamber equilibration time before the apparatus is calibrated. An interlaboratory test program was conducted to develop the precision data. In this study, seven laboratories performed tests on seven sets of flooring materials. Six carpets and one resilient flooring material were selected for the evaluation. The interlaboratory study was designed and carried out using procedures recommended in ASTM E 691 standard on interlaboratory studies. Results from the program show that precision for the revised ASTM E 648 method is generally well within the range expected for standard fire test procedures. Coefficients of variation for repeatability ranged from 2.2 to 19.7 percent, and coefficients of variation for reproducibility ranged from 3.6 to 25.2 percent. In addition to these findings, a carpet variability problem appears to have been identified. A large variation in test results for two carpet products appears to be associated with carpet non-uniformity. Recommendations are made for research to develop an understanding of the variations associated with the specific style of carpeting. Recommendations are also made for studies to further improve the test standard.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

Keywords: ASTM E 648, carpets, critical radiant flux, fire tests, flammability, floor coverings; interlaboratory evaluation; precision.

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