Comment to the Industry

ASTM E84:
Smoke Variability and Implications of Laboratory Selection Based on Smoke Area Calibration

Building & Construction
White Paper
April 2017

intertek.com/building
CONTENTS

Contents
Introduction

A Brief History
Sources of Smoke Variability
The Purpose of Calibration
Smoke Developed Index (SDI) and Calibration
Unintended Consequences
Steps to Ensure Test Results Accuracy
About Intertek
References
INTRODUCTION

Since the first prototype Steiner Tunnel test apparatus was developed in 1922, through adoption by ASTM and subsequent evolution into the standard we know today, ASTM E84 has become one of the most common fire tests required for building materials. Over the years, product developers and manufacturers have developed a love-hate relationship with ASTM E84.

In recent years, regulatory changes impacting a particular category of products have resulted in several periods of industry-wide reformulation and requalification. Among the minimum requirements for this particular category of products is classification of surface burning characteristics based on testing in accordance with ASTM E84. Recent feedback from our Clients has suggested an increase in the variability of Smoke Developed Index (SDI) results among the testing laboratories and that manufacturers were increasingly selecting laboratories based on Red Oak smoke area calibration values.

Intertek maintains accreditation for ASTM E84 at four laboratories under our Building & Construction business line in North America and Asia. In an effort to better understand variability of SDI results among our four laboratories and between our labs and other accredited labs, Intertek initiated an internal review of our equipment, procedures, and calibration results as well as the ASTM E84 standard itself. This article will briefly discuss some observations resulting from this review.

This paper has been produced by Intertek for consideration of our customers, partners, and peers in the building and construction industry. While we stand behind our work, we encourage the reader to always check for updates before making any decisions based off this document.
ASTM E84: DESCRIBED

A Brief History
In the simplest of terms, work that eventually became the current ASTM E84 picked up in the 1940's in response to several tragic fire events including the Coconut Grove nightclub fire (1942), the Winecoff, LaSalle, and Canfield hotel fires (1946), and the St. Anthony’s Hospital fire (1949). The final physical form of the tunnel test apparatus was completed around 1948; however, it did not become a full ASTM Standard Test Method until 1961. Since that time, task group activities related to ASTM E84 under ASTM Subcommittee E05.22 on Surface Burning have focused on measurement, control systems, calculations, and specimen mounting practices. As with any long standing and widely utilized test method, tunnel operators have developed an abundance of informal knowledge as to the nuances of this test standard.

Sources of Smoke Variability
For something so simple in appearance, smoke is actually extremely complex. Primarily the result of incomplete combustion, smoke is a mixture of solid and liquid particles of varying sizes dispersed within a turbulent mixture of moving hot air that is combined with gasses and vapors released during the combustion process. Over the years, several inter-laboratory and round-robin studies have documented challenges in the reproducibility of smoke measurement and reporting.

There is currently no NIST Standard Reference Material (SRM) for the purpose of calibration of ASTM E84 for either Flame Spread or Smoke Development. The Red Oak specified in the standard (Select Grade) is typically obtained by laboratories from a local source or from companies specializing in providing wood products (e.g. Red Oak, wood cribs, etc.) to fire testing labs. Our internal review of historical Red Oak smoke area (%Obscuration-min) calibration values suggested an approximate range of 60 to 125, both inter-lab and intra-lab. This observation prompted an internal round-robin
experiment among our three labs in the US and Canada using a single lot of Red Oak from a single source.

Results of the round-robin showed smoke area values having a range approximately one-half that of the previous range; an observation that may suggest greater inter-source variability among Red Oak suppliers than otherwise appreciated by the test method. Additional items identified as influencing the measured light obscuration (from which smoke area values are calculated) included the configuration of the opening of the vent pipe through which the light beam travels and the calibration of the photometer system to verify its linearity. The influence on SDI presented by these two items is potentially significant.

Other factors identified in the literature as influencing test results for both FSI and SDI included moisture content of the wood, temperature and humidity of the room in which the test apparatus is located, and air velocity through the test apparatus.
ASTM E84: CALIBRATION

The Purpose of Calibration

Calibration is defined in ASTM E2782-11 as “n - process of establishing a relationship between a measurement device and a known standard value(s).” One of the primary purposes of calibration is to reduce, or otherwise mitigate, bias in the measurement of a value. Bias, is defined in ASTM E456-13 as “n- the difference between the expectation of the test results and an accepted reference value.”

In the context of ASTM E84, the intent of the Red Oak calibration is to account for systematic error across different test apparatus (i.e. different labs) or variation that may arise within a given test apparatus (e.g. modifications, upgrades, maintenance of brick lining and windows, etc.). Stated in more practical terms, if the smoke %Obscuration-min measurement for Tunnel A “runs a little high” and Tunnel B “runs a little low”, then results for both Red Oak and the Test Specimen should also come in higher and lower in Tunnel A and Tunnel B, respectively.

The logic above assumes that (1) both Red Oak calibrations and testing of Test Specimens are performed in accordance with the requirements and limitations of the E84 standard test method, and (2) systematic error (or bias) in smoke measurement results produced by a particular test apparatus will influence both Red Oak and Test Specimen equally. When applied across different test apparatus, the logic further assumes that calibration sufficiently addresses bias and, therefore, will produce comparable SDI results for a given test specimen regardless of the test apparatus.

Over the last several years, ASTM Subcommittee E05.22 on Surface Burning has worked on an evaluation of Heptane as an alternate calibration standard for smoke development (only) under the E84 test method. Available data suggests that heptane produces smoke area values that are both more repeatable and more reproducible than Red Oak. Results of internal studies undertaken by Intertek have produced similar observations regarding heptane smoke area. Work is ongoing and expected to produce fruitful results in the future along with the eventual transition to the heptane smoke area calibration.
Smoke Developed Index (SDI) and Calculation

In addition to using Red Oak as the calibration standard, the E84 test method reports the Test Specimen smoke area as an index against the Red Oak smoke area, arbitrarily fixing the SDI of Red Oak at 100. As an index, the equation for calculating SDI is quite simple (basically a ratio multiplied by 100):

\[
SDI = \frac{\text{Smoke Area}_{\text{Specimen}}}{\text{Smoke Area}_{\text{Red Oak}}} \times 100
\]

By fixing the SDI of Red Oak at 100 it is inherently assumed that if Red Oak was treated as a Test Specimen, then the resulting smoke area would equal that of the Red Oak calibration smoke area and thereby produce an SDI equal to 100.

Unintended Consequences

Over the years, the simple mathematics of the SDI calculation mixed with anecdotal evidence from selected E84 test results has resulted in an impression that a higher Red Oak calibration value presents more opportunity to meet SDI limits set by the model building codes and other performance standards. This impression regarding the influence of the Red Oak calibration has resulted in a practice of “shopping” labs for the highest Red Oak smoke area. Such a practice goes against the principle purpose of standardization and encourages actions that focus on obtaining the “right” result instead of the accurate result that is representative of the relative comparison as is the stated intent of the ASTM E84 standard test method. If it is proven that different Red Oak calibration smoke areas result in statistically significant differences in SDI for a given product, then more work is necessary to improve understanding of the sources and control of the variability.

It is incumbent upon accredited testing agencies to participate in interlaboratory round-robin experiments and proficiency studies with Standards Development Organizations (SDOs) such as ASTM. These experiments and studies are critical to identify trends and ensure consistency across laboratories as well as the development and sharing of best practices among peers to ensure continuous improvement and understanding of the method. Accurate, high-quality test results require deep knowledge, competence, and proficiency with the test method in addition to properly designed, operated, and maintained equipment.
ASTM E84: MOVING FORWARD

Steps to Ensure Test Results Accuracy

In the end, the purpose of methods standardization and laboratory accreditation is to provide high confidence that testing of a given sample in accordance with a given method would produce the same result regardless of the laboratory that performed the test.

Having identified the issues presented above, Intertek is taking the following steps to further ensure the accuracy of test results obtained within our laboratory system and to continue doing our part to improve both the ASTM E84 test method and its execution:

1. Effective immediately, Intertek will modify our procedures to add collection of heptane smoke area concurrently with Red Oak smoke area at the time of calibration

2. Intertek will use the heptane smoke area data as a second, ‘internal’ standard to
   a. Check Red Oak smoke area in reference to SDI ≈ 100
   b. Build data to improve understanding of variability and bias originating in either equipment or calibration

3. Intertek will continue to perform internal procedural evaluations, standardization, and round-robin experiments within our laboratory system

4. Intertek will continue active participation in the ASTM E05.22 Subcommittee on Surface Burning in order to address the issues highlighted above and ensure the ASTM E84 method remains a robust test method worthy of reliance placed on it by model building codes and performance standards.

Intertek believes the measures enumerated above are in keeping with the highest standards of testing, certification, and our respective accreditations for both.
ABOUT INTERTEK:
TOTAL QUALITY. ASSURED.

Intertek is a leading Total Quality Assurance provider to industries worldwide. Through our network of more than 1,000 laboratories and offices and over 42,000 people in more than 100 countries, the Group is re-defining the industry with our Total Quality Assurance proposition. We go beyond physical quality control to provide total peace of mind through our innovative and bespoke Assurance, Testing, Inspection and Certification solutions for our customers’ operations and supply chains. Intertek Total Quality Assurance expertise, delivered consistently, with precision, pace and passion, enabling our customers to power ahead safely.

Contact Us
To connect with an expert on this topic, or to discuss a new project, contact your local Intertek at 1-800-WORLLAB (967-5352), via email at icenter@intertek.com, or visit www.intertek.com/building.

The addition of PSI and the MT Group to the Intertek family gives customers the industry’s most comprehensive suite of services in the building and construction industry. As a partner fully involved in the construction process - from the development of codes to building design, construction, maintenance, and decommissioning - Intertek’s unique industry perspective gives customer insight that no other firm can provide.

Intertek’s customers take advantage of its expansive global footprint, extensive portfolio of services, and vast breadth of industry expertise. These elements work together helping customers to gain access to domestic and global markets, ensure projects are completed to specifications, and risk is mitigated throughout all aspects of the built environment.
REFERENCES


800.967.5352
icente@intertek.com
intertek.com/building

This publication is copyrighted by Intertek and may not be reproduced or transmitted in any form in whole or in part without the prior written permission of Intertek. While due care has been taken during the preparation of this document, Intertek cannot be held responsible for the accuracy of the information herein or for any consequence arising from it. Clients are encouraged to seek Intertek’s current advice before acting upon any of the content.