

astm e165

Published: September 19, 2026 | Index ID: #-

Introduction

In the world of fire safety and building materials, knowing how a substance behaves when exposed to heat is paramount. Whether it's a new composite panel for a high rise, a polymer coating for an aircraft, or a fire blocking insulation in a data center, engineers and safety professionals must assess how quickly a material consumes oxygen. This is where the ASTM E165 standard steps in. ASTM International, formerly known as the American Society for Testing and Materials, publishes ASTM E165 as the definitive guide for measuring the oxygen consumption rate (OCR) of materials. The standard has become a cornerstone in the fire testing industry, providing a reliable, repeatable method for characterizing combustion behavior under controlled laboratory conditions.

In this article we'll dive deep into ASTM E165: its purpose, methodology, practical applications, and how it fits into the broader regulatory and testing landscape. By the end, you'll have a clear understanding of why this standard matters and how to use it effectively in product development, compliance, and research.

What Is ASTM E165?

ASTM E165 is titled "Standard Test Methods for Determining the Oxygen Consumption Rate of Materials by the Oxygen Consumption Method." The standard defines a systematic approach to measure how much oxygen a material consumes when it is exposed to a controlled temperature environment. The oxygen consumption rate is expressed in milligrams of oxygen per gram of material per hour ($\text{mg O}_2 / \text{g} \cdot \text{h}$). This metric is essential for estimating the fire hazard posed by a material, as it directly correlates with how quickly a material will burn and how much heat it will release.

Historical Context

The first ASTM E165 was published in 1974, reflecting growing concerns about fire safety in industrial and commercial settings. Over the years, the standard has undergone several revisions to incorporate advances in instrumentation, improve repeatability, and align with evolving regulatory requirements. The most recent edition, published in 2004, remains the reference for most laboratories worldwide.

Core Objectives

- Quantify oxygen consumption: Provide a standardized way to measure how much oxygen a material uses during combustion.
- Assess flammability: Offer a metric that can be compared across materials, helping engineers rank fire hazards.
- Support regulatory compliance: Serve as a foundation for meeting building codes, transportation regulations, and product safety standards.
- Facilitate product development: Enable manufacturers to screen new materials and formulations before full-scale testing.

How Does ASTM E165 Measure Oxygen Consumption?

The ASTM E165 test employs a controlled environment chamber where the sample is heated to a set temperature. The chamber's atmosphere is carefully monitored for oxygen depletion, which directly reflects the material's

combustion activity. Below we outline the key steps in the test procedure.

1. Sample Preparation

Samples must be prepared in a consistent manner to ensure repeatability:

- Dimensions: Typically a rectangular slab of 1 /cm × 1 /cm × 1 /cm, though the standard allows for variations depending on material type.
- Mass: The sample's mass should be recorded to the nearest milligram.
- Surface treatment: Any coatings, finishes, or surface treatments should be applied uniformly.

2. Test Chamber Setup

The test chamber is a sealed, temperature controlled vessel equipped with:

- Thermocouples or resistance temperature detectors (RTDs) for accurate temperature measurement.
- Oxygen analyzers (typically electrochemical or paramagnetic) to detect minute changes in O₂ concentration.
- Pressure transducers to monitor chamber pressure.

3. Temperature Control

ASTM E165 allows for two primary temperature regimes:

- Fixed temperature method: The chamber is set to a constant temperature (e.g., 600 °F or 315 °C) and maintained throughout the test.
- Temperature programmed method: The temperature is ramped at a controlled rate (e.g., 10 °C /min {¹}) to simulate real world fire scenarios.

4. Monitoring Oxygen Depletion

As the material burns, it consumes oxygen, causing a measurable drop in the chamber's O₂ concentration. The oxygen analyzer records this change continuously. The OCR is calculated using the following equation:

$$\text{OCR} = (9D_0 - r V) / (m \times t)$$

Where:

- $9D_0$ = Initial oxygen concentration (ppm).
- V = Chamber volume (liters).
- m = Sample mass (grams).
- t = Time over which $9D_0 - r V$ occurs (hours).

The result is expressed in mg O₂ / g {¹ h {¹}. A higher OCR indicates a material that burns more rapidly and releases more heat.

5. Data Recording and Interpretation

Test data are recorded in a structured format, including:

- Initial O₂ concentration.
- O₂ concentration at specified time intervals.
- Temperature profile.
- Pressure changes.
- Sample mass.

From these data, analysts can derive not only the OCR but also related parameters such as the heat release rate (HRR) and the total oxygen consumed over the test duration.

Why Is OCR Important?

The oxygen consumption rate is a direct measure of a material's combustibility. It informs several critical aspects of fire safety:

1. Heat Release Estimation

Oxygen consumption is proportional to heat release. By knowing the OCR, engineers can estimate the heat flux a material would generate in a fire, which is essential for fire load calculations and compartment fire modeling.

2. Fire Growth Prediction

Materials with high OCR values tend to support rapid fire growth. This information is vital for designing fire stop systems, selecting fire blocking assemblies, and determining evacuation strategies.

3. Regulatory Compliance

Building codes and transportation regulations often require specific fire performance criteria. OCR values derived from ASTM E165 tests are used to demonstrate compliance with these standards.

4. Material Selection and Design

During product development, manufacturers can screen candidate materials using ASTM E165 to identify formulations that meet fire safety goals while maintaining performance characteristics.

Applications Across Industries

ASTM E165 is widely adopted in many sectors, each with unique fire safety needs. Below are some of the most common applications.

1. Construction and Building Materials

Engineered wood products, gypsum boards, insulation foams, and composite panels are tested for OCR to ensure they meet fire resistance ratings for walls, floors, and ceilings.

2. Automotive and Aerospace

Interior trim, seat fabrics, and composite components undergo OCR testing to comply with stringent fire safety regulations for passenger safety and cargo protection.

3. Packaging and Consumer Goods

Plastic films, cardboard, and other packaging materials are evaluated to prevent ignition during transport and storage, especially in environments with high temperatures or flammable atmospheres.

4. Electronics and Data Centers

Printed circuit boards, cable insulation, and heat sink materials are tested to mitigate the risk of thermal runaway and to protect critical infrastructure.

5. Energy and Petrochemical Industries

Fluids, coatings, and structural materials used in refineries and chemical plants are evaluated for OCR to reduce the likelihood of catastrophic fires.

Interpreting OCR Results

While OCR provides a quantitative measure, interpreting the results requires context. Here are key factors to

consider.

1. Comparative Analysis

OCR values should be compared against baseline materials or regulatory thresholds. For example, a material with an OCR of 30 /mg /O₂ /g¹ /h¹ might be considered moderately flammable, whereas an OCR above 100 /mg /O₂ /g¹ /h¹ indicates a high risk material.

2. Temperature Dependence

OCR typically increases with temperature. Therefore, the test temperature must reflect the intended application environment. A material that performs well at 250 °C may behave differently at 400 °C.

3. Sample Geometry Effects

Smaller samples may exhibit higher OCR values due to increased surface area relative to mass. Standardizing sample dimensions mitigates this effect.

4. Combined Metrics

OCR is often paired with other metrics such as the Limiting Oxygen Index (LOI), Total Heat Release (THR), and Peak Heat Release Rate (PHRR) to provide a comprehensive fire performance profile.

Sample Calculation

Let's walk through a simplified example to illustrate how OCR is calculated.

Assume:

- Chamber volume (V) = 10 /L.
- Sample mass (m) = 2 /g.
- O₂ concentration drop (ΔC) = 32 %
- Time (t) = 0.5 /h (30 /minutes).

First, convert ppm to mg /O₂ /L¹. At standard conditions, 1 /ppm ≈ 1.33 /mg /O₂ /L¹.

- ΔC = 32 % × 1.33 /mg /O₂ /L¹ = 42.56 /mg /O₂ /L¹

Now, compute OCR:

$$\text{OCR} = (\Delta C \times V) / (m \times t) = (42.56 \text{ /mg /O}_2 \text{ /L}^1 \times 10 \text{ /L}) / (2 \text{ /g} \times 0.5 \text{ /h}) = (425.6 \text{ /mg}) / (1 \text{ /g /h}) = 425.6 \text{ /mg /O}_2 \text{ /g}^1 \text{ /h}^1$$

In practice, the values would be lower, but this example demonstrates the calculation process.

ASTM E165 vs. Other Fire Test Standards

ASTM E165 is part of a suite of ASTM standards that together provide a comprehensive fire testing framework. Below is a comparison with some related standards.

1. ASTM E1354 – Cone Calorimetry

While ASTM E165 measures oxygen consumption in a sealed chamber, ASTM E1354 uses a heat flux sensor to measure the heat release rate under a defined heat flux (e.g., 35 kW m⁻²). Cone calorimetry provides direct HRR data, whereas E165 gives OCR, which can be converted to HRR with additional assumptions.

2. ASTM E662 – Limiting Oxygen Index (LOI)

ASTM E662 determines the minimum oxygen concentration that supports combustion. LOI is complementary to

OCR: high OCR often correlates with low LOI values, indicating higher flammability.

3. ASTM E84 – Surface Burning Characteristics

ASTM E84 assesses flame spread and smoke development on a surface. Unlike E165, which focuses on material combustion in a controlled environment, E84 simulates real world surface ignition scenarios.

4. ASTM D3801 – Flammability of Polymer Materials

D3801 is

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