

Comprehensive Guide to ASTM F2413-11: Technical Performance Requirements for Protective Safety Footwear

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In the high-stakes environment of industrial safety, the integrity of personal protective equipment (PPE) is not merely a matter of comfort but a critical component of risk mitigation and regulatory compliance. Among the various standards governing safety gear, **ASTM F2413-11** stands as a cornerstone specification for protective toe cap footwear. This standard, established by the American Society for Testing and Materials (ASTM), outlines the minimum requirements for the performance of footwear designed to protect against a variety of workplace hazards, ranging from falling objects to electrical shocks.

The Evolution and Significance of ASTM F2413-11

Before delving into the technical specifics, it is essential to understand the context of the 2011 revision. Historically, safety footwear in the United States was governed by the ANSI Z41 standard. In 2005, this was replaced by ASTM F2412 (Test Methods) and ASTM F2413 (Performance Requirements). The **ASTM F2413-11** update refined these requirements, ensuring that workers in construction, manufacturing, and chemical processing had access to footwear that met rigorous, quantifiable safety benchmarks. While newer iterations like F2413-18 exist, the -11 standard remains a vital reference point for legacy equipment and secondary safety audits.

The primary objective of ASTM F2413-11 is the certification of protective footwear. Unlike some internal standards, this certification requires testing by **independent third-party laboratories**. This ensures that the manufacturer's claims regarding impact resistance, compression resistance, and metatarsal protection are verified through objective, standardized procedures. This transparency is vital for Occupational Safety and Health Administration (OSHA) compliance, specifically under **29 CFR 1910.136(a)**, which mandates that employers ensure employees use protective footwear when working in areas where there is a danger of foot injuries.

Core Performance Requirements: Impact and Compression

The foundation of ASTM F2413-11 rests on two mandatory categories: Impact Resistance (I) and Compression Resistance (C). Footwear cannot be certified under this standard unless it meets these two criteria first. The standard classifies these into two levels of protection: Class 75 and Class 50.

1. Impact Resistance (I/75 and I/50)

Impact resistance measures the ability of a shoe's toe area to protect the foot from a falling object. The test involves dropping a weight from a specific height to generate a calculated amount of energy. For **Class I/75**, the footwear must withstand an impact of **75 foot-pounds (101.7 Joules)**. For **Class I/50**, the requirement is **50 foot-pounds (67.8 Joules)**.

The success of this test is determined by the "clearance" inside the shoe after impact. ASTM F2413-11 specifies that for a men's size 9 shoe, the minimum interior height clearance must be at least **0.500 inches (12.7 mm)** after the impact. This ensures that even if the toe cap deforms, it does not crush the toes.

2. Compression Resistance (C/75 and C/50)

Compression resistance evaluates the footwear's ability to protect the foot against a steady, heavy rolling or

pressing load. This is distinct from impact, which is a sudden force. For **Class C/75**, the toe cap must withstand a compressive load of **2,500 pounds (11,121 Newtons)**. For **Class C/50**, the load is **1,750 pounds (7,784 Newtons)**.

Similar to the impact test, the criterion for passing is the maintenance of a minimum interior clearance (12.7 mm for men's size 9). This dual requirement ensures that the protective cap retains its structural integrity under both dynamic and static loads.

Detailed Breakdown of Supplemental Requirements

Beyond the mandatory impact and compression ratings, ASTM F2413-11 allows for several specialized protections. These are indicated by specific codes on the footwear label. Understanding these codes is essential for matching the shoe to the specific hazards of a job site.

Metatarsal Protection (Mt)

While standard safety toes protect the phalanges (toes), metatarsal protection extends this shield to the metatarsal bones in the mid-foot. This is critical in industries like heavy logging or metal casting where heavy objects may fall further back on the foot. The **Mt/75** rating indicates that the shoe provides the same level of impact protection for the metatarsal area as the toe cap (75 foot-pounds).

Conductive Protection (Cd)

Conductive footwear is designed to minimize static electricity buildup. This is used in environments where explosive mixtures or volatile chemicals are handled. The resistance of **Cd** footwear must range between **0 and 500,000 ohms**. It is important to note that Cd footwear should never be worn near open electrical circuits.

Electrical Hazard (EH)

Conversely, EH footwear is designed as a secondary source of protection against accidental contact with live electrical circuits. These shoes are manufactured with non-conductive, electrical-shock-resistant soles and heels. To pass the ASTM F2413-11 EH test, the footwear must withstand **18,000 volts at 60 Hz for one minute**, with no leakage current or dielectric breakdown in excess of 1.0 milliampere under dry conditions.

Static Dissipative (SD)

SD footwear is engineered to reduce the accumulation of excess static electricity by conducting body charge to the ground while maintaining a high enough level of electrical resistance. The resistance range for SD footwear is **10⁶ ohms (1 megohm) to 10⁸ ohms (100 megohms)**. This is critical in electronics manufacturing to prevent Electrostatic Discharge (ESD) damage to sensitive components.

Puncture Resistance (PR)

Footwear labeled with **PR** includes a puncture-resistant plate between the insole and the outsole. According to ASTM F2413-11, this plate must withstand a minimum force of **270 pounds (1,200 Newtons)** and show no signs of cracking after 1.5 million flexes.

Technical Comparison: ASTM F2413-11 vs. ASTM F2413-18

While the 2011 version is the focus of this analysis, the transition to the 2018 version introduced several updates in testing protocols and marking requirements. The following table provides a high-level comparison of the technical nuances between these two iterations.

Feature/Requirement	ASTM F2413-11	ASTM F2413-18
Impact/Compression	Mandatory for all certified shoes.	Mandatory; testing methods moved to F2412-18a.
Marking Format	Line 1: ASTM F2413-11 Line 2: M/I/75/C/75	Line 1: ASTM F2413-18 Line 2: M I/75 C/75
Puncture Resistance	270 lbs force requirement.	Enhanced test methods for non-metallic plates.
Static Dissipative	General SD rating.	Introduced SD 10, SD 35, and SD 100 sub-classes.
Laboratory Accreditation	Required third-party lab.	Mandatory ISO/IEC 17025 accreditation for labs.

Understanding the SD Sub-Classes in Newer Standards

One of the most significant changes post-2011 was the refinement of Static Dissipative (SD) ratings. In ASTM F2413-18, the SD category was split into **SD 10** (1.0 to 10 megohms), **SD 35** (1.0 to 35 megohms), and **SD 100** (1.0 to 100 megohms). For those working with the **ASTM F2413-11** standard, the SD rating is generally treated as a single range (1.0 to 100 megohms), which can sometimes lead to over-generalization in ultra-sensitive micro-electronic environments.

Step-by-Step Technical Testing Workflow (ASTM F2412 Context)

To understand the performance requirements of F2413-11, one must look at the testing procedures defined in its companion document, **ASTM F2412**. The workflow for certifying a new safety boot typically follows these technical steps:

1. **Sample Preparation:** Shoes are conditioned at 23°C (73.4°F) and 50% relative humidity for 24 hours to ensure consistency.
2. **Impact Test Execution:** A specified striker is dropped onto the center of the toe cap. A modeling clay cylinder is placed inside the toe to measure the minimum clearance distance achieved during the strike.
3. **Compression Test Execution:** The shoe is placed between two flat, parallel steel plates. Pressure is applied at a rate of 50 lbs/second until the target load (e.g., 2,500 lbs) is reached.
4. **Electrical Resistance Measurement:** For EH or SD ratings, electrodes are placed inside and outside the shoe. A high-voltage generator (for EH) or an ohmmeter (for SD/Cd) measures the flow of current.
5. **Puncture Testing:** A steel pin with a 4.5mm diameter is pushed through the sole at a speed of 10mm/min until penetration occurs.

Practical Implementation: Reading the Label

Every piece of footwear meeting **ASTM F2413-11** must be clearly marked. The marking is usually found on the inside of the tongue or the quarter lining. Here is a guide to interpreting a typical label: **"ASTM F2413-11 M I/75 C/75 EH PR"**.

- **ASTM F2413-11:** The standard and revision year.
- **M/F:** Gender (Male or Female), as clearance requirements differ slightly based on foot anatomy.
- **I/75:** Impact rating of 75 foot-pounds.

- C/75: Compression rating of 2,500 pounds.
- EH: Footwear provides Electrical Hazard protection.
- PR: Footwear contains a Puncture Resistant plate.

Safety managers must verify these markings during annual safety audits to ensure that the PPE remains appropriate for the specific hazard zones in the facility.

Case Study: Failure Modes and Troubleshooting

In a real-world scenario, a manufacturing plant using heavy hydraulic presses noted an increase in foot fatigue and a "clicking" sound in certain safety boots. Upon inspection, the following was discovered:

1. Compromised Toe Caps

The boots, rated **ASTM F2413-11 I/75 C/75**, had been subjected to repeated minor impacts. While the caps didn't collapse, the internal bonding between the steel cap and the leather had failed. This highlights a critical limitation: **impact protection is often a one-time event**. Once a toe cap has sustained a major impact, its structural integrity is compromised, even if there is no visible denting. The footwear must be replaced immediately.

2. Environmental Degradation of EH Protection

The plant's electrical maintenance team reported that their EH boots were failing routine resistance checks. Investigation revealed that the outsoles had become embedded with conductive metal shavings from the machine shop floor. **ASTM F2413-11EH** protection is dependent on the outsole remaining clean and free of conductive contaminants. Regular cleaning and inspection of the tread are mandatory for maintaining the EH rating.

3. The Impact of Aftermarket Insoles

Some employees had inserted thick, cushioned aftermarket insoles. This seemingly harmless modification actually **voided the ASTM certification**. By adding thickness to the footbed, they reduced the interior clearance between the foot and the toe cap. In the event of a 75 foot-pound impact, the cap might have performed as expected, but because the foot was closer to the top of the cap, the safety clearance (12.7 mm) would have been breached, leading to injury.

Engineering Principles of Toe Cap Materials

The performance of **ASTM F2413-11** footwear is heavily influenced by the materials used in the toe cap construction. Engineers must balance weight, thickness, and thermal conductivity.

- **Steel Toes:** The traditional choice. Steel offers maximum protection with minimal thickness, but it is heavy and conducts cold and electricity. It is the gold standard for meeting the C/75 requirement due to its high tensile strength.
- **Aluminum/Alloy Toes:** Approximately 30-50% lighter than steel. To meet I/75 requirements, alloy caps must be thicker than steel, which can result in a bulkier shoe profile.
- **Composite Toes:** Made from plastics, carbon fiber, or Kevlar. These are essential for EH environments because they do not conduct electricity and do not set off metal detectors. However, they are the thickest of the three options to maintain the required clearance under 2,500 lbs of pressure.

Maintenance and Longevity of Certified Footwear

To ensure that footwear continues to meet **ASTM F2413-11** standards throughout its lifecycle, a rigorous maintenance protocol must be followed. The standard does not specify an expiration date for safety shoes, as wear

depends on the environment. However, technical best practices include:

- Visual Inspections: Check for separation of the sole, exposure of the toe cap, or excessive wear in the tread.
- Moisture Management: Leather shoes should be allowed to dry naturally. High heat (like radiators) can make the leather brittle, potentially affecting the boot's ability to absorb energy during an impact.
- Sourcing Consistency: Always replace with footwear that meets the same or higher ASTM revision year to ensure no degradation in site-wide safety standards.

In summary, **ASTM F2413-11** is a comprehensive technical specification that ensures safety footwear is built to withstand the rigors of industrial labor. By mandating rigorous third-party testing for impact and compression, and providing a standardized language for supplemental protections like EH and PR, the standard provides a roadmap for both manufacturers and safety professionals. While the industry continues to evolve toward newer revisions, the fundamental principles of mechanical resistance and electrical insulation defined in F2413-11 remain the benchmark for foot protection in the modern era. Proper selection, guided by an understanding of the technical markings and material properties, is the only way to ensure that the worker's most foundational asset—their ability to stand and move safely—is fully protected.

Baca Juga (Artikel Terkait)

• [A Comprehensive Engineering Guide to UNE-EN ISO 12100:2012: The Foundation of Machinery Safety and Risk Assessment](http://alghafgolden.com/comprehensive-guide-une-en-iso-12100-2012-machinery-safety.pdf)

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