

TESTING AND CERTIFICATION OF STEELWORK FIRE PROTECTION

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ABSTRACT: With fire safety becoming increasingly critical, it is essential that published test methodologies are followed precisely. Products and systems must be testing under consistent conditions to help ensure they deliver the intended level of fire protection. Any deviation from approved design specifications can compromise fire performance and render the system ineffective. In high-risk environments, such failures can have severe consequences, making compliance not just a technical requirement but a matter of life safety.

Third-party certification processes are vital in helping to ensure fire safety by defining acceptable design parameters and enforcing proper testing procedures. These processes provide confidence that certified products will perform as intended under fire conditions. To maintain this confidence, certified designs must be followed exactly. Any deviation may reduce system effectiveness, putting lives and property at risk.

This article outlines key requirements for products and systems evaluated under UL 1709, the Standard for Rapid Rise Fire Tests of Protection Materials for Structural Steel, also known as the standard for hydrocarbon-type fires. It emphasizes the importance of compliance with UL 1709 to help meet applicable requirements for reliable fire protection. Compliance with this standard helps establish a product's suitability for high-risk environments and reinforces life safety by demonstrating systems behave as expected under extreme fire conditions.

KEYWORDS: UL 1709, Rapid rise fire test, structural steel, UL 2431, PFP, time-temperature curve (t-T curve).

1. INTRODUCTION

In today's increasingly critical fire safety landscape, it is essential that all certification body staff strictly follow the requirements of the applicable standards to help ensure consistency in evaluation. Certification through an accredited third party builds trust and confidence in the results, enabling engineers, specifiers, and end-users to make informed, consistent technical judgments about a product's suitability for specific applications. This is vital across all test methods but becomes especially critical in high-risk environments such as petrochemical facilities or high-rise buildings, where fire protection systems must perform reliably under extreme conditions.

1.1. UL 1709

As a nonprofit standards development and advocacy organization, UL Standards & Engagement has a deep and fundamental commitment to creating practical, action-oriented safety standards. Since its first standard in 1903,

UL Standards & Engagement has upheld this mission, continuously adapting to the evolving needs of industry and safety professionals. As users gain deeper insights into fire testing and as products and systems advance, the methodologies within published standards must also evolve. This is currently the case with UL 1709, which covers rapid-rise fire testing of protection materials for structural steel. Updating and refining this standard helps ensure it remains effective and aligned with real-world applications, ultimately supporting the overarching goal of life safety.

First introduced in 1983, UL 1709 addresses rapid-rise fire scenarios such as those found in petrochemical installations. Early editions were silent on the number of specimens, specimen size, and duration. However, a critical feature from the outset was the inclusion of a furnace calibration method to enable consistency across laboratories. Now in its sixth edition, UL 1709 has evolved significantly. The current version retains the essential calibration requirement of previous

versions but expands to include testing of protection systems for structural beams and methods for evaluating various steel sizes, shapes, and exposure durations.

This development is the result of collaboration with multiple stakeholders within the fire safety industry through the standards development process. The adoption of UL 1709 as a means of evaluating fire protection for structural steel continues to grow, with manufacturers increasingly using it as the primary hydrocarbon fire test method to demonstrate compliance. This significant increase in adoption has led to more test facilities offering UL 1709 testing, which, in turn, has introduced variations in the interpretation of the methodology. Such inconsistencies are not ideal, given the original objective of uniformity. Therefore, the purpose of this text is to provide clarity on critical areas within the test method, helping to ensure consistency and reinforce confidence in the results.

1.2. Passive Fire Protection for Structural Steel

Passive fire protection (PFP) systems are essential for structural steel in facilities handling hydrocarbons such as petroleum and natural gas. Hydrocarbon fires can exceed 1000°C, rapidly compromising unprotected steel, leading to structural failure and fire spread. Effective PFP materials provide critical time for evacuation and emergency response, reducing the risk of collapse.

PFP materials typically used to protect structural steel found in petrochemical plants and facilities include, but are not limited to:

- Cementitious products – Cement, concrete, and lightweight materials like mineral fiber, vermiculite, or perlite. These have low thermal conductivity, slowing heat transfer to steel.
- Intumescent and epoxy coatings – Spray- or trowel-applied products that form an insulating char when exposed to heat, protecting steel from extreme temperatures.
- Blanket systems – Thermal wraps and blankets made from various insulating materials to shield steel from heat.
- Mineral and fiber board systems – Rigid boards constructed around steel profiles to provide thermal protection.

Selecting the right PFP material depends on factors such as facility type, the types of hydrocarbon products processed, and environmental conditions. Additional considerations include weight, ease of installation, and appearance. Properly chosen and applied PFP systems are critical for maintaining structural integrity during hydrocarbon fires, ultimately safeguarding lives and assets.

PFP materials must be tested and certified under UL 1709 to support compliance and reliability in hydrocarbon fire scenarios. UL 1709 defines critical parameters, including furnace calibration, thermocouple placement, and acceptance criteria, ensuring consistency and comparability across different products and test facilities. The standard replicates rapid-rise fire conditions, reaching 1093°C (2000°F) in five minutes, to evaluate the performance of protective systems for structural steel. Manufacturers rely on UL 1709 certification to demonstrate that their PFP systems meet the required fire resistance standards, providing confidence to engineers, specifiers, and end-users. By adhering to UL 1709, the industry helps demonstrate that PFP solutions perform as intended, supporting life safety, structural integrity, and compliance with recognized fire protection standards.

2. FURNACE

2.1. Furnace Calibration

UL 1709 requires that test specimens be exposed to a fire environment representative of a petrochemical pool fire, characterized by both high temperature and intense heat flux. Specifically, the fire exposure must reach 1093°C (2000°F) and deliver a total heat flux of 204 kW/m² (65,000 Btu/h·ft²) within five minutes. To validate these conditions, the furnace is calibrated using a vertical calibration column constructed from non-combustible materials, which is instrumented with thermocouples and calorimeters to measure temperature and heat flux distribution. Calibration is required at a minimum every ten years, or whenever modifications are made to the furnace construction, to maintain continued compliance with the specified fire exposure profile.

The current furnace calibration method requires a single calibration column to be placed centrally within the furnace chamber. This approach helps ensure that thermal exposure

during calibration reflects the conditions of subsequent testing, providing the same thermal dose to the specimen under evaluation. This consistency is critical for accurately assessing the performance of fire protection systems across multiple tests.

Including more than one specimen in the furnace at the same time (without calibrating each specimen position) is not intended and should be avoided. Doing so can result in shielding, where one or more sides of the columns are partially protected from heat within the furnace chamber. This leads to deviations from the intended time-temperature (t-T) curve and heat flux exposure, compromising the validity of the test. Additionally, positioning multiple specimens often places some columns closer to the furnace walls, further reducing the thermal dose applied to the protection system under evaluation. Adhering to the single-specimen approach helps ensure uniformity, reliability, and compliance with the standard's objectives.

A proposed revision to the standard introduces a requirement for individual calibration of each specimen position within furnaces designed to accommodate multiple test specimens. Should this requirement be incorporated into a future edition of UL 1709, it would enhance the accuracy and consistency of thermal exposure by accounting for potential temperature variations across different locations within the furnace chamber.

2.2. Furnace Thermocouples

According to UL 1709, eight furnace thermocouples shall be positioned no more than 102 mm (4 in.) from the exposed face of the specimen. This arrangement helps ensure accurate control of furnace temperature, allowing the test specimen to follow the prescribed time-temperature (t-T) curve throughout the test. Each column must have eight furnace thermocouples to provide precise monitoring and maintain consistency in thermal exposure.

Equally important is the even distribution of these thermocouples within the furnace chamber. Proper placement helps ensure uniform heating and accurate evaluation of the thermal dose applied to the specimen. If thermocouples are unevenly distributed, a heat gradient can develop inside the furnace, resulting in inconsistent heating of the column. Such variations compromise the validity of the test and may lead to incorrect conclusions

about the performance of the fire protection system. Adhering to the specified thermocouple arrangement is essential for achieving reliable, repeatable results and maintaining compliance with the standard's objectives. This practice helps ensure that all PFP systems are evaluated under consistent conditions, supporting fair comparison and confidence in certification outcomes.

2.3. Furnace Control

As with most furnace-based fire testing, certain variables exist due to the nature of the equipment and operating conditions. The standard provides clear guidance on acceptable variations, particularly regarding furnace temperature and heat flux tolerances. These tolerances are intended to compensate for minor fluctuations during the test, not to serve as operating targets. Ideally, the furnace should follow the prescribed fire curve as closely as possible, operating near the mean values to minimize reliance on tolerance limits.

Consistently operating the furnace at the upper or lower tolerance limits introduces significant variability between tests and among protective systems being evaluated. This is especially concerning when the lower tolerance range is targeted, as it reduces the thermal severity applied to the specimen. Such practices compromise the comparability of results and undermine the integrity of the evaluation process, potentially leading to misleading conclusions about the fire performance of the tested system.

3. SPECIMEN THERMOCOUPLES

UL 1709 clearly specifies the number of thermocouples required for each specimen, and this requirement must be followed to help ensure consistency in evaluating fire protection systems. In some cases, fewer thermocouples than required have been used, which is not compliant with the standard. The greater concern, however, is that reducing the number of thermocouples increases the risk of overlooking critical areas of the protective system. Since this test evaluates performance based on temperature limits rather than structural limits, all instruments must be installed as specified to capture representative data across the entire specimen.

The standard explicitly requires 20 specimen thermocouples for wide flange columns and 16 specimen thermocouples for pipe or tube columns. The thermocouples are arranged across four

vertical levels on the column to help ensure accurate monitoring of temperature distribution and reliable assessment of the protection system's performance. As with furnace control tolerances, any data generated using fewer than the required quantity of thermocouples per column should be treated with caution and considered non-compliant with the requirements of UL 1709. Adhering to this specification is critical for maintaining test integrity and comparability.

During the test, the transmission of heat through the PFP material shall not raise the average temperature at any of the four levels of the column above 538°C (1000°F), and no individual thermocouple shall indicate a temperature greater than 649°C (1200°F). The time at which either of these temperature limits is reached is considered the endpoint time of the test.

4. PROTECTION SYSTEM

In all fire resistance tests, it is essential that the system being tested accurately represents the configuration intended for the final installation on site. Fire testing is designed to evaluate the performance of a specific system under standardized conditions, and any deviation from the tested and certified design can significantly affect its fire performance. Therefore, strict adherence to the tested configuration is critical for helping to ensure both safety and compliance.

When changes are introduced after certification—whether in materials, dimensions, or installation details—there is a high likelihood that the system's performance will be compromised. Even seemingly minor modifications can alter the thermal behavior of the assembly, leading to unexpected results during an actual fire event. For this reason, it is imperative that all details of the tested system are accurately documented during the certification process and that these details are followed precisely during installation.

Failure to replicate the tested configuration on site may result in a loss of fire resistance, creating a serious threat to life safety and structural integrity. For example, consider a scenario where a stainless steel wrap is added to the columns during the test. Although stainless steel itself does not provide significant thermal insulation, its presence can influence the system's performance in two important ways. First, the wrap creates an air gap that acts as an insulating layer, reducing heat

transfer to the steel. Second, it prevents the convection of hot furnace gases from penetrating the protective system, which would otherwise accelerate heat absorption by the column. This additional barrier can enhance the thermal protection of the steel column, even though the material itself has low insulation value.

This example illustrates how a small component—one that might appear to have little or no thermal resistance—can play a critical role in the overall fire performance of the system. Such effects can only be validated through fire testing, which is why the tested configuration must be replicated exactly in practice.

In summary, the whole configuration of the protective system, as tested and certified, must be installed on site without deviation. This helps ensure that the fire safety levels demonstrated during testing are achieved in real-world applications, safeguarding both property and human life.

5. DURABILITY

Protective products tested and certified to UL 1709 are often installed in harsh and demanding environments, such as offshore platforms, refineries, and heavy industrial facilities. These environments expose fire protection systems to conditions that can degrade their performance over time. For this reason, UL 1709 required durability testing to help ensure that certified systems can withstand such conditions without compromising fire resistance.

Durability testing is conducted in accordance with UL 2431, the Standard for Safety for Durability of Fire Resistive Coatings and Materials. Under this standard, protection systems must meet all requirements for Material Classification Category I-A: Outdoor, Heavy Industrial, which represents the most severe environmental exposure conditions. This classification includes resistance to factors such as moisture, salt spray, temperature cycling, and other environmental stresses.

Compliance with these durability requirements is confirmed during the certification process, and the results are reflected in the system's individual listing on UL Product iQ® database. The listing confirms that the system has successfully passed durability testing, ensuring long-term reliability and safety in real-world applications.

6. CERTIFICATION

Certification of passive fire protection materials to UL 1709 follows a structured process with three phases:

- Pre-Testing: UL Solutions witnesses the production of PFP material samples at the manufacturer's facility, documenting formulation and processes for traceability. Specific batches are selected for testing to help ensure transparency.

- Testing: UL Solutions oversees application of PFP to structural steel samples, recording details such as surface preparation, thickness, and application techniques. Samples remain under UL Solutions control until they undergo furnace testing in accordance with UL 1709 protocols. During testing, columns are evaluated individually, and results are analyzed to confirm compliance. Certified products are published on Product iQ database, including optional performance characteristics where applicable.

- Post-Testing: Before applying the UL Mark, UL Solutions conducts inspections to verify consistency with tested formulations. Ongoing surveillance and UL Solutions approval for material or process changes help ensure continued compliance and performance.

7. CONCLUSION

UL 1709 is increasingly recognized as the de facto standard for evaluating protective systems for structural steel in environments where rapid-rise hydrocarbon fires may occur. Its rigorous methodology ensures that passive fire protection systems deliver reliable performance under severe fire conditions. However, rigorous observance of the test methodology and certification requirements is essential to maintain the intended fire protection. Any deviation from UL Certification requirements or individual design details will void the fire rating and certification, potentially compromising safety and compliance.

UL Solutions' certification process provides confidence that listed products meet all specified requirements. This process involves witnessing the production of passive fire protection samples, verifying application methods, and analyzing test results before granting certification. Products that comply are listed in Product iQ® database, enabling transparency and traceability for specifiers, engineers, and end users.

By following UL 1709 and maintaining strict compliance with certification requirements, manufacturers can build stakeholder's confidence that passive fire protection systems perform as intended, providing the necessary fire safety in high-risk hydrocarbon fire scenarios. UL Solutions' robust certification framework not only evaluates safety and performance but also demonstrates that certified systems meet applicable standards for reliability and life safety.

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