

FIREPROOFING FOR HYDROCARBON FIRE EXPOSURES

INTRODUCTION

A hydrocarbon fire inflicts initial damage by directly heating metal beyond its limits and destroying the equipment or building. Even more damage occurs when the fire spreads due to the collapse or rupture of vessels caused by metal failing under the initial fire exposure. One way to mitigate this damage is to install fireproofing. Fireproofing is discussed in Section 6, Chapter 5 of the NFPA Handbook.¹ This GAP Guideline outlines the position of Global Asset Protection Services (GAP Services) on fireproofing for hydrocarbon fire exposures.

Fireproofing of structural steel exposed to hydrocarbon fires has been used for many years with varying degrees of success. Conventional concrete, lightweight concrete and brick gave a satisfactory degree of protection with little concern for the exact time-protection rating beyond the stipulation that designated thicknesses of these materials be installed. In the past 25 years, proprietary fireproofing products were developed. The protection times for these new materials needed to be determined.

Building materials or systems are tested for performance under fire conditions in a carefully controlled furnace. The standard time-temperature curve is defined in ASTM E-119² and represents a wood fire that does not reach 3400°F (1870°C) for 4 hrs (see Figure 1). Since hydrocarbon fires reach that temperature almost instantly, the ASTM E-119 curve **does not** adequately predict the performance of fireproofing materials under hydrocarbon fire exposure. Underwriters Laboratories developed the UL 1709³ test procedure based on hydrocarbon fire exposure. Listings for many proprietary products are based on this test.

POSITION

Use fireproofing tested in accordance with UL 1709 for hydrocarbon fire exposures. Determine the need for fireproofing as part of the hazard evaluation for every new or existing property. When designing a new process or modifying an old one, minor changes to the process itself or to its physical layout can significantly reduce the need for extensive (and expensive) fireproofing. With existing plants, fewer choices are available.

Fireproof all major load-bearing structural steel supports for buildings, outdoor process structures, process equipment and important pipe racks where exposed by liquefied flammable gases, flammable or combustible liquids, or molten salt heat transfer mediums. In facilities handling flammable gases only and having no flammable or combustible liquid hold-up, provide fireproofing for high valued, easily damaged or "long replacement time" equipment. The following guidelines explain the time ratings required and the installation locations for fireproofing.

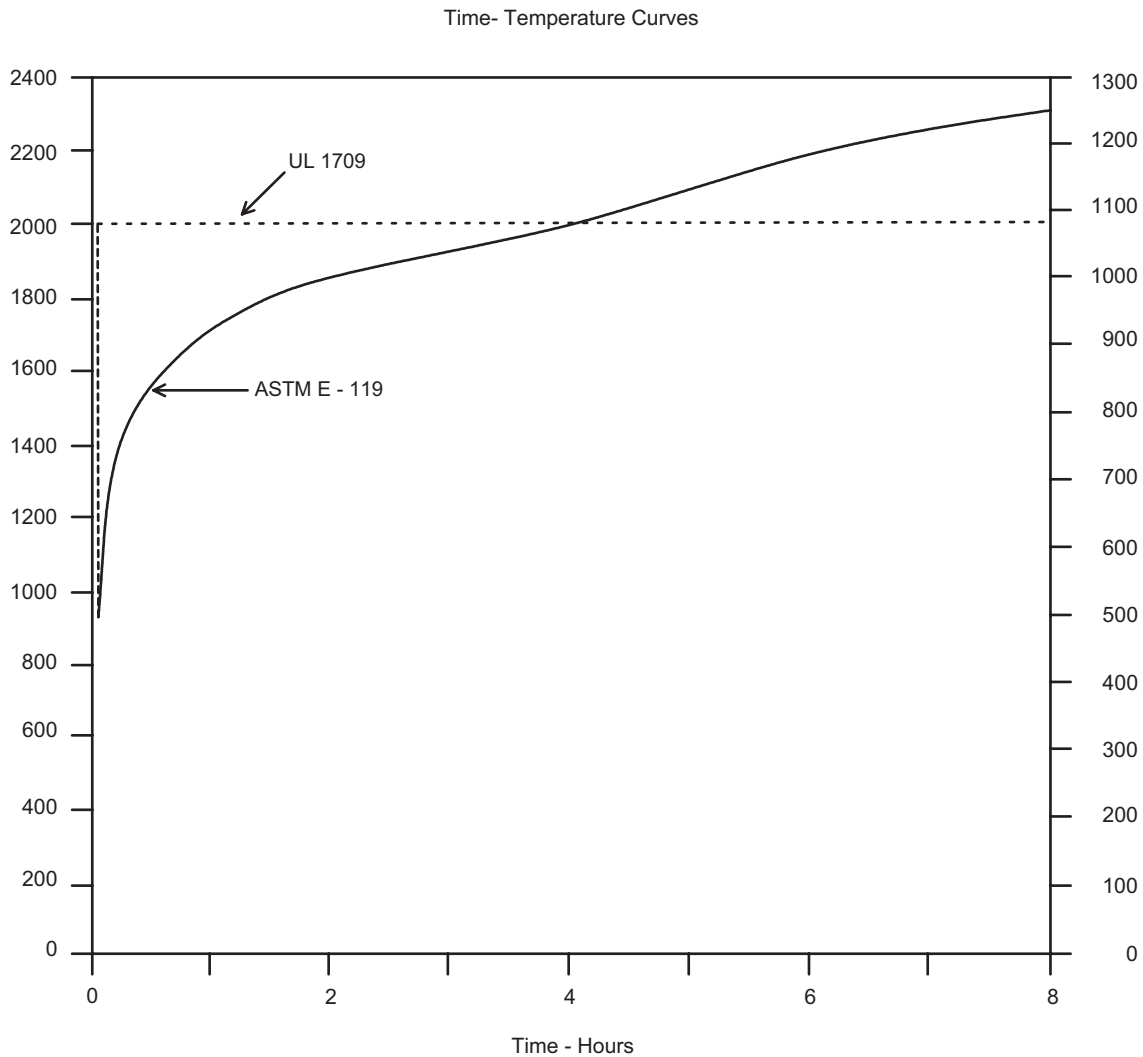


Figure 1. Time Temperature Curves.

Required Time Ratings

Apply 2½ h fireproofing for column protection unless stated otherwise. However, 1½ h ratings are acceptable for structures fully protected by automatic water spray systems and provided with adequate drainage. Water sprays must directly impinge upon all structural members and process vessel supports.

Structures And Supports Needing Fireproofing

Use the following guidelines and the drawings in [GAP.2.5.1.A](#):

- Fireproof supports for all horizontal, vertical and spherical storage tanks.
- Fireproof supports for all fired heaters elevated above grade. Also, protect high stacks, convection sections and common breaching that is wholly or partially supported by an external structure.

- Fireproof tower skirts, anchoring rings and bolts on the outside. Fireproof tower skirts on the inside if any of the following conditions exist:
 - Valves or breakable pipe joints are installed inside the skirt.
 - There is more than one access opening in the skirt, or if a single opening exceeds 18 in. (457 mm) in diameter. As an alternative, close all except one 18 in. (457 mm) diameter access opening with ¼ in. (6 mm) steel plate.
- Fireproof supports for vessels, such as receivers, accumulators, reboilers, reactors, heat exchangers and other vessels with liquid hold-up capacity, to the full load-bearing height. This includes vessels installed in elevated structures, above pipe racks or attached to towers or other vessels. Where vessels are supported on load cells, provide intermediate or secondary fireproofed supports to catch the vessel if the load cells fail.
- Fireproof all major load-bearing structures or buildings which support vessels such as receivers, accumulators, reboilers, reactors and heat exchangers to the full load-bearing height when exposed by flammable or combustible material spills.
- Design fireproofing for pipe rack supports as follows:
 - Fireproof both the vertical and horizontal members of the first level of a pipe rack located within 25 ft (7.6 m) of heaters, pumps, towers and major vessels handling flammable or combustible materials. Fireproof pipe rack supports located 25 ft (7.6 m) to 50 ft (15 m) from such major equipment for 1½ hr. Pipe rack supports over 50 ft (15 m) away from major equipment normally do not require fireproofing unless unusual conditions of exposure or loading, such as inadequate drainage, exist.
 - Do not locate pumps and compressors handling flammable or combustible materials under equipment or pipe racks. Fireproof pipe rack levels above pumps and compressors handling these materials.
 - If air-cooled heat exchangers are installed above pipe racks, fireproof pipe rack levels above the first level and the legs of heat exchangers to the full load-bearing height.
 - Do not install vessels with large liquid hold-up above pipe racks. If such vessels must be installed above pipe racks, fireproof them to the full load-bearing height of the vessel supports and all levels of the pipe rack supports.
- Protection is not generally needed for exposed pipe rack supports above the first level unless they support air-cooled exchangers, vessels with liquid hold-up or large piping carrying flammable liquids. Under such conditions, extend fireproofing to the upper levels.
- Fireproof the legs of air-cooled exchangers in flammable liquid service that are installed at grade level. Protection is not needed for air-cooled heat exchangers in other than flammable liquid service, installed at grade level and located over 50 ft (15 m) from process equipment and from a gas or spill hazard.
- Fireproof supports for compressors, turbines and turboexpanders to the full load-bearing height.
- Fireproof exposed, important grouped power, control and instrumentation cables; tubing or conduit; and fire-sensitive thermal insulation on critical equipment. The fireproofing for this application only needs a 30 min protection rating to allow sufficient time for shutdown of the process unit.
- Evaluate the processes and equipment and arrange the valves and controls to fail in the safe position. Then fireproofing of the cables would be unnecessary. In some cases, the safe position of a valve or control depends upon the location of the fire. In such cases, fireproof the cables to retain control for the first 30 min of the fire.

Installation

Because most fireproofing materials are now proprietary and vary widely in their design properties, use fireproofing listed by a nationally recognized testing laboratory to meet UL 1709 for the duration required, and apply them precisely according to manufacturer's instructions.

Maintenance

Include inspection of fireproofing in the plant maintenance program. Repair any defects found in accordance with manufacturers' instructions.

DISCUSSION

Fire Tests

Historically, companies handling large quantities of hydrocarbons and their insurers recommended concrete and brick for the fireproofing of structural steel. The following specifications provided adequate protection:

- 1½ in. (38 mm) of lightweight concrete
- 3 in. (76 mm) of dense concrete
- 4 in. (102 mm) of brick

These specifications were based on experience, not on the results of any fire endurance test.

During the 1960s, proprietary fireproofing products were introduced with a number of advantages over the traditional concrete and brick materials. Recommendations were developed for applying these products. An examination of available data led to the conclusion that the previously listed specifications were equivalent to materials which had a 3 h rating by ASTM E-119 (UL 263, NFPA 251.⁴)

ASTM E-119 is a fire test first published in 1918. It is based on a standard time-temperature curve that was established from burnout tests in structures incorporating materials having potential heat release values comparable to wood and paper. The time-temperature curve reaches a temperature of 1000°F (538°C) in 5 min, 1700°F (927°C) in 1 h, 2000°F (1093°C) in 4 h and 2300°F (1260°C) in 8 h. The ASTM E-119 time-temperature curve is shown in Figure 1.

It was generally recognized that ASTM E-119 did not adequately represent the fire exposure experienced in oil and chemical facilities. The ASTM E-5 Committee worked to develop a fire test that subjects fireproofing materials to an environment simulating a hydrocarbon fire exposure. In September 1983, Underwriters Laboratories circulated an "Outline of Proposed Investigation of Structural Steel Protected for Resistance to Rapid-Temperature-Rise Fires, UL 1709." This proposed test was based on the ASTM draft standard in effect at that time and was comparable to the draft standard tentatively published by ASTM. The UL 1709 time-temperature curve is also shown in Figure 1.

Since September 1983, UL has tested and listed fireproofing materials on the basis of UL 1709. The standard, in addition to characterizing the material for fire endurance, also requires tests to determine the weatherability of the material.

Correlation Between ASTM E-119 And UL 1709

Prior to May 1988, GAP Services recommended 3-h and 2-h time rating in accordance with ASTM E-119. Since the UL 1709 test is more appropriate for hydrocarbon fire exposures, rating from the ASTM E-119 and UL 1709 tests needed to be correlated. To this end GAP Services participated in a three-part research program. The first part involved testing of traditional concrete materials in both ASTM E-119 and UL 1709. The second part involved a review of published and unpublished data on materials subjected to both tests. The third part involved a calculation of the relative severity of the two tests based on the area under the respective time/temperature curves.

GAP Services Test Program

GAP Services contracted with Underwriters Laboratories to investigate the response of concrete-encased columns to the fire severities represented by ASTM E-119 and UL 1709. Eight columns were fire tested. Four were exposed to the rapid rise UL 1709 fire and four to the ASTM E-119 fire. The constructions tested represented traditional concrete fireproofing used in industry and were thought to be adequate to give 2 h and 3 h protection by ASTM E-119. Two concrete aggregates were used: sand and gravel, giving a concrete density of 143 lb/ft³ (2290 kg/m³); and vermiculite, giving a concrete density of 45 lb/ft³ (721 kg/m³). Each concrete was applied in two thicknesses on 9 ft (2.7 m) long 10W × 49 steel columns. Reinforcing was used on all constructions. Table 1 gives construction data on the test samples.

UL dried the samples to the 75% maximum relative humidity required by ASTM E-119 and UL 1709. Humidity-measuring instrumentation wells were mounted on the columns before pouring the concrete. The normal weight concrete samples required drying at 120°F (49°C) and 20% to 25% relative humidity for up to 351 days to achieve the required degree of dryness. The samples were 347 to 382 days old at the time they were tested. Table 1 gives the drying times and relative humidity of the samples.

The fire exposure tests showed that the concrete protection specified was considerably better than expected when the test program was developed. Both the normal weight and lightweight concrete in the traditional 3 h thickness gave over 6 h of protection in both ASTM E-119 and UL 1709 exposures. The lightweight concrete traditional 2 h protection gave over 4 h protection in both tests. The normal weight concrete traditional 2 h thickness gave 2½ h performance in the UL 1709 test and almost 3 h in the ASTM E-119 exposure. The test results are shown in Table 1.

TABLE 1
Underwriters Laboratories Test Program

Column No.	Fire exposure	Thickness in.	Days Of Drying At 120°F	Days Of Drying At 70°F	Age At Test Days	RH At Test Percent	End-Point h/min	End-Point min
Normal Weight Concretes								
1	UL 1709	3.0	323	49	372	44	6:33*	393*
2	ASTM E-119	3.0	351	29	380	62	6:34*	394*
3	UL 1709	1.25	323	50	373	51	2:39	159
5	ASTM E-119	1.25	323	59	382	51	2:58	178
Lightweight Concretes								
4	UL 1709	1.75	29	322	361	69	6:10*	370*
6	ASTM E-119	1.75	29	323	352	73	6:07*	367*
7	UL 1709	1.0	0	347	347	70	4:02	242
8	ASTM E-119	1.0	0	354	354	69	4:16	256

SI Units: 1 in. = 25.4 mm; F = (C × 1.8) + 32

* Estimated end point

TABLE 2
Comparisons Of ASTM E-119 And UL 1709 Ratings

Material	E-119 Rating (min)									
	30	45	60	90	120	150	180	240	300	360
	Corresponding Rating For UL 1709 (min)									
Intumescent Epoxy 1			39	52	72		125			
Ceramic mat					98		154			
Magnesium Oxychloride			35	60	90		150	240		
Intumescent Epoxy 2				62	90	115	138	240		
Filled Portland Cement Panels							148			
GAP Services Normal Wt Concrete							158			350
GAP Services Light Wt Concrete								225		355
Time/Temp Curve Basis	15	30	42	69	96	120	150	210	273	360
Recommended Correlation	15	30	45	60	90	120	150	240	300	360

Examination Of Data On Proprietary Materials

Fire test data conducted in both the ASTM E-119 and the UL 1709 tests on proprietary fireproofing materials were examined to extend the data from the GAP Services-sponsored tests at UL. In most cases, data was not available on the same thickness of material in both tests. Straight line log-log graphs of thickness versus time ratings for both tests were constructed. Comparable ratings were chosen from these graphs. The time ratings for UL 1709 corresponding to ASTM E-119 ratings are shown in Table 2.

Area Under Time-Temperature Curve

The area under the time-temperature curve was calculated for UL 1709 and compared to the area published in ASTM E-119. The time ratings for UL 1709 corresponding to ASTM E-119 ratings are shown in Table 2. The severity of the fire exposure in UL 1709 is not totally based on the time-temperature curve. The test criteria states that after 5 min the fire exposure will develop a total heat flux of 65,000 Btu/ft²/hr (205 kW/m²). At this time the convective heat flux is 10,000 Btu/ft²/hr (32 kW/m²). No comparison with the heat flux developed in the ASTM E-119 exposure was made; however, the comparison based on the area under time-temperature curves is considered a valid check against the comparisons based on the actual test data.

Size Of Structural Members

The rating obtained by a fireproofing material in any test is dependent upon the size of the structural member on which the fireproofing is applied. UL 1709 requires that a test of each fireproofing application be done on a 10W x 49 column, an average size member that might be used for structural steel in process structures and pipe racks. In addition, this size structural member has been traditionally used for fireproofing tests. GAP Services recommendations are based on thicknesses of fireproofing products tested on 10W x 49 columns.

Beam Or Column Ratings

When recommendations were based on ASTM E-119 ratings, it was important to specify "beam" or "column" ratings. Since structural supports used in process structures, like pipe racks, are likely to be

exposed on all sides of the member, the more stringent column rating should be used. In the UL 1709 listing criteria, only column configurations are tested, therefore, this distinction is not important.

Exterior Ratings

UL will give listings based on ASTM E-119 test criteria and will indicate if the product has been “investigated for exterior use.” Formerly, GAP Services recommended that products in this category be used for oil and chemical properties. However, since all products listed under UL 1709 are tested for weatherability, this distinction is no longer important.

Boxed Or Contour Construction

The UL listings are based on specific application methods for fireproofing material. Some designs call for the coating materials to follow the contour of the beam or column. Others use a construction which boxes the member with an obvious saving of material. Boxing leaves voids between the fireproofing on both sides of the web of the beam or column. If an incident occurs which damages the outer material at the bottom and top of a boxed column, a flue effect will be created which will cause hot gases to pass up through the boxing, causing rapid heating and early failure of the column. When boxed construction is used on columns over 20 ft (6.1 m) high, a “firestop” of metal, gypsum board or other noncombustible material should be provided for every 10 ft (3.1 m) of height.

Application

Manufacturers have specified the procedures and conditions for applying all of the listed proprietary-mix materials. If these procedures are not followed by the applicator, the material may not properly protect the steel or may not remain in place or properly weather. Follow fireproofing applications closely.

REFERENCES

1. *NFPA Fire Protection Handbook*, 17th edition, National Fire Protection Association, Quincy, MA.
2. ASTM E-119, *Method For Fire Tests Of Building Construction And Materials*, American Society for Testing and Materials, Philadelphia, PA.
3. UL 1709, *Rapid Rise Fire Tests Of Protection Materials For Structural Steel*, Underwriters Laboratories Inc., Northbrook, IL.
4. UL 263, *Fire Tests Of Building Construction And Materials*, Underwriters Laboratories Inc., Northbrook, IL.
NFPA 251-1999, *Fire Tests Of Building Construction And Materials*, National Fire Protection Association, Quincy, MA.