Fireproofing Practices in Petroleum and Petrochemical Processing Plants

API RECOMMENDED PRACTICE 2218
THIRD EDITION, JULY 2013

AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Classified areas may vary depending on the location, conditions, equipment, and substances involved in any given situation. Users of this recommended practice should consult with the appropriate authorities having jurisdiction.

Users of this recommended practice should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations to comply with authorities having jurisdiction.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Where applicable, authorities having jurisdiction should be consulted.

Work sites and equipment operations may differ. Users are solely responsible for assessing their specific equipment and premises in determining the appropriateness of applying the recommended practice. At all times users should employ sound business, scientific, engineering, and judgment safety when using this recommended practice.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations to comply with authorities having jurisdiction

Foreword

This recommended practice is intended to provide guidelines for developing effective methods of fireproofing in petroleum and petrochemical processing plants. It is not a design manual. This is a guideline—a starting place and not a prescriptive set of limits; each facility should review their needs and act accordingly. Thus the title is fireproofing "practices". It seeks to share good practice which has evolved over the years. Participants in developing this third edition included representation from both producers and users of fireproofing.

By its nature fireproofing is passive property protection. Effective protection of equipment in petroleum and petrochemical plants may reasonably be expected to have a benefit in reducing risks. Where fireproofing helps control structural damage and potential incident escalation it may also benefit life safety concerns.

API 2218 is a "pool fire" standard. It uses facility configuration and equipment knowledge as a means of identifying probable liquid fuel release locations and the extent of resulting pool fires. This leads to development of "fire-scenario envelopes". This is the first step in determining fireproofing needs. The process is shown in simple form in Figure 1.

Planning for (and prevention) of all types of fire is of concern. Although infrequent, jet fires are dramatic and can cause significant damage. Consequently, Annex C provides an overview of "Jet Fire Considerations" including the extensive body of research knowledge.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Shall: As used in a standard, "shall" denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the specification.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Page

Figures

Tables

Fireproofing Practices in Petroleum and Petrochemical Processing Plants

1 Scope

1.1 Purpose

This recommended practice (RP) is intended to provide guidance for selecting, applying, and maintaining fireproofing systems designed to limit the extent of fire-related property loss from pool fires in the petroleum and petrochemical industries. Where comparable hazards exist, and to the extent appropriate, it may be applied to other facilities that could experience similar severe fire exposure and potential losses

1.2 Scope

This RP identifies fireproofing needs for petroleum and petrochemical plants specifically focusing on property loss protection for pool fires scenarios in on-shore processing plants.

Only passive fireproofing systems are within the scope of this recommended practice. The following are outside the scope of this RP; however this RP contains information which may be useful in these applications:

— fireproofing for LPG storage vessels (see API 2510 and API 2510A);

— fireproofing for personnel protection;

— fireproofing for buildings.

1.3 Introduction

Properly implemented fireproofing (passive fire protection) can protect against intense and prolonged heat exposure which otherwise could cause collapse of unprotected equipment, leading to the spread of burning liquids and substantial loss of property. Fireproofing may also mitigate concerns for life safety and environmental impact by reducing escalation. Fireproofing and other fire protection measures may be appropriate for fire protection where hazardous chemicals could be released with the potential for exposure of employees or persons outside the facility.

The term “fireproofing” is widely used, although strictly speaking the term is misleading since almost nothing can be made totally safe from the effects of fire exposure for an unlimited time. In effect, fireproofing “buys time” for implementation of other protective systems or response plans such as isolation and use of emergency isolation valve/ remotely-operated shutoff valve (EIV/ROSOV), unit shutdown, deployment of fire brigades or evacuation.

This RP addresses fireproofing of structural supports in process units and supports for related equipment (such as tanks, utilities and relevant off-site facilities). Fireproofing can also be used to protect instruments, emergency shutoff valves and electrical equipment that may be used to mitigate fire.

1.4 Units of Measurement

Values for measurements used in this document are generally provided in both English and SI (metric) units. To avoid implying a greater level of precision than intended, the second cited value may be rounded off to a more appropriate number. Where specific test criteria are involved an exact mathematical conversion is used.

2 Normative References

There are no Normative References for this standard. Fire protection resources of potential relevance are listed in the Bibliography by subject.

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1
ablative
Dissipation of heat by oxidative erosion of a heat protection layer.

3.2
active protection
Automatic or manual intervention to activate protection such as water spray systems, emergency isolation valves, process depressuring, hose streams or fire water monitors.

3.3
char
A carbonaceous residue formed during pyrolysis which can provide heat protection.

3.4
cementitious mixtures
Binders, aggregates and fibers mixed with water.

3.5
emergency isolation valves
EIV
A valve intended to provide a means of shutting off flow of a fuel (see ROSOV) with either manual or remote power operation.

3.6
endothermic fire protection
Heat activated chemical and/or physical phase change reaction resulting in heat absorption by a non-insulating heat barrier.

3.7
fire performance
Response of a material, product, or assembly in a "real world" fire as contrasted to laboratory fire test results under controlled conditions.

3.8
fireproofing
A systematic process, including design, material selection, and the application of materials, that provides a degree of fire resistance for protected substrates and assemblies.

3.9
fire resistance rating
The number of hours in a standardized test without reaching a failure criterion. (In this publication, UL 1709 or functionally equivalent test conditions are presumed for pool fires unless otherwise stated.)

3.10
fire scenario areas
Areas where a potential fire is premised.

3.11
fire-scenario envelope
A three-dimensional space into which equipment might release flammable or combustible fluids capable of forming a pool fire which could burn long enough and with enough intensity to cause substantial property damage.

3.12
fire-test-response characteristic
A response characteristic of a material, product, or assembly to a prescribed source of heat or flame as in a standard test.

3.13
functionally equivalent performance
Ability to perform a given function under specific conditions in a manner equivalent to alternatives at the same conditions for a designated time duration.

3.14
hazard
A situation or inherent chemical or physical property with the potential to do harm (flammability, oxygen deficiency, toxicity, corrosivity, stored electrical, chemical or mechanical energy).

3.15
intumescent fire protection
A chemical reaction occurring in passive materials when exposed to high heat or direct flame impingement that protects primarily by expanding into an insulating layer of carbonaceous char or glasseous material.

3.16
jet fire
A turbulent diffusion flame resulting from the combustion of a pressurized fuel continuously released with some significant momentum in a particular direction or directions. Jet fires (sometimes called torch fires) can arise from pressurized releases of gaseous, flashing liquid (two phase) and pure liquid inventories.

3.17
mastic
A pasty material used as a protective coating or cement.

3.18
passive fire protection
PFP
A barrier, coating, or other safeguard which provides protection against the heat from a fire without additional intervention.

3.19
perlite
Natural volcanic glass which is heat-expanded to a form used for lightweight concrete aggregate.

3.20
pool fire
A turbulent diffusion flame burning above a horizontal pool of vaporizing fuel under conditions where the fuel vapor or gas has zero or very little initial momentum.

3.21
qualitative risk assessment
An experience-based evaluation of risk (as discussed in CCPS "Guidelines for Hazard Evaluation Procedures").

3.22
quantitative risk assessment
The systematic development of numerical estimates of the expected frequency and consequence of potential accidents based on engineering evaluation and mathematical techniques.

3.23
risk
A measure of potential injury, environmental damage, or economic loss in terms of both the incident likelihood and the severity of the loss or injury.

3.24
risk assessment
The identification and analysis, either qualitative or quantitative, of the likelihood and outcome of specific hazard exposure events or scenarios with judgments of probability and consequences.

3.25
risk-based analysis
A review of potential needs based on a risk assessment.

3.26
remotely-operated shut-off valve
ROSOV
Provided to stop flow of fuel to a fire (sometimes called EIV).

3.27
spalling
Breaking into chips or fragments that separate from the base material.

3.28
spray applied fire resistive materials
SFRM
Include two product types previously UL classified as “Cementitious Mixtures” and “Sprayed Fiber Materials”.

3.29
sprayed fiber materials
Binders, aggregates, and fibers conveyed by air through a hose to a nozzle, mixed with atomized water and sprayed to form a coating; included by UL in “Spray Applied Fire Resistive Materials” (SFRM).

3.30
substrate
The underlying layer being protected by a fireproofing barrier layer.

3.31
sublimation
Process where a material goes directly from a solid state to a gaseous state without becoming a liquid.

3.32
thermal diffusivity
Is conduction of heat through an intervening layer.

3.33
vermiculite
Hydrated laminar magnesium-aluminum-iron silicate which is heat-expanded 8 to 12 times to produce a lightweight non-combustible mineral material used for fireproofing and as aggregate in lightweight concrete.

3.34
W10×49column
Is a steel "I-beam" with a 10 in. wide flange weighing 49 lb/ft which is the *de facto* standard for industrial structural fireproofing tests.

4 General

4.1 The Function of Fireproofing

While equipment design, location, spacing, and area drainage are of substantial importance in minimizing equipment involvement in a fire, additional protective measures may still be necessary. One protective measure is to improve the capacity of equipment and its support structure to maintain their structural integrity during a fire. Another is to shield essential operating systems when they are exposed to fire. Fireproofing achieves these objectives with Passive Fire Protection (PFP) in contrast to fixed water spray systems, monitors, or portable hose lines which provide active protection.

The principal value of fireproofing is realized during the early stages of a fire when efforts are primarily directed at shutting down units, isolating fuel flow to the fire, actuating fixed suppression equipment, and setting up cooling firewater streams. During this critical period, if non-fireproofed pipe and equipment supports lose their strength due to fire-related heat exposure, they could collapse causing increased property damage, gasket failures, line breaks, and hydrocarbon leaks. In addition, if critical control or power wiring is damaged it may become impossible to operate emergency isolation valves, depressure vessels, or actuate water spray systems.

Fireproofing does not extinguish fires, and may have no significant effect on the final extent of property damage if intense fire exposure persists significantly longer than the PFP design. Properly applied cooling from fixed or portable firewater equipment can extend the effective fire protection time beyond its nominal fire resistance rating, providing that the force of the firewater application does not damage or dislodge the fireproofing material.

When properly implemented, fireproofing systems can help reduce losses by protecting equipment (and thus personnel) and by providing additional time to control or extinguish a fire before thermal effects cause piping/equipment support failure.

4.2 Determining Fireproofing Needs

Approaches for determining fireproofing requirements include, but are not limited to:

— qualitative or quantitative assessment of the consequences of fires scenarios;

— qualitative or quantitative assessment of the frequency and risks of fires;

— application of experience-based design rules (corporate or insurance guidelines);

— a scenario approach such as described in this RP.

These approaches may be based on generic equipment/processes or on application- specific equipment/processes.

This recommended practice proposes an evaluation process that includes developing *fire scenarios* from which a *needs analysis* evolves. This approach for selecting fireproofing systems is illustrated by the Figure 1A flow chart which includes:

a) hazard evaluation, including quantification of inventories of potential fuels;

b) development of fire scenarios including potential release rates and determining the dimensions of fire scenario envelopes;

c) determining fireproofing needs based on the probability of an incident considering company or industry experience, the potential impact of damage for each fire-scenario envelope, and technical, economic, environmental, regulatory and personnel risk factors;

d) choosing the level of protection (based on appropriate standard test procedures) which should be provided by fireproofing material for specific equipment based on the needs analysis.

Plant revisions subject to Management of Change (MOC) review should cycle back to the initial hazard evaluation sequence as shown in Figure 1B.

The fireproofing process, including installation and surveillance, is described in the subsequent sections of this document.

4.2.1 Fire Hazard Identification

4.2.1.1 General

The first step in evaluating fireproofing requirements is identifying the location and types of fire hazard areas including capacity and flow pattern of associated drainage areas. Factors considered include quantities, pressures, temperatures and chemistry of the materials present in the area which are potential fuels. This fire hazard identification may be included as part other process safety hazard evaluation work. This evaluation should recognize that PHA teams may not have the appropriate personnel for a Fire Hazard Analysis (FHA). A variety of approaches may be used in developing hazard analysis scenarios; references are included in the Bibliography.

Alternatively, some fire protection personnel use qualitative “fire-risk” categories to assist in hazard determination. This division of equipment into high, medium, low and non-fire potential as described in 4.2.1.2 through 4.2.1.5 has proven useful to some companies in determining fireproofing needs. These categories are based on experience which shows that some types of equipment have a higher fire potential than others based on historical incident frequency and/or severity. These “fire potential” definitions are intended to include most types of hydrocarbon-handling equipment that can release appreciable quantities of flammable fluids.

4.2.1.2 High Fire Potential Equipment

Complex process units such as catalytic crackers, hydrocrackers, ethylene units, hydrotreaters, or large crude distilling units typically contain high fire-potential equipment. The following are examples of equipment considered to have a high fire potential.

a) Fired heaters that process liquid or mixed-phase hydrocarbons, under the following conditions:

   1) operation at temperatures and flow rates that are capable of causing coking within the tubes;

   2) operation at pressures and flow rates that are high enough to cause large spills before the heater can be isolated;

   3) charging of potentially corrosive fluids.

b) Pumps with a rated capacity over 200 US gpm (45m^3/hr) that handle liquids above or within 15 °F (8 °C) of their flash point temperatures.

c) Pumps with a history of bearing failure or seal leakage (where engineering revisions have been unsuccessful at eliminating these as significant potential fuel sources).

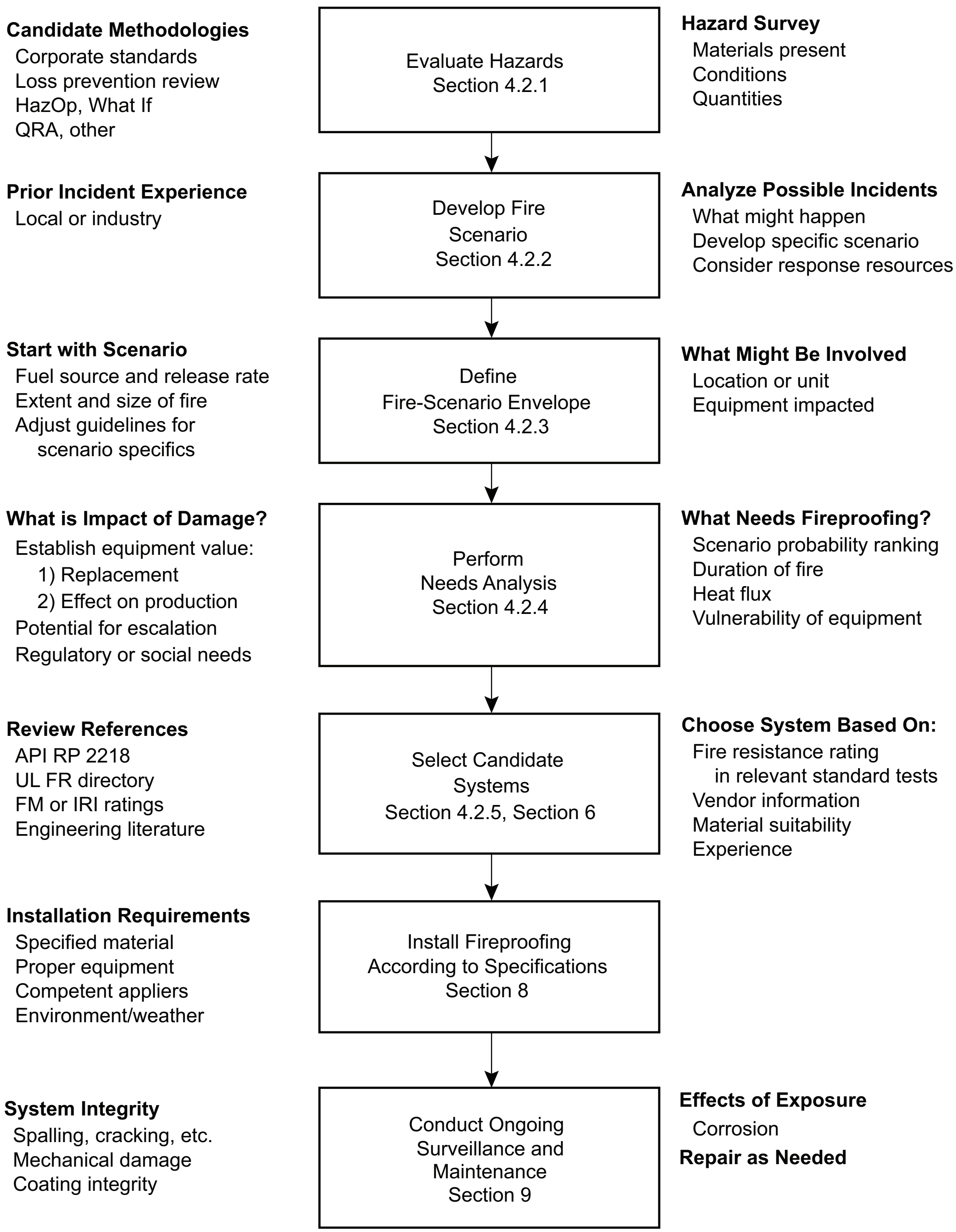

Figure 1A—Selecting Fireproofing Systems

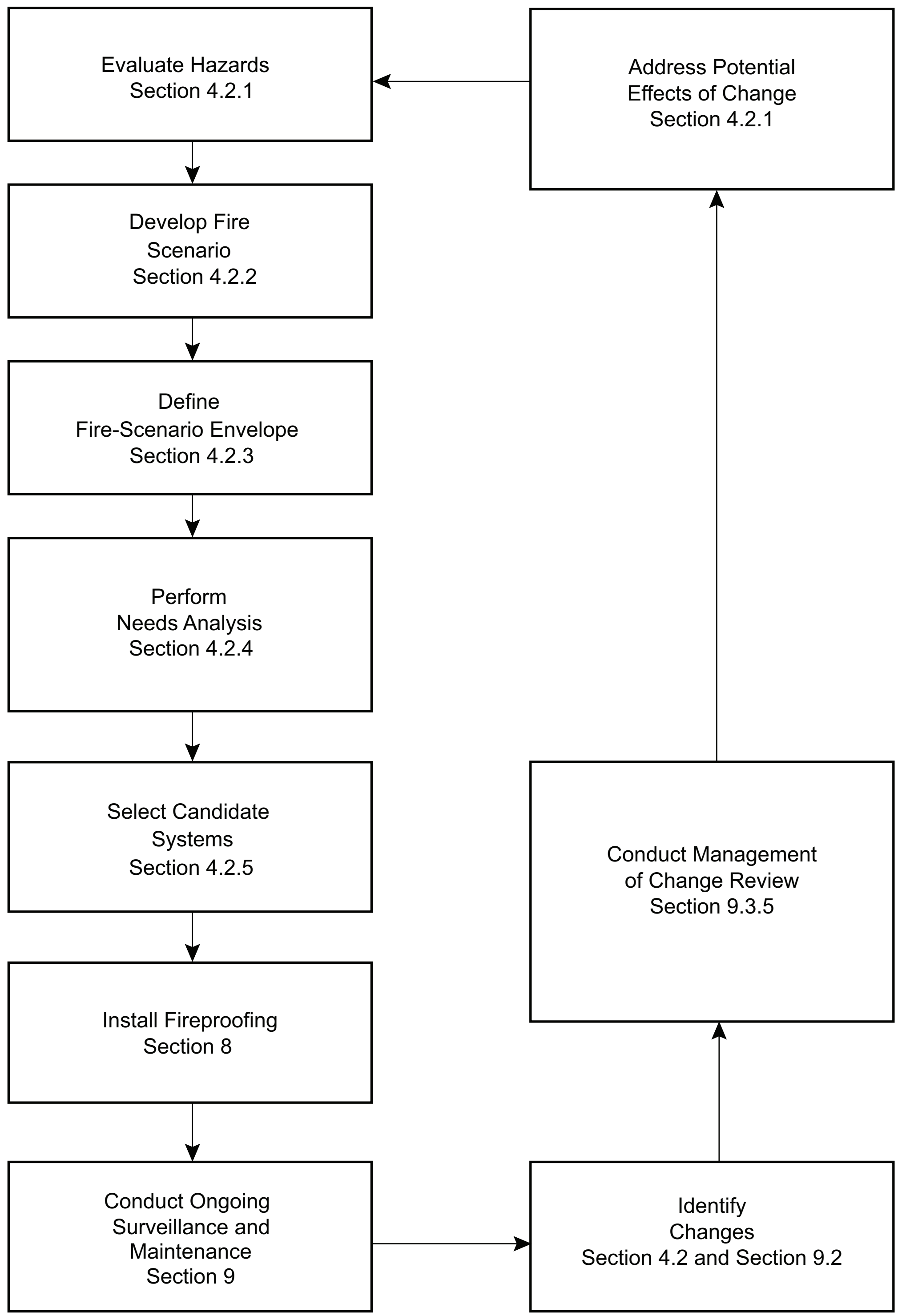

Figure 1B—Fireproofing Process with MOC

d) Pumps with small piping subject to fatigue failure.

e) Reactors that operate at high pressure or with the potential to experience runaway exothermic reactions that are not equipped with other safeguards such as depressuring systems, reaction inhibitor systems, etc.

f) Compressors together with related lube-oil systems.

NOTE While compressors do not have a high liquid-fire potential, they can generate a fire-scenario envelope if there is a prolonged release of gas and an intense fire in the vicinity of important structural supports. If the compressor is equipped to be remotely shut down and isolated from gas supplies or depressured during an emergency, then its potential for becoming involved in a serious fire should be lower.

g) Specific segments of process piping handling flammable liquids or gases in mixtures known to promote pipe failures through erosion, corrosion, or embrittlement. This includes hydrocarbon streams that may contain entrained catalyst, caustics, acids, hydrogen, or similar materials where development of an appropriate scenario envelope is feasible.

h) Vessels, heat exchangers (including air cooled exchangers), and other equipment containing flammable or combustible liquids over 600 °F (315 °C) or their auto-ignition temperature, whichever is less.

i) Equipment operating at temperatures which may accelerate corrosion under insulation and/or passive fire protection.

4.2.1.3 Medium Fire Potential Equipment

The following are examples of equipment considered to have a medium fire potential:

a) accumulators, feed drums, and other vessels that may leak as a result of broken instrumentation, ruptured gaskets, or other apparatus;

b) towers that may leak as a result of broken gauge columns or gasket failure on connected piping and bottom reboilers;

c) air-cooled fin fan exchangers that handle flammable and combustible liquids.

4.2.1.4 Low Fire Potential Equipment

The following are examples of equipment considered to have a low fire potential:

a) pumps that handle Class IIIB liquids below their flash points;

b) piping within battery limits which has a concentration of valves, fittings, and flanges;

c) heat exchangers that may develop flange leaks.

4.2.1.5 Non-fire Potential Equipment

Non-fire potential equipment is that which has little or no chance of releasing flammable or combustible fluids either before or shortly after the outbreak of a fire. Piping and other equipment that handles noncombustible fluids are considered to be non-fire potential equipment.

NOTE Although classified as non-fire potential equipment, water supply lines to active fire protection equipment within the envelope should be considered for fireproofing protection if analysis shows they are vulnerable. Similar consideration should be given to pipe rack supports if failure could result in incident escalation.

4.2.2 Fire Scenario Development

Development of a fire scenario uses information from hazard evaluations to determine what a fire would be like if it occurred. It seeks to define what sequence of events might release materials which could be fuel for a fire. Then, what elements affect the nature of the fire. The fire scenario considers what the situation would be if unabated. For each scenario the following data set should be developed.

a) What might happen to release materials which could fuel a fire?

b) Where is the potential fuel release scenario located?

c) How much material might be released?

   1) hydrocarbon hold-up capacity

   2) releasable inventory

d) How fast (flow rate) might potential fuel be released?

   1) pressure and temperature of source

   2) size of opening

   3) nature of potential leaks (liquid, vapor, both)

e) Would the released fuel spread?

f) Will the fuel be impounded locally by berms or diking?

g) Is the capacity of the drainage system sufficient to remove a hydrocarbon spill?

h) If ignited, what would be the character and extent of fire?

   1) volatility

   2) burning rate

   3) heat of combustion

i) Physical properties of materials that may be released?

j) How much heat would be released if ignited?

k) How long might the fire burn if unabated?

l) Does the piping or process equipment in the vicinity carry heat-sensitive material (e.g. ethylene) such that a decomposition or reaction could be propagated in the pipe?

This information defines the fire scenario based on both qualitative and quantitative information regarding plant configuration, appropriate for a “what if” approach to hazard analysis. Similar useful information may already exist in pre-incident fire suppression planning documents. Annex B discusses additional considerations relevant to jet fire scenarios.

4.2.3 Needs Analysis

The *needs analysis* determines what level of protection (if any) the structure or equipment needs. This analysis starts with factors relating to *severity and duration* of exposure developed in the scenario analysis for an area. It then considers which specific equipment might be exposed, the *vulnerability* of that equipment to heat exposure, and the resulting *impacts* of a scenario incident. These include social, environmental and personnel impacts as well as the intrinsic and production value of that equipment. During the needs analysis the effectiveness of active fire mitigation (intervention and suppression resources) is considered. Finally, the needs analysis reviews the *probability* of a scenario incident.

The first phase of analysis considers potential severity and vulnerability.

a) The location and potential heat release of potential leaks:

   1) What equipment/structure is potentially exposed?

   2) What type of fire exposure and how close to the structure or equipment of concern?

b) The severity of operating conditions in potentially exposed equipment:

   1) Process temperature and pressure.

   2) Whether process materials are above their autoignition points.

   3) Whether equipment contains liquid which can absorb heat or help cool the vessel walls upon vaporizing.

c) The fire potential category of equipment in the area (4.2.1.2 through 4.2.1.5).

d) Unit spacing, layout of equipment, potential fire exposure hazard to adjacent facilities and the possible impact on the surrounding area.

e) The estimated duration of an unabated fire (from 4.2.2).

Further analysis considers intervention capability (and time requirements, see 4.2.5.1).

a) The effectiveness of the area drainage system to remove a hydrocarbon spill.

b) Capability to isolate, de-inventory, or depressure systems.

c) Presence of manual and automatic shutdown systems.

d) Active fire protection provided by fixed water spray systems or fixed monitors.

e) Unit spacing, the layout of equipment and access for emergency response.

Finally risk is evaluated.

a) The potential impact on employees, the public or the environment.

b) Scenario event probability (traditionally based on qualitative evaluations).

c) The intrinsic value of potentially exposed plant or equipment.

d) The importance of unit equipment to continued plant operations and earnings.

The result of the needs analysis should define the extent of structural fireproofing and for what heat-exposure intensity and duration the fireproofing should provide protection. This evaluation should include the benefit and impact of active systems.

Alternatives to experience-based proximity guidelines are now coming into use in some areas to assist the process of needs analysis. API RP 2510A discusses radiation from pool fires and provides a chart for estimating heat exposure from propane pool fires assuming a specific set of conditions. Sophisticated computer *Hazard Consequence or Fire Effects* modeling can provide calculated heat flux exposure values for specific equipment and scenarios. These models require explicit definition of the scenario as discussed in several Bibliography references.

4.2.4 Fire Scenario Envelope Definition

Based on the fire scenario, a fire-scenario envelope can be developed. The fire-scenario envelope is the three dimensional space into which fire potential equipment can release flammable or combustible fluids forming a pool fire capable of burning long enough and with enough intensity to cause substantial property damage. Defining this premised fire-scenario envelope, along with the nature and severity of potential fires within the envelope, becomes the basis for determining the extent of passive fireproofing and selecting the type and fire resistance rating of the fireproofing materials used.

The locations and dimensions of the fire scenario envelope can be established using consequence-based, qualitative/ quantitative risk-based or experienced-based design rules (corporate or insurance).

For liquid hydrocarbon fuels, a frequently used frame of reference for the fire-scenario envelope is one that extends 20 ft to 40 ft (6 m to 12 m) horizontally and 20 ft to 40 ft (6 m to 12 m) vertically from the source of liquid fuel. The source may be considered to be the periphery of the fire where the periphery is defined by dikes. In other instances estimates of the fire-scenario envelope may be based on spill quantity and knowledge of unit topography and drainage as in 5.2.1.2.

In considering application of these traditional ranges several characteristics can be evaluated to provide insight into establishing the fire scenario envelope. Factors potentially affecting envelope size include area drainage (e.g. pooling, number of catch basins, catch basin spacing, and size of the sewer system) and the estimated hydrocarbon discharge rate (e.g. higher pressures, volumes, and flow rates) which will affect the size and potential duration of a pool fire.

Elevated floors and platforms that could retain significant quantities of liquid hydrocarbons should be treated as though they were on the ground floor level for purposes of calculating vertical distances for fireproofing (see Figure 3B).

LPG vessels are considered to be the source of a fire scenario exposure and require fireproofing on their supports and nearby piperacks unless protected by a fixed water spray system. API Standard 2510 recommends fireproofing pipe supports within 50 ft (15 m) of the LPG vessel or within the spill containment area.

Table 1 is based on experience-based design rules from a number of operating companies and other guidelines and provides a summary of typical fireproofing guideline values describing the dimensions of the fire scenario envelope. Table 2 cites guidance for the UL 1709 (or functional equivalent) fire resistance rating for selected equipment. See Section 5 for additional considerations for extending the fire scenario envelope.

4.2.5 Fire Resistance Rating Selection

Choosing a "fire resistance rating" requires determining the length of time the fireproofing is intended to provide protection. The needs analysis in 4.2.4 identified risk factors related to severity and duration. For a few situations industry standards have defined minimum requirements as shown in Table 2. Review of these requirements should be included in the needs analysis to ensure that they are appropriately protective. For other equipment the next step is to define more specifically the desired protection time.

Table 1—Initial Planning Dimensions for Fire Scenario Envelope

Protected Equipment (or Potential Source of Fuel Release)	Dimensions of Fire Scenario Envelope (see note)		Section in API 2218 or other Reference
	Horizontal	Vertical	
Equipment within a fire scenario source of liquid fuel pool release – General	20 ft to 40 ft (6 m to 12 m)	20 ft to 40 ft (6 m to 12 m)	2218 Section 4.2.3
Pipe racks	20 ft to 40 ft (6 m to 12 m)	20 ft to 40 ft (6 m to 12 m)	2218 Section 5.2.1
Pipe racks near process units containing highly pressurized flammables	Review release scenario for fireproofing needs.	Review release scenario for fireproofing needs.	2218 Section 4.2.3
Process equipment structures	20 ft to 40 ft (6 m to 12 m)	30 ft to 40 ft (8 m to 12 m) Or up to the highest level supporting equipment.	2218 Section 5.1.1.1
Non-fire potential equipment structures above fire potential equipment	20 ft to 40 ft (6 m to 12 m)	20 ft to 40 ft (6 m to 12 m)	2218 Section 5.1.1.3
LPG vessels as potential source of pool fire exposure	Pipe supports within 50 ft (15 m) or within spill containment area.	20 ft to 40 ft (6 m to 12 m)	2218 Section 4.2.3 API 2510 API 2510A
Fin-fan coolers on pipe racks within pool fire scenario envelope	20 ft to 40 ft (6 m to 12 m)	30 ft to 40 ft (8 m to 12 m) Or up to the highest level supporting equipment.	2218 Section 5.1.2
Rotating equipment	20 ft to 40 ft (6 m to 12 m) from the scenario source of leakage.	20 ft to 40 ft (6 m to 12 m)	
Tanks, spheres, and spheroids, containing liquid flammable material other than LPG	The area shall extend to the dike wall, or 20 ft (6 m) from the storage vessel, whichever is greater.	20 ft to 40 ft (6 m to 12 m) Or as specified for equipment of concern.	
Marine docks where flammable materials are handled	100 ft (30 m) horizontally from the manifolds or loading connections.	From the water surface up to and including the dock surface.	

NOTE These initial planning values should be adjusted if a fire hazard analysis or modeling suggests different protective values.

Table 2—Level of Fireproofing Protection in Pool Fire Scenario Envelope

Equipment	Protection Level (see note)	Section in API 2218 or other Reference
LPG vessels if not protected by fixed water spray systems	Fireproofed equivalent to $1^1/2$. hours min in UL 1709 (or functional equivalent) for pool fires.	API 2510 2218 Section 8.7
Pipe supports within 50 ft or in spill containment area of LPG vessels, whichever is greater	Fireproofed equivalent to $1^1/2$ hours min. in UL 1709 (or functional equivalent) for pool fires.	2218 Section 2.2.3 API 2510
Critical wiring and control systems	15 to 30 minutes Protection in UL 1709 (or functional equivalent) test conditions.	2218 Section 3.1,8.1 API 2510

NOTE Some company standards require base fire rating on detailed analysis. As a result, the required fire rating may be less than or more than the values shown above.

4.2.5.1 Time Aspects for Fire Resistance Rating Selection

The fire resistance rating must be specified. This may be determined by considering the following.

a) The time required to block flows and backflows of fuel that may be released.

b) The availability and flow capacity of an uninterrupted water supply.

c) The time required to initiate application of adequate, reliable cooling from fixed water spray systems or fixed monitors.

d) Response time and capability of plant or other fire brigades to apply portable or mobile fire response resources (including foam for suppression).

e) The time required for the area's drainage system to remove a hydrocarbon spill.

Increased fire resistance should be considered for supports on important equipment that could cause extensive damage if they collapsed. Certain large, important vessels such as reactors, regenerators, and vacuum towers may be mounted on high support structures; in these cases the fire rating of the fireproofing may be constant regardless of height. In some other instances, particularly at higher elevations within a fire-scenario envelope, the fire-resistance rating may be reduced. The tables in Section 4 and figures in Section 5 reflect common industry practice, with the recognition that these are guidelines which must be implemented using personnel experienced in fire protection and fireproofing techniques.

For example, if the expected fire would only be a moderate exposure, with reasonable expectations that manual water cooling of exposed structure could effectively be in place within an hour or less, a $1^1/_2$ hour UL 1709 (or functional equivalent) rating might be a reasonable choice. However, if emergency response personnel were $1^1/_2$ hours away or exposure was more severe a more protective rating (such as 3 hours) might be chosen. The fireproofing goal is protection of equipment (such as structural supports) within a "real world" fire-scenario envelope.

4.2.5.2 Laboratory Fire Resistance Ratings

Once the fire exposure time period has been estimated, the task of specifying the fireproofing "fire resistance rating" can proceed for the various equipment and support systems within the fire-scenario envelope.

It is important to recognize that "fire resistance ratings" are laboratory test results. The rating, expressed in hours, represents the time for a protected member (such as a steel column) to reach a specific temperature (e.g. 1000 °F for UL 1709) when a fireproofing system (precise assembly of structural member and fire proofing materials) is exposed to a strictly controlled fire using a specific test protocol. The amount of heat a steel member can absorb (its "thermal mass" or section factor) is a primary factor in determining the fire protection required. Consequently the "fire resistance rating" of structures/assemblies with different thermal mass may vary from the tested member. The specific results do not apply for fireproofing equipment or structural members other than exactly represented by the assembly tested

4.2.5.3 PFP Thickness Determination

Considering the nature of laboratory tests, it is clear that the fire resistance rating is a useful relative measure for comparing fireproofing systems, but must be used with judgment when considering application to real facilities. This may include the inclusion of a reasonable safety factor agreed with the PFP supplier. Simply increasing thickness of PFP may not provide a proportional increase in protection.

As an example, a steel column fireproofed to a 1^1/2 hour laboratory rating may or may not withstand a 'real-world' fire for 1^1/2 hours without damage or failure, depending on the similarity of the field application to the laboratory assembly and the scenario fire to the laboratory test conditions. And as discussed in 4.2.5.2 the rating is for a specific configuration so if a certain fireproofing material applied to a W10×49 steel beam provides a 1^1/2 hour rated column, one cannot expect the same thickness of material applied to a light-weight beam or to sheet steel would allow either to survive for 1^1/2 hours with the same fire exposure. Alternatively, beams heavier than W10×49 could have a higher fire rating given the same fireproofing material, thickness and fire exposure. Multiple tests may be required to establish response of a varied section sizes and shapes to specific fire conditions. Extrapolation of results should not be undertaken without reliable guidance.

In general, the number of hours of fire resistance selected would apply to most of the structural supports within the fire-scenario envelope. Typically, designers would not specify different fireproofing thicknesses for different weight members within the fire exposure envelope.

For low mass elements (those substantially lighter than W10×49) that require fireproofing, the determination of fireproofing thickness can be problematic. If enough test data is available, a linear analysis can determine protection needs for low mass elements

An alternative to fireproofing these small elements is using fireproofed "catch beams."

Interpolation between results for tested system assemblies (for instance different thicknesses of the same fireproofing material) should be done by the manufacturer or personnel experienced in fireproofing design. Extrapolation to items of less than tested mass should be avoided.

It is the manufacturer's responsibility to establish a technical basis for determining PFP thicknesses to beam sizes and structural elements other than the 10W49. In particular, fireproofing materials that expand with fire exposure may not perform as well on a tubular member as it does on a 10W49 beam.

4.2.6 Effect of Heat on Structural Steel

The effect of heat exposure of structural steel is of concern during the fire and after the fire (there may be heat soak issues of radiation from adjacent members and equipment). Steel loses significant strength at elevated temperatures. If, during a fire, structural steel is hot enough for a long enough time it can weaken and lose its ability to support its load. Fireproofing tests simulating hydrocarbon fire conditions are designed to reach 2000 °F in five minutes to represent fire exposure temperature and duration. If heat continues to enter the steel after the fire duration period, even though the fire has been put out, further weakening is possible. Some steel can change its internal structure when heated and cooled, resulting in the possibility of post-fire concerns. This concern normally involves alloy steels but not mild steels that are typically used for structures.

Concerns during fire exposure increase as the temperature increases. Standardized tests use 1000 °F (538 °C) as the "failure" point.

Figure 2A represents the strength of a typical structural steel as it is heated; it loses about one-half of its strength at 1000 °F (538 °C).

Steel objects with smaller thermal mass will heat faster. Figure 2B shows the effect of steel plate thickness on the rate of temperature increase for plates of different thickness exposed to an open gasoline fire of about 2000 °F (1093 °C).

NOTE This is not a standard test.

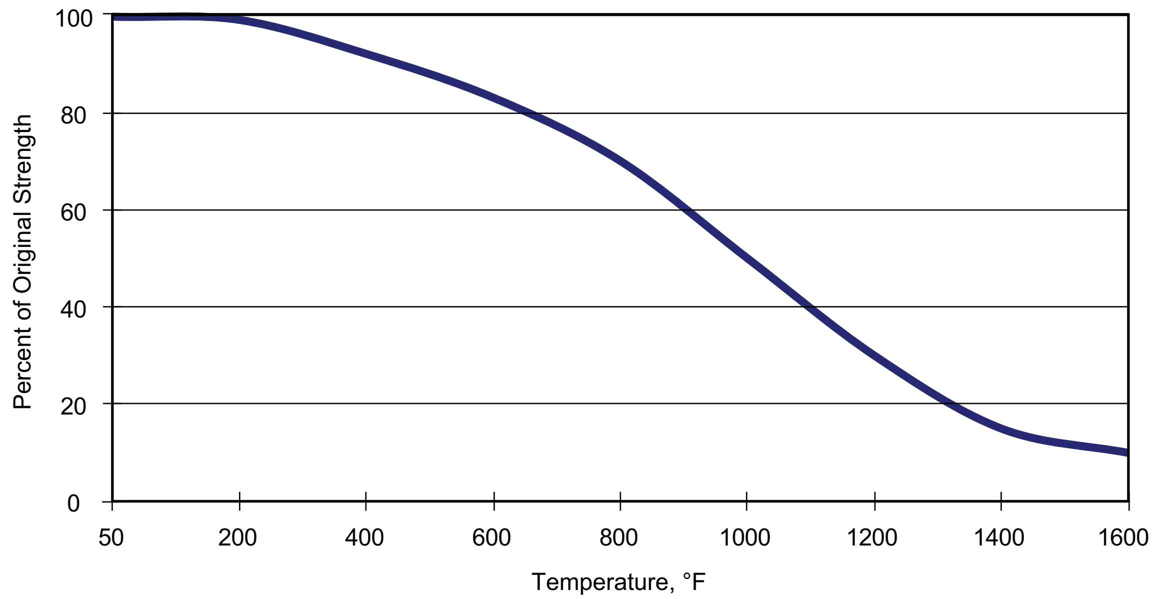

Figure 2A—Example of Effect of Temperature on Strength of Structural Steel

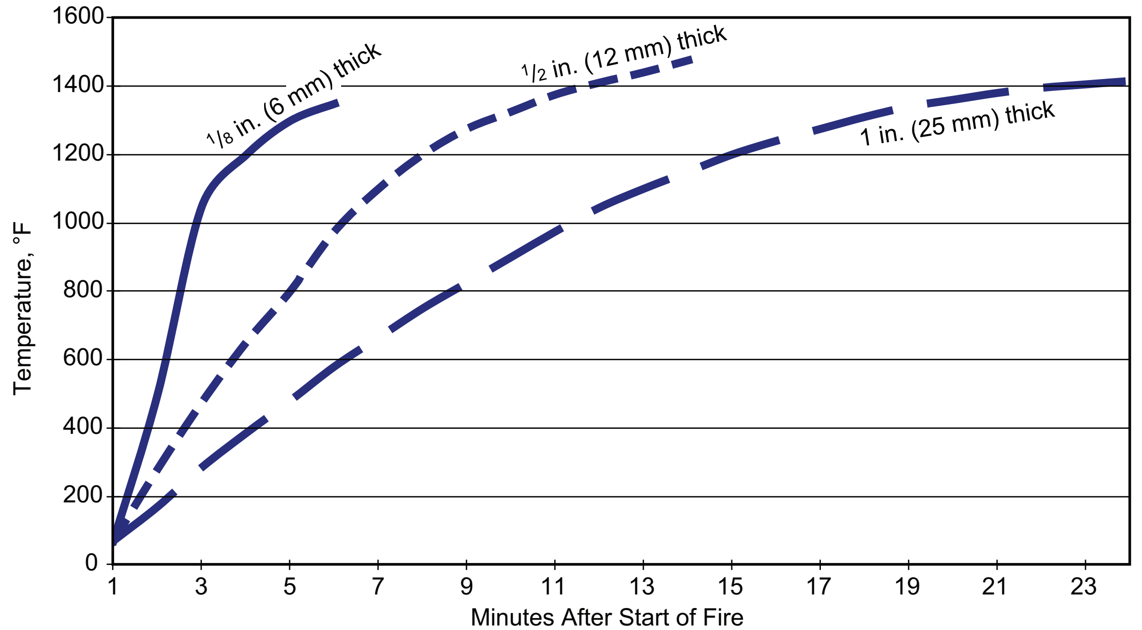

Figure 2B—Heating of Unwetted Steel Plates Exposed to Gasoline Fire on One Side

5 Fire Scenario Envelope Fireproofing Considerations

5.1 Fireproofing Inside Processing Areas

5.1.1 Multi-level Equipment Structures (Excluding Pipe Racks) within a Fire Scenario Envelope

5.1.1.1 When structures support equipment that has the potential to add a significant amount of fuel or escalate the fire, fireproofing should be considered for the vertical and horizontal steel support members from grade up to the highest level at which the equipment is supported (see Figure 3A).

5.1.1.2 Within a fire scenario envelope, if potential collapse of unprotected structures supporting equipment could result in substantial damage to nearby fire potential equipment, fireproofing should be considered for the vertical and horizontal steel members from grade level up to and including the level that is nearest to a 30-ft (9.1-m) elevation above grade (see Figure 3C).

5.1.1.3 Fireproofing should be considered for knee and diagonal bracing that contribute to the support of vertical loads or to the horizontal stability of columns located within the fire-scenario envelope. Although considered rare, bracing exposed to fire can conduct heat into the fireproofed portions of a structure and negatively affect the fire rating of the fireproofing system. Fireproofing suppliers may be able to provide test-based recommendations for coverage of non-critical members. In many cases where knee and diagonal bracing are used only for wind, earthquake, or surge loading they need not be fireproofed (see Figure 3A).

5.1.1.4 When reactors, towers, or similar vessels are installed on protected steel or reinforced concrete structures, fireproofing should be considered for equivalent protection of supporting steel brackets, lugs, or skirts (see Figure 3A). Material selection and design details are particularly important when fireproofing supports for vessels that operate at high temperatures. Beware that the insulating effect of the fireproofing material may result in overheating the supports for vessels that operate at high temperatures. To avoid thermal stresses and cracking of the fireproofing, often the fireproofing is terminated 1 ft to 2 ft below the skirt/vessel weld and the bare area is covered in fireproof insulation.

5.1.1.5 Where fireproofing is required for horizontal beams supporting piping in fire-scenario areas the upper surface of the beam need not be fireproofed if the smooth surface is needed for pipe movement reasons.

5.1.2 Supports for Pipe Racks within a Fire Scenario Envelope

5.1.2.1 When a pipe rack is within a fire scenario envelope, fireproofing should be considered for vertical and horizontal supports up to and including the first level, especially if the supported piping contains flammable materials, combustible liquids or toxic materials. If a pipe rack carries piping that has a diameter greater than 6 in. (150 mm) at levels above the first horizontal beam, or large hydrocarbon pumps are installed beneath the rack, fireproofing should be considered up to and including the level that is nearest to a 30-ft (9-m) elevation (see Figure 4A and Figure 4B). Wind or earthquake bracing and non-load-bearing stringer beams that run parallel to piping need not be fireproof (see Figure 4C). If conduction into primary beams is a concern the fireproofing can be extended back 18 in. (450 mm) from the primary beams.

5.1.2.2 If air fin fan coolers are installed on top of a pipe rack within a fire scenario envelope, fireproofing should be considered for all vertical and horizontal support members on all levels of the pipe rack including support members for the air fin-fan coolers, regardless of their elevation above grade (see Figure 4C).

5.1.2.3 Fireproofing should be considered for knee and diagonal bracing that contributes to the support of vertical loads (see Figure 4B and Figure 4D). Bracing that is exposed to the fire condition should be reviewed for possible heat conductivity effects (see 5.1.1.3). Knee or diagonal bracing used only for wind or earthquake loading need not be fireproofed.

5.1.2.4 Frequently, the layout of piping requires that auxiliary pipe supports be placed outside the main pipe rack. These supports include small lateral pipe racks, independent stanchions, individual T columns, and columns with brackets. Whenever these members support piping with a diameter greater than 6 in. (150 mm) or important piping such as relief lines, blowdown lines, or pump suction lines from accumulators or towers, fireproofing should be considered (see Figure 4E).

5.1.2.5 When piping containing flammable materials, combustible liquids or toxic materials is hung by rod or spring type connections from a pipe rack support member, and the rod or spring is in a fire scenario envelope, a “catch beam” should be provided. The “catch beam” and its support members should be fireproofed. If the pipe which is hung by rod or spring type connections is the only line on the pipe rack which contains flammable or toxic material, then the pipe rack support members should be fireproofed to the extent they support the “catch beam”. Sufficient clearance should be provided between the bracket or beam and the pipe to permit free movement (see Figure 4D).

5.1.3 Air Coolers within a Fire Scenario Envelope

5.1.3.1 When air fin-fan coolers in liquid hydrocarbon service are located at grade level within a fire scenario envelope fireproofing should be considered for their supports.

5.1.3.2 Fireproofing should be considered for the structural supports of all air cooled exchangers handling flammable or combustible liquids at an inlet temperature above their auto-ignition temperature or above 600 °F (315 °C), whichever is lower.

5.1.3.3 When air cooled exchangers are located above vessels or equipment that contain flammable materials, fireproofing should be considered for the structural supports located within a 20 ft to 40 ft (6 m to 12 m) horizontal radius of such vessels or equipment, regardless of height (see Figure 4C).

5.1.3.4 Fireproofing for air cooled exchangers located above pipe racks is covered in 5.1.2.2.

5.1.3.5 If air coolers are handling gas only and are not exposed to a fire from other equipment at grade, then fireproofing the support structure may not provide added value, if when the gas coolers fail (and if there is no liquid to spill) the fire will be above the coolers without the potential to jet downwards causing flame impingement.

5.1.4 Tower and Vessel Skirts within a Fire Scenario Envelope

5.1.4.1 Fireproofing should be considered for the exterior surfaces of skirts that support towers and vertical vessels. Consideration should also be given to fireproofing interior surfaces of skirts if there are flanges or valves inside the skirt or if there are unsealed openings exceeding 24 in. (600 mm) equivalent diameter in the skirt.

Openings other than the single manway may be closed with removable steel plate at least $^1/_4$ in. (6 mm) thick. Consideration should be given to minimizing the effects of draft through vent openings and space that surrounds pipe penetrations in the skirt.

5.1.4.2 Fireproofing should be considered for brackets or lugs that are used to attach vertical reboilers or heat exchangers to towers or tower skirts. Specific requirements apply to LPG vessels (see 5.2.2 and 5.2.3).

5.1.5 Leg Supports for Towers and Vessels within a Fire Scenario Envelope

If towers or vessels are elevated on exposed steel legs, fireproofing the leg supports to their full load bearing height should be considered.

5.1.6 Supports for Horizontal Exchangers, Coolers, Condensers, Drums, Receivers, and Accumulators within a Fire Scenario Envelope

Fireproofing should be considered for steel saddles that support horizontal heat exchangers, coolers, condensers, drums, receivers, and accumulators that have a diameter greater than 30 in. (750 mm) if the narrowest vertical distance between the concrete pier and the shell of the vessel exceeds 12 in. (300 mm).

5.1.7 Fired Heaters within a Fire-Scenario Envelope

5.1.7.1 Structural members supporting fired heaters handling flammable or combustible liquids should be fireproofed. Structural steel members supporting fired heaters in other services should be fireproofed if located within a fire scenario area. This includes fired heaters in other than hydrocarbon service, such as steam superheaters or catalytic cracking-unit air heaters, if a collapse would result in damage to adjacent hydrocarbon-processing equipment or piping.

5.1.7.2 If structural support is provided by horizontal steel beams beneath the firebox of an elevated heater, fireproofing should be considered for the beams unless at least one flange face is in continuous contact with the elevated firebox.

5.1.7.3 If common chimneys or stacks handle flue gas from several heaters, fireproofing should be considered for the structural supports for ducts or breeching between heaters and stacks if located within a fire scenario area.

5.1.8 Power and Control Lines within a Fire Scenario Envelope

5.1.8.1 Electrical Power and Instrument Cable

Electrical, instrument and control systems used to activate emergency systems needed to control a fire or mitigate its consequences (such as emergency shut-down systems, emergency isolation systems or emergency depressuring systems) should be protected from fire damage unless they are designed to fail safe during a fire exposure. The need to protect other electrical, instrument or control systems not associated with control or mitigation of the fire should be based on a risk assessment. If the control wiring used to activate emergency systems during a fire could be exposed to the fire, the wiring should be protected against a 15 to 30 minute fire exposure equivalent to UL 1709 (or functional equivalent). If activation of these emergency systems would not be necessary during any fire to which it might be exposed, then protection of the wiring is not required for emergency response purposes.

Protection may be considered if trays with cables servicing neighboring units run through the fire scenario envelope. A loss control review may indicate need for fire protection as replacement of critical electrical feeder lines and rewiring cable trays after a fire can be very time consuming. Power and instrument cable can quickly be destroyed in a fire, impeding the ability to have a controlled shutdown.

The primary methods of avoiding early cable failure in a fire situation include the following.

a) Burying cable below grade.

b) Routing cable around areas that have a high fire potential.

c) If neither of the above methods have been used and continued cable service is advisable within a fire exposed envelope, the following fireproofing designs may provide additional protection and extend operating time.

   1) The use of cable rated for high temperatures (minimum 15 to 30 minutes in UL 1709 or functional equivalent fire conditions) such as stainless steel jacketed (MI/SI) mineral insulated cable, protected by intumescent material fireproofing.

   2) The use of foil-backed endothermic wrap insulating systems properly sealed to exclude moisture in accordance with the manufacturer’s recommendations.

   3) The use of cable tray systems designed to protect the cables from fire:

      a) special vendor-certified fireproofed cable tray systems;

      b) completely enclosed cable trays made of galvanized sheet metal lined inside with insulating fire-resistant fiber mats or calcium silicate block;

      c) cable trays encased with calcium silicate insulating panels with calcium silicate sleepers to hold cables away from bottom of the cable tray;

      d) trays with exterior surfaces made of galvanized sheet metal coated with mastic fireproofing material;

      e) The application of preformed pipe insulation rated for service at 1200 °F (650 °C), covered with stainless steel sheet metal held in place by stainless steel bands and screws.

Aluminum is not acceptable for any of the preceding in this service.

The above items may or may not be listed and approved by national testing laboratories. However, two relevant tests are now available.

ASTM E1725-95, *Standard Test Methods for Fire Tests of Fire-Resistive Barrier Systems for Electrical System Components* is designed to measure and describe the response of electrical system materials, products or assemblies to heat and flame under controlled conditions. It can be run using either ASTM E119 or ASTM E1529 temperature curve conditions. For applicability to petroleum and petrochemical processing plants the ASTM E1529 "pool fire" conditions should be specified. The test measures the time for the electrical system component to reach an average temperature 250 °F (139 °C) above the initial temperature.

UL 2196, *Standard for Tests of Fire Resistive Cables* is like ASTM E1725 in that it has two alternate temperature curves for testing: the "normal temperature rise curve" is the same as UL 263 (ASTM E119); the "rapid temperature rise curve" coincides with UL 1709. For use in petroleum and petrochemical processing plants the "rapid temperature rise curve" should be specified.

The protection system selected should be proven by acceptable tests to be able to keep the temperature of the cable within operating limits (usually below 300 °F (150 °C) for ordinary polyvinyl chloride cable). When exposed to UL 1709 hydrocarbon fire temperatures of 2000 °F (1093 °C) this protection should extend for the time necessary to actuate critical valves and shut down equipment.

Experience indicates that fireproofing applied directly to thermo-plastic jacketed cables or conduit has low probability of success. Because the plastic melts at a low temperature the fireproofing is shed and the cable fails quickly, or the conduit becomes hot enough to melt the insulation of the wire inside. Whatever system is selected should be tested or have manufacturer's evidence that it can protect the cable to an appropriate temperature for the wire insulation for not less than 15 to 30 minutes (or longer if required) based on the Fire Hazard Analysis.

Most fireproofing systems for cable result in cable operating temperatures that are higher than normal, so the electrical capacity of the cable may need to be derated.

5.1.8.2 Pneumatic and Hydraulic instrument Lines

Pneumatic and hydraulic instrument lines are protected for the same reasons and by the same methods as those described in 5.1.8.1 for electrical cable. ASTM Type 304, Type 316, and Type 321 stainless steel tubing is highly resistant to failure during a hydrocarbon fire and does not have to be protected with insulating materials. Other types of control tubing could fail within a few minutes when exposed to fire; fireproofing these types of tubing with preformed pipe insulation rated for service at 1200 °F (650 °C) or higher should be considered. The assembly should be weather protected with stainless or galvanized steel sheeting held in place by stainless steel bands and screws.

5.1.9 Emergency Valves within a Fire Scenario Envelope

The operation of emergency valves and valve actuators in areas exposed to fire can be important to shutting down units safely, depressurizing equipment, or isolating fuel feeding a fire. Examples of important emergency isolation valves include suction valves in piping to pumps that are fed from large towers, accumulators, or feed surge drums.

To improve the probability that emergency isolation valves will operate properly, fireproofing should be considered for both the power and signal lines that are connected to the valve. The valve's motor operator should be sufficiently fire protected to provide enough time for the valve to fully open or close. Valves that fail to the safe position need not be fireproofed (but should be able to fail to their fail safe position when under a fire challenge).

Power and instrument lines can be protected as described in 5.1.8.1. Motor operators may be protected by various fire rated systems that use preformed fire resistant material, specially designed lace-up fire-resistant blankets, assemblies that use mastic materials or intumescent epoxy coatings permanently molded to the equipment. For each of the above options it is important to confirm that the fireproofing material is suitable for the operating temperature of the equipment being protected. Some are limited to normal non-fire temperatures as low as 150 °F (65 °C) even though they can provide a 30 minute rating under UL 1709 (or functional equivalent) conditions. Cold weather considerations should also be reviewed.

The following items require special consideration.

a) Thermal-limit switches built into electric motors may cause the motors to fail before valves are fully closed or opened when the motor operation is exposed to fire. Deactivation of the thermal limit switches should be considered or the equipment supplier should be consulted about possible modifications to ensure that motor operation is of sufficient duration to obtain the desired valve operation.

b) The valve's hand wheel and engaging lever must not be fireproofed to the extent that the valve is made inoperable.

c) The valve's position indicator must remain visible after the valve is fireproofed.

d) The solenoid on solenoid-operated valves may be fireproofed with the materials described above. Since the insulating material retains heat and blocks ventilation, the design must be investigated to ensure satisfactory operation.

e) The diaphragm housing on diaphragm-operated valves should be fireproofed with the materials described above, unless the valve is designed to fail to the safe position.

f) The fireproofing system selected must be rated for use at the operating temperature of the equipment being protected and its environment.

5.1.10 Special Hazard Fireproofing

Process units which use radioactive sources (as frequently used in level indicators) or have toxic gas analyzers (such as for sulfur dioxide) should ensure that these are protected to avoid potentially harmful releases. Enclosures made of fireproof materials can be used for this purpose.

5.2 Fireproofing Outside Processing Units

5.2.1 Pipe Racks within a Fire Scenario Envelope

5.2.1.1 If pipe rack supports outside processing units are located within a fire-scenario envelope they may be considered for fireproofing. Traditional practice is not to fireproof bracing for earthquakes, wind, or surge protection and stringer beams that run parallel to piping. Some recommendations recommend extending fireproofing from the primary members to a distance 18 in. (450 mm) from the primary member.

5.2.1.2 If important pipe racks run within 20 ft to 40 ft (6 m to 12 m) of open drainage ditches or channels that may contain oil waste or receive accidental spills, either fireproofing should be considered for the pipe rack supports as described in 5.2.1.1 or the ditch should be covered.

5.2.1.3 Similar considerations to those in 5.2.1.2 should be considered where piping carrying hydrocarbons uses bellows-style expansion joints.

5.2.2 LPG Storage Spheres within a Fire Scenario Envelope

API 2510 provides specific recommendations for the fireproofing of LPG storage vessels against pool fires. For the vessel itself this calls for fireproofing of potentially impinged portions of the vessel identified in the fire-scenario, if there is no fixed firewater protection. Where fireproofing is used, a fire resistance rating of $1^1/2$ hours protection under UL 1709 conditions is cited. The fireproofing should be capable of withstanding exposure to pool fire and shall be resistant to direct impact from fire water streams as demonstrated in NFPA 58, Appendix H (NFPA 290 or ASTM E2226).

NOTE It should be noted that deluge systems are not effective against jet fires.

Structural supports should be fireproofed to the same fire resistance for all above ground portions of the structure required to support the static load of the full vessel. Fireproofing shall be provided on horizontal vessel saddles where the distance between the bottom of the vessel and the top of the support structure is more than 12 in. (300 mm). Where provided, it shall extend from the support structure to the vessel, but shall not encase the points at which the saddles or other structural supports are welded to the vessel. When a vertical vessel is supported by a skirt, the exterior of the skirt shall be fireproofed in accordance with 5.1.4.1 and the interior shall also be fireproofed where there is more than one access opening in the skirt that is not covered with a plate.

5.2.3 Horizontal Pressurized LPG Storage Tanks within a Fire-Scenario Envelope

Horizontal pressurized LPG storage tanks should meet essentially the same requirements as for spheres. Preferably they should be installed on reinforced concrete saddles. All vessel support structures of concrete shall meet the same fire resistance rating ($1^1/2$ hours in UL 1709) required for steel support fireproofing. Fireproofing should be used for exposed steel vessel supports that exceed 12 in. (300 mm) minimum distance at the narrowest point.

5.2.4 Flare Lines within a Fire-Scenario Envelope

Fireproofing should be considered for supports for flare lines if they are within a fire-scenario envelope or if they are close to open ditches or drainage channels that may receive large accidental spills of hydrocarbons.

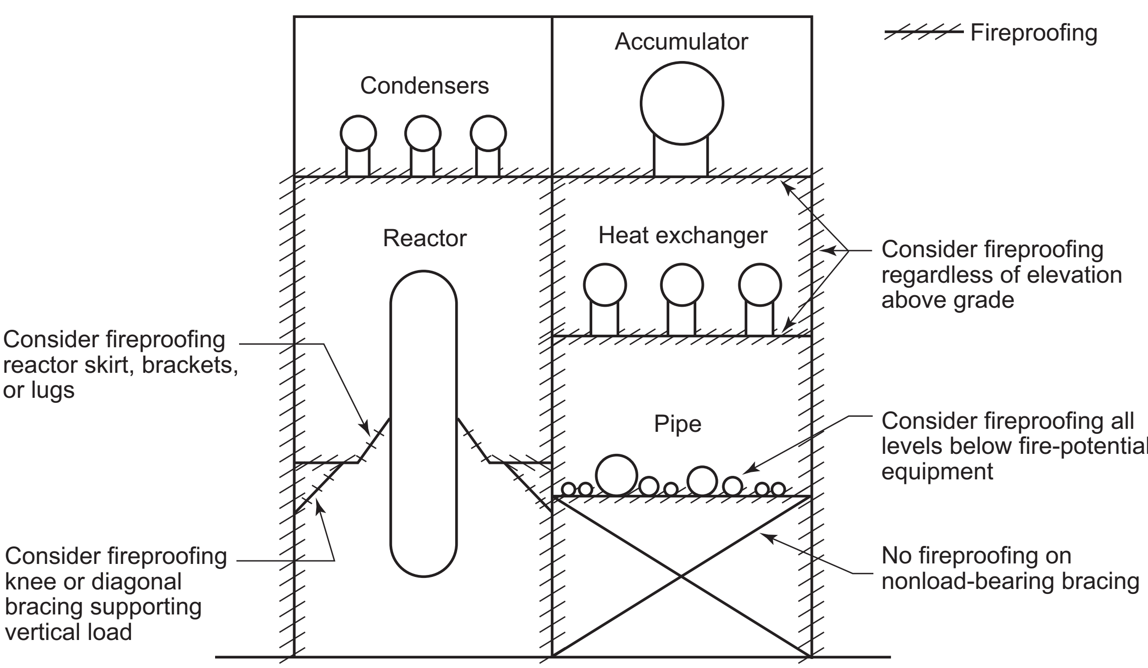

Figure 3A—Structure Supporting Fire Potential Equipment in a Fire Scenario Area

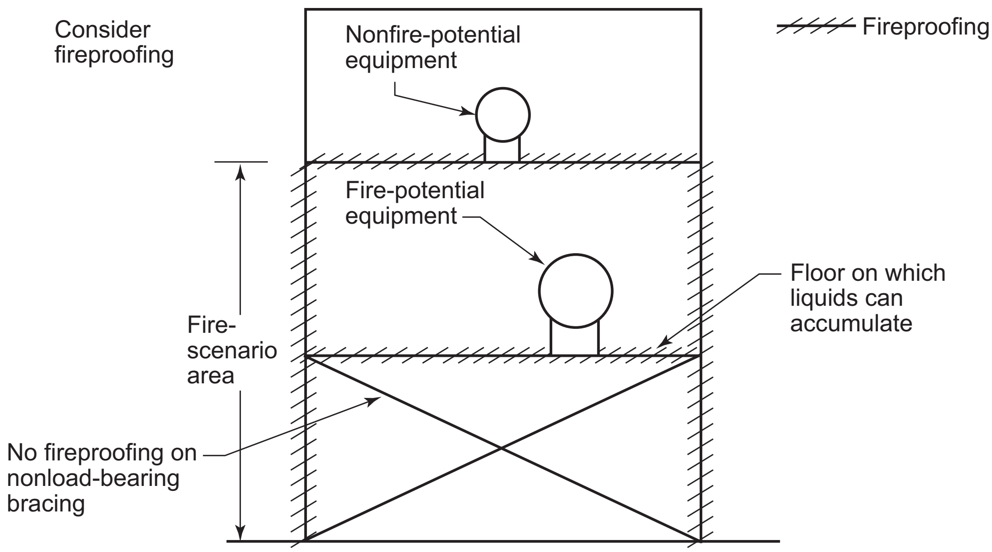

Figure 3B—Structure Supporting Fire Potential and Non-fire Potential Equipment in a Fire Scenario Area

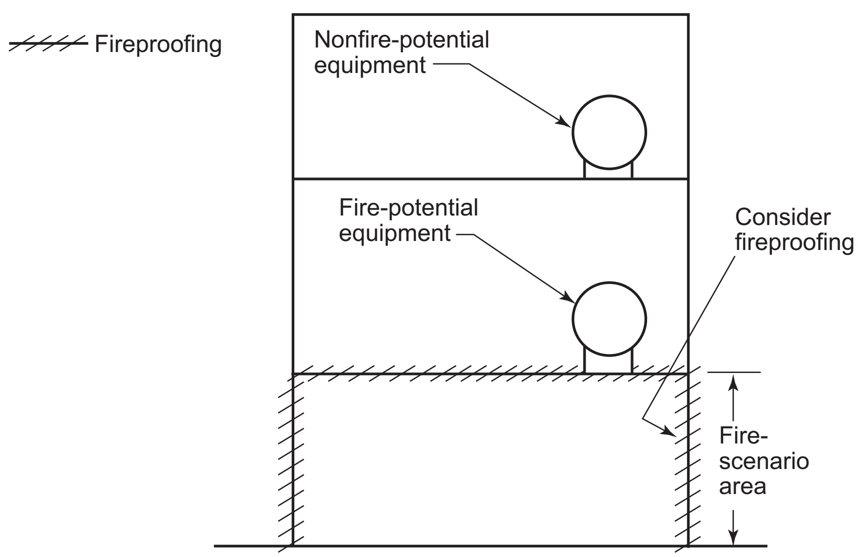

Figure 3C—Structure Supporting Non-fire Potential Equipment in a Fire Scenario Area

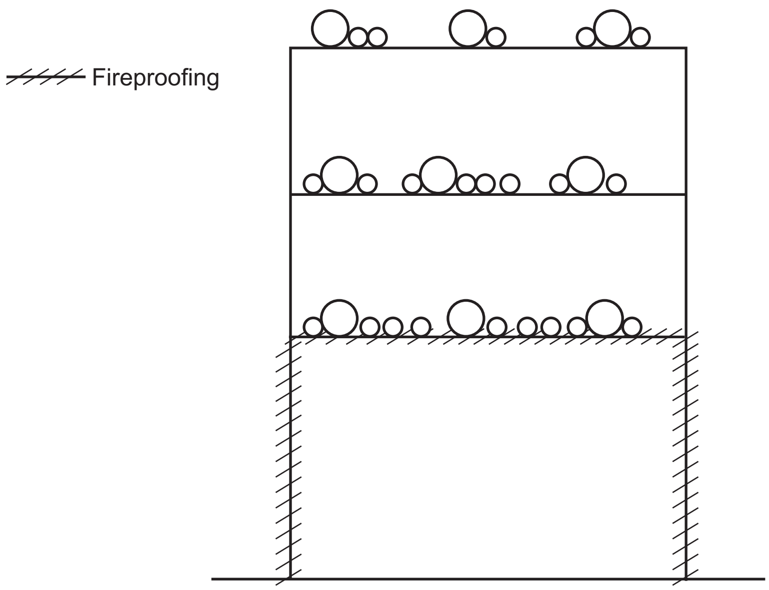

Figure 4A—Pipe Rack without Pumps in a Fire Scenario Area

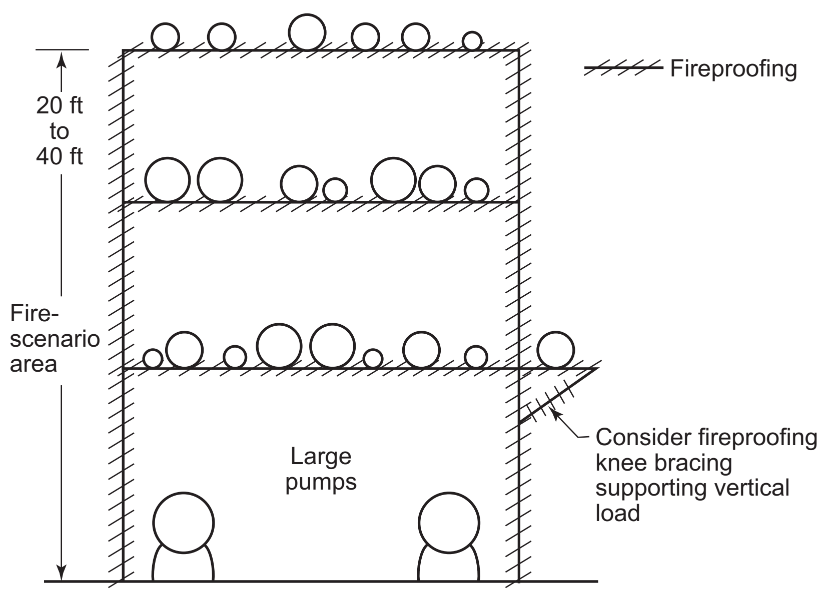

Figure 4B—Pipe Rack with Large Fire-potential Pumps Installed Below

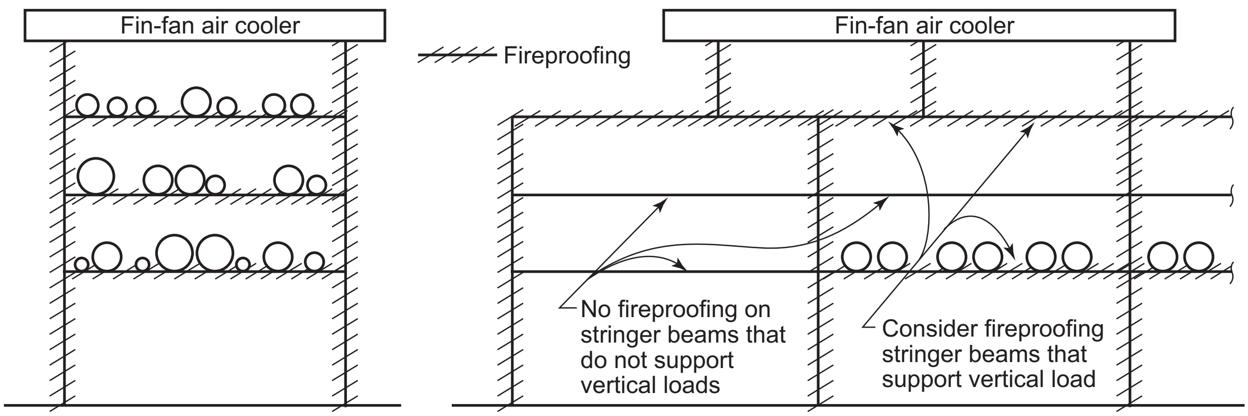

Figure 4C—Pipe Rack Supporting Fin-Fan Air Coolers in a Fire Scenario Area

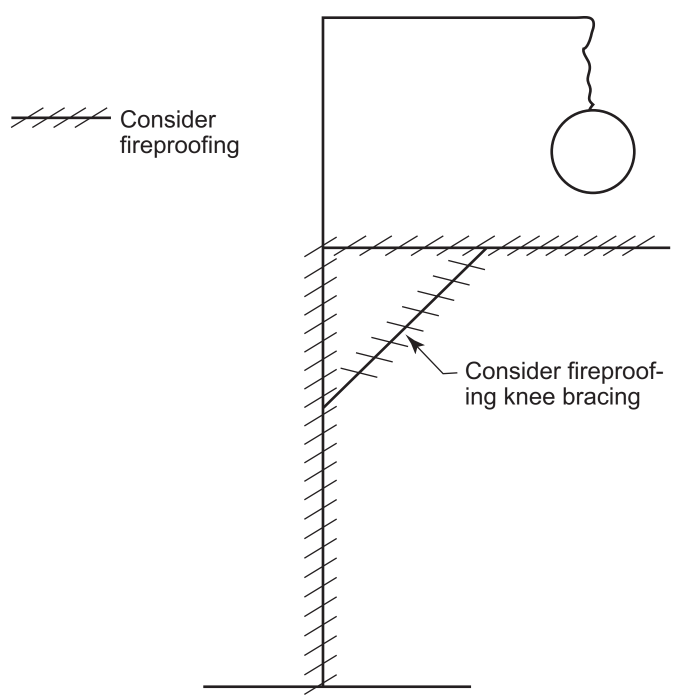

Figure 4D—Transfer Line with Hanger Support in a Fire Scenario Area

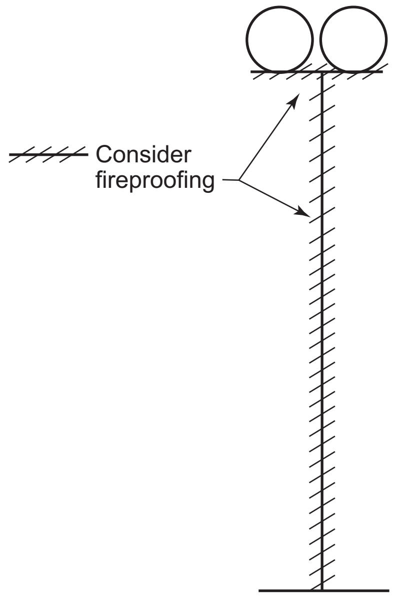

Figure 4E—Transfer Line Support in a Fire Scenario Area

6 Fireproofing Materials

6.1 General

Each type of fireproofing system uses a different combination of materials with various physical and chemical properties. These properties should be taken into consideration so that the system selected will be appropriate for its intended application. Where fireproofing coatings could be applied directly to steel most manufacturers recommend the use of primers chosen for compatibility with the coating and appropriate for corrosion control and the environmental conditions.

The following are important factors to consider when selecting fireproofing.

a) The weight and volume limitations imposed by the project including the strength of the steel supports for the assembly to be fireproofed.

b) The weight limitations imposed by the strength of the steel supports for the assembly to be fireproofed. The assembly must be able to carry the additional weight of fireproofing at the temperature reached during fire exposure when the metal strength is reduced. (Normal civil engineering design rules for gravity loads should be satisfactory.) See 4.2.6.

c) The fire resistance rating (in hours) selected (see 4.2.5).

d) The material's adhesion strength and durability. Specific surface preparation (cleaning and priming, etc.) and/or anchors and reinforcements specified.

e) Whether the material is to be specified for equipment in the design stage (shop application) or applied to existing equipment (field application).

NOTE Many systems that are cost effective on new construction may require dismantling and preparations that are costly or infeasible for existing facilities.)

f) The material's ease of application, maintenance and repair.

g) The corrosiveness of the atmosphere and of fireproofing materials to the substrate (stainless steel and aluminum can be especially susceptible to some conditions, especially chlorine exposure).

h) Equipment operating temperature limitations in non-fire conditions.

i) Expected or warranted lifetime of the fireproofing system.

j) Whether the fireproofed equipment is indoors or outdoors (some fireproofing coatings produce toxic fumes and smoke when exposed to fire and might not be suitable for enclosed areas commonly staffed).

k) Inspection requirements to manage potential corrosion under fireproofing.

l) Continuing maintenance requirements to ensure longevity of fireproofing system.

m) Risk associated with fireproofing impairment during maintenance (including adjacent equipment).

n) Regulatory requirements.

o) Life cycle cost (including maintenance and surveillance expense).

6.2 Characteristics of Fireproofing Materials

6.2.1 General

When fireproofing materials are selected, care should be taken to obtain the desired degree of protection during the system's service life. In addition to the system's degree of fire resistance, a variety of other characteristics should be evaluated to ensure that its materials perform properly in the environment in which installed. Some of the standard tests used are listed in Annex B.2. Some principal characteristics that govern the selection of fireproofing materials are discussed in 6.2.2 and 6.2.3.

6.2.2 Physical Properties

6.2.2.1 Resistance to Thermal Diffusivity

Fireproofing materials are generally designed to limit the temperature of steel supports to 1000 °F (538 °C) for a predetermined period. This temperature is at a point at which steel has lost about one-half of its strength (see 4.2.6) and is rapidly losing more strength. Different end point temperatures may be specified for fireproofing of vessel shells and fireproofing of instruments/electronics.

Organizations such as Underwriters Laboratories, Factory Mutual, and Lloyds Register test fireproofing materials and publish ratings, expressed in number of hours of protection. This is based on the time for enough heat to pass through the protective barrier to cause the substrate temperatures to reach 1000 °F (538 °C) when the materials are exposed to a given time-temperature environment. Some listings also give ratings as function of fire duration, critical core temperature, and steel size enabling effective selection of fire protection materials for particular structures. See Annex B for discussion and comparison of various standard tests.

6.2.2.2 Specific Weight (Density)

The specific weight (sometimes called density) of fireproofing materials can be important, especially on pipe racks, since additional deadweight loading is imposed. Different fireproofing materials should be compared using the weight per square foot of protected surface required to provide a given degree of fire resistance, since the required thickness may vary considerably. The specific weight of lightweight materials generally runs from 25 lbs/ft^3 to

80 lbs/ft^3 (from 400 kg/m^3 to 1300 kg/m^3) which is substantially less than dense concrete at 140 lbs/ft^3 to 150 lbs/ft^3 (2240 kg/m^3 to 2400 kg/m^3). Use of lightweight fireproofing systems may permit the specification of lighter steel in newly constructed pipe racks. The low density of lightweight materials may also be advantageous for retrofitting on existing racks where weight limitations exist. Thermal conductivity tends to be inversely proportional to specific weight.

However, specific weight for some materials (e.g. intumescents) which expand in a fire is totally different to that in a pre-fire scenario.

6.2.2.3 Bonding Strength

Bonding must be strong enough to ensure that fireproofing materials will withstand mechanical impact and protect the substrate against corrosion. Poor bonding can accelerate corrosion under insulation significantly reduce the service life of equipment being protected and can cause premature failures of the fireproofing materials, making them subject to total failure if they are exposed to a stress such as a fire hose stream (see 6.2.3.2). A standard bonding test (ASTM E736) is used for determining the "cohesion/adhesion" of spray-applied fire resistive materials, either fibrous or cementitious.

6.2.2.4 Weatherability and Chemical Tolerance

A material's ability to withstand the effects of humidity, rain, sunlight, and ambient temperature can influence its insulating quality, the life expectancy of its coating, and possible corrosion of the substrate and its reinforcing material. Materials differ in their weatherability. Some require no surface protection; others require a sealer or top coat that may have to be renewed periodically during the service life of the fireproofing material.

Exposure to certain acids, bases, salts, or solvents can destroy fireproofing materials; for applications where there is the potential for such exposure the materials should be checked for chemical stability with respect to liquids and vapors that may be present.

UL 1709 tests of fireproofing system assemblies includes a standard set of exposures for weatherability (accelerated aging, high humidity, cycling effects of water/freezing temperature/dryness) and chemical tolerance (salt spray, carbon dioxide, sulfur dioxide) as part of normal testing protocol; optional tests for exposures to solvents or acids can be added if required. As in UL-1709, ASTM E1529 includes a recommended set of accelerated weathering and aging tests. Some manufacturers conduct other accelerated weathering tests (such as ISO 20340), especially for marine or off-shore environments.

6.2.2.5 Protection from Corrosion

Depending on factors such as permeability, porosity, and pH, fireproofing materials may either inhibit or promote corrosion of the substrate and its steel reinforcements.

Vapors and liquids that might be present in some plant atmospheres could be highly corrosive if they are trapped between the fireproofing and the substrate and corrosion can seriously weaken structural supports. When some types of fireproofing are penetrated by water, salts can be leached out of the fireproofing and deposited on the substrate, resulting in corrosion. Chloride salts from some fireproofing materials, such as magnesium oxychloride, may leach through to a stainless steel substrate. If the substrate is subject to high temperatures, stress corrosion can rapidly lead to metal failure. With most materials the substrate must be properly cleaned and primed; with many, caulking and weather shields must be kept serviceable. With porous lightweight materials a good top coat must be maintained to prevent contaminant or water intrusion and subsequent corrosion.

6.2.2.6 Hardness and Impact Resistance

Where rigging and maintenance operations may be necessary or when using off-site application, fireproofing materials must be able to withstand a reasonable amount of mechanical impact and abrasion. If the integrity of fireproofing system elements is impaired the degree of fire resistance is seriously compromised, and the coating or fabricated structure may have to be repaired.

6.2.2.7 Vibration Resistance and Compressive, Tensile, and Flexural Strength

Vibration resistance and compressive, tensile, and flexural strength may be important to the life expectancy of fireproofing. In some applications vibration can fracture fireproofing material and destroy bonding of rigid coatings to the substrate. Epoxy intumescent fireproofing materials with elasticity and vibration tolerance and flexible endothermic wrap systems perform well in such applications.

6.2.2.8 Coefficient of Expansion

The coefficient of expansion can be significant when fireproofing materials are used on substrates that are subject to expansion caused by changes in temperature or in the operating pressure of the equipment. Too rigid a material can easily lose its bond to the substrate and spall off the protected member. Flexible epoxy intumescent fireproofing materials incorporating elasticity, thermal insulation designed for fire protection and endothermic wrap systems are able to effectively contain such assemblies.

6.2.2.9 Vapor Permeability and Porosity

Vapor permeability and porosity mainly relate to corrosion prevention and are most important in moist environments or in the presence of chemicals that can penetrate the coating and attack the support members. Fireproofing that contains a significant amount of free water can readily spall off when it is subjected to the high temperatures that are common to hydrocarbon fires. While free water inclusion or intrusion is potentially harmful many endothermic, intumescent or ablative fireproofing materials have chemically bound water which is released as an integral element of their fire protection mechanism.

6.2.2.10 Surface Temperature of Substrate

Certain materials used for thermal insulation of process vessels or piping may provide some fire protection (if properly installed and protected). But, as a general rule fireproofing materials should not be considered for thermal insulation. Some fireproofing materials have definite limitations on their operating temperatures. Specifically some fireproofing materials may be limited to operating (non-fire) temperatures no higher than 150 °F (65 °C) and no lower than –30 °C for low temperature application. Other organic fire proofing materials may be suitable for operation up to 260 °F (120 °C) for high temperature applications and as low as –50 °C for low temperature applications. A material that is suitable for the substrate's normal range of operating temperatures should be selected by carefully reviewing the vendor data sheets for possible thermal restrictions. Where products are outside their limits, PFP may be used in combination with insulation materials such as epoxy syntactic foams, cellular glass and PIR foams.

6.2.3 Behavior During Exposure To Fire

6.2.3.1 Combustibility

Some fireproofing materials, particularly organic systems (including some intumescent fireproofing), have levels of combustibility that can be assigned values, according to ASTM E 84 (NFPA 255), for flame spread and smoke developed.

When fireproofing materials are used in enclosed occupied structures, combustibility should be limited as follows:

— Flame spread index 0 to 25

— Smoke developed 0 to 450

NOTE The limits above conform to NFPA 101, Class A interior finish.

When fireproofing materials are used in the open, or in areas not normally occupied, combustibility should be limited as follows:

— Flame spread 26 to 75

— Smoke developed (No limit)

NOTE The limits above conform to NFPA 101, Class B.

While there is no smoke limit, the toxicity of heat-exposed fireproofing off-gases should be evaluated if these will be used in areas where employee or responder exposure is a concern.

6.2.3.2 Resistance to Hydraulic Erosion and Thermal Shock

If fireproofing materials must remain in place when water cooling streams are applied, a hose-stream test should be conducted to compare the ability of different materials to withstand hydraulic erosion and thermal shock. NFPA 290 (also NFPA 58 Appendix H) is an appropriate test standard for the hydrocarbon industry as it determines the effect of a concurrent water stream for the 10 minutes in the middle of the 50 minute hydrocarbon torch test fire and ascertains if the fire protection can keep the steel below 800 °F (427 °C) for the final 20 minutes after the hose stream has been terminated. (ASTM E2226 is an alternate hose test for use after fireproofing tests.)

6.3 Types of Fireproofing Materials

6.3.1 Dense Concretes

Concretes made with Portland cement have a specific weight of 140 lbs/ft^3 to 150 lbs/ft^3 (2200 kg/m^3 to 2400 kg/m^3). Dense concretes can be formed in place or pneumatically sprayed to the required thickness using steel reinforcement. The corrosive effect of chlorides on the steel surface in moist environments dictates the use of protective primers and topcoat sealers.

Major advantages of dense concretes are:

a) durability; can withstand thermal shock and direct hose streams;

b) can withstand direct flame impingement up to 2000 °F (1100 °C);

c) ability for most contractors to satisfactorily apply (no specialty contractors required);

d) extensive proven performance; can provide 4 or more hours of protection.

Disadvantages of dense concretes include:

a) relatively high weight;

b) relatively high thermal conductivity;

c) need for steel reinforcement;

d) installation cost and time involved in forming in place, especially when applied to existing facilities.

Concretes absorb heat through an endothermic heat of reaction when chemically bound water is released from the crystalline structure and they are reduced to lime by high heats; this adds to their fire barrier effect which directionally compensates for their relatively high thermal conductivity.

Proper application of dense concrete is important to achieve the required fire protection. Testing shall be performed to monitor density and cold crushing strength. A cold crushing strength of 3000 PSI (21 MPa) is a minimum; concretes with 4000 PSI (28 MPa) has been found to perform better.

6.3.2 Lightweight Concretes

Lightweight concretes use very light aggregates such as vermiculite or perlite (instead of gravel) with cements that are resistant to high temperatures. Dry densities range from 25 lbs/ft^3 to 80 lbs/ft^3 (400 kg/m^3 to1300 kg/m^3).

Lightweight concretes are usually sprayed on, but may be troweled or formed in place using reinforcing mesh. Pneumatically applied material is about 20 % heavier than poured-in-place lightweight concrete. As with all concretes, moisture creates a corrosive condition at the surface of the steel. Protective coating of the substrate surface is needed to protect against corrosion. In practice dense concrete is usually preferred.

Advantages of lightweight concretes include the following.

a) They can withstand thermal shock and moderate pressure hose.

b) Lightweight concrete fireproofing can be used at thinner coating thickness for equivalent fire exposure time ratings.

c) They are capable of withstanding direct flame impingement up to 2000 °F (1100 °C).

d) They can be satisfactorily applied by most contractors.

Disadvantages of lightweight concrete materials include the following.

a) Porosity which can allow penetration by water (with potential for corrosion (and eventual hydrocarbon leakage).

b) Moisture absorption can lead to cracking and spalling in freezing climates.

c) Maintaining a top coating is often overlooked.

d) Shielding and/or caulking are necessary to prevent moisture or hydrocarbons from penetrating.

e) Lightweight concretes are more susceptible to mechanical damage than dense concrete materials (but can be shielded if mechanical damage is a threat).

6.3.3 Spray-applied Fire Resistive Materials (SFRM)

6.3.3.1 Organic SFRM

Mastics provide fire protection through one or more of the following mechanisms.

a) Subliming mastics absorb large amounts of heat as they change directly from a solid to a gaseous state.

b) Intumescent mastics expand to several times their volume when exposed to heat and form a protective insulating char. This char then serves as a thermal barrier to insulate the steel.

c) Ablative mastics absorb heat as they lose mass through oxidative erosion.

Advantages include the following.

a) They can be speedily applied.

b) They are lighter than cement based products per unit area making them candidates for use on existing equipment supports that may not handle additional weight.

c) Excellent damage resistance.

d) Properly applied, some have excellent bonding, durability and corrosion protection.

e) Product is available which is flexible and tolerates vibration.

f) Certain materials have demonstrated exceptional durability in severe jet-fire tests and hose stream tests.

g) Because they are based on an organic system special characteristics can be designed into the coating.

Disadvantages include the following.

a) Since coat thickness and proper bonding to the substrate are important to satisfactory performance, application techniques as specified by the manufacturer must be rigorously followed to ensure good long-term performance.

b) In all cases it is preferable to use experienced appliers.

c) For some materials use of only vendor-approved application equipment and trained appliers experienced with the specific material are required.

d) Some mastics tend to shrink while drying; specifications should indicate the wet thickness that will yield the required dry thickness.

e) Materials rated for protection with thin coats must be applied skillfully to maintain adequate thickness. To ensure proper thickness, a qualified person should frequently check the applier's work (see 8.4).

f) Some mastics require stringent environmental controls (e.g. temperature and humidity) during application.

g) Substantial QA during application should be considered to monitor quality and to avoid costly rework.

h) Some materials may have to be repaired or replaced after a brief flash fire. (Consultation with the supplier is advisable as some materials are intended only for new construction and require special post-fire repair techniques.)

i) Using hose streams on some products during a fire can knock off part of the protective char or the material itself, thereby reducing the overall effectiveness.

j) For some products there is a possibility of char erosion of the during a fire if subject to impingement by fire hose streams.

k) They require expertise and quality control in application, and may require multiple coats or special equipment which can apply dual components simultaneously.

l) Some manufacturers require certified approved application personnel.

m) Are not suitable for areas which are permanently staffed due to smoke generation during a fire.

n) Some mastics use a flammable solvent requiring appropriate precautions during application to avoid sources of ignition such as operating fired heaters and boilers.

o) Some mastics are less durable than more traditional concrete materials when subjected to mechanical impact and abrasion.

Certain intumescent mastic materials may not be affected by small scratches or chips because the coating can perform some degree of "self-healing" when the coating swells under the heat of a fire. However, the ability of materials to change in volume and density when exposed to heat may also lead to cracking as a result of swelling and shrinking, exposing the protected assembly to fire on edges, sharp curves, or intricate shapes. Fire performance should not be extrapolated from flat surfaces to such shapes. Documented ratings should be obtained for shapes or assemblies similar to the application being specified.

6.3.3.2 Inorganic SFRM

Lightweight Cementitious Fireproofing: A sprayed (or troweled) coating formulated from Portland cement and vermiculite or perlite provides excellent fireproofing insulation.

Advantages include the following.

a) Up to 4 hours in UL 1709 or (functional equivalent tests) with durability in exterior applications.

b) The properties of the vermiculite can allow it to dent rather than crack or shatter on moderate impact.

c) The material is relatively light weight at 45 lbs/ft^3 to 50 lbs/ft^3 (700 kg/m^3 to 800 kg/m^3) with respect to other forms of concrete fire protection.

d) Low material costs.

e) Can use relatively unskilled labor and equipment for application.

f) Can be troweled to give a plastered appearance.

Disadvantages include the following.

a) Does not protect (nor accelerate) steel from corrosion.

b) The primer is compromised by the application of the pins required for the mesh.

c) Typically two coats of finish are required to ensure adequate corrosion protection.

d) Requires continuing maintenance of the top-coat to ensure fire performance and minimize corrosion.

e) Difficult to determine extent of corrosion without destructive testing.

f) Slow drying, mechanical properties and large crew sizes not favorable to offsite application.

6.3.4 Preformed Units or Masonry

6.3.4.1 Preformed Inorganic Panels or Epoxy PFP Molds/Panels

Preformed fire-resistant inorganic panels can be cast or compressed from lightweight aggregate and a cement binder or from compressed inorganic insulating material such as calcium silicate or from epoxy PFP materials. The panels are attached to the substrate by mechanical fasteners designed to withstand fire exposure without appreciable loss of strength. When panels are used outdoors, an external weatherproofing system to prevent moisture penetration is typically required. All joints or penetrations through fireproofing (such as clips or attachments) must be caulked or sealed.

Preformed materials are advantageous because:

a) they can be applied cleanly;

b) they have no curing time;

c) they have low conductivity;

d) improved control of thickness.

Disadvantages of preformed materials are:

a) labor-intensive application when unit instruments and appurtenances are attached to columns;

b) preformed materials are more susceptible than concretes to damage from impact after installation.

Unless specified for fireproofing use, materials sold as pipe insulation might not survive the high temperatures generated in tests incorporating a high rise hydrocarbon curve. The user should ensure the fireproofing system components are fire rated before specifying.

6.3.4.2 Masonry Blocks and Bricks

Masonry blocks of lightweight blast-furnace slag (used as coarse aggregate) are sometimes used. These units are laid up with thin staggered joints not more than $^{1}/_{3}$ in. (8 mm) thick. Joints must be made using fire-resistant mortar.

Brick and block are no longer commonly used because of their high installation cost and fairly extensive maintenance requirements. Brick-and-block assemblies tend to crack and admit moisture, which can lead to serious corrosion and spalling.

6.3.5 Endothermic Wrap Fireproofing

Endothermic materials absorb heat chemically, generally with the concurrent release of water, and physically through heat absorption by the released water. This flexible, tough, inorganic sheet material with a bonded aluminum foil outer layer is formed from a maximum of inorganic highly endothermic filler and a minimum of organic binder and fiber. It can be wrapped around a wide variety of potentially exposed vulnerable equipment. Electrical cable trays are particularly suited for this type of protection, providing rated performance under UL 1709 (or functionally equivalent) conditions. In most applications the wrap is held in place by stainless steel bands with foil tape and/or fireproofing caulk on seams, gaps and termination points. For structural steel in new construction, surface preparation of the substrate should include fresh prime paint to provide corrosion protection.

Advantages include the following.

a) Fire rated wrap systems are easily reentered and repaired, allowing retrofitting over steel without dissembling wiring and other attached items.

b) The wrap material does not catalyze corrosion (nor protect against corrosion).

c) Endothermic wrap systems can be applied directly over existing cement or block where additional protection is required.

d) These systems can be applied directly over other fireproofing, although a reduction in rated system requirements may not be allowed for the existing materials.

e) Flexible endothermic wrap systems are explosion rated.

Disadvantages include the following.

a) When used outdoors where weather proofing is required for the wrapped assembly, the fire protection system must be protected; recommended protection is stainless steel jacketing or wrapping with the manufacturer's specified environmental protection tape.

b) Long term susceptibility to water or moisture ingress.

7 Testing and Rating Fireproofing Materials

Fire-resistant materials used in petroleum or petrochemical facilities should be tested and rated according to procedures that are accepted by the industry as indicating how those materials will perform when subjected to conditions representative of petroleum or petrochemical fires. Hydrocarbon pool fires can reach 2000 °F (1100 °C) shortly after ignition. This recommended practice recommends the use of UL 1709 *Standard for Rapid Rise Fire Tests for Protection Materials for Structural Steel* (or a functional equivalent) as the primary standard representing such a test. Other suitable fire test standards for assessing the performance of materials exposed to a high rise hydrocarbon fire curve are ASTM E1529, ISO TR 834-3 and EN1363-2.

ASTM E119 is no longer recommended as a test procedure for petroleum and petrochemical processing plant applications.

Tests procedures are compared and discussed in Annex B. Additional information is in Annex C (Jet Fire Considerations) and Annex D (Fireproofing Questions and Answers).

8 Installation and Quality Assurance

8.1 General

Fireproofing systems must be applied properly to be successful. A variety of factors are involved which include: the availability of the proper on-specification material, the proper equipment, and qualified personnel to complete the task in accordance with the manufacturer's specifications. For most fireproofing systems the long term success depends on attention to detail during installation.

8.2 Ease of Application

When ease of application reduces the potential for error it will ultimately benefit the cost, durability and effectiveness of the installed fireproofing system.

The following factors impact the ease of installing fireproofing systems.

a) Whether required surface preparation can safely be performed in the area.

b) Availability of experienced appliers to do the job properly and efficiently.

c) Shelf life and handling requirements of the raw materials.

d) Pot life of mixed materials.

e) The ability to use low-velocity spray guns that minimize overspray.

f) The type of thinners, if used (whether water based or containing solvents that could be hazardous or may require special ventilation).

g) Weather conditions (temperature and humidity) required at the time of application.

h) The need and complexity of embedded reinforcement in thick coatings.

i) The need for application of a sealer or top coat to protect fireproofing materials from the weather or plant environment.

j) Cleanup time and cost.

k) Disposal of solvents requiring special handling.

l) Downtime required for installation on existing facilities.

8.3 Fireproofing Installation Considerations

All rated fireproofing systems must be carefully installed to specifications and the manufacturer's requirements. Factors discussed in Section 6.1 regarding ease of application are the first part of an overall set of installation considerations.

In most cases substrate surfaces must be cleaned so that they are free from oil, grease, liquid contaminants, rust, scale, and dust. If a primer is required, it must be compatible with the fireproofing. Specifications to be followed include the specified thickness or number of layers, adequate attachment, and proper caulking, sealing or top-coating of the systems.

Installation of dense concrete can be satisfactorily applied by facility personnel or fireproofing contractors who are familiar with fireproofing work. However, to apply lightweight concrete, mastics, and magnesium oxychloride plasters, the applicators must understand and have experience with the specific materials and their use. If improperly applied the application may lose its bond, deteriorate or fail to perform as expected during a fire.

The following installation considerations apply to fireproofing coatings and wet cementitious materials.

a) Shelf life should be determined and conformance maintained.

b) Materials should be stored on site in accordance with the manufacturer's recommendations (some materials must remain upright in their containers for proper sealing).

c) Some materials are temperature sensitive and cannot tolerate extremes during storage and shipping.

d) Fireproofing materials should be applied directly from their original sealed containers to avoid possible additions to, or changes in, their formulation.

e) Some materials require a controlled curing period to develop full strength and prevent serious cracking in the future.

f) Materials that contain free water require a drying period during which temperatures are above freezing.

g) Applicators must understand that the specified thickness is a dry thickness rather than the wet thickness when the material is applied. Some mastic coatings shrink as much as 30 % when cured.

8.4 Quality Control in Application

Fireproofing practice continues to innovate and utilize high technology (intumescent rigid and flexible epoxies, flexible endothermic wraps, etc.) at the same time traditional lower technology (dense and lightweight concrete) approaches continue to be used.

Satisfactory performance of the fireproofing material over its expected lifetime depends on the user's and the applicator's knowledge of materials and application techniques and on continuing inspection by qualified personnel. Specifically, once a fireproofing system has been chosen, it is imperative that the personnel involved in each phase of the project be familiar with the relevant aspects of the manufacturer's requirements and specifications for that phase. Failure to actively manage the quality of the application can result in time consuming (and expensive) rework.

Attention to the following points will help to ensure that a quality job will be performed.

a) Both the user and the applier should have a detailed knowledge of the characteristics of the fireproofing material along with the application and maintenance techniques that are necessary to achieve the desired degree of fire resistance. Much of this information can be found by reviewing data sheets and manuals provided by the manufacturer, visiting sites where the fireproofing material has been applied, or consulting with previous users of the fireproofing material.

b) Coatings require the following special considerations.

   1) The applier may be required to provide a sample of the finished work so that there is no misunderstanding about the desired texture and smoothness of the finished surface. (This sometimes is done on a piece of representative on-site equipment or structure.)

   2) Qualified personnel familiar with job specifications should monitor items such as mixing, density, substrate preparation, application thickness, installation of imbedded reinforcement and surface finishing in accordance with the demonstration sample, and surface top-coating (if required).

   3) The materials must be applied in accordance with the manufacturer's recommendations for dry thickness. Small variations are significant to the fire resistance of the finished coating when using thin mastic coatings. Such variations are most often found in parts of the structure that are congested or difficult to reach.

   4) The user and the applier should agree concerning the extent of random core sampling necessary to verify coat thickness, proper bonding and lack of voids, and the specific procedures to be used for these evaluations.

The UL Fire Resistance Directory quotes ASTM E605 quality assurance requirements for thickness of sprayed coatings and ASTM E736 for bond strength. Users should consult with suppliers regarding applicable standards and tolerances.

9 Inspection and Maintenance

9.1 Effects of Long-term Exposure

As fireproofing materials age, problems can develop that affect the function of the system or coating and possibly weaken the protected structural supports. Inspection seeks to discover problems in physical property areas discussed in 6.2.2 while maintenance should correct identified problems and maintain scheduled preventive maintenance programs (for instance periodic renewal of top-coat sealers).

Any fireproofing material is subject to degradation over time; however, some applications have been known to fail at a rapid rate. While failure may be caused by materials that are improperly selected, experience shows that in many cases failure resulted from poor application (this reinforces the significance of quality assurance, Section 8).

Cracking or bulging of the surface of the material is an early sign of a problem. If the problem is not corrected, moisture, chemicals, corrosive vapor, or condensation could enter and lead to corrosion of both the substrate and the reinforcement materials.

Weathering or the use of the wrong top coat can cause fireproofing to become permeable to moisture and vapor. This permeability can lead to corrosion and deterioration. The weathering effects of sunlight and chemical atmospheres have been known to affect some coating materials to the extent that they lose a significant amount of their ability to protect.

Loss of bonding to the substrate seriously affects the material’s performance and may be caused by moisture penetration, corrosion, the use of an improper primer on the substrate, or poor preparation of the substrate before the fireproofing is applied.

Fireproofing is sometimes accidentally scraped or knocked off equipment during construction or maintenance.

9.2 Inspection

Periodic inspection and testing maximizes the useful life of the fireproofing system. The manufacturer or applier may be invited to participate in the inspection. An inspection and testing program may include the following steps.

a) Survey coatings for surface cracking, delamination, rust staining, bubbles or bulging.

b) Survey coatings for signs of weathering (color change, powdering, thinning of coat).

c) Selectively remove small sections of fireproofing to examine conditions at the face of the substrate and the surface of reinforcing wire (look for evidence of corrosion). Repair the inspection area.

d) Visually check for the loss of fireproofing materials as a result of mechanical abuse.

e) When the fireproofing material is applied, coat and set aside several pieces of structural steel for periodic fire testing over the expected life of the coating. (This is not necessary with rigid box or flexible containment systems.)

f) Inspect to make sure that the fireproofing hasn’t been removed for maintenance and not replaced.

g) Maintain vigilance during inspections for “things which are different” which might be potential new hazard sources or equipment needing fireproofing. Alert appropriate people for evaluation. See section 9.3.5.

9.3 Maintenance

Timely and consistent maintenance provides assurance that the system is physically in the condition intended.

9.3.1 Hairline Cracking

When more than hairline cracking appears, the openings should be cleaned out and filled with new material according to the manufacturer's instructions.

9.3.2 Substrate Bonding

Loss of bonding to the substrate may be determined by surface bulges or an abnormal sound when the surface is tapped with a light hammer.

9.3.3 Bond Failure

In areas that have evidence of bond failure, fireproofing should be removed and the substrate should be thoroughly cleaned and properly primed before new material is applied.

9.3.4 Top Coating

Particular care needs to be taken with respect to top-coat maintenance for fire protection where no inherent corrosion protection is afforded or where water uptake could be an issue. If top coating of the fireproofing material is required it must be renewed at intervals recommended by the manufacturer. The previously listed inspections should be done before renewal of coating so that defects are not hidden by the coating.

9.3.5 Management of Change (MOC)

Changes in operations, equipment or fireproofing materials can introduce new hazards or affect the risks from identified hazards. Persons responsible for MOC should be informed of potential "change" impacts on fireproofing and a "need to know" by those responsible for fireproofing. Needs should then be re-evaluated (see Figure 1B).

Annex A
(informative)

Definition of Terms Used in this Standard which are in General Use in the Petroleum Industry

A.1
autoignition temperature
Minimum temperature to which a fuel in air must be heated to start self-sustained combustion without a separate ignition source. This means that, should a leak occur on a line containing a petroleum product above its ignition temperature, ignition can occur independent of an ignition source.

A.2
boiling point
The temperature at which the vapor pressure of a liquid equals the surrounding atmospheric pressure. For purposes of defining the boiling point, atmospheric pressure shall be considered to be 14.7 psia (760 mm Hg). For mixtures that do not have a constant boiling point, the 20 percent evaporated point of a distillation performed in accordance with ASTM D86 shall be considered to be the boiling point.

A.3
fire point
The temperature (usually a few degrees above the *flash point)* at which a liquid produces enough vapors to sustain combustion.

A.4
flammable materials
Flammable liquids, hydrocarbon vapors, gases (such as LPG or hydrogen) and other vapors (such as carbon disulfide), with a flash point below 100 °F (37.8 °C).

A.5
flammable range
A range of vapor-to-air ratios within which ignition can occur. The lower flammable limit (LFL) is the minimum vapor-to-air concentration below which ignition cannot occur. Atmospheres below the LFL are referred to as too lean to burn. The upper flammable limit (UFL) is the maximum vapor-to-air concentration above which ignition cannot occur. Atmospheres above the UFL are referred to as too rich to burn. Flammable ranges can vary widely, as illustrated by flammable vapor-to-air ranges for gasoline (1.4 % to 7.6 %) and acetylene (2.5 % to 100 %).

A.6
flash point
The lowest temperature at which a liquid gives off enough vapor to produce a flammable mixture with air immediately above the surface. A source of ignition is needed for flash to occur. When this temperature is above ambient, vapors will ignite but will not continue to burn until heated to the “fire point”. The *Flash Point* temperature can be very low for volatile petroleum products; for instance, the flash point for gasoline is typically quoted as about –45 °F (–43 °C).

A.6.1
flammable liquids
Flammable liquids have flash points below 100 °F (37.8 °C) and vapor pressures not exceeding 40 psia (2068.6 mm Hg) at 100 °F (37.8 °C). Liquids with vapor pressures above 40 psia (276 kPa) at 100 °F (37.8 °C) are considered gases by NFPA.

Class IA – flash point below 73 °F (22.8 °C) and boiling point below 100 °F (37.8 °C)

Class IB – flash point below 73 °F (22.8 °C) and boiling point above 100 °F (37.8 °C)

Class IC – flash point at or above 73 °F (22.8 °C) and below 100 °F (37.8 °C)

A.6.2
combustible liquids

Combustible liquids have flash points at or above 100 °F (37.8 °C)

Class II – flash point at or above 100 °F (37.8 °C) and below 140 °F (60 °C)

Class IIIA – flash point at or above 140 °F (60 °C) and below 200 °F (93 °C)

Class IIIB – flash point at or above 200 °F (93 °C)

OSHA uses NFPA definitions for flammable and combustible. Alternate systems using 140 °F (60 °C) as the dividing point between flammable and combustible appear in ANSI/CMA Z129.1-1994 and the regulations of the U.S. Department of Transportation and the United Nations. The NFPA classification system is used in this document and is widely used for facility-based fire protection purposes in the USA. For regulatory compliance purposes (such as labeling for off-site transportation) reference should be made to the specific regulations or codes governing the activity of concern.

Annex B
(informative)

Testing and Rating Fireproofing Materials

B.1 General

Fire-resistant materials should be tested and rated according to procedures that are accepted by the industry as indicating how the material will perform when it is subjected to a realistic petroleum or petrochemical fire. This document recommends the use of UL 1709 (or functional equivalent) as the primary standard for fireproofing in petroleum and petrochemical plants.

B.2 Rapid Rise Hydrocarbon Pool Fire Tests

Two test procedures designed to simulate hydrocarbon fires have been developed to represent pool fire test conditions. UL 1709, *Standard for Rapid Rise Fire Tests for Protection Materials for Structural Steel* was introduced in 1984 and was approved as an ANSI/UL standard on Feb 27, 1991. ASTM E1529, *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies* was published in July 1993. Both reach 2000 °F within 5 minutes and maintain that temperature for the duration of the test. The primary difference is that UL 1709 subjects the test fireproofing system assembly to a heat flux of 65,000 BTU/ft^2-hr vs. 50,000 BTU/ft^2-hr for ASTM E1529. Determination of that equivalency rests with the user in dialogue with the fireproofing system supplier.

B.3 Standard Testing for Fireproofing of Structural Supports

B.3.1 General

In the past most ratings for fireproofing of structural supports were based the ASTM E119 standard time-temperature curve developed in 1918 to simulate interior structural building fires. This does not correlate with the actual time-temperature and heat flux experienced during a hydrocarbon spill fire, which can rapidly produce a temperature of 2000 °F (1100 °C) shortly after ignition. ASTM E119 is not recommended as a test procedure for petroleum and petrochemical processing plant applications. UL 1709 is the current recommended standard.

B.3.2 UL 1709, *Standard for Rapid Rise Fire Tests for Protection Materials for Structural Steel*

Underwriters Laboratories in 1984 adopted the first high temperature rise test that simulated hydrocarbon pool fire conditions. It subjects a protected steel column to a heat flux that produces a temperature of 2000 °F (1093 °C) in 5 minutes. After that time, the furnace temperature is held constant for the remainder of the test. The test is terminated when the average temperature of the steel substrate reaches 1000 °F (538 °C). This standardized test was developed in conjunction with the oil industry. The more severe regime is considered significant not only because thicker protective coatings may be necessary, but also because the behavior of some materials may be significantly poorer under the hydrocarbon fire conditions which subject the test material to substantially higher heat flux. UL 1709 (or functional equivalent) is recommended as a standard test for evaluating fireproofing systems for petroleum and petrochemical processing plants.

B.3.3 ASTM E1529, *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*

This test method is used to determine the response of structural components and assemblies used in the hydrocarbon processing industries when exposed to conditions representative of large free-burning exterior liquid hydrocarbon pool fires. Temperatures and rate of temperature rise are essentially the same as UL 1709. The heat flux is higher of UL 1709 heat flux is about 30 percent higher than ASTM E1529. This test procedure evaluates materials intended for outdoor use and recommends an included set of accelerated weathering and aging tests. The appendices to ASTM E1529 provide an informative commentary on test methods, heat flux and pool fires. The analysis of “reasonably worst case” describes the history and rationale for choosing 50,000 BTU/ft^2-hr (158 kW/m^2). Some companies judge test results from ASTM E 1529 to be “functionally equivalent” to those from UL 1709.

B.3.4 ASTM E1725, *Standard Test Methods for Fire Tests of Fire-Resistive Barrier Systems for Electrical System Components*

ASTM E1725-95 is designed to measure and describe the response of materials, products or assemblies to heat and flame under controlled conditions. It can be run using either ASTM E119 or ASTM E1529 temperature curve conditions. For use in petroleum and petrochemical processing plants the ASTM E1529 “pool fire” conditions should be specified. The test measures the time for the electrical system component to reach an average temperature 250 °F (139 °C) above the initial temperature.

B.3.5 UL 2196, *Standard for Tests of Fire Resistive Cables*

UL 2196 has two alternate temperature curves for testing: “normal temperature rise” uses the same temperature curve as UL 263 (ASTM E119); the “rapid temperature rise curve” coincides with UL 1709 (and ASTM E1529). For use in petroleum and petrochemical processing plants the “rapid temperature rise curve” should be specified.

B.3.6 ASTM E119, *Method for Fire Tests of Building Construction and Materials*

ASTM E119 describes procedures for testing structural components for buildings where the primary fuel is solid in nature. This does not correlate well with either the actual time-temperature or the heat flux experienced during a hydrocarbon spill fire. ASTM E119 is not recommended as a test procedure for petroleum and petrochemical processing plants. (Note that ANSI A2.1, NFPA 251 and UL 263 are essentially the same tests.)

B.4 Summary of Other Tests Related To Fireproofing

Performance characteristics other than resistance to heat penetration can be important to the satisfactory performance of fireproofing materials during their anticipated life span. Section 6.2 lists properties of fireproofing materials. The following list references tests used in manufacturer’s technical literature to characterize non-fire performance.

B.4.1 Reference Tests

ASTM E605, *Standard Test Methods for Thickness and Density of Sprayed Fire Resistive Material Applied to Structural Members*

ASTM E736, *Standard Test Methods for Cohesion/Adhesion of Sprayed Fire Resistive Material Applied to Structural Members*

ASTM E759, *Effect of Deflection on Sprayed-on Fire Resistive Material Applied to Structural Members*

ASTM E760, *Effect of Impact on Bonding of Sprayed-on Fire Resistive Material Applied to Structural Members*

ASTM E761, *Compressive Strength of Sprayed-on Fire Resistive Material Applied to Structural Members*

ASTM E859, *Air-Erosion of Sprayed-on Fire Resistive Material Applied to Structural Members*

ASTM E937, *Corrosion of Steel by Sprayed Fire Resistive Material Applied to Structural Members*

ASTM G21, *Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi*

B.4.2 Interpreting results from ASTM E84, *Method of Test for Surface Burning Characteristics of Building Materials*

The ratings from ASTM E84 are indices based on the flame spread or smoke development in a 10 minute "Steiner Tunnel" test. Both tests originally were based on the performance of red oak with an index of "100" and the ratings as percent of red oak performance. The Flame Spread Index is now an arbitrary rating while the "smoke developed" test still is based on percent of red oak as the standard with a rating of 100.

Annex C
(informative)

Jet Fire Considerations

C.1 General

While all jet fires are pressure fires, not all pressure fires are jet fires. A key differentiating characteristic is that jet fires are “directional”. The orientation of the jet is highly variable and is dependent on the location and geometry of the leak path. This challenges development of a simple jet fire scenario. This Annex provides background material for consideration and provides references to an extensive body of research.

C.2 What Do We Know About Jet Fires?

Since the tragic Piper Alpha incident [1] on July 6, 1988 with 167 fatalities there has been much study of jet fires. Piper Alpha is one of the cases where a jet fire had major impact, but where the jet fire was not the initial fire incident. Because of the human impact of Piper Alpha and large economic losses, a major body of work has accumulated. Although based on off-shore facilities, much of the work characterizing jet fires is relevant for onshore facilities. The following quote from a UK HSE document describes the significance of jet fires on offshore oil platforms in the first paragraph while the second paragraph describes factors in the challenge to define a “standard” scenario.

“Jet fires represent a significant element of the risk associated with major accidents on offshore installations. The high heat fluxes to impinged or engulfed objects can lead to structural failure or vessel/pipework failure and possible further escalation. The rapid development of a jet fire has important consequences for control and isolation strategies.”

“The properties of jet fires depend on the fuel composition, release conditions, release rate, release geometry, direction and ambient wind conditions. Low velocity two-phase releases of condensate material can produce lazy, wind affected buoyant, sooty and highly radiative flames similar to pool fires. Sonic releases of natural gas can produce relatively high velocity fires that are much less buoyant, less sooty and hence less radiative.” [2]

C.3 Pool Fires vs Jet Fires

C.3.1 Pool Fires

The nature of pool fires is reasonably predictable: they form on horizontal surfaces (typically the ground) and radiate heat both up and out. They are single phase, not pressurized, and the affected “envelope” boundaries can be reasonably defined or calculated [3, 4, 5]. With knowledge of characteristics and inventories of potential fuel a general pool fire scenario can be developed for a facility.

C.3.2 Jet Fires

The nature and circumstances associated with jet fires makes a scenario-development process comparable to pool fires very difficult. Significant differences are: jet fires are pressure fed, are typically elevated above ground level, are randomly directional, can create immediate localized heat flux, and vary in length and duration. They are highly dependent on many factors, including release source (hole size and configuration), fuel inventory, pressure, temperature, wind, obstacles in the jet plume path, and phase of the fuel as it is released. Jet fires transfer heat by radiation, convection, and conduction. By their nature jet fires can be erosive to the materials they impinge.

C.4 Studies Conducted

After Piper Alpha, government agencies, industry, and research organizations studied multiple facets of the jet fire phenomenon. Most of this work was done in Europe, especially by those having safety responsibilities for off-shore oil exploration and production in the North Sea. Much of this multiparty cooperative work was under the aegis of the UK Health & Safety Executive (HSE). Several dozen jet-fire related research reports are posted on the HSE web site. Reference 2 summarizes the review strategy and cites 76 references for research on related subjects sponsored by the HSE, industry and academia.

Fireproofing criteria for offshore modules is based primarily on life safety considerations whereas for on-shore petroleum or petrochemical facilities the basis is property protection since there are typically no barriers to safe egress from the fire area.

C.5 Background Knowledge: Jet Fire Hazards Research

The hazards, characteristics and physical properties of hydrocarbon jet fires are appraised in the Phase 1 reports of the Joint Industry Project on 'Blast and Fire Engineering of Topside Structures'. These scholarly works provide insight into the world of fire research and characterization. References 3, 4, and 5 are comprehensive reports which can be downloaded from the indicated UK HSE web sites.

C.6 Jet Fire Computer Modeling

Substantial research has focused on development of CFD (computational fluid dynamics) programs for predicting various fire effects and comparison with semi-empirical models. CFD fire modeling programs help quantify exposure heat loads using a defined scenario. Although powerful, each program requires the scenario definition as input data before CFD computations are made [6]. CFD modeling is complex, less frequently used compared to other modeling methods, has extensive data input requirements, requires users with advanced experience and may have long processing times.

For non-CFD models care should be taken to understand the jet fire algorithms used. While for vertical jet orientations there is significant correlation of calculated jet fire data to actual jet fires, this correlation diminishes significantly when the jet fire is oriented horizontally. The horizontal jet fire phenomenon of “flame lift off” may not be represented in non-CFD models. (Flame lift off in a horizontal jet fire is the point where flame temperature gains control over the momentum of the release and the flame stops extending horizontally and starts extending vertically.) Thus for a horizontal release the actual flame shape may actually look like a sideways “L”. Many non-CFD models simply extend the flame horizontally (representing the length of both legs of the “L” shape) which can give a result reaching substantially farther than in reality. Care should be taken to fully understand each model under consideration and the phenomena being represented.

C.7 Jet Fire Fireproofing Tests

One major thrust of the HSE/industry cooperative research was to develop jet fire test procedures to define the performance of PFP (passive fire protection) materials. Small, medium and large scale tests were developed which are considered to provide internally consistent PFP performance results. The research achieved the goal of developing usable tests of PFP. The small scale “JFRT” (*Jet Fire Resistance Test)* correlated satisfactorily with the larger scale tests and is widely used. [7] Variants of this test are used and accepted as meaningful. An even smaller scale specialized jet fire test procedure is in NFPA 290: *Standard for Fire Testing of Passive Protection Materials for Use on LP-Gas Containers*, 2009 Edition [8]. ISO 22899-1 *“Determination of the resistance to jet fires of passive fire protection materials”* is an international medium scale jet fire standard based on the OTI 95 634 jet fire test; it is generally accepted as the preferred jet fire test. Although jet fire tests provide useful tools for evaluating potential consequences and fireproofing effectiveness, they shed no light on scenario definition of actual real world jet fires.

C.8 Available Options To Address Jet Fires

Addressing potential jet fires presents three options: prevention, intervention and protection. As in all safety considerations, prevention has the highest priority in the hierarchy of controls.

C.9 Prevention

Guidance for jet fire prevention parallels general fire prevention activities such as those included in API 2001, *Fire Protection in Refineries*, equipment inspection programs outlined in numerous API (and other) documents and in the broad application of PSM (Process Safety Management). Analysis of historical incidents may help facilities identify and address areas of potential vulnerability such as: deadlegs; freeze vulnerability, vibration susceptible, or traffic-exposed process piping; or corrosion under insulation. Effective prevention includes integrating knowledge of past events into surveillance, recognition and correction of identified concerns (e.g. PRV vent piping directed toward a vessel or other structure).

C.10 Intervention and Active Protection

Once a potential pressurized fuel is released and ignited there may be an opportunity to avoid or reduce jet fire consequences. Jet fire intensity (and thus amount of heat transferred) depends on pressure and flow rate (aperture size) while duration depends on the inventory available to release. Intervention includes cooling (firewater application on the impinged surface—not direct attack on the jet flame), pressure reduction (emergency depressuring), and stopping fuel flow (automatic or manual isolation).

Use of firewater can mitigate the impact of jet fires. A high flow-rate firewater stream directed on the point of impingement has been shown to be effective in preventing escalation with jet fires. [9] API 2510A uses an example flow rate of 250 to 500 gpm at the point of impingement. Active systems such as fixed water spray system can provide protection from radiant heat but may not help at the point of impingement. Extinguishing jet fires using firewater is discouraged due to risk or re-ignition. Personnel responding in emergencies should be aware of the potential for rapid incident escalation resulting from jet fire exposures and have contingency plans prepared. Example impingement exposures with the potential for escalation include pressure vessels and supports for piping or equipment.

C.11 Passive Protection

Passive protection includes good equipment layout and practical use of fireproofing. Many fireproofing materials have inherent torch (jet) fire resistance although they may not be rated as such. For example, concrete has been used as a fireproofing material for well over 50 years and has demonstrated very good protection in real fires (some of which include jet fires), Some fireproofing materials can be specified to have a jet fire rating based on live fire tests such as those mentioned above.

C.12 Conclusion

Many processing facilities hold the potential for a jet fire. Although difficult, the capability exists to model jet fires. This requires scenario definition which is subject to many variables. This modeling is resource intensive, with questionable validity for some models with certain jet fire types (particularly those that are not vertical). Fireproofing systems for this very specialized application can be engineered, but an attempt to extend such fireproofing systems plant-wide is impractical and could introduce other hazards (such as corrosion). Experience has shown that a combination of design practices, maintenance, operating procedures and inspection help prevent all fires, including jet fires. Mitigation measures such as active and passive fire protection have been effective in reducing fire damage consequences, including for jet fires.

For this historical reason, liquid pool fire exposures remain the basis for defining structural fireproofing in this API standard.

Where jet fires are a concern a Fire Hazard Analysis should evaluate potential release sites, associated hazards and risks and consider needs. Scenario definition responsibility remains with the facility owner/operator [10]. Emphasis should remain on:

prevention, appropriate use of active protection for important systems where jet fires are possible (even though specific scenarios remain undefined), and passive fireproofing for both pool fires (using a scenario approach such as outlined in this standard) and jet fires based on a Fire Hazard Analysis

The results of the Fire Hazard Analysis may identify jet fire scenarios [14] which require more protective fireproofing radii for pipe rack support steel near process units containing highly pressurized flammables, and/or other measures such as emergency isolation valves and depressuring systems. [15, 16] Where identified these needs should be prioritized and integrated into the facility's fire protection program.

C.13 Annex C References [many are available on-line at the indicated URLs]

[1] Piper Alpha Case History, *Building Process Safety Culture: Tools to Enhance Process Safety Performance.* http://www.aiche.org/uploadedFiles/CCPS/Resources/KnowledgeBase/Piper_Alpha.pdf

[2] *HSE Strategy - Jet Fires,* posted at http://www.hse.gov.uk/offshore/strategy/jet.htm. Summarizing the HSE jet fire review strategy citing 76 references for research on related subjects sponsored by the UK Health & Safety Executive (HSE), industry and academia.

[3] OTI 92 596, "Oil & Gas Fires: Characteristics and Impact" (173 references). This discusses research work and describes some of the quantitative information required (from scenarios) to proceed with studies. http://www.hse.gov.uk/research/otipdf/oti92596.pdf

[4] OTI 92 597, *"Behaviour of Oil and Gas Fires in the Presence of Confinement and Obstacles"* (87 references), http://www.hse.gov.uk/research/otipdf/oti92597.pdf

[5] OTI 92 598, "*Current Fire Research: Experimental, Theoretical and Predictive Modelling Resources"* (54 references). http://www.hse.gov.uk/research/otipdf/oti92598ai.pdf

[6] OTO 1999/011, *CFD calculation of impinging gas jet flames.* http://www.hse.gov.uk/research/otohtm/1999/oto99011.htm

[7] OTI 95 634, *Jet Fire Resistance Test of Passive Fire Protection Materials.* http://www.hse.gov.uk/research/otipdf/oti95634.pdf

[8] NFPA 290, *Standard for Fire Testing of Passive Protection Materials for Use on LP-Gas Containers*, 2009 Edition. http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=290

[9] *Offshore Technology Report*, OTO 2000 051, "Review of the Response of Pressurised Process Vessels and Equipment to Fire Attack", Date of Issue: June 2000 Project: DATA. *http://www.hse.gov.uk/research/otopdf/2000/oto00051.pdf*

[10] HSE OTI 92 586, "Representative Range of Blast and Fire Scenarios". *http://www.hse.gov.uk/research/otipdf/oti92586.pdf*

[11] OTC 14132, *Controlling Hydrocarbon Fires in Offshore Structures*, G. A. Chamberlain, Shell Global Solutions (this paper was prepared for presentation at the 2002 Offshore Technology Conference held in Houston, Texas U.S.A., 6 to 9 May 2002) (44 references).

[12] "An Overview of the Nature of Hydrocarbon Jet Fire Hazards in the Oil and Gas Industry and a Simplified Approach to Assessing the Hazards", B. J. Lowesmith (Loughborough University, Loughborough, UK), G. Hankinson (Advantica Limited [formerly British Gas Research and Development], Loughborough, UK), M.R. Acton, and G. Chamberlain (Shell Global Solutions, Chester, UK), Transactions of the IChemE, Part B, Process Safety and Environmental Protection, 2007, 85(B3) 207-220. Also *Process Safety and Environmental Protection*, May 2007, Copyright © 2007, The Institution of Chemical Engineers Published by Elsevier B.V.

[14] HSE Research Report 285, *Protection of piping systems subject to fires and explosions.* http://www.hse.gov.uk/research/rrpdf/rr285.pdf

[15] U.S. Chemical Safety Board Investigation Report, July 9, 2008, *Valero Refinery Propane Fire*. http://www.csb.gov/assets/document/CSBFinalReportValeroSunray.pdf

[16] U.S. Chemical Safety Board video, *Fire From Ice*. http://www.csb.gov/videoroom/detail.aspx?vid=4&F=0&CID=1&pg=1&F_All=y

[17] ISO 22899-1, "Determination of the resistance to jet fires of passive fire protection materials".

Annex D
(informative)

Fireproofing Questions and Answers

The material included in this section is provided as a service to the user of this document. While believed to be useful, it has not been subjected to rigorous technical review. It contains generalizations, “rules of thumb”, historical sharing of individual experience and suggestions for further research on the subject of fireproofing. The reader is advised to ensure that the information is accurate and appropriate to the intended application before use. It is organized in sections which generally parallel the main text of this recommended practice.

Section 1—Introduction

Question: Are there forms of Passive Fire Protection other than Fireproofing?

Answer: Any form of fire protection is *passive* if it functions without intervention which requires energy [human or mechanical]. Separation distances, spacing, drainage and spill control systems (for instance, as described in NFPA 30) fire-resistant construction, thermal insulation and fire barriers all can be forms of passive fire protection.

Question: Why is fireproofing research so active in the European Community?

Answer: On July 6, 1988 a fire on the Piper Alpha off-shore North Sea oil platform resulted in 167 fatalities. Fireproofing was cited as an area of concern and a potential contributing cause of escalation (although not a primary cause of the incident). Government regulation followed, accompanied by joint industry and government research which included fireproofing.

Question: What is the allowable heat flux exposure for humans?

Answer 1: Radiant heat levels up to 2500 BTU/hr-ft^2 (7.9 kW/m^2) may be tolerated for 5 to 15 seconds if the only concern is short-time exposure of personnel to permit escape from the area under emergency release conditions.

Source: CCPS Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires and BLEVEs – p 181, Table 6.5, Table 6.6, and Figure 6.10.

Answer 2: The EPA in *RMP Offsite Consequence Analysis Guidance* for “Worst Case Scenarios” uses 5 kW/m^2 (1582 BTU/hr-ft^2) for 40 seconds as a level of exposure which will cause second degree burns.

Answer 3: A study for the UK HSE (HSL/2004/04 *Human Vulnerability to Thermal Radiation Offshore)* puts radiation into context stating that 2 kW/m^{2}corresponds to strong sunlight while the exposure time to 2nd degree burns can be as low as 10 seconds for a 10 kW/m^{2}heat flux.

Section 2—General

Question: What is the general goal of structural fireproofing?

Answer: The goal is to prevent structures or equipment from collapsing or failing. Typically, fire proofing is designed to protect structural steel supporting high risk or valuable equipment from reaching 1000 °F for a period of 2 to 4 hours (depending upon the fire scenario). Allowable temperature for other equipment may be much lower (e.g. wiring).

Question: Is fireproofing in accordance with API 2218 intended only for new facilities or when making major modifications?

Answer: Conducting a risk/needs analysis to decide where fireproofing is needed is good practice for existing facilities as well as new or modified plant. In many cases fireproofing can be retrofit or risk exposures reduced.

Question: Is a Fire Hazard Analysis (FHA) the same as a Process Hazards Analysis (PHA)?

Answer No—although related they have different goals, need different skill sets, anddifferent people. The FHA is a performance-based voluntary review. The PHA includes" process safety" regulatory aspects and may not include fire protection and emergency response.

Question: Is 1000 °F a satisfactory operating temperature for steel?

Answer: 1000 °F is used as the failure point in standard tests, not a "safe" operating temperature. Section 4.2.6 shows that a typical structural steel drops to ½ of its strength by 1000 °F. Significant losses of strength occur as low as 410 °C to 440 °C (770 °F to 824 °F). The significance of temperature in real fire exposure situations relates to many factors, including the safety margins built into the structure during the design phase.

Question: What is the most important aspect in planning for fireproofing?

Answer: Understanding potential fire exposures in developing a fire scenario envelope.

Question: How can topography (drainage) affect fireproofing needs?

Answer: Ground configuration (topography) and engineering design which "drains away" spilled product (a potential fire) away from equipment removes exposure and thus diminishes the need for fireproofing. Some companies do a drainage pattern study as part of their initial hazard evaluation. They find In some instances the most cost effective approach is drainage improvement which eliminates or greatly reduces the need to fireproof.

Question: What is the difference in heating value among hydrocarbon fuels?

Answer: For pure hydrocarbons the heating values per pound is within a relatively small range for materials from methane (23,850 BTU/lb) to dodecane (21,300 BTU/lb). Alcohols are substantially lower in heat content. Other significant properties are specific heat, latent heat of evaporation, specific gravity and volatility which combine to determine the rate at which fuels will evaporate and be available to burn.

Question: How hot are flames from a liquid hydrocarbon pool fire?

Answer: Underwriters Laboratories and ASTM both chose 2000 °F (1093 °C) as representative of hydrocarbon fire exposure. The commentary on pool fires in appendices to ASTM E1529 cites core temperatures from a variety of reports in the range from 1600 °F to 2000 °F (870 °C to 1100 °C). Other studies of 30 and 50 meter pan tests of kerosene measured <u>maximum</u> flame temperatures of 1380 °C [2520 °F].

Question: How rapidly will a pool fire burn?

Answer: Historically used values based on experience use a burning rate of 6 to 12 inches per hour for gasoline and 5 to 8 inches per hour for kerosene from pool fires in depth. Thin layers of fuel burn faster because the radiant heat from the flames evaporates fuel from the pool faster.

Question: How big a pool will a given spill make?

Answer 1: For burning pools, a Bureau of Mines study cited in the NFPA Fire Protection Handbook 17th edition, page 3-51 concludes that a fire from a flowing spill will reach an equilibrium area of about 8 square ft per gpm for liquid petroleum burning at the rate of 1 foot per hour. For example, a 100 gpm spill would have an equilibrium pool fire area of about 800 square ft. Faster burning materials will cover smaller areas and slower materials will cover larger areas.

Answer 2: For non-burning situations, the EPA in *RMP Offsite Consequence Analysis Guidance* for "Worst Case Scenarios" assumes that an unconstrained liquid spill onto a non-absorbing surface will form a pool 1 cm (0.39 in) deep; based on this assumption each gallon (231 square in.) of spilled material would cover about 4 square ft.

Answer 3: FM Global Property Loss Prevention Data Sheet 7-88 March 2009 "Flammable Liquid Storage Tanks" assumes an unconstrained fuel spill on a non-absorbent surface will be about $^{1}/_{16}$ inch deep. On this basis each gallon of spilled material will cover about 25 square ft. FM also expect that a fire of such a shallow spill would be of short duration (burning at 7 minutes/inch of fuel depth).

Question: How high will a pool fire burn?

Answer 1: The CCPS book, *Guidelines for Safe Automation of Chemical Processes*, provides the following estimate for VCM (which has physical properties similar to propane or butane): residual liquid from a flashing release forms a pool which may ignite and burn with a flame height that is two or three times the width of the pool.

Answer 2: For flowing kerosine, FM Global Property Loss Prevention Data Sheets 7-88 cites flame height 2.5 to 4 times the pool diameter.

Question: Are U.S. Government resources available for Hazard Analysis?

Answer: Yes—with the caveat that since these programs are intended for environmental planning they treat all assumptions at the most conservative (protective) end of a range. They intentionally err toward overestimating consequences in making a "worst case" analysis.

The *Handbook of Chemical Hazards Analysis Procedures* ("Brown Book"), published by FEMA, EPA, and DOT, addresses hazards analysis and introduces the Automated Resource for Chemical Hazard (ARCHIE) computer software package. More specifically, chapters 10 and 11 offer extensive information to aid you in assessing rail, highway, water. and pipeline transportation. You can order a free copy of the Brown Book at: http://www.fema.gov/library/viewRecord.do?id=1700 [FEMA's website, Sept 2010] requesting *Handbook of Chemical Hazard Analysis Procedures (with ARCHIE software).*

ARCHIE: Automated Resource for Chemical Hazard Incident Evaluation

ARCHIE is described as: performing release rate, pool evaporation, neutral and dense gas dispersion, pool fire, jet fire, fireball, BLEVE, and vapor cloud explosion calculations. ARCHIE uses simple methods. The user must provide chemical data (no chemical database) but little or no modeling experience is required.

Section 3—Fireproofing Materials

Question: What is an example of "functionally equivalent performance" for fireproofing materials.

Answer: For fireproofing materials "functionally equivalent performance" could be the ability to perform the fire protection function (of preventing substrate failure) under the specific fire scenario conditions in a manner equivalent to alternatives under those same conditions. For instance, under lower heat flux or shorter times exposures a thick and thin coating may both provide sufficient protection to prevent failure, even though the substrate temperatures may differ.

For hydrocarbon pool fires UL 1709 is the standard cited by API 2218 while ASME E1529, ISO 8-34-3 and EN 1363-2 are considered by many as functionally equivalent.

Question: What is a typical composition for dense concrete?

Answer: The following mixes are commonly used for dense concrete:

<u>Formed concrete</u> made of I part cement, $2^1/2$ parts sand, and $2^1/2$ parts gravel that passes through a $^3/8$-in. (9.5-mm) sieve. Water should not exceed 6 gallons per cubic foot of cement (802 liters per cubic meter of cement).

<u>Pneumatically applied concrete</u> made of I part cement and 4 parts sand. Water should not exceed 6 gallons per cubic foot of cement (800 liters per cubic meter of cement).

Question: What is typical reinforcement for dense concrete?

Answer: Dense concretes can be formed in place or pneumatically sprayed to the required thickness using steel reinforcement such as galvanized, electrically welded 14 U.S. gauge steel mesh with openings of 2 in. by 2 in. (50 mm by 50 mm) usually spaced to be at the midpoint of the concrete layer.

Question: What types of reinforcement is needed for other fireproofing?

Answer: Because fireproofing is considered a "system" the reinforcement required depends on the fireproofing material being used and the manufacturer's specifications. Examples are: galvanized metal lath, wire mesh, specially coated wire mesh, glass fiber ribbon and proprietary hexagonal mesh.

Question: What level of protection can be expected from dense concrete?

Answer: API 2510A cites 2 in. of reinforced or poured-in-place concrete as being satisfactory for steel supports of LPG vessels & piping. This is consistent with GAP 2.5.1

One company uses the following "rules of thumb" for level of protection:

2 in. of dense concrete = 3 hr ASTM E119 rating or 2 hr UL 1709 protection.

$2^1/2$ in. of dense concrete is approximately a 3 hr UL 1709 rating.

3 in. of dense concrete is approximately a 4 hr UL 1709 rating.

Question: Do reinforced high-strength concrete structures need fireproofing?

Answer: Work evaluating the effect of hydrocarbon fires on high-strength concrete (NIST Special Publication 919) indicated that (relative to low and medium strength concrete) high strength concrete is more vulnerable to loss of compressive strength as a result of fire exposure. Results showed that even when post fire-spalling was minor that reduction in strength could be severe. Beams with passive fire protection (LightCem LC5) showed no loss of strength and no spalling.

Question: What is a typical composition for lightweight concrete?

Answer: The following range of mixes of cement and lightweight aggregate is cited for lightweight concrete: I part volume cement with 4 to 8 parts by volume of vermiculite.

Question: What is a typical composition for fire-resistant mortar?

Answer: Fire-resistant mortar might be made of a mixture such as I part lime, 4 parts Portland cement, and 12 parts perlite.

Section 4—Testing and Rating Fireproofing Materials

Question: Why is heat flux used as a fireproofing test parameter when the temperature regime is specified?

Answer: Heat flux more accurately defines the amount of heat stress being placed on a fireproofing system. As the quantity of material burning increases heat transfer to the receiver goes up because the size of the emitter increases, even though the temperature differential remains the same. Temperature is comparable to pressure while heat flux relates to flow.

Question: How do I convert between conventional and SI heat flux units?

Answer: 1.00 kW/m^2 = 317 BTU/hr/ft^2; 1000 BTU/hr/ft^2 = 3.16 kW/m^2

Question: What is the difference in performance of the same fireproofing system in different tests?

Answer 1: Standardized fire testing is time consuming and expensive. Published data comparing various standardized tests is still hard to find. An extensive body of data exists using building-oriented tests (such as ASTM E119).

Fire ratings for the same fireproofing system tested in E119 typically show significantly more hours of protection than in UL 1709. One petroleum company uses a “rule of thumb” equivalence that an ASTM E119 4 hr rating roughly equals a UL 1709 3 hr rating. Another used a rule of thumb that if only E119 data was available they would consider that it would only last half as long under hydrocarbon fire exposure.

Answer 2: Based on another petroleum company’s testing done for North Sea platforms there was a very wide range of difference in comparative test results depending upon the fireproofing material, the actual member being protected and the time rating desired. In general, the UL1709 rating for the same identical configuration was from 85 % to 50 % of the E119 rating.

Answer 3: Global Asset Protection Services GAP.2.5.1, *Fireproofing for Hydrocarbon Fire Exposures* December 1, 2006 has an extensive discussion of correlation between ASTM E119 And UL 1709. Their position is “Use fireproofing tested in accordance with UL 1709 for hydrocarbon fire exposures”

Answer 4: It is not recommended to extrapolate pool fire performance from E119 ratings to UL 1709. Extrapolation to jet fire conditions from non-jet fire tests is considered not valid.

Question: Why did ASTM E1529 choose a lower heat flux than UL 1709?

Answer: The appendices to ASTM E1529 provide an informative commentary on test methods, heat flux and pool fires. Their analysis of "reasonably worst case" describes the history and rationale for choosing 50,000 BTU/ft^2-hr (158 kW/m^2). It is reported that an earlier industry test called the "pit test" provided background for development of ASTM E1529.

Question: How is heat flux measured and controlled?

Answer: Section 4 of UL 1709 specifies furnace calibration using a test assembly fitted with 100,000 BTU/ft^2-hr, 180° view angle water-cooled calorimeters. Test conditions including combustion gas oxygen content are established and maintained during tests (without calorimeters being used).

Question: What is an example of "functionally equivalent performance" for fireproofing test procedures?

Answer: For fireproofing test procedures, functionally equivalent performance could be the ability to predict the "real world" fire protection function (preventing substrate failure) under specific fire scenario conditions in a manner equivalent to results from an alternative test procedure. For instance, for a given fireproofing system (same material, thickness etc.) tests which use comparable temperature rise and exposure with different heat flux may both predict functionally equivalent field performance (preventing failure) depending on the scenario conditions, time of exposure and relevance of the test conditions to the "real world".

Question: What fireproofing test procedures are used for "jet fires"?

Answer 1: ISO 22899 is generally accepted as the standard procedure for "jet fires". This is technically equivalent to OTI 95-634 (UK HSE) which is an indicative test designed to test the resistance of materials to jet fires applied to tubular sections and structural members. Other proprietary tests are conducted on flat panels, corrugated wall elements, simulated valve tubular, penetration seal panel, and GRE pipe spools with flowing water. In many cases these tests do not yet have a formal non-proprietary standard but are tested "as is" and witnessed by an "approving authority". NFPA-58 and NFPA 290 describe a flat panel protocol for a "torch fire".

Answer 2: ISO 22899 is the only current jet fire standard which is globally recognized and is a complementary standard to ISO TR 834/pr EN13381-8 (EN1363-2). The test set-up is technically equivalent to OTI95 634. The test is designed to evaluate the resistance of materials to a specific jet fire configuration when applied to tubular sections and flange edges. The section size of the tubular (0.39 A/P) and flange edges (1.34 W/D) are compared with the same section sizes tested in the hydrocarbon pool fire and the erosion thickness calculated as the difference in thickness required to meet the same fire duration.

Question: How severe are "jet fires" fireproofing test procedures?

Answer: Results from proprietary tests show exposure of the test specimen to a jet flow emanating at sonic velocity from a nozzle with impingement velocity of about 130 ft/sec. Flame temperatures are up to1400 °C (2500 °F). Heat flux is up to 320 kW/m^2 (100,000 BTU/hr/ft^2). Other tests may use different conditions. In all cases the test challenges both the ability of the test specimen to withstand erosion of the fire protection caused by high speed gas flow as well as the heat flux.

Section 5—Installation and Quality Assurance

Question: What is the most important aspect in installing fireproofing?

Answer: Fully understanding and following all of detailed requirements in the manufacturer's instructions for handling the received fireproofing material, surface preparation, proper mixing in the proper equipment, application exactly as specified using manufacturer approved equipment and approved or trained applier personnel if specified.

Question: Does the entire surface of horizontal beams need to be fireproofed to protect against a ground fire?

Answer: Opinions vary based on scenario. For the upper most beams on the perimeter of the envelope the top side may be uncoated because pipes have to rest and slide across. Thus fireproofing may not be specified for the top flange of beams where a fire scenario exposure is heat radiation (not flame contact) from a fire below the beam. Note that unfireproofed metal can conduct heat into a fireproofed portion. The interface of fireproofing and an uncoated beam must be rigorously sealed to prevent water incursion under the fireproofing. Fireproofing experts recommend that only fire engineered solutions should allow for not fireproofing all sides of the beams.

Bibliography

This Bibliography has informative references which may be of interest to the users of this standard.

Note to users: while some of the references in this Bibliography address subjects outside the Scope of API 2218 they may be of use for readers concerned with facilities which are not petroleum or petrochemical processing plants.

General

API Recommended Practice 2001, *Fire Protection in Refineries*

API Recommended Practice 2030, *Application of Fixed Water Spray System for Fire Protection in the Petroleum Industry*

API Standard 2510, *Design and Construction of LPG Installations*

API Recommended Practice 2510, *A Fire Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities*

API Standard 521, *Pressure-Relieving and Depressuring Systems*

ASTM E1529 [1], *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*

ASTM E1725, *Standard Test Methods for Fire Tests of Fire-Resistive Barrier Systems for Electrical System Components*

ASTM E2226-10, *Standard Practice for Application of Hose Stream*

Department of Commerce, NISTIR 6381 1999 [2], *A Global Model for Predicting the Burning Rates of Liquid Pool Fires*

FM Global Property Loss Prevention Data Sheet 7-88 [3], *Flammable Liquid Storage Tanks*, March 2009

NFPA 15 [4], *Standard for Water Spray Fixed Systems for Fire Protection*, 2007

NFPA 30, *Flammable & Combustible Liquids Code*, 2008

NFPA 58, *Liquid Petroleum Gas Code*, 2008

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*

NFPA 290, *Standard for Fire Testing of Passive Protection Materials for Use on LPGas Containers*, 2009 Edition

OSHA 1910.119 [5], *Process Safety Management of Highly Hazardous Chemicals*

---

1 ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
2 U.S. Department of Commerce, 1401 Constitution Ave., NW, Washington, D.C. 20230, www.commerce.gov.
3 Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, Massachusetts 02062, www.fmglobal.com.
4 National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.
5 U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov.

Fireproofing Related Standards & Guidelines (US, EN, ISO)

API Recommended Practice 14G, *Fire Prevention and Control on Open Type Offshore Production Platforms*

ASTM E119-09c, *Standard Test Methods for Fire Tests of Building Construction and Materials*

ASTM E736, *Standard Test Method for Cohesion/Adhesion of Sprayed Fire Resistive Materials Applied to Structural Members*

ASTM E605, *Standard Test Methods for Thickness and Density of Sprayed Fire Resistive Material Applied to Structural Members*

ASTM E1529-06, *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*

ASTM E2226-08, *Standard Practice for Application of Hose Stream*

ISO TR-834-3 [6], Hydrocarbon SO/TR 834-3:1994, *Fire-resistance tests—Elements of building construction—Part 3: Commentary on test method and test data application*

ISO 20340, *Paints and varnishes—Performance requirements for protective paint systems for offshore and related structures*

ISO BS 476, App. D (Hydrocarbon)

UL 263 [7], *Standard for Fire Tests of Building Construction and Materials*

UL 1709, *UL Standard for Rapid Rise Fire Tests for Protection Materials for Structural Steel*

UL 2196, *UL Standard for Safety Tests for Fire Resistive Cables*

XL GAPS (Global Asset Protection Services) www.xlgaps.com/store.

IM.2.5.1, *Fireproofing for Hydrocarbon Fire Exposures*

Jet Fire Test Standards

ISO 22899-1 2007, *Determination of the resistance to jet fires of passive fire*

OTI 95634, *Jet Fire Resistance Test of Passive Fire Protection Materials*
Issued by Health and Safety Executive, UK and Norwegian Petroleum Directorate

Additional jet fire studies are cited in Annex C

---

6 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.
7 Underwriters Laboratories, 333 Pfingsten Road, North Brook, Illinois 60062, www.ul.com.

Fire Hazard Analysis

(Readers should note that while the concepts and methodology may be applicable, some of the following references primarily focus on structures.)

AIChE (CCPS) [8], *Guidelines for Hazard Evaluation Procedures*, 3rd Edition 2008

AIChE (CCPS), *Guidelines for Fire Protection in Chemical, Petrochemical and Hydrocarbon Processing Facilities,* ISBN: 0-8169-0898-1 Pub No: G-83

AIChE (CCPS), Fire Hazard Analysis Techniques. Hurley, M. J.; Bukowski, R. W.

EPA [9], *Handbook of Chemical Hazard Analysis Procedures*
(with ARCHIE Software) http://www.fema.gov/library/viewRecord.do?id=1700

NFPA, *Fire Protection Handbook*, 20th Edition. Volume 1. Chapter 7. Section 3.

NFPA, *Fire Safety Analysis Manual for LP-Gas Storage Facilities*
Based on the 2004 Edition of NFPA 58, *Liquefied Petroleum Gas Code*,
Developed by the National Fire Protection Association and the National Propane Gas Association. Available for free download from NPGA.org or NFPA.org

NISTIR 6381, US Building and Fire Research Laboratory, *A Global Model for Predicting the Burning Rates of Liquid Pool Fires*

UK HSE HSL/2004/04, *Human Vulnerability to Thermal Radiation Offshore*

Offshore Technology Report OTO 2000 051, *Review of the Response of Pressurized Process Vessels and Equipment to Fire Attack*

Contract Research Report 405/2002: A series of experiments to study the spreading of liquid pools with different bund arrangements. Prepared by Advantica Technologies Limited for the Health and Safety Executive.

Emergency Isolation

UK HSE, Chemicals Sheet No 2, January 1999, *Emergency isolation of process plant in the chemical industry*. Download at http://www.hse.gov.uk/comah/sragtech/techmeasisolatio.htm#sectorind

Hazard and Risk

OGP Risk Assessment Data Directory Report No. 434, 15 March 2010 (free download)
International Association of Oil & Gas Producers, http://www.ogp.org.uk/pubs/434-15.pdf

*Risk-informed, performance-based industrial fire protection: An alternative to prescriptive codes*Thomas F. Barry, PE., Copyright T F Barry Publications, 2002. Hardcover: 704 pages, Publisher: Tennessee Valley Pub; 1st edition (May 10, 2002), ISBN-10: 1882194098, ISBN-13: 978-1882194094.

Managing Risk: Systematic Loss Prevention for Executives, Vernon L. Grose. Publisher: Prentice Hall (August 1987). ISBN-10: 0135511100. ISBN-13: 978-0135511107.

---

8 American Institute of Chemical Engineers, Center for Chemical Process Safety, 3 Park Avenue, 19th Floor, New York, New York 10016, www.aiche.org/ccps.

9 U.S. Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue, Washington, DC 20460, www.epa.gov.

Know the Risk: Learning from Errors and Accidents: Safety and Risk in Today's Technology, Romney Duffey Ph.D. B.Sc. John Saull. Publisher: Butterworth-Heinemann; 1 edition (November 22, 2002). ISBN-10: 0750675969, ISBN-13: 978-0750675963.

Managing Risk: The Human Element by Romney Beecher Duffey and John Walton Saull (Dec 10, 2008). Publisher: Wiley; illustrated edition (December 10, 2008). ISBN-10: 0470699760. ISBN-13: 978-0470699768.

Reducing the Carcinogenic Risks in Industry, Chapter 7, Paul F. Deisler, Jr. Publisher: Marcel Dekker; 1 edition (October 22, 1984). ISBN-10: 0824772504, ISBN-13: 978-0824772505

Corrosion Under Insulation or Fireproofing

NACE RP 0198 [10], *The Control of Corrosion Under Thermal Insulation and Fireproofing Materials - A Systems Approach*, Date: 03/31/04.

NACE Paper Number 03022, *Corrosion*, March, 2003, San Diego CA. *Corrosion Under Thermal Insulation and Fireproofing - An Overview*, John F. Delahunt, Carmagen Engineering Inc., Copyright 2003, NACE International

Killing Rattlesnakes Before They Bite You!, John B. Prows, Performance Products Division, Huntsman Petrochemical, 4241 Savannah Ave., Port Arthur, TX 77640,

Paper 108B *108, Ethylene Plant Safety Paper Session,* 21st Ethylene Producers' Conference Proceedings, April 26-30, 2009, Tampa, Florida, Wednesday, April 29, 2009.

Regulations

UK Standard EN1363-2 [11], *Fire resistance tests. Alternative and additional procedures,* British-Adopted European Standard, 15 Nov 1999, 20 pages.

EPA *CFR* 40 Part 68, *Chemical Accident Prevention Provisions*
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div5&view=text&node=40%3A15.0.1.1.5&idno=40

[10] NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.
[11] European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu.

EXPLORE SOME MORE

Check out more of API's certification and training programs, standards, statistics and publications.

API Monogram™ Licensing Program

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: certification@api.org
Web: www.api.org/monogram

API Quality Registrar (APIQR™)

- ISO 9001
- ISO/TS 29001
- ISO 14001
- OHSAS 18001
- API Spec Q1®
- API Spec Q2™
- API Quality*Plus*™
- Dual Registration

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: certification@api.org
Web: www.api.org/apiqr

API Training Provider Certification Program (API TPCP®)

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: tpcp@api.org
Web: www.api.org/tpcp

API Individual Certification Programs (ICP™)

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: icp@api.org
Web: www.api.org/icp

API Engine Oil Licensing and Certification System (EOLCS™)

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: eolcs@api.org
Web: www.api.org/eolcs

Motor Oil Matters™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: motoroilmatters@api.org
Web: www.motoroilmatters.org

API Diesel Exhaust Fluid™ Certification Program

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: apidef@api.org
Web: www.apidef.org

API Perforator Design™ Registration Program

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: perfdesign@api.org
Web: www.api.org/perforators

API WorkSafe™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: apiworksafe@api.org
Web: www.api.org/worksafe

API-U®

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: training@api.org
Web: www.api-u.org

API eMaintenance™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: apiemaint@api.org
Web: www.apiemaintenance.com

API Standards

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: standards@api.org
Web: www.api.org/standards

API Data™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Service: (+1) 202-682-8042
Email: data@api.org
Web: www.api.org/data

API Publications

Phone: 1-800-854-7179
(Toll-free U.S. and Canada)
(+1) 303-397-7956
(Local and International)
Fax: (+1) 303-397-2740
Web: www.api.org/pubs
global.ihs.com

AMERICAN PETROLEUM INSTITUTE

1220 L Street, NW
Washington, DC 20005-4070
USA

202-682-8000

Additional copies are available online at www.api.org/pubs

Phone Orders:	1-800-854-7179	(Toll-free in the U.S. and Canada)
	303-397-7956	(Local and International)
Fax Orders:	303-397-2740	

Information about API publications, programs and services is available on the web at www.api.org.

Product No. K22183