

Fireproofing Practices in Petroleum and Petrochemical Processing Plants

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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.

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

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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 glassy 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 (45m³/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).

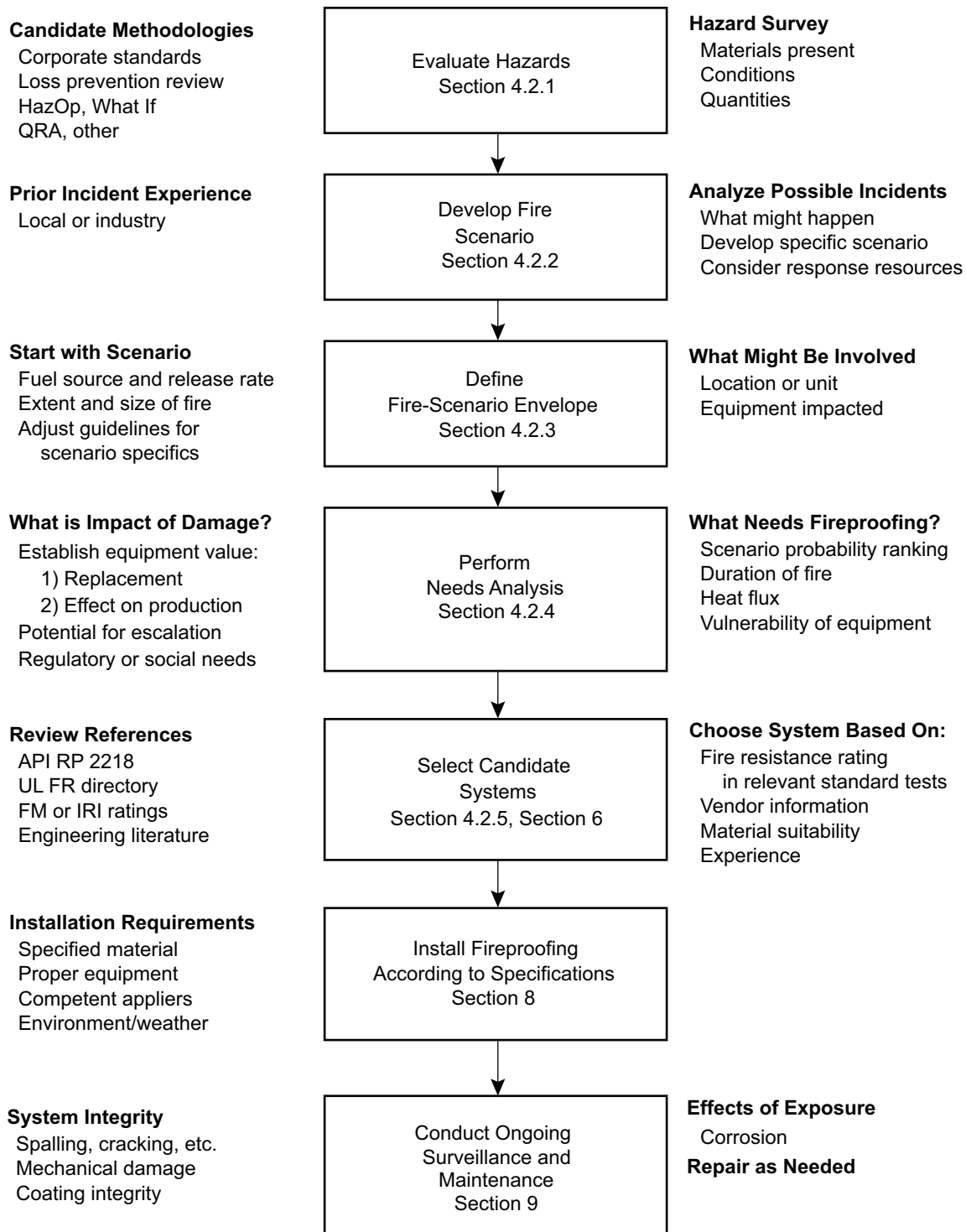


Figure 1A—Selecting Fireproofing Systems

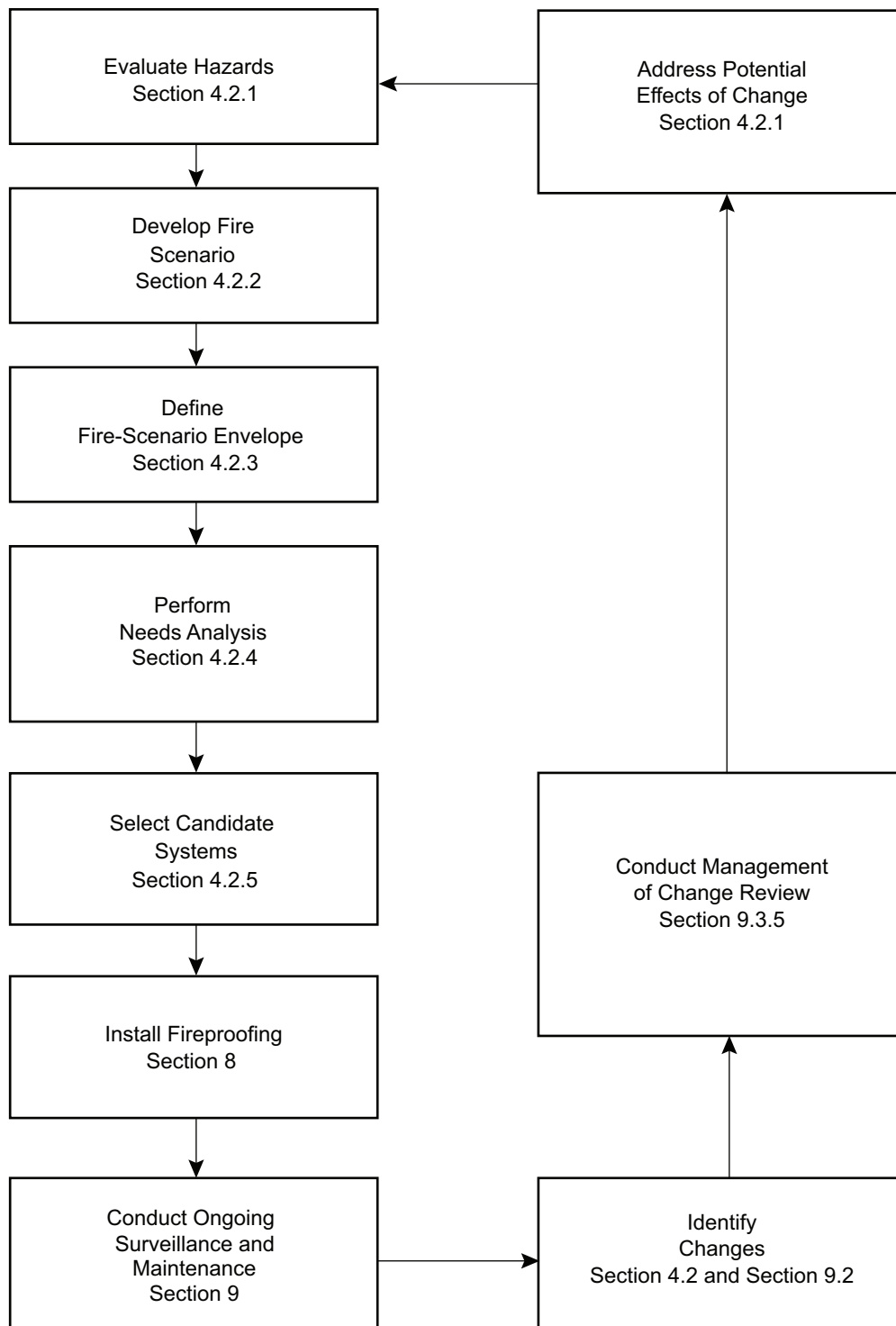


Figure 1B—Fireproofing Process with MOC

- 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 1½ 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 1½ 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 1½ hour UL 1709 (or functional equivalent) rating might be a reasonable choice. However, if emergency response personnel were 1½ 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 1½ hour laboratory rating may or may not withstand a ‘real-world’ fire for 1½ 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 1½ 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 1½ 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.