Fire Hazard Analysis

Quantifying and Mitigating Design Basis Fire Events
The concept of a Fire Hazard Analysis (FHA) is referenced in many of the standards, practices, and guidance documents that are applied in industry. It also has other names - Fire Risk Assessment (FRA) and Fire and Explosion Analysis (FEA) to name two. The analysis efforts may also be bundled with other hazard requirements in standards and guidance documents that are often vague and somewhat subjective when discussing FHA methodology. This document provides field tested suggestions and best practices to help bridge the gap between the standards and fire hazard studies.

A FHA usually involves the identification of credible fire scenarios and the impacts that those fires pose to a facility, its employees, its neighbors, and the environment.

The primary objectives of an FHA, according to the Center for Chemical Process Safety (CCPS) [1] guidance, are to:
• Provide an understanding of the hazards.
• Enable the specification of performance-based fire protection.
• Form part of an overall risk assessment.

Per CCPS, a facility benefits by conducting an FHA in that it:
• Provides an inventory of fire hazards, including quantities [of flammable materials].
• Provides a comprehensive understanding of the fire hazard(s), including potential magnitude and duration.
• Provides an estimate of the potential impact of a fire on personnel, equipment, the community, and the environment.
• Allows for the development of a list of appropriate mitigation options.

Building on the CCPS guidance and years of experience conducting fire risk assessments internationally, BakerRisk has identified and developed a Best Practice methodology as it relates to performing an FHA. The focus of this Best Practice is to redefine the FHA to go a step beyond merely "developing a list" of mitigations. In our view, it is more desirable and effective to include a thorough review and analysis of available and necessary mitigations that already exist at the facility, and/or those that may be recommended, in addition to examining the hazards and consequences of the fire.

Such a process, which we refer to as "Fire Hazard and Mitigation Analysis", or FHMA, ensures a more comprehensive examination of both the fire and consequences as well as the protection systems, emergency response capabilities, and other supporting resources.
2 FHMA Basics

An FHMA can be performed in a variety of ways; however, the following steps should be included:

1. Identify fire scenarios onsite through a review of process flow diagrams, heat and material balances, available inventories, and tank lists.
2. Perform consequence modeling for the design basis fires.
3. Build in mitigation layers such as the firewater system, which should include a site walkdown to verify the extent and condition of fireproofing, locations of fire monitors, coverage and condition of fixed protection systems such as deluge, and other factors that may affect fire geometry such as site drainage and potential obstructions.
4. Conduct a PHA-Style Workshop with the ERT, safety group, operations, and others as needed to review the fire scenarios, expected responses, capabilities, and mitigation already in place at the facility.
5. Identify gaps in firewater coverage or deficiencies in firewater supply for each scenario.
6. Provide recommendations to close any gaps identified during the analysis.

3 Preparing for an FHMA

One of the most important steps in conducting an effective fire hazard and mitigation analysis is preparing for the workshop.

3.1 Understanding the Site's Firefighting Philosophy

Before starting to assemble the team or gather documentation, it is key to gain an understanding of the firefighting philosophy for the facility. Will the site rely on fixed fire protection systems such as deluge or sprinklers to protect their equipment? Or will the site rely more on prompt and effective emergency response team (ERT) actions to fight the fire with fixed monitors and mobile apparatus? Does the site depend on outside help such as the local fire department or a mutual aid group?

There is no "right" answer to what the firefighting philosophy should be; however, it is critical to ensure that the chosen philosophy aligns with the site's actual capabilities in order to achieve the ultimate goal of timely fire suppression with minimal potential for injury to personnel, damage to assets, impact to the environment, or other negative consequences.

For example, a site that plans to rely heavily on fixed protection must ensure that fixed protection is designed, installed, and maintained to a level that will support successful suppression. If the site plans to rely more heavily on the ERT response, the ERT staffing, equipment, and training plans must reflect that intent, and the ERT should have all the necessary assets and resources available to ensure the desired response is carried out with minimal delay.

Since most philosophies and related systems rely heavily on an adequate and reliable firewater supply, it is usually critical to ensure that there is enough water available to supply both the fixed and mobile delivery systems, and that the supply components carry a high degree of reliability and resiliency.
3.2 Design Case Fire - Can You Keep It Manageable

Design case fire scenarios are scenarios that are expected to be "credible" worst-case but still manageable by fixed system installations and/or emergency response procedures. It is critical to select appropriate design case fires and compare those to the available mitigations in order to determine if the available systems and responses are adequate.

It is rarely practical to design fixed protection systems for the largest possible (worst-case) fire. Such scenarios would quickly defeat or overtax even the most capable of fixed systems, and response measures shift from attempting to suppress a fire to more defensive measures such as attempting to limit fire spread to adjacent units/areas. Preventing catastrophic events is best done through good detection, isolation, and other preventive measures that stop a manageable event progressing to an unmanageable one. For this reason, catastrophic scenarios such as explosions preceding fire events are outside the scope of the FHMA as they are already typically unmanageable events.

Once the design basis fire cases are identified, they can then be analyzed to determine the best combination of mitigations to control, suppress, and ultimately extinguish those fires. Once those fire cases are understood, the following questions can then be answered credibly:

- What prevention and mitigation systems will be required?
- What response capabilities are needed to augment fixed systems to ensure full suppression and extinguishment of a fire event?
- How will time of response impact success?

The goal of establishing a design case fire is to ensure a "likely to occur" fire can be managed effectively to prevent it from escalating to a catastrophic size.

Without an understanding of how the fires will be fought, it is difficult to determine the maximum firewater demand or to assess any gaps in the response plan or firewater coverage.

Is your system robust enough to allow for occasional, unplanned outages of key components such as fire pumps and critical underground fire mains without jeopardizing your ability to successfully suppress your design-case fires?

Is equipment still performing as intended or is age, wear, corrosion, or neglect preventing the system from performing as originally intended?

Are there challenges to existing capabilities such as obstacles that block coverage from fixed systems, access/egress challenges for mobile apparatus, or system degradation?

What actions do you need to take to compensate for identified challenges?

Do your fire protection systems align with applicable RAGAGEP as well as corporate and site philosophy/intent?

The important questions to ask are:

- Does your firewater supply and delivery capability fully meet the maximum firewater demand for all fire areas in your facility?

Is your system robust enough to allow for occasional, unplanned outages of key components such as fire pumps and critical underground fire mains without jeopardizing your ability to successfully suppress your design-case fires?

Figure 3-3. Automatic Deluge System Response

Figure 3-4. Design Case Fire—Is it Manageable or Catastrophic?
4 FHMA Fundamentals

4.1 Understand the Impacts of Fire

Many driving factors can cause a site to invest in fire protection equipment. While conducting an FHMA, it is important to understand the range of possible consequences of the potential fire including impact to: personnel, environment, assets, revenue, reputation, or market share. Reviewing and understanding the potential impacts are an important part of conducting the FHMA.

For most companies, the potential impact to personnel, assets, and revenue are obvious; however, the impact of a fire to the environment and company reputation are often overlooked. Large scale fires and fire fights can damage the company reputation due to visible smoke plume, etc. or the environment due to contaminated water runoff or foam/water runoff. These types of impacts should be considered as they may warrant a different response than if only impact to personnel/assets are considered.

It is also critical to understand the progression of fire events over time to determine if the response capabilities are adequate. The flowchart below shows a typical response timeline for a fire scenario. Understanding response time and the potential consequences at each phase of the scenario’s progression will help in identifying improvements at the facility that could reduce overall response time and what resources will be needed to accomplish that goal.

Finally, it is necessary for FHMA participants to visualize the fire. Many response drills are based on a written or verbal description of a fire scenario; however, without a visual depiction of the hazard extents, the team may have differing mental images of the severity of a given fire scenario.
Below is an example of a visual representation of the thermal radiation from a fire using SafeSite®.

![Thermal Radiation Contour](image)

**Heat Radiation kW/m²**
- Unprotected Steel Fails (37.5)
- Limit of Approach for Firefighters in Bunker Gear (12.5)
- Limit of Approach for Operator in Typical FRC (6.3)

4.2 Understand your Mitigation Capabilities

After understanding the types of fires that could occur at the facility, the site should know and understand the facility’s full range of mitigation capabilities and ensure that the right combination of fixed, mobile, and emergency response resources is available for a successful fire response. Further, the site must be confident that the mitigations will remain able to perform as intended through regular inspection, testing, and maintenance. Repairs to fire protection assets, when necessary, should be expedited and managed with rigor similar to that applied to repairs to other plant critical safety systems and assets.

On the right is an example of a visual representation of the thermal radiation generated by a fire. This image also shows the potential range and coverage for fixed and mobile assets within reach of the fire. Such visual representations are extremely helpful in determining potential fire consequences (including possible knock-on consequences) and can help to determine if the fixed and/or mobile assets can effectively reach a fire area.

![Thermal Radiation Contour with Firewater Overlay](image)

Companies sometimes focus too much attention on one specific asset or resource without considering the relationship between different types of mitigations. For example, a site that relies on good flammable gas detection systems to alarm during a release may fail to recognize that those types of systems are not reliable for detecting an active fire. Other sites may rely on mobile response assets such as fire trucks, but they may not fully recognize the importance of the fire pumps and delivery systems that ensure the water source can actually reach the fire truck. Therefore, with regards to fighting fire, the plan is only as strong as the weakest link.

In short, an effective FHMA allows companies to develop a full understanding of both the fire and the mitigation (fixed systems, response assets and teams, and other supporting measures). Any gaps between the two will emerge from this comprehensive analysis. Once those gaps are identified and remedied, a facility can have an enhanced level of comfort in its ability to combat design basis fires and associated impacts to people and assets.

5 Applications of FHMA

This section summarizes the main applications for the FHMA methodology highlighted in this best practice.

5.1 Determining Credible Maximum Firewater Demand

There are several techniques for estimating maximum firewater demand. API and CCPS offer two such methodologies to estimate maximum firewater needs, based on facility size and other factors. However, most estimating methods are one-size-fits-all approaches to complex occupancies such as refineries and petrochemical plants with many different variables that can impact the severity of a fire. These also assume that the facility has the capability to deliver the estimated firewater demand where it is needed.

One important flaw in most estimation techniques is that those approaches do not consider actual capabilities or expectations at any specific site. For example, sites that have widespread fixed system coverage can often expect a design basis fire to be controlled using only the water needed for those systems, plus an additional allowance for hoses to complete extinguishment. In cases such as those, a firewater demand estimation may over-predict the actual maximum credible firewater demand if that demand is determined based on the size/footprint of an entire operating area or process unit.

Conversely, a site that relies more on mobile response may require higher volumes of firewater than the estimate would predict, especially once fire escalation is factored into the estimate. This becomes increasingly important if a site’s emergency response team could expect delays in reaching the fire area or deploying their equipment. Delays usually translate into fire growth due to additional failures in primary containment loops, which add more fuel to a fire. In cases where a fire could escalate to involve an entire process unit, the maximum firewater demand may indeed be based on the entire footprint of the unit, but the estimated density of application needed would then be much higher than most estimating techniques would predict.

The workshop-based FHMA approach allows the site to calculate their maximum firewater demand by first determining the applicable firefighting philosophy, then determining and summing individual demands from those assets that are expected to be deployed simultaneously. More importantly, by reviewing the existing coverage capabilities versus the expected extent of the fire, gaps can be identified and closed, and the maximum firewater demand can be kept evergreen based on the changes and improvements implemented.

By ensuring the needed coverage and the existing or recommended delivery needs are taken into account, a much more credible Maximum Firewater Demand can be determined with greater confidence.
5.2 Capital Project Design Reviews

New facilities under design need careful review to ensure they meet corporate and RAGAGEP best practices. Experience has shown repeatedly that it is cheaper and less disruptive to design and install good fire protection during initial construction, rather than attempting to retrofit needed systems after a unit or facility is built. Experience has also shown that there are often misalignments between Capital Projects stakeholders (builders) and site safety/operations staff (owners) whose lives and assets depend on the protection schemes built into a new unit. Capital projects managers are often pressured to achieve an optimal design for the lowest cost - sometimes at the detriment of the safety systems. If it is determined that a site needs to close gaps in the original design after the facility is constructed, higher costs and disruptions emerge.

Some important questions to ask at the beginning of facility design:

- Does the design meet the intent of RAGAGEP, corporate, and site protection expectations?
- Will external stakeholders, such as joint venture partners, lenders, or insurers, apply pressure to increase protection levels beyond those in the original design?
- Do site personnel have an opportunity to review the design at each decision stage of the project?
- Is the project budget for fire protection systems sufficient to address gaps between minimal design conformance and desired intent of the owners and external stakeholders?

FHMA, if done at the earliest stages of design and reviewed periodically as design changes are incorporated, can help maintain alignment between the stakeholders and help to ensure that there are no last minute surprises that impact project scope and schedules.

5.3 Fireproofing Gap Analysis

An FHMA can be performed or expanded to evaluate the adequacy of installed fireproofing or planned fireproofing for an existing or new asset. Fire consequence information can be used to determine where within the facility pool fires are likely to occur and a review of the grading/terrain onsite can be used to evaluate where the pools can travel. Firewater system capabilities to keep steel cool as well as fixed fireproofing are then reviewed overlaid with the potential pool fire locations to determine where the gaps in fireproofing exist.

5.4 Fire Pre-plan Development

Fire preplans can easily be developed based on the scenarios evaluated during an FHMA. The FHMA analysis provides credible hazard scenarios and evaluates available mitigations. With little additional effort unit-specific fire pre-plans can be developed using the data derived from the FHMA.
5.5 ERT Training

The interactive hazard workshop allows the site to better understand the impact of process fires in relation to available protection and response capabilities. This can be leveraged as a training tool to support realistic drills and exercises and fine tune capabilities.

5.6 Specialized Applications

The FHMA approach is flexible enough to apply to a wide range of applications where fire is the critical exposure. The FHMA approach has been applied to evaluating protection for safety critical process components such as emergency isolation valves and cable trays. It has also been used to determine credible exposures related to atmospheric PSVs by evaluating the benefit of cooling equipment before a PSV can lift.

6 Conclusions

Properly aligned with your site or corporate fire response philosophy, FHMAs provide a thorough understanding of the potential fire exposures and help determine if those exposures are being adequately managed. This methodology of combining the best elements of qualitative and quantitative review provides a sound basis for understanding gaps between fire risks and fire mitigation capabilities, and produces valuable data to use in event response planning, capital project resourcing, and training.

7 Reference

1. Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities. CCPS (Center for Chemical Process Safety), 2010
2. API Recommended Practice 2001 Fire Protection in Refineries. 10th Edition, 2019

Our Experts

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