Fight or Flight: What's your Fire Response?

Kristen Graham, Senior Process Safety Consultant, Baker Engineering & Risk Consultants, Inc., 11011 Richmond Ave, Houston, TX 77042

Karen Vilas, Principal Process Safety Consultant, Baker Engineering & Risk Consultants, Inc., 11011 Richmond Ave, Houston, TX 77042

The concept of a Fire Hazard Analysis (FHA), or Fire Risk Assessment (FRA), is referenced in many standards, practices, and guidance documents. However, the standards and guidance documents are often somewhat subjective when discussing methodology application. Many facilities simply default to a prescriptive, area-based firewater coverage calculation. Using a real petrochemical facility case study, this paper helps bridge the gap between the subjective language in standards and an actual fire hazard study by applying a semi-quantitative method for determining the maximum credible firewater demand for a major hazard site.

An FHA/FRA, or fire hazard and mitigation analysis (FHMA), involves identifying credible fire scenarios and determining whether those scenarios are manageable if existing fire mitigation systems are used, to the extent reasonably practicable. It is critical to consider the available fire protection systems (both passive and active), the site fire-fighting philosophy, and the fire hazards when determining firewater demand. This balanced approach is not common practice for an area-based approach, which may either significantly under or overestimate the required maximum firewater demand when applied in isolation. For example, if a site has limited fixed or mobile response equipment, it may not be able to physically deliver the amount of water calculated using the area/density approach. On the other hand, a site with numerous fixed systems that would likely all be activated in the case of a fire, may require significantly more water to feed those systems than what would be calculated based on the area/density approach.

There is no "right" answer to what the fire-fighting philosophy should be; however, it is critical to ensure that it aligns with the site's actual capabilities. A site that plans to rely heavily on fixed protection must ensure that fixed protection is designed, installed, and maintained to ensure successful suppression. If the site relies on an emergency response team (ERT) response, the ERT staffing, equipment, and training plans must support that intent. Since most philosophies and related systems rely heavily on an adequate and reliable firewater supply, ensuring there is enough water available to supply the fixed and mobile systems, the water can reach the intended locations, and that supply components have a high degree of reliability and redundancy is critical.

This paper will use the case study described above to highlight the importance of determining a corporate and/or site-specific philosophy for fire protection which is supported by fire protection systems and emergency response plans available.

Introduction

The concept of a Fire Hazard Analysis (FHA) is referenced in many of the industry safety and loss prevention standards and guidance documents. FHA also has other names including, but not limited to, Fire Risk Assessment (FRA) and Fire and Explosion Analysis (FEA). Often, the industry standards and guidance documents bundle the FHA with other hazard requirements in standards and guidance documents. All of the above results in a vague and somewhat subjective interpretation of the methodology to be used for performing an FHA, which can be further complicated when working to put together a corporate FHA methodology that adheres to the local requirements but is one component of a global asset portfolio.

The overall intent of an FHA is to identify the hazards that fires pose to a facility, its employees, its neighbours, and the environment. In order to determine these hazards, the FHA should identify and analyse the potential fire hazards as well as the protection systems, both active/passive and fixed/mobile that are available to the facility. A previously published best practice document (BakerRisk 2021) reviews a methodology for FHA that meets the intent of most industry safety and loss prevention standards and guidance documents—notably, it indicates that the determination of fire water demand is a key component of the FHA. Determination of fire water demand is often difficult to do on a fire scenario basis due to the somewhat subjective methodology applications. As a result, many facilities simply default to a prescriptive, area-based firewater coverage calculation. In fact, the CCPS (CCPS 2003) guidance recommends that in the absence of having fire pre-plans developed, a facility may use an area-based firewater coverage calculation. This paper explores the difference in applying a semi-quantitative method versus using an area-based approach when reviewing the maximum credible firewater demand for a major hazard facility.

Fire Hazard Analysis Approach

Understanding the Site's Firefighting Philosophy

Before starting to assemble an FHA team or gather documentation for such a study, it is key to gain an understanding of the facility's firefighting philosophy. Would the site rely on fixed fire protection systems such as deluge or sprinklers to protect their equipment? Would the site rely more on prompt and effective emergency response team (ERT) actions to fight the fire with a mixture of fixed monitors and mobile apparatus? Or 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 fire fighting 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 the 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 be updated and well maintained to 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. Failure to achieve alignment between philosophy and capabilities may result in the inability to adequately respond to and mitigate a fire hazard.

However, regardless of the method selected, 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. Additionally, it is critical that the supply components carry a high degree of reliability and resiliency. The determination of how much "is enough" with respect to available firewater can be determined in a variety of ways but, ultimately, should be based on the specifics of the philosophy and the site. The answer to firewater demand may also differ geographically, considering somewhat subjective standards and best practices, and that can become a challenge for corporations with assets around the globe. This paper proposes an approach to firewater demand calculations that leverages existing hazard models to determine, quantitatively, the firewater demands for a specific facility. This approach removes subjectivity and ensures a cohesive approach to demand calculation that is both globally accepted and corporately consistent.

Establishing The Design Case Fire

Design case fire scenarios in an FHA are scenarios that are expected to be "credible" worst-case but still manageable by fixed system installations and/or emergency response procedures. The goal of establishing a design case fire is to ensure that a "likely to occur" fire could be managed effectively to prevent it from escalating to a catastrophic size. Preventing catastrophic events is best done though good detection, isolation, and other preventive measures that prevent the progression of a manageable event to an unmanageable one. For this reason, catastrophic scenarios such as explosions preceding fire events are outside the scope of the FHA as they are already considered to be typically unmanageable events. This may be true of many Major Accident Hazard scenarios identified by facilities falling under the COMAH (Control of Major Accident Hazard) Regulations. However, the FHA approach could be applied to MAH fire events at a point before they have escalated into the MAH scenarios.

It is critical to select appropriate design case fires and compare those to the available mitigations at the facility to determine if the systems and responses already in place are adequate. Once the design basis fire cases are identified, they can then be analysed to determine the best combination of mitigations to control, suppress, and ultimately extinguish those fires. Figure 1 shows mitigating and aggravating factors between manageable and unmanageable fire events.

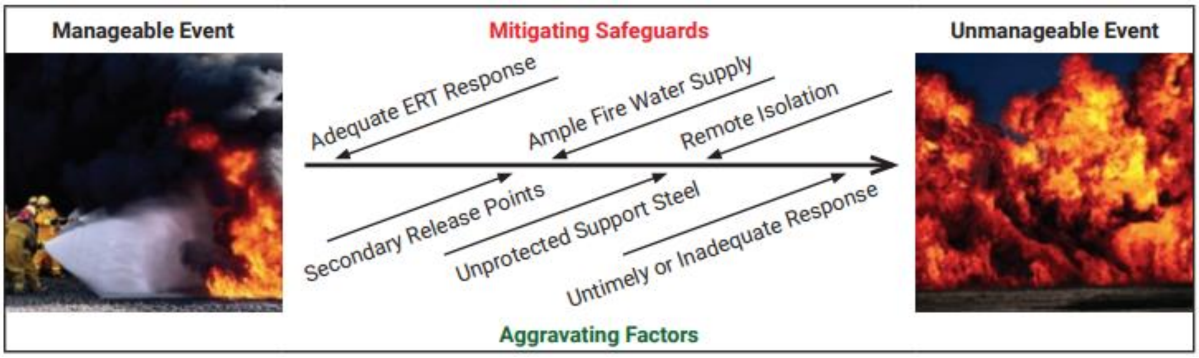

Figure 1. Manageable vs Unmanageable Fire Event

Determination of Fire Water Demand

The CCPS (CCPS 2003) Section 7.4.2 "Firewater Demand" recommends using fire pre-plans to determine maximum firewater demands. However, if pre-plans are not available, CCPS suggests that the firewater demand be based on the "Risk Area" for the process unit. The CCPS methodology specifies that the "Risk Area" is equivalent to the full surface area of the involved unit (i.e., the full "battery limits"). It further recommends that the minimum manual firewater demand be no less than what is shown in Figure 7-8 from that guideline (reproduced below in Figure 2). Additionally, flow demands for fixed water spray/deluge systems must be added to the value that is determined from Figure 2, to determine the full firewater demand for that Risk Area.

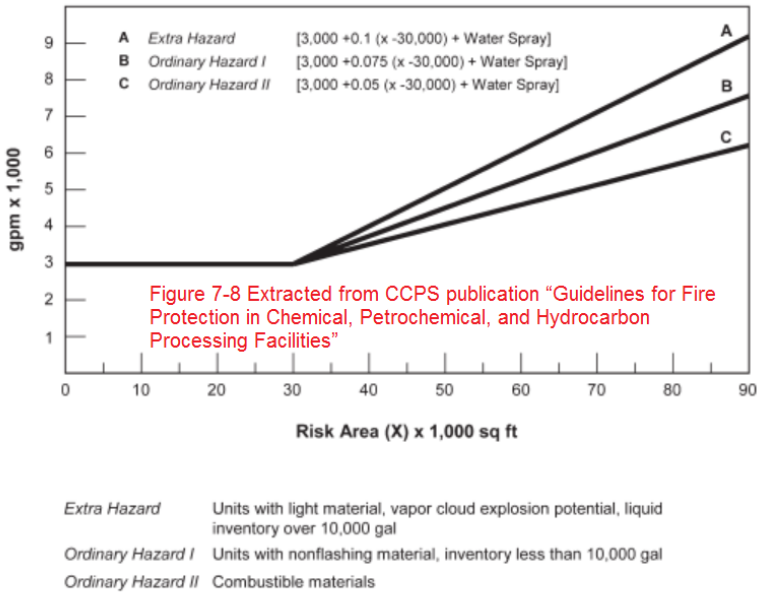

Figure 2. Firewater Demand Graph from CCPS Guideline

As stated previously, different regulatory requirements for determination of fire water demands exist, depending on the facility location. However, most locations allow for determination of fire water demands using a fire risk assessment methodology and/or a unit-based methodology. Regardless of the methodology used to determine fire water requirements, most locations also require an FHA in some form. One example for determination of fire water demand is included in this paper; it is important that each facility review location requirements to ensure proper compliance with local regulations.

For the purposes of the two case studies presented herein, dimensions of the Risk Areas were obtained using the scaling tool provided by the Google Earth™ mapping service. Plant units located closer than 50 feet (15.2 m) from one another were considered as a single unit, or "Risk Area" as defined by the CCPS guidance. For the determination of water demand using the FHA process, it is assumed that the FHA calculation forms the basis of fire pre-plans and the value shown in Figure 2 would not apply.

Case Studies

Two Case Studies are presented to illustrate the difference in calculated firewater demands depending on how the firewater demand is determined and the subsequent effects that may have on fixed and mobile fire response. The examples are intended to represent "typical" units within a petroleum or petrochemical facility in order to demonstrate the approach and are not meant to represent philosophies or systems that actual facilities must follow. The results from these examples are not intended to provide recommended firewater demand based on facility or unit type alone, as each facility should perform an independent analysis that reflects available resources.

Case Study 1

Case Study 1 illustrates how the *area-based approach* could significantly overestimate the firewater demand for a large ethylene unit. The "risk area" for the unit based on the size of the unit is 339,500 ft^2 (31,540 m^2) as shown in Figure 3. Using the CCPS guidance shown above in Figure 2, this correlates to a firewater demand of 33,900 gpm[1] (128 m^3pm) for manual response. Assuming the unit also has about 10,000 gpm (38 m^3pm) in fixed system demand, which per CCPS guidance should be added to the manual firewater demand, the total calculated demand is 43,900 gpm (166 m^3pm).

To achieve this demand, the facility would need 12-inch to 18-inch size mains with a high C-factor, 9 pumps rated for 5,000 gpm (19 m^3pm), and enough fixed fire water systems to deliver that capacity (for example, ninety fire water monitors rated to 500 gpm or 1.9 m^3pm). For most facilities this would be an impractical amount of water and pumping capacity to have onsite.

[1] All quoted gpm values are US gpm.

Figure 3. Case Study 1- Fire area defined for ethylene unit based on CCPS guidance

Note that large units such as those shown in Figure 3 not only result in high unit-based firewater demand calculations, but also present two challenges to fire response. First, any fixed systems located within the unit may be unreachable in the event of a fire due to exposure to high thermal loads. Second, fixed systems on the unit boundaries likely will have trouble reaching the interior parts of the unit. Simply put, the unit-based approach for large units calculates large demands but does not address the actual ability to respond to a fire.

In a detailed FHA, the technical team conducts a *scenario-based approach* by reviewing a range of fire scenarios in the unit to determine which results in the highest firewater demand. The calculated demand is based on the fire footprint for the design basis fire as well as the fixed systems in place and anticipated mobile response from operations and the emergency response team. For Case Study 1, the total firewater demand for the highest demand scenario, shown in Figure 4, is 10,000 gpm (38 m^3pm). This total is based on 2,000 gpm (7.5 m^3pm) in fixed deluge on the compressor deck, 2,000 gpm in the form of four 500 gpm (1.9 m^3pm) monitors in the area and use of two onsite pumper trucks with a capacity of 3,000 gpm (11 m^3pm) each.

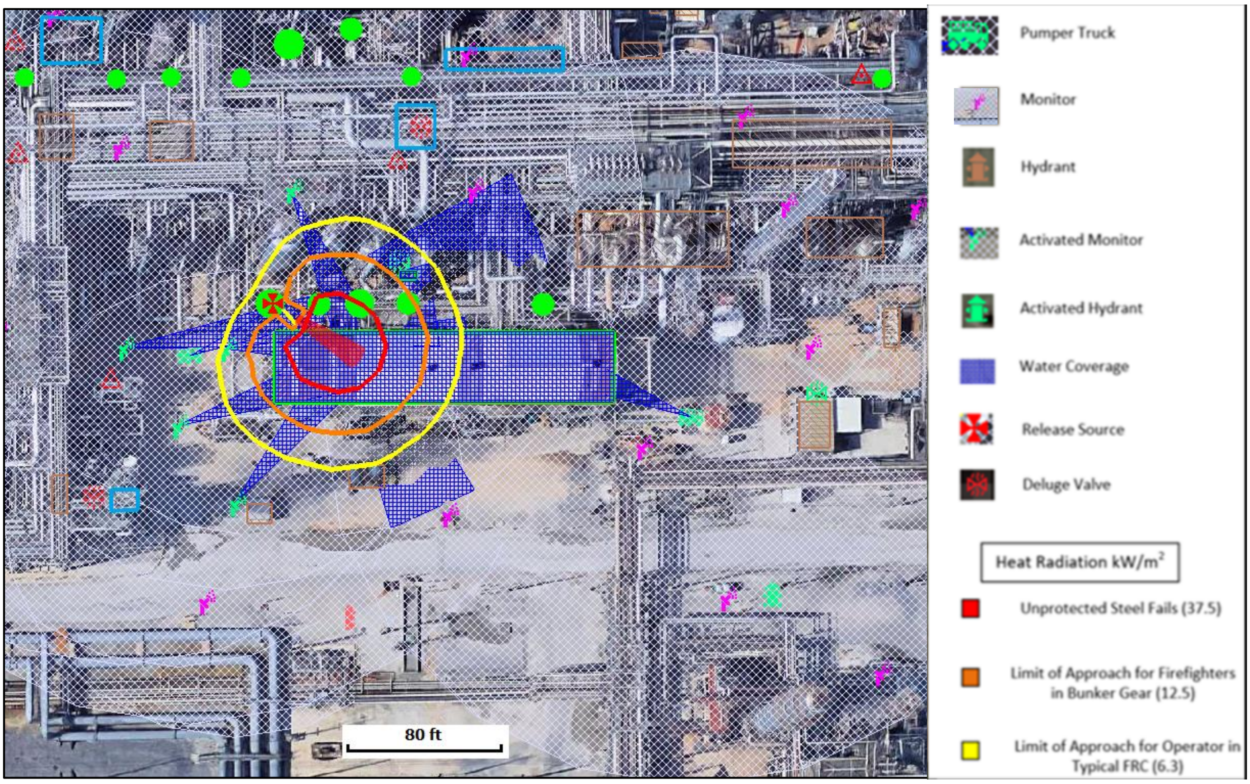

Figure 4. Case Study 1- Firewater demand calculation using Fire Hazard Analysis

While the fire could potentially escalate beyond the initial fire footprint, the onsite team was confident that the initial response would be effective based on the training and fire fighting capabilities of the ERT and previous response experience. In this case, the area density approach results in a large demand that is unlikely to be needed in a design basis fire response in this unit. The FHA methodology results in a far more practical firewater demand estimate based on the site's actual hazards, fixed fire equipment, ERT training, and firefighting philosophy. Furthermore, it takes into account the actual fire response and ensures that firewater is not just available but is also available in a way that enables safe firefighting by operations and/or emergency response personnel.

Case Study 2

Case Study 2 illustrates how the area-based approach could underestimate the firewater demand water for a fired heater area. The "risk area" for the unit based on the size of the unit is 56,000 ft^2 (5,200 m^2) as shown in Figure 5**Error! Reference source not found.**. Based on the chart in Figure 2, this correlates to a firewater demand of 5,600 gpm (21.2 m^3pm) for manual response.

Figure 5. Case Study 2- Fire area defined for a fired heater unit based on CCPS guidance

Using a scenario-based approach, the range of fire scenarios in the unit are reviewed by the technical team to determine which one would result in the highest firewater demand based on the fixed systems in place and anticipated mobile response from operations and the emergency response team. The total firewater demand for the highest demand scenario, shown in Figure 6, was 8,000 gpm (30 m^3pm). This calculated demand includes four 1,000 gpm (3.8 m^3pm) monitors in the area and four 1,000 gpm monitors in the neighbouring unit. This estimate does not include a pumper truck response, but it is likely a truck would also be used and either increase the demand or an incident command would turn off monitors that are not as effective in the response.

This scenario is significant because it illustrates that a fire can stretch beyond the "risk area" even if there is significant spacing between areas. Based on the process conditions, it is very possible to see large enough jet fires that multiple "risk areas" are impacted. In this case, the area density approach results in a lower demand because it does not include the neighbouring unit impact due to the distance. The FHA methodology results in a more practical firewater demand estimate based on the site's actual hazards and layout.

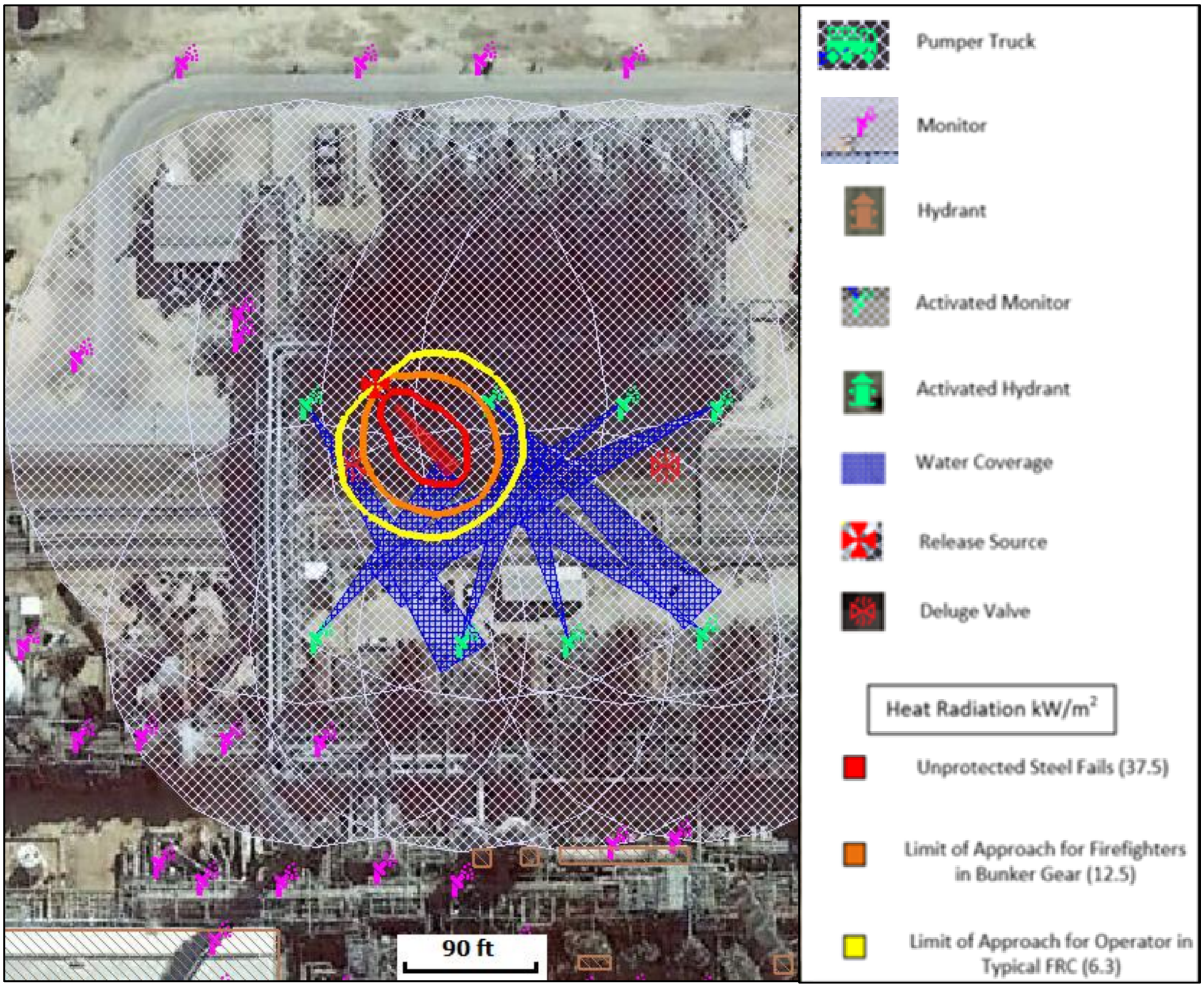

Figure 6. Case Study 2- Firewater demand calculation using Fire Hazard Analysis

This scenario is significant because it illustrates that a fire can stretch beyond the "risk area" even if there is significant spacing between areas and it draws from water sources available in multiple units in order to properly respond to the fire scenario. Based on the process conditions, it is possible to see large enough jet fires that multiple "risk areas" are impacted. In this case, the area density approach results in a lower demand since it does not include the neighbouring unit impact due to the distance. The FHA methodology results in a more practical firewater demand estimate based on the site's actual hazards and layout.

Next Steps

After performing a scenario-based FHA, fire pre plans can easily be developed based on the scenarios that were evaluated during the FHA study. The FHA analysis provides credible hazard scenarios and evaluates available mitigations while defining the anticipated response and corresponding firefighting philosophy. From this information, the technical team can then prepare unit-specific fire pre-plans with minimal additional effort. The fire pre-plans can be leveraged as a training tool to support realistic drills and exercises and fine-tune capabilities as well as provide input to the site's emergency response plan.

It is important to remember that firewater availability is only one part of a facility's firefighting philosophy and should be used in tandem with other considerations such as passive fire protection, mutual aid response, and potential offsite influences on accessibility and exposure.

Conclusions

Development of a formal FHA provides a facility an understanding of the potential fire exposures and helps management determine if those exposures are being adequately addressed. The most important thing to determine before beginning an FHA is what the philosophy on fire protection for the site is: does the site lean more toward fixed protections or more toward mobile/brigade response? That philosophy will then guide the discussion when determining how each specific fire scenario would be mitigated. Conducting a full FHA to determine maximum firewater demand ensures a more comprehensive examination of both the fire and consequences as well as the protection systems, emergency response capabilities, and other supporting resources. Such an approach allows companies with multiple facilities across the globe to ensure they are meeting local requirements while having a cohesive corporate approach to fire fighting capabilities.

References

1. Baker Engineering and Risk Consultants, Inc. *Best Practice for Fire Hazard Analysis*, June 2021.

2. Center for Chemical Process Safety (CCPS) *Guidelines for Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities*, 2003 edition.