Performance vs. Prescriptive Fire Protection for the Offshore Industry

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Most companies have standards for fire protection on offshore installations. These standards typically are prescriptive in nature and require that fire protection be installed, generally, without regard to the actual hazard. Fire protection generally consists of fireproofing, water systems and detection systems.

The fire protection community is slowly using performance based criteria in determining appropriate fire protection. Performance based criteria using the latest modeling programs to assess the hazards of fires and explosions on the offshore installation. Based on the results of these studies, the fire protection engineer can then determine the appropriate fire protection required for the hazard.

This paper addresses the use of performance based standards for fire protection in the process industry.

1.0 INTRODUCTION – MORE IS BETTER!

Many of us remember the Piper Alpha incident in 1989 where 168 people lost their lives as a result of an explosion and resulting fire. Would more fire protection have helped in that incident? Figure 1 is one example of the need for fire protection. I am sure you can think of other incidents where the question of adequate detection and mitigation could have reduced the impact of the incident.

2.0 WHY NOT?

There has always been debate about the amount of fire protection that is necessary in an offshore environment. Under protection can lead to potential loss of life and property loss resulting in reduced production and possible environmental impact. Over protection can lead to increased cost and maintenance. More importantly, overprotection can lead to a false sense of security by management that the facility is safe. So what is the correct level of fire protection?

Figure 1. Piper Alpha

3.0 WHAT IS PRESCRIPTIVE FIRE PROTECTION?

Prescriptive fire protection is installing mitigation systems based on the guidance or requirements defined without much deviation. For example, providing two 2,500 gpm fire pumps on all platforms is one company's approach to fire water systems. The size of the platform or water demand is not considered. Prescriptive approaches to fire protection generally are a result of regulation, insurance requirements, industry practice and company procedures. Table 1 illustrates examples of prescriptive approaches to fire protection. Each of these tend to be based on past incidents rather then trying to look forward and determine what could happen.

Table 1. Examples of Some Prescriptive Requirements

Source	Requirement
Regulation	MMS
	Coast Guard
	UK HSE
Insurance	Active fire protection
	Passive fire protection
	Safety systems
	Specific equipment requirements for compressors and heaters
Industry Practice	American Petroleum Institute • API RP 500 Electrical Classification • API 2030 Water Spray • API 2018 Fireproofing • API 2031 Gas Detection
	International Maritime Organization – Safety of Life at Sea (SOLAS)
	Classification Organizations • American Bureau of Shipping • Lloyd's Register • Det Norske Veritas
	National Fire Protection Association • Fire Extinguishers • 12 Carbon Dioxide Systems • 13 Sprinkler Systems • 15 Water Spray Systems • 20 Fire Water Pumps
Company Requirements	Standard or procedures for: • Equipment spacing • Electrical area classification • Water spray and sprinklers • Fireproofing • Safety shutdown systems • Isolation and blowdown • Relief and flare design • Pressurization systems • Drainage

4.0 *Approach to Performance Based Fire Protection*

Performance based fire protection is determined by conducting some form of analysis or calculations to define the fire protection required to mitigate the hazards. This process is illustrated in Figure 2.

5.0 *Hazard Analysis*

The first step in any performance-based approach is to conduct a hazard analysis. The hazard analysis techniques used to identify potential hazards in the process and facility are shown in Table 2. Typical offshore facilities where hazard analyses are performed include platforms, FPSO/FSOs, drilling (such as jack-up, semi or ship), SPARs or TLP, or any combination of these.

Table 2. Hazard Analysis Methods

Hazard Analysis Methods
• Checklist • HAZID • What-If? • HAZOP • FMEA

The outcome of the hazard analysis is a list of potential fire hazards that may occur on the facility. A partial list could include, jet fire, pool fire, explosion, electrical fire, or Class A fire. The list would also include the corresponding location where each could occur. These hazards can then be turned into scenarios for further analysis. There is a difference between a hazard and a scenario; a scenario is a series of events that need to occur to create a hazard.

6.0 *Consequence Analysis*

Consequence analysis is the process to determine the impact of the scenarios. For example, one scenario could be a seal failure that results in a vapor cloud forming with an explosion in the separation area if ignited. In assessing the consequences, you need to answer two very important questions

- What is the range in size of the events that can occur?
- What is the impact of the event?

In assessing the impact, you normally take into account radiant heat, overpressure, toxic effects on the temporary refuge, evacuation routes, escape equipment and process equipment that could be involved in escalation.

Toxic effects can include products of combustion from fires, such as smoke, carbon monoxide and hydrogen sulfide contained in the material.

In performing any consequence assessment, it is important to recognize that analytical tools can be very useful to determine the consequences of a scenario. In most cases, each scenario will have a variety of conditions that need to be evaluated in the consequence assessment. This includes factors such as size of the release, orientation of release, temperature and pressure of operation and weather conditions (that will all vary).

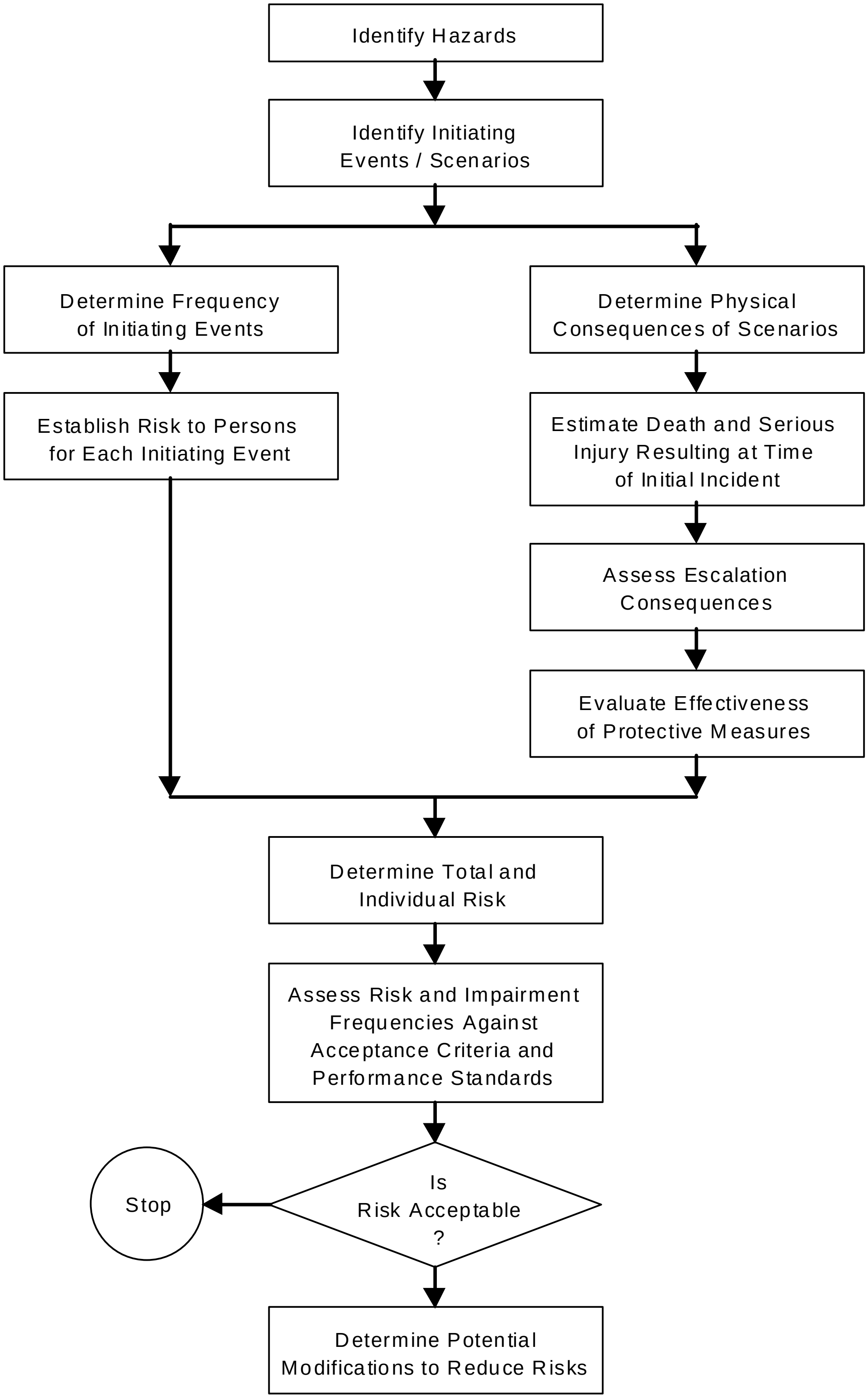

Figure 2. Hazard Analysis Process

One interesting question that arises during the consequence analysis is how sophisticated the computer program needs to be. Programs range from spreadsheets that use simple equations to CFD modeling that can take a day for one scenario evaluation. The answer is that it depends on the level of the design, the time the analysis is being performed and the desired results. In the conceptual or feed-stage simple models can be used, but as the design details increase, the complexity of the consequence analysis will also need to increase. Models such as PC-CHAOS[1] (explosion), ARAMAS[2] (explosion, fire, toxic), PHAST[3] (explosion, fire, toxic) are typically used.

7.0 LIKELIHOOD DETERMINATION

If installed fire protection would be based on only the consequence analysis, then the offshore industry would be very well protected. In reality, the likelihood of the consequences must be taken into consideration. In determining the likelihood of the consequences, certain key information is required, such as the frequency of the initiating event, frequency of ignition, probability of escalation, likelihood that the weather will be favorable or not, etc. In any likelihood determination, there are generally a large number of scenarios to be analyzed. This means that computer models need to be used to ensure that the iterative process of evaluating each variable of each scenario is performed.

8.0 RISK

Risk is the product of consequence and likelihood of each scenario. The risk for each scenario can be combined by specific areas or for the whole facility to obtain desired risk profiles. The risk is calculated using event and fault trees that take into account safety and mitigation systems. There are several computer programs that assist the analyst in these calculations, such as OHRAT and ARAMAS.

The main problem associated with any risk assessment is the appropriateness of the data used in the calculations. There are several references such as OREDA, E & P Forum, company specific sources and other industry documents that have been used in the past. Obviously, the use of generic industry data may result in risk numbers that vary widely. It is best if company specific data can be used.

9.0 RISK TOLERANCE

After the risk is calculated, the results must be compared to either governmental or company criteria to determine if the risk is tolerable. This means that the risk is at a level we are willing to accept. If it is, then additional fire protection is not required and the level of fire protection (mitigation) used in the risk calculation is adequate.

If the level of risk does not meet the risk criteria, then additional mitigation may be required. The options for reducing the risk are selected and the analysis recalculated to determine the impact on the risk. In some cases, the options (for example, fire proofing on a quarters wall to reduce impact of jet fire) provide significant risk reduction, whereas others (water spray of process vessels to protect from jet fire) have very little impact on the risk.

One concept that has been used extensively in the North Sea is ALARP (as low as reasonable practical). Figure 3 shows the ALARP concept. This concept suggests that at some point the cost to mitigate a hazard is so high that it is not longer practical to implement the option.

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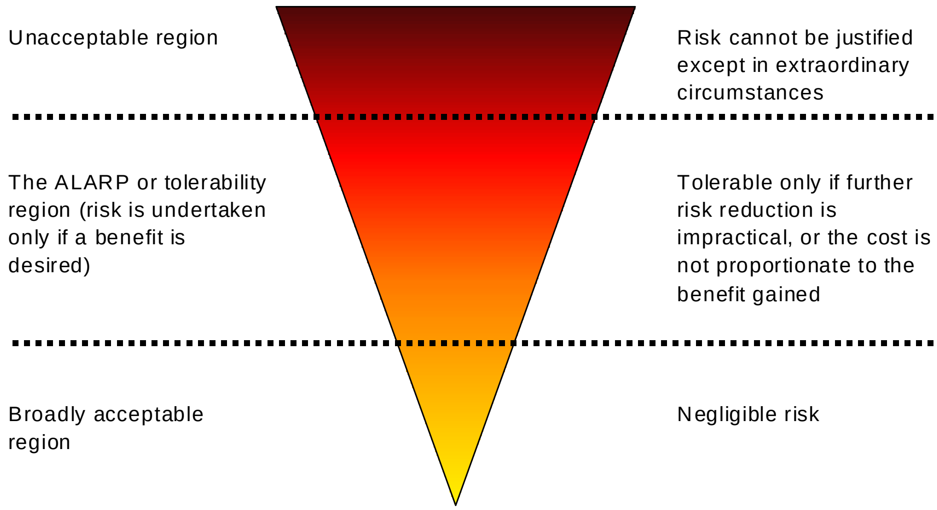
[1] **BG Technology.**

[2] **BG Technology.**

[3] **DNV.**



As the risk is reduced, the less it is necessary to spend to reduce it further.
The concept diminishing proportional return is shown by the triangle.

Figure 3. ALARP

10.0 RADIATE HEAT EXAMPLE ON FPSO

In jet fire assessment, the two important parameters are the flame dimensions and the calculation of the thermal radiation field around the flame. The convective heat transfer rate can be very high, leading to rapid failure of objects inside the flame envelope. Thermal radiation outside the flame envelope can also lead to equipment failure. In addition, there is the potential for fatalities and to block escape routes over a large fraction of the deck of an FPSO. Below 37.5 kW/m^2, most equipment items with the exception of load bearing steel plates will survive, while personnel fatalities are credible down to below 12.5 kW/m^2.

There are many methods available to calculate flame lengths and thermal radiation contours for an ignited release of gas from a leak on process equipment. Most commercial consequence assessment codes, such as PHAST and ARAMAS can be used to calculate thermal radiation contours for jet fires.

The following example considers a release of lift gas, which is primarily methane, at 250 barg and 60°C. The release occurs from a riser near the turret and is immediately ignited, resulting in a jet fire. The windspeed used is 5 m/s.

For a medium sized 10 kg/s release the calculated hole size is 14.6 mm. Radiation contours are shown in Figure 4 for 37.5 kW/m^2, 12.5 kW/m^2 and 6.3 kW/m^2, where:

37.5 kW/m^2 The yellow inner contour is typically taken as the criterion for immediate fatality. At this level, the pain threshold is virtually instantaneous and probit analysis gives a 50% probability of lethality in around 20 seconds.

12.5 kW/m^2 The green contour is typically taken as the limiting radiation intensity for escape actions lasting a few seconds (such as jumping into the sea). At this level, the pain threshold is reached in around 4 seconds and probit analysis predicts 50% lethality in around 80 seconds. 50% fatalities would be expected for personnel in the zone between 37.5 and 12.5 kW/m^2.

6.3 kW/m^2 The blue contour is typically taken as the limiting radiation intensity for escape actions lasting more than 1 minute. This is equivalent to the exposure level in API 521 [Ref. 7] for escape actions lasting up to 1 minute for personnel in appropriate clothing. Egress routes exposed to radiation intensities above this level are considered impaired.

Figure 4 shows that there is the potential for immediate fatalities from the event. The figure shows that the escape routes will be impaired for personnel aft of the release. Personnel at these locations need to go to alternative muster points and may become fatalities if the event escalates while they are at these alternative locations. Evaluation of the potential for fatalities of personnel trapped on escalation of the event are considered as part of the QRA.

There is no discernable effect on the TSR for the release shown. However, if the release is directed towards the TSR there will be direct flame impingement on the firewall in front of the TSR. An "A" rated firewall will be penetrated in around 15 minutes with direct impingement of a jet flame. An "H" rated firewall will survive over 1 hour in these conditions. Thus the additional expense of "H" rated firewalls is typically justified on FPSOs.

There is also potential for escalation as unprotected process equipment, steel plates and beams will rupture or fail in under 10 minutes when directly exposed to jet flame. When exposed to 37.5 kW/m^2 process equipment and steel beams under load will likely survive for 60 minutes.

11.0 CONCLUSION

Fire protection for offshore installations is no longer something that can occur by following the prescriptive approaches of the past. Performance based fire protection can be effectively used to determine the hazards, calculate the consequences, determine the likelihood of the consequences and ultimate risk. Once a true risk picture has been developed for the facility, options for reducing the risk can be developed that are based on ALARP. Figures 5 an d6 show examples of installations that can benefit from performance based fire protection.

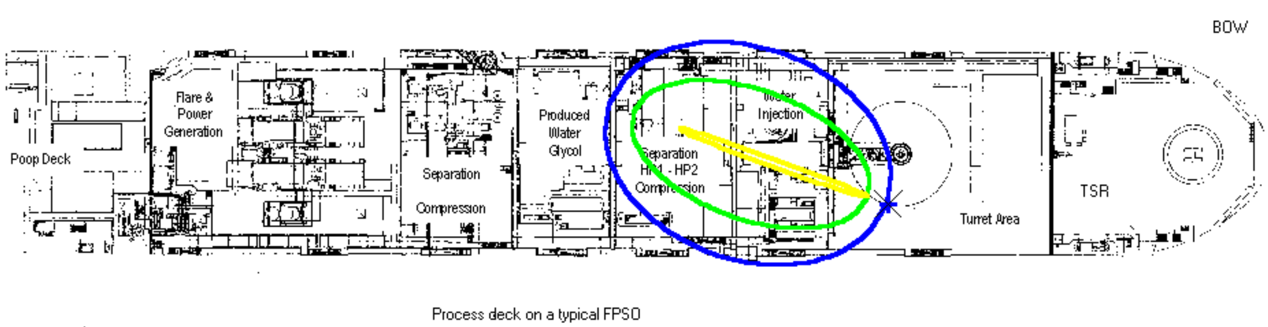


Figure 4. Examples on an FPSO Contours

Figure 5. Offshore MODU, Platform, and Hotel

Figure 6. Floating, Production and Storage Offloading (FPSO)