Introduction

Hazardous area classification and major hazards risk assessments have a common objective: to assure a plants operability and safety by preventing ignition. Yet, the two tasks are often carried out without much consideration of the other. Hazardous area classification is prescriptive and oriented toward high frequency events whereas risk analysis is usually performance oriented and focus on rare events. Legislative requirements for major hazards typically refer to rare events: those occurring every 10 000 or 100 000 years [ref i, ii] with the requirement being that unacceptable events cannot occur more frequent than this. Consequently, the scenarios being of concern to the risk assessor can be much different to those normally thought of for zoning purposes even if they are somehow dealing with the same problem: preventing ignition. Ignition is a major factor in a risk analysis and a potent ignition source outside a classified area may be of crucial importance. Similarly there may be areas where classification is mandated but of lesser importance in the eyes of a risk assessor. A key point for this paper is ignition hazard beyond the boundaries of area classification. Case examples will be used to illustrate how ignition from non EX areas impact on risk as well as examples of where EX proofing is less critical – at least in the eyes of a risk assessor.

Risk and ignition probability

Fire and explosion risks constitute a large part of the major hazard potential for the oil and gas industry and various legislation and industry standards calls for detailed analysis of these hazards. For many facilities, the consequences of a worst case events cannot be designed out, and the only feasible approach is to also take into account probability of occurrence. The use of a probabilistic approach adds a lot of complexity to the risk analysis and also implies that the probability of ignition needs to be determined. Ignition models of various degrees of sophistication are available [ref.iii,iv,v,vi], but the inherent difficult in predicting ignition means that these models are associated with considerable uncertainty. Consequently, the outcome of a risk analysis can be sensitive to what model is used and how ignition is modelled. Although the reliability of such models are a point of concern, the use of more advanced models coupled with the use of CFD simulations can teach us a lot about how the presence and location of potential ignition sources affect risk. Even if the overwhelming majority of gas releases in a process module never extend beyond the module, a few odd scenarios often do. Given the right release and wind conditions, gas may reach into areas where it shouldn’t be and if encountering a potent ignition source, risk may be substantially affected. In this context a key point is to acknowledge the wide parameter span for ignition: whereas probability of ignition of a gas release in a zoned area is very, very small, it may be fair to
assume 100% probability of ignition if the gas reach a particularly potent ignition source. In other words: probability of ignition in different areas can in principle vary with more than one order of magnitude.

Major hazard events are rare and overall ignition probability estimates based on historical records is often stated in the range of 2-3 percent [ref vii]. For zoned areas and areas with strict control measures like those typically seen offshore, it is not uncommon with ignition probability calculated to values as low as one out of a 1000 (note that immediate ignition leading to fire are excluded in this number). With such low numbers it is quite obvious that even if just a very few gas release scenarios are capable of extending into an area with a strong ignition source, the impact to the overall risk will be dramatic. Besides the risk itself, this may have severe design implications as well: the blast load predicted in risk analyses are commonly used as a design basis. Failure to address ignition control measures or place possible ignition sources in unfortunate locations potentially have tremendous design cost implications even for objects located far beyond the zoned areas. Both from a risk and cost perspective there therefore is strong incentive to bring attention to ignition control measures in an extended area.

A case example

To illustrate how risk is affected by strong ignition sources outside classified areas we take a look at an explosion risk analysis performed for a large offshore platform. The platform in question was is a typical North Sea design: compartmentalised with numerous process modules separated by blast walls and decks where gas cannot easily migrate between units. In the event of an accidental release gas migration paths will largely be governed by confining elements like decks and walls. For all but one of the 7 process modules, the gas migration paths were such that gas would not reach the “safe” utility areas and the turbine inlets. It is not entirely obvious how ignition would propagate from the turbines ignition chamber and out to the explosive atmosphere: nevertheless turbines have been identified as the ignition source in several offshore explosions. In the study the probability of ignition was set to 50% up until gas detection and successful shut down of the turbine (no more flames inside the turbine). For one of the seven modules, a handful of scenarios did in fact expose the turbine air inlets to combustible gas and even if the number of scenarios were limited, the high ignition probability turned out to have a major impact on risk. In fact the high likelihood if ignition from these few scenarios was about as important for risk as ignition by all other ignition sources and all the remaining scenarios. Figure 1 illustrates gas dispersion as simulated by FLACS and how gas exposes the turbine air inlet. Figure 2 shows how the relative contribution of the different ignition sources is. The example illustrates how a potent source located away from the area where leaks are likely to occur can severely impact on risk.
Figure 1  Example of gas release simulated with FLACS. The flow path of the buoyant gas are severely affected by the walls and decks and with a sufficiently large release in the central section of module M2 flammable gas concentrations occur at the turbine outlet.

Figure 2  Summary of ignition frequency for module M2. The flow path of the buoyant gas is severely affected by the walls and decks and with a sufficiently large release in the central section of Module M2 flammable gas concentrations occur at the turbine outlet.
Mitigating methods

As often is the case offshore, finding mitigating measures may be challenging and the option may be to pose operational restrictions and ban any future modifications that would increase risk. For projects in the design phase and also existing onshore plants it may be easier to implement risk reducing measures. For onshore plants the issue may also be a lot more pressing for the two following reasons. Firstly onshore plants typically contain a much larger range of particularly potent ignition sources such as burners, various equipment, substations, air inlets and non ex electrical equipment in “safe areas”. Secondly, onshore plants are often more exposed by non-buoyant gas that can travel along ground for longer distances, slump down into low lying areas and otherwise find gas migration paths to areas with possible ignition sources.

Preventing ignition from these sources would be a major improvement with respect to risk and may substantially reduce cost by lowering design accidental loads. Various measures can be applied to reach this goal such as relocate particular equipment items, relocate or raise air inlets of burners, measures to prevent gas ingress in buildings, rooms and compartments containing electrical equipment, gas dispersion barriers, adequate gas detection and shutdown, use of ex proof equipment etc. A key point for all these measures is to have a good understanding of where flammable gas concentrations may occur – also in those few odd scenarios that were seen to be of paramount importance in the above example.

Gas releases are often conceived of as creating round spherical clouds encompassing the region where the gas is being released. Although this may sometimes be the case for hazardous area classification the rule is rather that a larger pressurised gas release will cause most cloud exposure a good distance away from the source. As seen from the figures in this text gas exposure is often irregular and sometimes counterintuitive like that illustrated in the next example. CFD modelling may be an efficient way to determine exposure level and case studies may be very valuable to provide input for the designing engineer or risk analyst. As a rule of thumb some points should raise special awareness:

- Non buoyant gas and topography (gravity driven gas dispersion)
- Ditches, bounds or other features that will act to enhance gas accumulation.
- Obstructions that will channel wind pattern and “focus” gas exposure toward certain areas
- Elevation of air inlets and the potential of gas ingress in buildings and confined areas

Much can be achieved with sound engineering judgement and good knowledge of gas dispersion and the conditions that will promote ignition. For certain situation dedicated analysis of gas dispersion may be effective to target preventive measures. Classical examples are elevation of air inlets which will typically be sensitive to the type of gas, release conditions and the general
shape and geometry of plant and release area. Other potentially effective measures may involve gas migration barriers as illustrated in the figure below.

Figure 3  Example of pool release in LNG depot and formation of gas cloud (shown in blue). A two meter tall wall effectively prevents exposure to a portion of the car park area. However, wall would need to be extended to effectively prevent ignition from the vehicles

Zoning requirement versus the consequence of ignition

From a major hazard or risk point of view there are quite a few situations where zoning requirement will be of little influence. Zoning requirements often calls for EX equipment in circumstances where the consequences of ignition are quite modest - at least in the eyes of a risk assessor. Gas exposure and ignition in areas with high congestion or confinement levels are well documented [ref viii] and usually one of the biggest concerns in risk analysis. Ignition in these circumstances generally cause high explosion loads with severe damage and large escalation potential. On the other end of the spectre there will be smaller units in open areas where ignition will give no pressure build up and the only risk potential would be smaller flash fires with modest implication for risk. Surely, representing a real risk to an operator but not really a concern with respect to major hazards. The below figure show explosion pressures for two situations where cloud size is identical, but with different level of congestion and confinement. Ignition in the high congestion situation produce pressure loads well above 0.5 barg capable of severely damaging the structure and even targets in the far field [ref viii]. In the low congestion situation, pressure load is insignificant and incapable of even causing glass damage.

The prescriptive nature of area classification implies that these two situations with very different risk potential may be equally ranked and given equal portion of attention. The stringent zoning requirement may not allow for a differentiated view on the two situations but from a risk perspective the two situations are very different.
Figure 4  Ignition of a 900 m$^3$ propane cloud in a low congestion situation. Peak load about 0.01 barg or a third of the load typically needed to break a glass window.

Figure 5  Ignition of a 900 m$^3$ propane cloud in a medium/high congestion situation. Peak load about 0.5 barg or exceeding strength of typical platform design and capable of causing major structural damage. Blue color indicate pressure loads above 0.05 barg generally sufficient to cause damage on a surrounding building
Summary

Hazardous area classification share the same goal as the risk assessor in trying to minimize ignition. Area classification provide limited incentive to look at possible ignition sources that may be very important to risk, nor does it make any differentiation in terms of the consequences of ignition. From a risk point of view there would be a number of situations where the principles and practices in zoning should be extended beyond the areas currently dictated by zoning guidelines. In these situations engineering judgement and more performance based approach should take precedence over prescriptive zoning requirement. CFD models provide the means to map gas exposure in detail and also to test or verify mitigating measures. Such studies are common place for new development and may be relatively easily available for zoning purposes however the full potential is rarely utilised.

As shown by examples, the key lesson is that the potential for ignition outside the zoned area can have major impact on risk and should receive more focus. Failure to properly address these issues can insure severe penalties in terms of blast load requirements and cost. Even if “best engineering practice” is followed there will be situations where substantial reduction to risk can be achieved by reducing ignition probability and especially so for onshore plants.

References

[ii] “Petroleum and Natural Gas Industries - Specific Requirements for Offshore Structures” ISO 19903
[v] Ignition Modelling in Risk Analysis”, OLF/ Scandpower, March 2010
[vi] “Guidelines for the JIP Ignition model” – DNV/Scandpower 1999