

THE ONGOING CHALLENGE OF DEMONSTRATING ALARP IN COMAH SAFETY REPORTS

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The requirement in the 'Seveso II' directive to demonstrate that 'all measures necessary' have been taken to prevent and limit the effects of major accidents presents a considerable challenge to both the regulator in defining a suitable and sufficient approach and to those charged with writing safety reports. Based on practical experience of COMAH risk assessments for several companies, this paper will present the approach developed by ABB Eutech. It covers the key issues and challenges that have arisen, how these have been addressed, the results of initial assessments and the direction of the regulator based on latest guidance. One of the key issues has been to demonstrate a proportionate approach whilst avoiding the excessive costs associated with extensive quantified risk assessments. The paper presents a screening methodology built around a semi-quantitative risk matrix that has been used successfully to make the necessary demonstrations. Recent guidance from the HSE is driving towards a greater level of quantification, especially for high consequence and high risk events, and these new requirements are discussed at the end of the paper.

KEYWORDS: COMAH, Predictive, ALARP, Risk assessment, Safety Critical Events

INTRODUCTION

The Control of Major Accident Hazards (COMAH) Regulations 1999 came into force in the UK in April 1999 implementing the European Union Directive commonly known as 'Seveso II'. The regulations require duty holders or site operators storing quantities of named or generic dangerous substances above prescribed threshold limits to prepare a safety report. A key requirement of the safety report is to demonstrate that 'all measures necessary' have been taken to prevent or mitigate hazardous events with the potential to cause serious harm to people or the environment. In keeping with UK Health and Safety law requiring risks to be reduced 'so far as is reasonably practicable', the HSE has interpreted 'all measures necessary' as reducing risks to 'as low as reasonably practical' (ALARP).

To achieve ALARP it is implicit that some form of risk assessment has been carried out to judge the current level of risk and then decide whether the costs to implement further risk reduction measures can be justified against the likely benefits. Whilst conceptually this requirement is clear the depth of the assessment could range from simple qualitative assessment at one extreme to full quantified risk assessment (QRA) backed by detailed cost benefit analysis at the other extreme. Faced with the requirement to assess a large set of representative scenarios, most operators have tried to avoid the high costs associated with extensive use of QRA.

This paper explores the development in risk assessment guidance from the HSE for COMAH including the most recently published material. The concept of proportionality was initially proposed to define the depth of the demonstrations required, but the guidance was non-prescriptive. To meet the deadlines for safety reports, operators were therefore forced to develop their own approaches to COMAH risk assessments. This paper describes the approach

developed by ABB Eutech from well-proven process hazard analysis techniques that has been used with a number operators. This methodology is based on semi-quantitative risk assessment using a calibrated risk matrix. The judgements are supported by quantified consequence assessment where appropriate and in particular for high severity scenarios. Based on assessment feedback and recent HSE guidance, the requirements from the regulator have recently become more prescriptive. Experience in meeting these further requirements is described in this paper and issues to be faced during the ongoing assessment process are discussed.

To illustrate the practical aspects of the risk assessment methodology a case study is described in the paper. This relates to a liquid sulphur dioxide road tanker offloading and storage system, installed on the site of a COMAH 'top tier' speciality chemical manufacturer located a short distance from housing. The main hazard on such an installation is loss of containment releasing sulphur dioxide and creating a toxic plume. If the release is not quickly isolated, it is possible in certain wind and weather conditions for such an incident to result in serious injuries and fatalities.

INITIAL GUIDANCE ON DEMONSTRATING ALARP

The general duty under the 'Seveso II' Directive is that every operator shall take 'all measures necessary' to prevent major accidents and limit their consequences to persons and the environment. The fact that limitation measures are mentioned has been interpreted in the UK as recognising that risk cannot be completely eliminated and that some form of risk assessment is required to judge whether the measures to reduce risk are adequate. The HSE guidance on the COMAH regulations[1] and on preparing safety reports[2] introduces the concept of 'proportionality' in determining the depth of risk assessment required. This is related to the scale of hazard and the residual risk. A complex chlorine manufacturing site close to a centre of population therefore requires a more in-depth assessment than a simple chlorine storage system in a remote location.

Although not defined in the 'Seveso II' Directive, the HSE has interpreted the general duty as requiring operators to demonstrate that risks have been reduced to 'as low as reasonably practicable' (ALARP) to be consistent with UK Health and Safety legislation. A hierarchical approach is required for demonstrating ALARP, initially considering inherent safety principles to eliminate or reduce the hazard, then following Approved Codes of Practice, industry standards, company standards and good engineering practice. Any shortfalls in meeting these standards needs to be justified by the operator.

Initially the HSE avoided prescriptive guidance for COMAH risk assessments, but included guidance on their interpretation of the Directive. For all the dangerous substances held on site the assessment must include a hazard identification and consequence assessment. By considering the 'worst case scenarios', these may be found in some cases to be trivial, and it can be concluded that no major accident hazards exist. Where the consequences are non-trivial a risk analysis is required with information on frequency or likelihood. This requirement is fundamental to the demonstration that 'all measures necessary' have been taken.

Due to the complexity of hazards in the chemical industry it is essential that a systematic methodology is used to identify a representative set of foreseeable major accidents. Recommended processes for this exercise are hazard and operability (HAZOP) studies, reviews of past accidents and incidents, bespoke industry checklists or failure mode

and effects analysis (FMEA). Where protection against major accidents is dependent on the action of an automatic shutdown system or human intervention, the risk assessment must consider whether the reliability of these measures ensures that risks remain ALARP. Where consequence assessment models have been used, these must be clearly referenced and a justification made for their use and for any key variables or assumptions made, such as wind speed and weather type in the case of toxic gas dispersion models.

INITIAL RISK ASSESSMENT METHODOLOGY

A methodology was developed by a group within ABB Eutech based on well-established process hazard analysis (PHA) techniques as practised by their former owner ICI. This aims to answer a number of key questions, namely; what can go wrong, how bad could the consequences be, how often could it happen, are the risks acceptable against established criteria and if not what further measures should be taken.

HAZARD IDENTIFICATION

Under the COMAH Regulations a 'suitable and sufficient' set of major accident scenarios must be identified for the site. These must represent the full range of potential major accidents including fires/explosions, toxic releases and damage to the environment. The ABB Eutech approach uses a team comprised of experienced and competent technical, operating and maintenance staff from the plant, lead by a process safety specialist. The ABB Eutech 'Process Hazard Review' (PHR) technique was used for the studies. This utilises a guide diagram with prompts to identify all the credible loss of containment events with the potential to lead to major accidents, including generic causes such as the failure of equipment and control systems or human error. The guidewords and examples of the prompts for causes are shown in table 1.

Table 1. Main headings for hazard identification guide diagram

Type of event	Hazardous event	Prompts
Operated outside design limits	Internal explosion	e.g. static discharge
	Runaway reaction	e.g. double charging catalyst
	Physical overpressure	e.g. tube failure
	Temperature excursion	e.g. brittle failure
	Vessel overfill	e.g. operator error
Loss of containment under designed operating conditions	Long-term weakening	e.g. internal corrosion
	Seal failure	e.g. gasket blow-out
	Moving equipment failure	e.g. compressor rupture
	Maloperation of openings	e.g. drain valve
External events	Vehicle impact	e.g. road tanker collision
	Knock-on effect	e.g. explosion on nearby plant
	Loss of utilities	e.g. cooling water failure
	Fire	e.g. warehouse fire

For the sulphur dioxide storage system the guideword 'vehicle impact' prompted the team to consider the potential for the road tanker to move off due to driver error whilst still unloading causing the offloading hose to rupture.

For small to medium sites the above approach was used for all the operations involving dangerous substances where a loss of containment had the potential for a major accident. For larger sites this approach was felt to be too demanding, and it was more appropriate to consider a representative set of scenarios. This generally involved the study team considering the most severe or highest risk scenarios and checking that the protective measures were consistent for other less severe operations. For example a number of storage tanks containing flammable substances or a set of reactors with similar processes could be assessed generically with a considerable saving in time and effort.

CONSEQUENCE ASSESSMENT

Having identified a credible mechanism for loss of containment the study team next consider the consequences in terms of harm to people or the environment. An issue commonly encountered was in defining whether events were credible. For instance was it credible for a vessel to rupture catastrophically when pressure relief had been provided. As COMAH requires a focus on high severity events as well as more likely events, the general approach was to only take credit for passive protection measures such as bunds when determining the worst credible consequence.

The main aim of this stage is to understand the types of hazardous events that could occur based on the properties of the material released. These will generally include the effects due to thermal radiation from fires, overpressure from explosions, acute toxicity from vapour releases and impact on the environment. A qualitative judgement is initially taken by the team on the extent and severity of the consequences. For high consequence events, particularly those with the potential to cause on-site or off-site fatalities, quantification of the hazard range is generally carried out using specialised computer based programmes. Models for effects on the environment are not so well developed, and generally a qualitative judgement has been made.

Based on the results of the consequence assessment and an ABB Eutech guide diagram with word models, the severity is ranked on a scale of 1 to 5. A number of categories are used including safety impact to workers and the public, harm to the environment by airborne or liquid releases, acute health affects, media attention or action by the regulators. As an example for on-site harm to workers the effects are classified in table 2.

Consequence categories 3, 4 and 5 are defined as meeting the criteria for a major accident, the other levels were included on the assessment sheets to demonstrate the thoroughness of the hazard identification process and to take credit for associated protective measures.

For the example offloading hose rupture resulting in liquid sulphur dioxide being released, the consequences are a flash of vapour forming a toxic plume and further vapour release from the resultant liquid pool. Using published data of the fatal dose for sulphur dioxide and modelling the release in a number of weather conditions, it was found that the hazard range to a 1% probability of fatality extended to several hundred metres from the point of release. As this extends a considerable distance off-site the severity level was set as 'Catastrophic'.

Table 2. Examples of consequence word models

Consequence category	Word model for on-site safety impact
5 – Catastrophic	Many fatalities
4 – Extremely serious	One or few fatalities. Many major injuries.
3 – Major	One or few major injuries. Many serious injuries, hospital for > 24 hr
2 – Serious	One or few serious injuries, hospital treatment. Many minor injuries.
1 – Minor	One or few minor injuries, medical attention.

FREQUENCY ASSESSMENT

Risk is a function of both the consequences of a hazardous event and the likelihood expressed as a frequency. To complete a risk assessment it is therefore necessary to make an estimate of the frequency. A qualitative judgement on a scale of low, medium and high may be suitable for simple hazards, but for events with the potential for major accidents it is judged that a semi-quantitative approach is required. The study team starts by identifying and listing the associated protection measures including prevention, control and limitation measures involving plant hardware, safe systems of work and human factors. The reliability of the protection measures throughout the life cycle of the plant are considered to determine how effective they are in providing protection. For safety critical systems it is likely that a specialist audit is required to provide the necessary demonstration for COMAH. As an example, the sizing of a pressure relief system for an overpressure event may not have suitable design documentation to ensure that it would provide effective relief.

For the tanker drive away hazard the prevention measure is a procedure for gates to be closed on either side of the road tanker when it has parked in the offloading bay. The gates are only opened by the operators when the offloading hose has been disconnected. Should the gate not be closed due to operator error and the drive away occurs causing the offloading hose to rupture, liquid sulphur dioxide will be released and the strong smell provides a warning. As a limitation measure the road tanker driver and operator have breathing apparatus available to allow isolation of the tanker outlet valve or operation of the emergency shut-down system at a remote location isolating the tanker outlet line. A local wind sock gives an indication of the cloud direction, and the on-site and off-site emergency plans can be brought into operation, including on-site personnel moving into toxic safe havens. For the initial safety report a semi-quantitative assessment of event frequency was carried out using the ABB Eutech word models as shown in table 3 for guidance.

Table 3. Frequency word models

Frequency Category	Frequency range (per year)	Word model
A - Frequent	10^{-1} to 1	Has occurred during lifetime of plant
B - Probable	10^{-2} to 10^{-1}	Could occur during remaining lifetime of plant
C - Occasional	10^{-3} to 10^{-2}	Not expected to occur during remaining plant lifetime
D - Remote	10^{-4} to 10^{-3}	Incidents in industry on similar technology
E - Improbable	10^{-5} to 10^{-4}	Foreseeable but requires the failure of more than one layer of protection
F - Very Unlikely	10^{-6} to 10^{-5}	Credible but requires the failure of several layers of protection
G - Extremely Unlikely	10^{-7} to 10^{-6}	Very unlikely event in area with low occupancy

For high severity or high-risk events a quantitative approach may be required to refine the estimate of event frequency. This may use historical data from previous incidents or fault tree analysis for more complex events. Such methods are time consuming and need to be carried out by specialists. The costs of quantified frequency analysis are therefore high and its use needs to be proportionate to the scale of hazard and risk.

The likelihood of tanker drive away leading to loss of containment was judged to be remote based on known incidents in industry on similar technology. The risk is reduced by the various additional protective measures such as locked gates and emergency shut-down system and it was judged that the frequency was therefore reduced by an order of magnitude to improbable.

In general the semi-quantitative estimate of event frequency was found to be far more difficult for study teams than the assignment of a consequence category. This is due to the complexity of most processes and indicates the benefits of a fully quantified approach in providing clarity. It was found to be beneficial to develop some rules for carrying out the assessments to ensure consistency.

RISK ANALYSIS

With the consequence and frequency of the hazardous event categorised, a comparison can be made with suitable criteria to provide guidance on the overall level of risk and whether further improvements should be considered. For major accident hazards where the potential exists for serious injury or fatality to workers and members of the public, criteria have been set by the HSE in the document 'Reducing Risks, Protecting People' (often referred to as R2P2)[3]. Risk criteria are not normally expressed as a single value, above which risk is unacceptable and below which risk is acceptable. Instead there is a tolerability band within which risks must be reduced to ALARP. This brings in the need to carry out some form of cost-benefit analysis to determine if the costs of an improvement can be justified by the risk reduction achieved. Above the tolerable band the risks are said to be 'unacceptable' with improvements seen as essential in

all but exceptional circumstances, and below the tolerable band the risks are judged as 'broadly acceptable', with no further working required to reduce risks.

R2P2[3] defines the upper boundary between intolerable and tolerable if ALARP levels of risk for members of the public as a fatality once in 10,000 years and for workers as a fatality once in 1,000 years, with the lower limit between tolerable and broadly acceptable levels of risk as 1 in a million years for all people. The above thresholds were used to produce the ABB Eutech calibrated risk matrix shown in figure 1 with an explanation of the risk levels in figure 2. Note that upper and lower ALARP regions have been introduced to distinguish between the level of gross disproportionality to be applied when considering the need for further measures.

Catastrophic							
Extremely Serious							
Major							
Serious							
Minor							
	Extremely Unlikely	Very Unlikely	Improbable	Remote	Occasional	Probable	Frequent

Figure 1. Calibrated risk matrix

	Broadly acceptable	No need for detailed working to demonstrate ALARP
	Lower ALARP	Tolerable if cost of risk reduction would exceed the improvement gained
	Upper ALARP	Tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate to the improvement gained
	Unacceptable	Risk cannot be justified except in extraordinary circumstances

Figure 2. Definition of levels of risk

For the tanker drive-away scenario the consequences of an offloading hose rupture were judged as catastrophic and the frequency of a tanker drive-away and failure to isolate the leak was estimated as improbable. The risk is therefore in the upper ALARP region meaning that further measures should be considered unless it can be shown that the cost of these is grossly disproportionate to the likely improvement. The improvements considered can either reduce the consequences of the event or reduce the frequency of the event, in either case it is necessary to make reference to current standards for the technology under review.

Whilst the risk matrix approach for COMAH safety reports has many advantages there are a number of issues as raised by Middleton[4]. Hazardous events can have several outcomes dependent on subsequent events such as ineffective pressure relief, ignition or delayed ignition

of flammable substances or failure of secondary containment. The tendency is to consider the worst-case outcome to avoid an excessive number of points on the matrix but this can lead to an unrepresentative set of scenarios. The published criteria for individual risk refer to the cumulative risk from a medium sized operation, including all the hazardous events that could harm an individual. The risk matrix is being used to consider individual scenarios and it is therefore important to consider the number of events within each consequence category. It has been found effective to plot all the scenarios on the risk matrix to give a graphical representation of the spread of risk. For high severity events the risk matrix does not differentiate between events that could kill one or a few people off-site and those with the potential to cause tens of fatalities where criteria for societal risk need to be considered. Such events were classified in safety reports as 'catastrophic with the potential for multiple fatalities'. The author believes the limitation of risk matrices to individual risk needs to be accepted and that for high severity events a more detailed quantified risk assessment methodology is more appropriate.

ALARP DEMONSTRATION

Positioning events within the lower or upper ALARP bands does not necessarily mean that the risk is ALARP as further measures may be appropriate. A definition in more recent HSE guidance of this band is 'Tolerable if ALARP', with the responsibility on the operator to demonstrate that all reasonably practicable measures have been taken. Only when the assessment has been carried out and the necessary improvements implemented can the risk be classified as ALARP. The assessment is however subject to ongoing reviews based on further experience within the industry and advances in technology.

The CEFIC[5] code of practice for sulphur dioxide storage systems includes the following considerations for protection against tanker drive away:

- Automatic valves upstream and downstream of hose, operated locally and remotely,
- Trip on detection of low pressure in system,
- Wheel chocks or clamps to prevent movement,
- Fail-safe braking system on road tanker,
- Mechanical interlock to ensure barriers are dropped with hose connected.

None of the above protection measures were incorporated into the existing design and a qualitative cost benefit assessment was carried out by the study team. The first and third options are procedural and therefore less reliable than automatic systems. The second option will generally be more reliable but could be in a failed state. The forth option, whilst a reliable method, relies on the road tanker being fitted with the brake locking device and its' being maintained by the haulier. The new protective measure selected was an interlocked barrier system to ensure that the barriers are closed whenever the offloading hose is in use with periodic inspection of the system to ensure that it is still functioning correctly. The above measure was judged to give considerable risk reduction whilst only requiring modest cost, and a decision was taken to go ahead with this improvement.

SAFETY REPORT ASSESSMENT EXPERIENCE

The timetable for COMAH safety report submissions meant that a number of sites previously regulated under the CIMAH Regulations submitted reports in February 2001.

Early feedback indicated a rejection rate of around 35% with the main reason being a failure to link the major accident scenarios with the associated protective measures. As CIMAH did not require such a link to be made it is possible that these sites had failed to recognise the new requirements under COMAH. The ABB Eutech approach provides a major accident table format where each scenario has details of the causes, consequences, protection measures and event frequency. It is felt that this format provides the linkage required by the HSE and this view has been supported by successful assessment outcomes.

Sites new to the major accident regime have mostly submitted their safety reports in February 2002. Following earlier experience HSE has modified its' assessment strategy to initially consider only the predictive sections of the report. The objective is to ensure that a suitable and sufficient set of scenarios has been considered prior to a full assessment being started, thereby avoiding wasted effort for the HSE and cost for the operator. A number of common themes have emerged leading to safety reports either being rejected or the assessment process being put on hold pending further information.

The HSE are making a clear distinction between the extent and severity of major accidents for consequence assessments. The method described earlier provides an estimate of the extent or hazard range and from this the assessor determines if the harm will be very localised, extend across the site or extend into off-site industrial or public areas. The severity is defined as the number of people that might be harmed or for environmental effects the area that might be harmed. Operators are being asked to estimate the severity of their worst case scenario in terms of the number of fatalities to people on-site and off-site. A standard approach has been developed by ABB Eutech that initially calculates the areas under risk contours for lethal doses at the 1%, 10%, 50% and 90% levels. For toxic releases the plume direction towards the areas with the highest population density is used to find the worst case severity. Two weather conditions are considered with different probabilities for the proportion of people indoors and outdoors, the mitigating effect of being indoors is also calculated. The above approach is effective in giving a worst case figure for numbers of fatalities although the need for a conservative approach tends to over-estimate the severity. For this reason and a concern over how information on numbers of fatalities will be interpreted by local residents, operators are generally reluctant to release data in a public document.

Another key area for further information is the demonstration made in safety reports that risks have been reduced to ALARP. The approach described earlier results in a qualitative assessment of the need for further measures to be taken based on the judgement of the team against known standards and good engineering practice. The competence and knowledge of the team are critical and the leader needs to have a challenging approach to avoid acceptance of the status quo. It is argued that the degree of improvement actions arising from the risk assessment process provides a demonstration on the adequacy of the ALARP demonstration. For example an assessment that did not raise any improvements would no doubt raise suspicions that the team had not been sufficiently rigorous. The HSE are taking the requirement a step further and requesting that the assessment considers *all* the feasible additional measures that could be taken, providing a justification for those not implemented. The basis for this decision might be that the improvement is impracticable or that the costs outweigh the benefits.

The HSE requirement for ALARP demonstration would be very onerous if applied across the full range of major accident scenarios for a site. The concept of safety critical events (SCEs) has been introduced by Middleton[4]. These are defined as the events within each consequence category with the highest frequency and those with very high consequences. For each SCE a detailed ALARP demonstration is required to justify why further measures are not being taken. The HSE are currently preparing an extensive list of possible protection measures to be used as a checklist or guide diagram when carrying out such assessments.

To meet this new requirement the study team have searched for further protective measures against the hierarchy of inherent safety, prevention, control and limitation measures. No possibilities should be ignored at this stage. The company is likely to have discarded several options due to impracticability, the justification for these decisions needs to be recorded. For other options the costs may be considered too high compared to the risk reduction that can be achieved and a simple cost benefit assessment technique can be used to justify the decision not to implement any further measures. In practice it has been found that such assessments have resulted in new measures being agreed. With the sulphur dioxide tanker drive away hazard for instance, further measures included a procedure for removal of keys from the road tanker driver during offloading.

LATEST HSE GUIDANCE

The HSE has recently published a policy[6] and guidance[7] on making ALARP decisions in the context of COMAH. The policy document provides a basis for making decisions on gross disproportion when carrying out cost benefit analyses. A 'proportion factor' (PF) is defined as the total cost of implementing the measure divided by the value of the fatalities thereby prevented. Measures must be implemented if the PF is one or less when close to the Broadly Acceptable boundary or if the PF value is 10 or less when close to the Unacceptable boundary. Detailed quantified analysis is not essential as the policy advises the professional judgement of a team supported by a crude form of cost benefit analysis will be adequate. For new plants good practice contained in approved codes of practice, HSE guidance and industry standards should be considered as a minimum requirement, with confirmation of the relevance and currency to the specific hazard. It is recognised that for existing plants, applying good practice retrospectively will be subject to a test of reasonable practicability.

The policy document[6] states that ALARP decisions need to consider both the risk to individuals and societal risk. The latter requirement is new to COMAH as the HSE has previously stated that societal risk assessments were not required due to difficulties in interpreting the results. A distinction is made between societal risk and societal concern, the latter being the socio-political response to hazards with the potential to cause multiple fatalities or affect vulnerable groups despite a low level of risk. If societal concerns exist for a specific installation it may be necessary to implement further measures beyond any societal risk considerations.

The guidance document[7] is more specific to the needs of the chemical industry and COMAH in particular. It gives guidance on the depth of the risk assessment and ALARP demonstration required as interpreted on table 4.

Table 4. Proportionality in risk assessments and ALARP demonstrations

Risk matrix position	Depth of risk assessment	Type of ALARP demonstration
Intolerable	Quantified Risk Assessment (QRA)	Risk reduction required regardless of cost
Upper ALARP	QRA if close to intolerable semi-quantitative	Apply relevant good practice plus Consider further risk reduction measures applying proportion factor of 10
Lower ALARP	Semi-quantitative Qualitative if close to broadly acceptable	Apply relevant good practice plus Consider further risk reduction measures applying proportion factor of 1
Broadly acceptable	Qualitative	Apply relevant good practice

For societal risk R2P2[3] gives the criteria of 50 fatalities once in 5000 years as the boundary between the intolerable and tolerable if ALARP regions. Other published 'anchor points' for societal risk have been reported by Ball[9] along with a number of FN curves to be used for societal risk assessments. To avoid the complexity and cost of a fully quantified risk assessment, HSE has developed a 'rough but rapid' technique to indicate the level of societal risk. An approximate risk integral (ARI) is calculated as a function of the maximum number of fatalities for the worst case event and the frequency of this event. HSE are providing a simple program for calculating the ARI from these values, further details on the development of the methodology and the equations involved can be found in a paper by Hirst and Carter[8]. The ARI approach now favoured by the HSE explains why they are requesting companies to provide an estimate of the number of fatalities for the worst case event as discussed earlier.

The HSE guidance document[7] gives the criteria for individual risk in agreement with R2P2[3] and the new criteria for societal risk as shown on table 5.

CONCLUSIONS

The COMAH Regulations place an onerous duty on operators of sites with large inventories of dangerous substances including the need to carry out detailed risk assessments. The procedures developed from established process hazard analysis techniques have proved effective for a number of COMAH risk assessments carried out by ABB Eutech. The structured approach demonstrates that a thorough evaluation of the risks posed by the operation has been undertaken, and the semi-quantitative use of a risk matrix avoids the use of time consuming and costly quantified risk assessments.

Table 5. HSE risk criteria

Risk matrix position	Individual risk frequency of fatality per year	Societal risk Approximate Risk Integral (ARI)
Boundary between intolerable and Tolerable if ALARP regions	1×10^{-3} for worker 1×10^{-4} for public	500,000
Boundary between Tolerable if ALARP and broadly acceptable regions	1×10^{-6} for all	2,000

The methodology provides the opportunity to review the existing protection measures against current industry standards, and to use a risk based analysis to determine if further risk reduction measures are required. For the illustrative example of a road tanker drive away and hose rupture the risk was judged to be at the upper end of the tolerable region. A recommendation has been made to install an interlocked barrier system to prevent the road tanker moving whilst the offloading hose is attached and further recent assessment has added a procedure for the driver's keys to be removed.

Many companies consider the COMAH Regulations to be a costly burden on their business and the strict application in the UK has lead to claims that a level playing field does not exist in Europe. The approach described in this report allows a focused and risk prioritised improvement plan to be developed. This will achieve genuine reductions in the risks of major accidents and in the long term will protect companies from the highly damaging effects of a serious accident. A second benefit from the involvement of site personnel in the risk assessment process is a greater awareness of the potential for high consequence, low frequency events. It is common to find that the primary focus for those involved in health and safety are regular low severity events such as slips, trips and falls. COMAH has helped to redress the balance in favour of the high severity events that, although rare, are an ever-present danger should attention to the critical safety measures lapse.

Recent guidance from the HSE has clarified a number of the earlier problems in determining a proportionate approach for COMAH risk assessments and ALARP demonstrations. The difficulty for operators and those writing safety reports is that the guidance is late and is being applied by HSE retrospectively. The requirement to include a measure of societal risk when making ALARP decisions is a new approach and it is likely that for operators of sites with high consequence events this will form part of ongoing assessments.

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