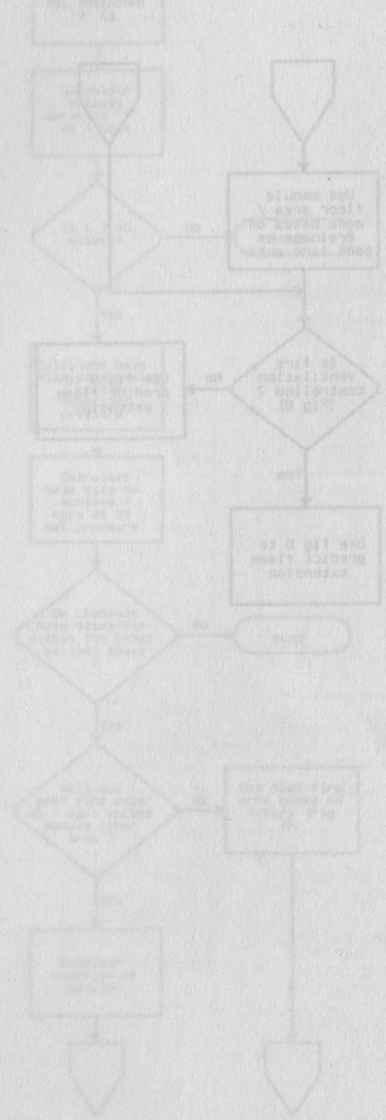
Flowchart 4A : Oil Release
Long Duration Small Fire (Cont)



THE ROLE OF QRA IN OFFSHORE SAFETY CASES

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An outline is given of the Cullen Report recommendations on the use of QRA for offshore installation safety assessment. The implementation of these recommendations in regulations and guidance is described. Comments are made about some uncertainties in QRA, strategies for handling these, and areas where further refinement may be possible.

Keywords: Offshore, Safety, Risk, Assessment, QRA.

Introduction

The Piper Alpha disaster on July 1988 was the world's worst offshore accident, claiming the lives of 165 workers from the platform and two rescuers. It began with a leakage of hydrocarbon which vaporised, mixed with air to form a flammable mixture, ignited and burned with explosive violence, damaging safety systems and other containment. Hydrocarbon fires escalated through the platform, leading to ruptures of high-pressure gas pipelines which injected fuel into the fire, initially at a rate of several hundred kilograms per second. Eventually the heat from these fires weakened the support structures so that much of the platform collapsed into the sea. Most of the fatalities occurred in the accommodation block, due to asphyxiation from fumes which had either penetrated from outside or been released by the effects of heat on the fabric and fittings of the block.

The disaster led to an exhaustive public inquiry under Lord Cullen, whose report was published in November 1990[1]. The first part of the Report describes the development of the accident and the likely initial cause, namely a leak from a temporary flange which was inadvertently exposed to a high pressure of hydrocarbon condensate (C_3 - C_6 fractions). The second part of the Cullen Report considers what changes are necessary to improve the safety of installations offshore, particularly from major hazards. While much work had already been done to improve safety before the publication of the Cullen Report, it produced a major new impetus in several areas and further urgent work has been proceeding since then to implement the recommendations. The paper by Mr A C Barrell to this Conference describes this progress.

Lord Cullen proposed two fundamental changes to the regulation of safety offshore. One change is a move from detailed prescriptive legislation to goal-setting regulations. This means that operators will be required to meet broad performance goals, but not told how to do this. Within the broad goals, they will need to develop more detailed specifications or criteria, and to produce design and operational solutions to satisfy those specifications. This will allow flexibility and scope for technical ingenuity, while ensuring that the solutions are driven by the real needs of the local situation. There will still be a role for guidance on ways to achieve the goals, but with the proviso that the guidance is not mandatory and should not inhibit the use of reasonably practicable alternatives.

The Health and Safety Commission is currently considering its strategy for the review of legislation which is needed to accomplish the move to goal-setting legislation. New regulations are likely to be needed in a number of key areas, for example: evacuation, escape and rescue; fire and explosion; and construction, covering the design and layout of installations. New regulations will be brought forward over the next 3-4 years.

The other, and complementary, fundamental change is that an operator should produce a Safety Case to demonstrate that the activity is as safe as is reasonably practicable. This builds on, but goes beyond, the basic concept of the onshore CIMAH Regulations Safety Report[2]. It aims to ensure that the operator has properly assessed the hazards, evaluated the risks and put in place adequate management, operational and hardware systems. Offshore, it is required for HSE formally to accept the Safety Case; beyond a certain date, it will be illegal to operate an installation without such acceptance. Note that HSE's acceptance of a Safety Case does not diminish the responsibility of the operator for the safety of the installation. HSE will have said that it is satisfied with the case for safety in the documentation, which should include the operator's own commitment and awareness of responsibility.

The other recommendations in the Cullen Report cover many aspects of safety offshore, including:

- Regulation by HSE;
- Workforce safety representatives;
- Improvements in permit-to-work systems;
- Incident reporting;
- Process control and control-room functions;
- Hydrocarbon inventory isolation and protection;
- Fire and gas detection and action;
- Fire and explosion protection;
- Emergency control and procedures;
- Evacuation, escape and rescue.

These points do of course arise from the context of a hydrocarbon fire and explosion disaster on an integrated drilling and production platform offshore. However, many of them suggest lessons for other situations, both off and onshore. The Offshore installations (Safety Case) Regulations (see below) will cover all registered offshore installations, including mobile units except those in transit[3]. A specific offshore point is the emphasis on evacuation, escape and rescue, and about a third of Lord Cullen's recommendations relate to this. Another important point is the concept of a "Temporary Safe Refuge" (TSR).

A TSR is a provision for people to be protected from the effects of an incident while they muster and decide what to do - whether to evacuate the installation, or try to control the incident, or to wait it out. The value of such a provision was shown by the Piper Alpha disaster. Uncertainty and confusion in the accommodation block led to many deaths which might have been avoided, if people had had confidence in the ability of the block to survive a certain time, and access to protected escape routes of known capabilities. A parallel might be drawn between the TSR concept and the protected control-room for major hazards onshore, as discussed by the Advisory Committee on Major Hazards[4]. The major differences are that the offshore TSR needs to provide for all people on the installation, and escape may be more difficult. Also, the required functions and types of hazard may differ in detail - and this can be very significant in practice.

The Offshore Installations (Safety Case) Regulations

It may be useful to highlight a few points from the proposed regulations. First, there are legal definitions of "major accident" and "QRA". The definition of major accident (see below) differs from CIMAH, in that the latter is based on a release of substance or energy, while the OI(SC) definition is based directly on injury to people (except for major structural damage and helicopter crash, which are very likely to lead to injury).

Major accident (in OI(SC) Regulations,[3]) means:

" (a) *a fire, explosion or the release of a dangerous substance involving death or serious personal injury to persons on the installation or engaged in an activity in connection with it;*

(b) *any event involving major damage to the structure of the installation or plant affixed thereto or any loss in the stability of the installations;*

(c) *the collision of a helicopter with the installations;*

(d) *the failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations; or*

(e) *any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity in connection with it."*

Note the last clause - this is included to allow for incidents such as a crane-load falling onto a group of workers. It must be emphasised that this definition is not meant to imply that accidents harming fewer people are unimportant; but there are usually significant differences between the approaches to assessment and protection against major accidents and against others.

Quantitative Risk Assessment (QRA) means:

" *the identification of hazards and the evaluation of the extent of risk arising therefrom incorporating calculations based upon the frequency and magnitude of hazardous events".*

The distinction between QRA and other risk assessments is discussed further below.

The definition of "acceptance" by HSE may also be of interest.

" *Any reference in these Regulations to the Executive accepting a safety case or revision is a reference to the Executive notifying the person who sent the safety case or revision to the Executive that it is satisfied with the case for health and safety made out in it or in the revision, as appropriate".*

Note that it is the <u>case</u> that is required to satisfy HSE. In the course of its work to investigate a Safety Case, HSE will probably need to probe beyond the basic document into supporting references, and it may need to check the situation offshore by visits, but it is hoped that the Safety Case will be a stand-alone document.

At the time of writing, the draft OI(SC) Regulations and guidance have been published in an HSC Consultation Document[3] and the comments received are being considered. It is hoped to mention to the Conference any particular points arising from the consultation process, and the timetable for implementation.

The Role of QRA

The Cullen Inquiry heard evidence on the usefulness of QRA from experts in Industry, Consultants and Norwegian and UK regulatory authorities. Lord Cullen concluded that QRA, properly used, would be a valuable source of information to aid decisions about safety provisions offshore. He noted the following points in favour of QRA:

- It is clearly practical for offshore installations;
- The effort required to do QRA is justified because large members of people work and live on installations;
- The risks are relatively high;
- The benefit will be substantial for most cases;
- The installations are less heterogeneous than onshore hazards;
- For such substantial installations the costs of QRA are justified;

- The hazards have been realised, showing that they need to be assessed by the whole range of techniques.

Lord Cullen did not say how or where QRA should be used in specific detail, except for the TSR. There, he recommended that a Safety Case should include "a demonstration by quantified risk assessment of major hazards that the acceptance standards have been met in respect of risk to the integrity of the TSR, escape routes and embarkation points and lifeboats from design accidental events and that all reasonably practicable steps have been taken to ensure the safety of persons in the TSR and using escape routes and embarkation points".

The implementation of Lord Cullen's recommendations in the draft OI(SC) Regulations and Guidance treats QRA in two parts, namely the general Case and the TSR. For the general Case, the Guidance suggests that use should be made of QRA wherever it is reasonably practicable to do so. This does not mean that full QRA (ie QRA producing integrated risk figures) need necessarily be used for all elements of the installation and all hazards. It is acknowledged that QRA can be a laborious exercise, requiring the input of scarce resources and taking time to perform which might conflict with a need for urgent decisions. Also QRA does not produce highly precise figures, and the degree of uncertainty may limit its usefulness. In some areas, partial QRA may be sufficient (eg to produce the frequency or conditional probability of an event or to assess the scale of an incident); or valuable insights may be gained from an unquantified analysis using the tools of QRA; or it may be better to rely on tried and tested engineering standards. However, the extra insights and quantified results from QRA will often be worth the effort. A sincere acceptance of this point, and a thoughtful attitude towards the use of QRA, will lend credibility to a Safety Case.

HSE will expect a Safety Case to develop a policy for the use of QRA, including a company's own criteria for judgement of the results, and if appropriate its basis for cost-benefit assessment to show that the risks are as low as is reasonably practicable (ie ALARP). HSE does not intend to produce criteria (except initially for TSRs - see below), but it is possible that experience with the first round of Safety Cases will point to a general consensus which it may be useful to develop. For the present, it is emphasised that ALARP does in principle permit significant differences between installations, where the practicalities of improvement differ. It

also implies that new designs should in general reflect the relative ease of improvements on the drawing-board compared to the backfitting of existing installations, by incorporating state-of-the-art safety features.

QRA and Criteria for TSR

For the TSR, the OI(SC) Guidance follows Lord Cullen's recommendation quoted above. The TSR concept is regarded as a system or set of functions, comprising a central mustering-point together with access routes to it from occupied parts of the installation, and escape-routes from it to the helideck and lifeboats (ie TEMPSC). The central mustering-point includes facilities for command, control and communication. It is expected that it will usually be the main accommodation-block or perhaps a specially-hardened part of that block, but alternatives are not ruled out if they can be shown to be effective. Variations from this simple description may be needed for particular installations, for example subsidiary muster-points where people may be trapped away from the main point by the incident.

The QRA of the TSR will concentrate on fire and explosion hazards, including flammable gas or smoke ingress, and taking account of possible loss of integrity by collapse of the supporting structure as well as breach of the barriers. Interest need not be confined to these hazards if there are others for which a TSR seems relevant (eg toxic gas). Potential events will probably be divided into design-basis events, ie those which the TSR is designed to resist, and extreme events, ie those which exceed the design basis. The QRA should show the frequency of failure of the TSR due both to failure within the design envelope (eg ventilator intake fails to close on demand), and to extreme events.

"Failure" of the TSR means that conditions inimical to life occur within it before sufficient time for people to muster, assess the situation, decide whether to evacuate the platform or to attempt to control the incident or wait for it to subside, then if necessary to prepare to evacuate and carry out the evacuation. Noting that the TSR is a system, it is helpful to analyse all of the functions required of its components, to see where failure could occur and how significant it is. This leads to insights such as the need to ensure safe access for less time than the full endurance of the TSR, since access precedes the other actions and requires less decision-making etc. Also, in principle the escape-routes need only be passable for a brief period of time compared to the endurance required of the central mustering-point. This period of time occurs after the muster-assessment-control-decision, so it may be well after the start of the incident. It might be engineered as a brief period of protection, for passability rather than static occupation, allowing for the use of temporary personal protection such as smoke-hoods.

It falls to HSE initially to suggest acceptance criteria for the TSR. In due course, companies will be expected to set their own criteria, but some initial benchmarks will help to set the scene. The basic criterion is that the risk of failure should be as low as is reasonably practicable, ie ALARP. In general, this would be expected to be below 10^{-3}/y frequency of failure within the stated minimum endurance time, which should not be less than one hour, this period being judged as the minimum usually likely to be necessary for the functions outlined above. It remains open for companies to show that part or all of a TSR system is unnecessary by achieving a similar standard of safety by other means, following the test of ALARP; but this will be acceptable only for special cases where the TSR functions are clearly unnecessary. Note that it must be shown that one hour is sufficient for the particular installation, or a longer time must be invoked. A proposal to adopt a shorter time criterion would require very stringent justification.

In assessing cases, HSE will of course take due account of the uncertainties in QRA and the limited precision of the numerical results. It would be hoped that QRA assumptions will err on the side of pessimism in areas of doubt. HSE will look for clear indications of the assumptions made and the company's views on the uncertainties, sensitivities and degree of pessimism or optimism. Then HSE can judge the significance of the risk figures against the benchmarks.

It must be emphasised that the purpose of QRA is not simply to satisfy some target imposed from outside. It is to provide information to assist an operator to discharge the responsibility to reduce risks ALARP. HSE will consider how the process and results of QRA fit into an operator's approach to safety assessment and management. It is appreciated that not every company has the resources in-house to carry out all aspects of QRA, but it is vital that any work done out-of-house is integrated into the company's awareness and decision-making systems. Apart from the risk results, this includes the use of QRA to:

Identify safety-critical hardware and operations;

Design systems of management information on safety performance;

Evaluate options, eg between automatic and human operation;

Consider manning patterns;

Integrate the various components of a safety system to produce a balanced solution;

Optimise maintenance and replacement schedules;
Assess costs and benefits of options;

Consider the adequacy of standard designs or specifications;

Evaluate radical design proposals;

Etc.

Note that all of these areas include the possibility of optimisation to minimise costs while achieving the necessary degree of safety. Apart from it being reasonably practicable to do QRA to improve safety, it may well pay for itself in helping to do this most efficiently.

Some Current Issues in QRA

Although QRA in some form has been in use for fifty years, there are areas of doubt and uncertainty. In many cases the significance of these can be minimised by a careful choice of assessment approach or decision strategy(5). Some remaining problem areas are discussed below. It must be noted that the degrees of uncertainty are not necessarily greater than those in other forecasting situations which are generally accepted for decision-making. For example, a book entitled "Risk Analysis" turns out to be mainly about prospecting for petroleum and bidding for concessions(6). It suggests that a winning sealed bid is often double the next highest, and maybe 10-100 times the lowest, implying a high degree of variation in assessments of the value of the prospect (and of the likely valuation by other bidders).

Failure-Rate Data

Detailed QRA relies on data on failure-rates of hardware components. The most relevant source of such data is a company's own record from routine testing during planned maintenance, and unplanned breakdowns. Where such information is inadequate, it may be necessary to use industry-wide average data. This may arouse concern that the local performance will differ from the industry average. A company may be able to infer such differences, for example, by comparing its accident record with the average. Care is needed not to stretch the train of inference unduly.

HSE and others are reviewing the sources of industry-average data, and work is also in hand to see how company records might be used. Current indications are promising. There has existed for many years an industry data-pooling scheme OREDA, similar to the NCSR system onshore in the UK(7)(8).

Human Error

The development of QRA (among other things) has provided a stimulus to considerations of the role of human error and human performance in man-machine systems. There seem to be two main strands of development, namely the analytical - to identify points where a human action enters the chain of causation and the derivation of failure-rates at those points; and the global - to see whether some overall human performance factor can be derived to modify a QRA based on industry-average hardware data. There are of course areas where these strands overlap or interact. Also, more certainty is possible for the more frequent unwitting or skill-based errors than for those involving knowledge and judgement or rule-breaking. Considerable progress in quantifying human error has been made, but more work is still desirable.

The strategy for dealing with human error in a particular QRA needs to be given consideration bearing in mind the purpose of the QRA. For example, a hardware-based QRA has implicit within it the average human error performance of the source of hardware data. This may be quite reasonable, but it needs to be ensured that future performance will not deteriorate significantly, by proper continuing management (see(9) for an outline of a technique for applying management performance factors to QRA). Another aspect - the rare, major violations of rules - may not appear in average hardware data. Then the QRA might be used to show how resistant the whole system is to

such a major violation at one point, or it might show how frequent a major violation would need to be to upset the results of a hardware QRA. The significance of major violation could then be inferred.

Consequence and Escalation Modelling

Some major accidents, eg Flixborough, are the immediate result of a single failure. Others, eg Piper Alpha, begin with a failure which leads by escalation to a much larger event. The nature of offshore installations, with their close-packed process plant in three dimensions, emphasises the need to consider escalation. This is a challenging phenomenon to simulate, but models are emerging (eg(10)). The problem is to avoid over-simplification while keeping manageable the number of combinations of event source, direction, impact on other components, and mitigating actions etc.

The consequence modelling of events may need refinement offshore compared to the approaches onshore. Much emphasis has already been placed on the prediction of vapour-cloud explosions in platform modules, and more work is likely(11). Other areas include the effects of heat and explosion on structural supports, and the resistance of TSRs to fire, smoke and blast.

Human Response to Incidents

This area includes the effects of smoke, fumes, heat and other impacts on human performance and the behaviour of people in emergency. To do QRA for a TSR, it is necessary to define what constitutes "failure", ie conditions likely to lead to serious injury and death. At some lesser levels, people will become incapable of constructive action (NB it may in practice be impractical to distinguish between levels of impact intensity as implied here). Guidelines do exist, for example for heat stress(12), but they may need to be adapted for the more short-term and once-off nature of a major incident. HSE is considering whether to develop guidance here, in collaboration with industry and others.

The behaviour of people in emergency may be modelled at a mechanical level, for example to show how quickly a group may move from one point to another assuming certain rules about choice of route, speed of motion etc. Several models are being developed for offshore use. Also, a full QRA takes into account the likelihood of successful escape, noting that the use of lifeboats or descent into the sea involves a degree of risk. Usually, such risks are quantified on the basis of survival rates from past incidents.

Validation

It is important to seek validation for the results of QRA. This may require data on past accidents and incidents. Several databases exist or are being developed. Lord Cullen recommended improvements to the collection of incident data by the UK, specifically for releases of hydrocarbons offshore. Such data might either be used as the input to QRA if they are sufficiently comprehensive, or as a cross-check on predictions of leak frequencies from a hardware-based QRA. HSE has begun to implement this recommendation through the incident reporting system, and data will be made available. Note that 'validation' by the use of such data would be just on a part of a full QRA. Even so, it is useful. With ingenuity and imagination, partial validation can go some way to fill gaps in the availability of top event data.

Conclusions

Lord Cullen's report firmly recommends the use of QRA to assess risks at offshore installations for the purposes of Offshore Safety Cases. This should be done where the extra information from QRA justifies the effort needed to do it, following the principles of ALARP - the more severe the risks, the more effort is needed to assess and control them. Offshore QRA may differ in some details from that elsewhere, but there is much in common as well. The problem areas leading to uncertainties in results can be minimised by the choice of strategy in the approach to QRA and the use of best current QRA technology.

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