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Reducing the Risk of Low-Probability High-Consequence Events

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Abstract

Low-Probability High-Consequence (LPHC) events are accidents that are unexpected, with few similar historical events; however, when they do happen the impact is extreme. With few prior events available to learn from, it can be difficult for a single company or organization to completely understand, manage and fully mitigate the risks involved with LPHC events. This is because they do not have enough learning opportunities to improve their overall risk management performance, and properly address the hazards.

Part of the problem in managing against LPHC events occurring has been the lack of appropriate metrics. While efforts are underway by industry to develop a suite of Process Safety metrics, there is still a gap where Operational Safety is concerned.

The author proposes that the best way to reduce the risks is by working issues at a sector or total industry level, rather than on a company by company basis. At an industry sector level there is greater knowledge and awareness of a larger number of previous events and a broader group of experts to develop industry practices and risk management guidelines.

Examples are given of how successful this concept has been for a specific hazard, then at a national level, and finally in the geophysical sector of the oil and gas industry between the International Association of Geophysical Contractors (IAGC) HSE&S Steering Committee and International Association of Oil and Gas Producers (OGP) Geophysical HSSE Sub-committee, where contractors and operators have worked together on Health, Safety, Security and Environmental (HSSE) issues for a number of years.

The oil and gas industry can improve its overall safety performance for LPHC events by working at a global sector level, or even globally across the industry by better sharing of the right kind of information on incidents. In addition, industry should capture the key aspects and lesson learned in databases that can then be used for several purposes: to drive the development of guidance documents; to help create improved and more consistent risk assessments across industry; to help develop the improved metrics still needed for Operational Safety, and potentially to guide any new regulatory requirements.

To accomplish all of this on a global basis may require the creation of a new industry body. It is worth bearing in mind what occurred in the US after the Three Mile Island nuclear incident. The nuclear power industry was at risk, and it established the Institute of Nuclear Power Operations (INPO) in 1979, with a mission to "promote the highest levels of safety and reliability – to promote excellence – in the operation of commercial nuclear power plants". In the 30 years since INPO was established it has built an excellent safety and reliability record, but they are still cognizant of continuing challenges. The best way forward may be to establish a similar but global body for the world-wide oil and gas industry.

Introduction

Low-Probability High-Consequence (LPHC) events are accidents that occur rarely and are unexpected when they arise; however, when they do happen the outcome is severe or catastrophic in terms of loss of human life, severe injuries to people and/or damage to the environment. With few historical incidents available it can be difficult for a single company or organization to completely understand, manage and fully mitigate the risks involved with LPHC events. Typically a single organization would not have enough learning opportunities from which to improve their overall risk management performance, and properly address the hazards. One reason they are unexpected is that LPHC events are typically the result of the breakdown of numerous controls or barriers (Craddock, 2004), and the chances of a large number of barriers failing at

the same time is much lower than the probability of a single barrier failing. Following the old adage about needing to measure something to be able to properly manage it, a short discussion on metrics is included in the next section.

Low-Probability High-Consequence Events and Metrics

Figure 1a is a plot of 2007 data from the US Bureau of Labor Statistics, as published in 2009, showing the ratio of Days Away From Work Cases (or Lost Time Injuries) per Fatality, across multiple industries. This data has been presented previously in Threadgold et al. (2010), Anderson and Denkl (2010) and Denkl et al. (2010) and has been useful for demonstrating several points. On the horizontal scale, the data is broken down into different hazard or incident categories. The vertical scale, which shows values of the ratio, is non-linear. The categories on the left hand side have tens of incidents per fatality, whereas the categories on the right hand side have thousands of incidents per fatality. The types of incidents on the left, by the nature of their severity, are also more likely to be multiple fatality events (e.g. explosions, road transportation) than the incident categories on the right (e.g. slips, trips, over exertion).

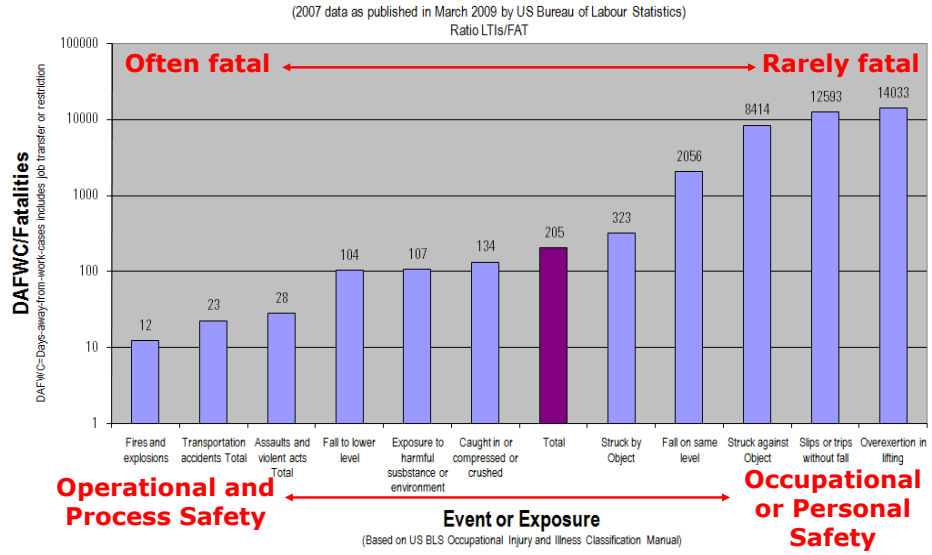

Figure 1a: Ratio of DAFWC / Fatalities across multiple industries

It is the incidents on the left hand side of this chart that are Low-Probability High-Consequence events. There have been only a small number of similar previous incidents before a catastrophic event occurred. Although the data shown are across multiple industries, a similar plot would result from purely oil and gas industry statistics. Anderson and Denkl (2010) showed this for a large oil field services company, and they supplemented the data by using the potential severity (for purposes of learning), as opposed to the actual severity from an event. This was specifically to provide themselves with more data to analyze, for the purpose of trying to help minimize catastrophic loss.

In the oil and gas industry these LPHC events fall into two areas, Process Safety and Operational Safety, depending on the nature of the work being performed. Process Safety concerns any activity where hydrocarbons are processed, stored, transported, or handled in anyway. Operational Safety concerns any other oil and gas industry activity that is not covered by Process Safety, such as acquiring a seismic survey, or oil field construction operation, etc. It is important to make this distinction, as different metrics are needed to measure Process Safety versus measuring Operational Safety performance.

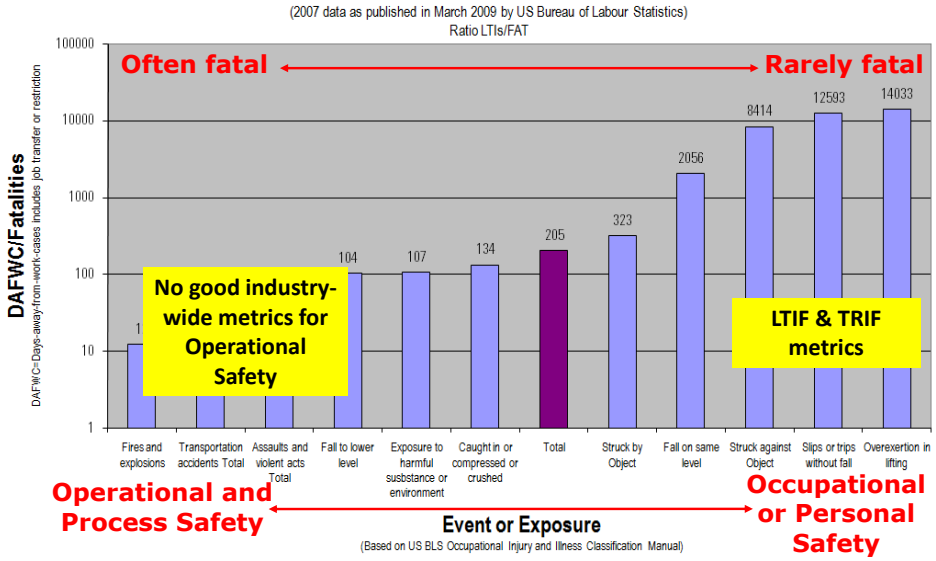

Figure 1b: Ratio of DAFWC / Fatalities across multiple industries and Metrics

As per Figure 1b, Lost Time Injury Frequency (LTIF) and Total Recordable Injury Frequency (TRIF) have proved to be good metrics over the years for Occupational Safety (also known as Personal Safety), but there have been no similarly useful metrics for LPHC events in the past. Craddock (2004) concluded that injury frequency rates "are not necessarily indicative of the potential for a major accident event" (i.e. Low-Probability High-Consequence events). The lack of development of good metrics for LPHC events has in part been driven by the over-reliance of some companies on Personal Safety metrics. Hopkins (2000 and 2009) along with the "*Baker Panel report*" (Baker et al., 2007), in reviewing major LPHC events, have discussed the problems associated with an over-reliance on Personal Safety metrics including complacency about managing major hazards.

Because LPHC events happen infrequently, and because they are typically the result of numerous controls failing, there is no single simple metric that can be used for performance managing Process Safety activities. This is why a portfolio of metrics is required for better prediction and prevention of LPHC events. Hopkins (2009) states that "research has shown that major accidents are always preceded by warning signs, that for one reason or another are not recognized as such". It is these pre-cursor indicators that need to be captured by metrics.

In his 2004 paper, Craddock also recommended monitoring and improving the implementation of high priority corrective actions as a metric for reducing Low-Probability High-Consequence event risk. A safety performance metric based on a quantitative evaluation of corrective actions (Veley, 2002 and Veley et el., 2004) is in use by some companies, but this is not an industry-wide standard.

It was only after the 2005 bp Texas City incident that industry effort seriously began developing a set of Process Safety metrics. There is still a critical need to develop a parallel set of Operational Safety metrics for oil and gas field activities that do not directly involve the processing, storing, handling, etc., of hydrocarbons.

Working Issues Jointly Across Industry

The author proposes that the best way to reduce the risks of LPHC events is by working issues at a global sector or industry level where representatives from operators, contractors, service companies and trade associations work jointly together, rather than working an issue on an individual company by company basis. This could be done even more broadly, where appropriate, by including other stakeholders such as regulators, union representatives, etc. At a global industry sector level there is greater knowledge and awareness of a larger number of similar incidents and a broader group of experts to develop industry practices and risk management guidelines. In addition, the broader discussion itself helps create a greater overall understanding of the issues and potential solutions or mitigations. This type of effort in the HSSE realm between operators and contractors, or service companies also fosters better overall business relationships and understanding between companies.

There are a few shining examples of how well this has worked in some niches of the oil and gas industry, around a specific hazard, at a national level, or a specific industry sector. However, overall oil and gas industry performance can be further improved, and especially for LPHC incidents, by working at a global industry level across all sectors, and between sectors where the hazards are common.

Example of success for a specific hazard

One example of success in working an issue between contractors, oil and gas companies and service companies for a particular hazard is *DROPS*, or the *Dropped Objects Prevention Scheme*. *DROPS* started in 1997 as part of the Step Change initiative in the UK in the drilling sector. *DROPS* is an industry-wide initiative focused on preventing dropped objects, and the process is shown in Figure 2. With a global and several regional workgroups, representatives from service companies, contractors, operators and industry bodies work together with a common goal of reducing dropped object incidents. One of the significant tools *DROPS* has created is a dropped objects incident database, which is called *DORIS* (*Dropped Object Register of Incidents and Statistics*) and available at http://www.doris.dropsonline.org/. This database allows information of incidents to be more widely shared and learned from. After its success in the drilling sector, *DROPS* moved into production operations and is now being looked at in the geophysical sector, and by the construction industry as well. The *DROPS* program is available at http://www.dropsonline.org/.

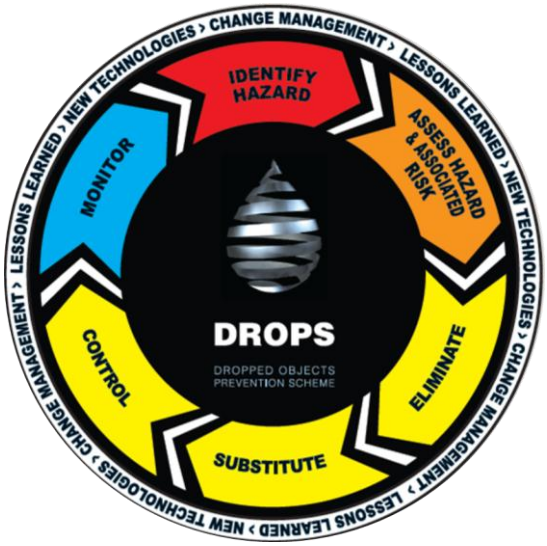

Figure 2: The DROPS process

Examples of success at a national level

Two examples of success in working safety issues at a national level are the UK's *Step Change in Safety* and Norway's *Samarbeid for Sikkerhet (SfS)* or (in English) *Working Together for Safety*. These were both initially aimed at personnel working on offshore installations.

The *Step Change in Safety* initiative was launched in 1997 by a group of industry trade associations, with the goals of improved sharing of safety information, and delivering a significant improvement in safety performance in the UK offshore oil and gas industry. They have been successful across industry in the UK offshore in part due to their broad stakeholder base, including regulatory personnel, trade union representatives, trade association staff, and people from operators, contractors and services companies working together. Besides safety on offshore installations their current focus includes aviation and marine safety, and the prevention of major accidents on the UK Continental Shelf. Their website contains a wealth of information at http://stepchangeinsafety.net/

SfS started at the end of 2000, and again there is broad representation from unions, operators, regulators, contractors of various kinds, ship-owners, trade associations, and other interested groups. *Working Together for Safety*'s current areas of cooperation include falling objects, marine operations, harmonizing permit to work and job safety analyses, harmonizing safety procedures, and safety culture training and competence. It has received acclaim for its recommended best practice documents and the animated safety films it has produced. The website for this initiative can be found at http://www.samarbeidforsikkerhet.no/

Examples of success from an industry sector

In the geophysical sector of the oil and gas industry, the International Association of Geophysical Contractors' (IAGC) HSE&S Steering Committee and the International Association of Oil and Gas Producers' (OGP) Geophysical HSSE Sub-committee have worked together collaboratively for a number of years. This collaboration is now at a stage where there are visible examples that the joint work of contractors and operators together on HSSE issues, has saved lives and made work activities safer (Threadgold et al., 2010). This progress has been made primarily through the open sharing of information, joint meetings, joint databases, and joint development of guidelines and HSSE contract specifications.

Joint meetings and sharing
The IAGC HSE&S Steering Committee and OGP Geophysical HSSE Sub-committee hold a Joint Global HSSE Forum twice a year, with the venue alternating between Europe and the Americas. At these meetings, there is a real sense of cooperation and collaboration between competitors and across the client-contractor boundary, with all working towards the common goals of preventing accidents, saving lives, reducing injuries and avoiding damage to the environment. One example is the 2-3 hours session at each meeting where high-potential near misses and major incidents, and the lessons learned from these, are shared and openly discussed. This process has evolved over time as feelings of trust have developed, along with a realization of the value of this open dialog.

Joint databases
One of the tools developed jointly between the IAGC and OGP committees has been a simple fatality database for the geophysical industry covering almost the last 40 years. This tool is called the *Aide Memoir for Geophysical Risk Assessors* and it is available on the IAGC website at http://www.iagc.org/AideMemoir/. As the database name implies, this was constructed with geophysical risk assessors in mind. The intent was that any single person or company performing a risk assessment for a geophysical operation (and using the tool) would come out with the same evaluation when trying to assess the likelihood of a particular hazard ending in a fatality (e.g. it had "happened in industry once a year", or "once every 10 years", etc.). So it was built for the purpose of improving learning for the whole sector and developed from the collective experience of the industry sector.

The end result is much better risk assessments across the sector than would have occurred in individual companies. Work is now being considered to try and create a larger sector-wide database for all the lessons learned from all of the high potential near miss events that the sector has been sharing so widely, so that this information can be used more consistently sector wide and create improved risk assessments.

Joint development of guidelines and HSSE contract specifications
Over time the OGP has developed a tiered system (Figure 3a) of guidelines for the development and utilization of Health, Safety and Environmental Management Systems in the oil and gas industry. The highest level is a guideline document for developing the management systems (OGP 210). The second level is a guideline document (OGP 423) that lays out an 8 stage process for how clients and contractors should work together in a contracting environment. The geophysical sector (through the IAGC and OGP committees) has developed the only third tier guideline document which is called OGP 432 – Managing HSE in a geophysical contract. As far as the author is aware, no other sector of the oil and gas industry has a similar third tier document.

OGP 210	Guidelines for the Development and Application of Health, Safety and Environmental Management Systems (1994; currently under revision)
OGP 423	HSE management guidelines for working together in a contract environment (2010, updated from 1999)

Geophysical Operations	Drilling	Projects / Construction	Production Operations	Marine Operations	Diving Operations
OGP 432					
Managing HSE in a geophysical contract (2009, updated from 2001)	TBD	TBD	TBD	TBD	TBD

Figure 3a: The three tier system of industry guideline documents for HSE management systems

OGP 432 contains recommended model HSE contract clauses which express the industry standard HSE specifications for geophysical operations, and also the requirements for project specific HSE plans. The true value of this three tier system is in using them as a package. When used they allow the operator and contractor to work together to agreed industry guidelines and this minimizes any contractual differences. It also makes the tendering process more efficient because when used, the contractors HSE staff can focus on HSE issues, rather than having to take valuable time to write a response to a tender that is in an alien format.

Documents specific to Geophysical Operations		
Contract schedules	**Auditing**	**Competence Assessment**
OGP 432	OGP 245	OGP 292
Managing HSE in a geophysical contract (2009, updated from 2001)	Guidelines for HSE auditing in the geophysical industry (1996)	HSE competence assessment training guidelines for the geophysical industry (1999)

Figure 3b: OGP guidelines specific to geophysical operations

As shown in Figure 3b, the committees have also developed other guidance documents at the management systems level specifically for the geophysical sector, and these are for auditing and competence assessment. In addition, jointly developed guidelines have been published by both the IAGC and OGP around numerous specific hazard areas, and field safety manuals.

One use of the *Aide Memoir for Geophysical Risk Assessors* was to identify the hazard areas or activities where most deaths were occurring in geophysical operations. This then allowed the geophysical sector to prioritize what areas needed work to develop new activity-specific guidelines. A particular example of this was the realization that drowning was one of the highest causes of death on land and transition zone geophysical surveys. A workgroup was set up and a guideline was published in 2004 called *Watercraft and water in geophysical operations – a guideline to operations and management* (OGP 355). After publication, drowning incidents on land and transition zone operations began dropping from a rate of up to 6 per year during the previous decade, to where there have now been zero known instances in 2007, 2008 and 2009.

This is just one of several examples where the joint efforts between the IAGC and OGP committees (contractors and clients working together) have saved lives and improved safety performance across the geophysical sector of the industry. The IAGC and OGP Joint Global HSSE Forums are unique also in terms of being multi-disciplinary, i.e. Health, Safety, Environmental and Security (and occasionally with a few Social Responsibility and Sustainable Development issues being reviewed). The Geophysical HSSE Sub-committee is the only multi-disciplinary sub-committee in the OGP's extensive structure of approximately 50 committees, sub-committees and task forces. The formation of similar multi-disciplinary sub-committees for other industry sectors might be a catalyst for broader industry development of guidelines, databases etc., in much the same way that the geophysical sector has performed.

Discussion

Professor Andrew Hopkins is an Australian social scientist at the Australian National University, who has written several books on the outcomes of specific LPHC events, as well as participating on some investigation or inquiry boards into LPHC events. Hopkins (2000) wrote that "the prevention of rare but catastrophic events should not be left to local managers with no experience of such events. Head office has both greater past experience and greater future exposure". This is easily taken a step further to where a company that has not experienced a major accident themselves, is probably not best placed to manage such hazards based solely on their own experiences; they need to incorporate learnings from other companies or other industries into their hazard assessment and risk management.

By discussing, reviewing, sharing, etc. of information at industry level and developing shared databases, guidelines, HSE contract clauses, etc. at an industry level, we can develop the "collective mindfulness" that Hopkins (2000) describes, where hazards are so thoroughly evaluated we become pre-occupied with the chance of failure, which is a hallmark of a high-reliability organization. As Hopkins (2000) further states "mindfulness about the possibility of failure extends to learning the lessons from elsewhere" which goes to the heart of working these issues at a global sector or industry level.

A final interesting observation from Hopkins (2000) is that "the technical failures vary from one accident to another but the organisational failures which accident analyses reveal seem remarkably similar. A focus on organisational rather than technical causes therefore offers the best opportunity for generalisation, that is, the best opportunity for types of learning that can be transferred from one enterprise or industry to another". Therefore, it is important that these organizational learnings are captured, and not just the technical details, when incident information is shared, if re-occurrence of similar incidents are to be prevented.

Given the geophysical sector results and other examples discussed such as *DROPS*, *Step Change in Safety* and *Samarbeid for Sikkerhet*, there is sufficient evidence to demonstrate the value of joint efforts by industry for improving safety performance. A step forward would be to implement this concept further, across all sectors of the oil and gas industry, fostering collaboration wherever possible.

The oil and gas industry can improve its overall safety performance for low-probability high-consequence events by working at a global sector level, or even globally across the industry by better sharing of the right kind of information on incidents. In addition, industry should capture the key aspects and lesson learned in databases that can then be used for several purposes: to drive the development of guidance documents; to aid in creating improved and more consistent risk assessments across the industry; to assist in the development of the improved metrics that are still needed for Operational Safety, and perhaps even to guide any regulatory requirements.

To succeed in all of this on a global industry basis may require the creation of a new industry body. It is worth bearing in mind what was put in place in the US after the Three Mile Island nuclear incident. The nuclear power industry itself was at risk - demonized at the time, similarly to the oil and gas industry after the Macondo incident. In 1979 the nuclear industry established the Institute of Nuclear Power Operations (INPO), with a mission to "promote the highest levels of safety and reliability – to promote excellence – in the operation of commercial nuclear power plants". In the 30 years since INPO was established it has built an excellent safety and reliability record, but they are still cognizant of continuing challenges. The best way forward may be to establish a similar but global body for the world-wide oil and gas industry.

Conclusions

(1) Collaborative cross sector efforts (versus those of any single company), with a larger group of stakeholders, can only help improve safety performance and reduce the risk of low-probability high-consequence events in all sectors of the oil and gas industry.

(2) Although the oil and gas industry has been developing a portfolio of Process Safety metrics, effort is still needed to develop an industry-wide set of metrics for Operational Safety, and then encourage the use of them across the industry.

(3) More industry or sector-wide databases are needed to capture and share incident information and lessons learned, similar to the *Aide Memoir for Geophysical Risk Assessors*, and the *Dropped Object Register of Incidents and Statistics*, to help improve risk assessment across the industry, steer the development of guidelines and in critical cases, perhaps even become part of the regulatory requirements.

(4) It is recommended that the OGP consider establishing more sector specific multi HSE discipline workgroups (like the Geophysical HSSE sub-committee), that could work more closely with other sector-specific trade association committees, such as those from IADC, IMCA, and others.

(5) The oil and gas industry should consider establishing a global safety institute, for improving safety performance in the industry. This entity would be responsible for developing safety standards; conducting independent evaluations; collecting, collating and communicating incident information and lessons learned, at a minimum.

Acknowledgments

The author would like to acknowledge the contributions made by all the individuals in the variety of joint workgroups mentioned in this paper, and their companies who committed their time towards a common goal, with the hope of reaching that level of commitment from all organizations involved in the global oil and gas industry. By doing this together, we can achieve more than by doing it on our own.

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