Progress on Process Safety Indicators - Necessary but Not Sufficient?

A DISCUSSION PAPER FOR THE US CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

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Introduction

The CSB commissioned this paper which reviews the progress made in developing process safety indicators both in the United States and overseas over the last few years. Much of this work was stimulated by the Texas City disaster in 2005, the Buncefield oil terminal explosion in the same year in the UK and of course the more recent Macondo disaster in the Gulf of Mexico. The paper is intended to encourage debate about safety indicators and suggest how further improvements may be made. In particular, the paper considers whether or not the safety indicator guidance published by a variety of organisations such as the American Petroleum Institute (API) in 2010[1] and the International Association of Oil and Gas Producers (2011)[2] is sufficient to assist companies and regulators in preventing another Macondo (or Montara) type incident, given what we know about the causes of accidents.

The paper concludes that whilst there is tangible progress on safety indicators relevant to the major incidents which can occur in offshore petroleum safety, this progress seems limited in scope compared with what could be done in the light of existing knowledge. Meanwhile despite the progress made on *process* safety indicators, personal safety measures such as Lost Time Injury Frequency Rates (LTIFR) or similar measures appear to be still given too much prominence by companies despite their well-known weaknesses in relation to major accident prevention. Further work seems to be warranted to publicise their limitations.

The paper suggests how we can get better indicators, especially in relation to offshore drilling. This involves identifying the specific hazards and risks presented by drilling and assigning indicators to the causes. There are a relatively limited number of these which are well known. The paper goes on to report on a practical example of how this methodology is *currently* being applied by one upstream oil and gas company following the Montara blowout in Australia. The paper also considers the approach adopted by the mining industry in Queensland, Australia to risk management. The underground coal mining industry, like petroleum drilling, is also faced with the risk of catastrophic events such as fires and explosions in circumstances where natural phenomena have a bearing on the risk. This line of thought is offered by analogy to see if this mining approach offers any insights for the upstream oil and gas industry.

Finally, it is argued that even with the addition of indicators which address drilling more specifically, in addition to the losses of containment measures, these would still not be sufficient. This is because not all foreseeable major incident types are neither *process* safety related nor drilling related, as the recent loss of the jack-up Kolskaya demonstrates.

Indicators: Definitions and Uses

Indicators are generally regarded as an important part of an organisation's system for measuring its performance. "What gets measured gets done" is a well-known adage frequently quoted in popular

[1] ANSI/API Recommended Practice 754: Process Safety Indicators for the Refining and Petrochemical Industries, 2010.
[2] OGP Process Safety – Recommended Practice on Key Performance Indicators, Report 456, November 2011.

books on management theory and practice.[3] Indicators, or "key performance indicators" in general management applications, are typically used by an organisation to evaluate its performance as a whole or the performance of a particular activity in which it is engaged. What is implied by the "what gets measured *gets done*," adage is that measurement is not an end in itself but enables *action* to be taken.

By contrast the Organisation for Economic Cooperation and Development (OECD) defines *safety performance indicators* as "…observable measures that provide insights into a concept – safety – that is difficult to measure directly."[4] The OECD definition usefully reminds us of the obvious but important point that safety is not easy to measure and we have to do it by inference from a surrogate indicator which we believe tells us something about safety. The relevance of the surrogate measures we choose is discussed later. Although at first sight the OECD appears to have a weaker definition with less emphasis on action, the OECD (following the work done by the UK safety regulatory body, the Health and Safety Executive (HSE)[5] emphasises the importance of *acting* on the indicators. Put another way, indicators are generally regarded as being an enabler for managerial control and in another popular adage it is said that "you cannot manage what you do not measure." All this seems obvious and straightforward, but as with most management concepts, the difficulties lie in their detailed application.

Regulators tend to want indicators to direct regulatory interventions and safety improvement programs. This requires data over a time period long enough to determine the causes of accidents - typically years - and preferably statistically reliable. Company boards and senior executives are also interested in these broad industry trends because this information is needed to inform the action taken in their own companies. But more specifically, they need to know how their company's safety strategy is working in practice to determine what adjustments to company strategies and plans are needed. This information is typically collated over a shorter period, say a year. At a plant or facility level, personnel also need to know about accident causation in their industry and of course should know what is going on in their company. However, they are specifically tasked with managing the day to day risks as well. Consequently, they need much more specific information in (near) real time on which to take action to manage the risks.

What have we learnt about Safety Indicators?

The most popular measures or indicators of "safety" are frequency rates and severity rates of accidents based on personal injury such as lost time injury frequency rates (LTIFR). LTIFR and similar data are valued by government regulators and companies alike for their apparent value in being able to compare companies and industries. They can discriminate, at least in theory, which are the best and worst industries and which companies or parts of companies are doing better than others. They have proved remarkably durable. Although there has been much greater take up by companies of

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[3] See for example Wayne W. Eckerson, "Measuring, Monitoring and Managing Your Business" ISBN 978-0471 – 75765-8.

[4] Guidance on Developing Safety Performance Indicators related to Chemical Accident Prevention, Preparedness and Response 2nd edition 2008, OECD, Paris 2008.

[5] Developing process safety indicators: A step by step guide for chemical and major hazard industries, HSG 254, ISBN 978 0 7176 6180 0.

process safety indicators, LTIFR type safety indicators still seem to have great prominence as will be seen below.

Problems with Personal Safety Indicators

Personal safety indicators, such as LTIFR, are not without their problems, beyond what should be the familiar issue of their lack of applicability to relatively rare process safety events. These include their focus on consequences as opposed to causes, their lack of utility for occupational health (despite this being a much greater health and safety issue as measured by the number of deaths compared to personal safety) and their susceptibility to manipulation. These are discussed further below. There is an underlying assumption that personal safety data do provide valid comparisons on health and safety performance despite these well-known problems. For example, OGP hope to "… gain the KPI consistency and benchmarking value that took many years to achieve for *personal safety* [and as a result] OGP have aligned definitions…with RP 754."[6] Although this is the orthodoxy, it is far from clear that personal safety measures represent the pinnacle of achievement implied by OGP. The following section briefly considers personal safety measures such as LTIFR to see if there are any lessons to be learnt for process safety.

Cause or Consequence?

Consider the following hypothetical example. A person walks out of the office down a flight of stairs and slips on some spilt oil. What are the consequences of this? The person may land heavily on their bottom and only their dignity is hurt! Alternatively they may fall so that the back of their skull hits the edge of the step, fracturing their skull resulting in hospitalisation. The second incident is captured by the LTIFR measure but the first is not, although the underlying condition, the slippery step, is exactly the same in both incidents.

Thus there is an element of randomness in LTI rates because they measure the *consequences* of incidents and not the causes and the consequences are highly susceptible to chance over which the company has no control. This is an important criticism of LTI rates. Because of the randomness of the consequences measured by LTIs, it may be difficult for employees and their managers to see the connection between the efforts they expend on safety and what is measured. In other words they have only very limited control over the results or consequences as measured by LTIs but companies should have much more control over the causes or circumstances which led to the incident. Effective prevention therefore has to focus on the *causes* of incidents because outcomes or consequences can be random and uncontrollable.

This has long been known. Although expressed in the language from an earlier era, in a pamphlet published in 1932,[7] the UK safety regulator (a forerunner of HSE) pointed out that:

"It is also extremely useful to have records kept of all accidents to plant etc which might [emphasis added] *have resulted in personal injuries. A careful analysis of these records and a proper study of them will indicate the location and causes of the various accident risks."*

[6] OGP 2011 Appendix B, page 24.
[7] Home Office "*Safety Organisation in Factories*," published by HMSO 1932.

In other words we need to know what could have happened not just what did. Is process safety any different? It is axiomatic that the success of the indicator is dependent on a good understanding of what it is important to measure to indicate performance. Whilst this is self-evident, significant mistakes are made about the linkages between what is measured in an organisation such as LTIs and the reality on the ground. A recent example from the UK railway industry illustrates this graphically.[8] The body which regulates safety on the railway found that:

... significant under-reporting has taken place – and estimates that between 500 – 600 ... reportable accidents were not reported between 2005 and 2010. Some of the under-reporting relates to misinterpretation of the [regulatory] requirements, ***but the majority is explained by staff and contractors choosing not to report accident events. This was caused by both real and perceived pressure, and in some cases fear****, (*emphasis added*) felt by Network Rail staff and contractors if they reported accidents. The reason this was not identified by Network Rail itself was because it believed that the significant efforts it was making to improve safety, including investment in protective clothing, quantified targets and league tables, were driving the numbers of accidents down.*

Again this has long been known. In 1992 the author attended an International Loss Control Institute training course called the "Fundamentals of Modern Safety Management" run by Det Norske Veritas (DNV).[9] I attended it in my capacity as a regulator in the UK's Health and Safety Executive's Offshore Safety Division. I was a member of a team developing standards against which safety cases for offshore installations would be assessed in the post Piper Alpha disaster era. The manual which accompanied the course commented about the knowledge of some managers on measuring safety:

About the only "safety" measurements they know about are accident consequences such as "frequency rates" and "severity rates." They are the most abused and misused measurements of "safety" and are subject to many variables and forms of manipulation. But their greatest weakness is that they are after the fact and reactive. As Charles E. Gilmore pointed out in an address at the National Safety Congress: ***What is the sense in measuring if the loss must occur before you can act? That's reaction, not control.***[10]

Despite the problems identified above, the incidents measured by LTIFR are relatively easy to identify. The incident causing injury is usually obvious and the consequences have an immediate impact. This is not necessarily so with the much larger number of occupationally related illnesses and deaths associated with chronic exposure to contaminants in the workplace.

Personal Safety Indicators and Major Incidents

In relation to process safety, the most important weakness of LTIFR type data is that they "are particularly limited for assessing the future risk of high consequence, low probability accidents."[11] One of the first people to bring this to the attention of a wider audience was Professor Andrew

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[8] Rail Safety and Standards Board (UK) (25 January 2011) Press Release. http://www.rssb.co.uk/SiteCollectionDocuments/press/2011/RSSB%20RIDDOR%20Review%20Press%20Release.pdf.
[9] Fundamentals of Modern Safety Management, ILCI, reprinted from "Practical Loss Control Leadership" by Frank E. Bird, Jr and George L. Germain. Revised Edition 1990, International Loss Control Institute (ILCI).
[10] ILCI manual, "Management Control of Loss" 3 – 9.
[11] Amis, Richard and Richard T. Booth, "Monitoring Health and Safety Management," The Safety and Health Practitioner, vol. 10, February 1992, pp 43 – 46 .

Hopkins whose analysis of Esso's Longford incident, "The Lessons of Longford" was both very readable and influential. The almost self-evident conclusion that a focus on typical LTIs, (slips, trips, sprains and strains) does not tell one much about process plant integrity, essential to prevent fires and explosions has since become much more mainstream and recognised in industry. For example, Chevron analysed all of its major incidents and concluded, amongst other things, that a "focus on individual safety may not address the precursors to major process incidents."[12]

However, personal safety and LTIFR type data are still given prominence by companies in the oil and gas industry, at least in some of their public utterances. For example a major upstream company has recently published an open letter on its website from its President on Safety. It mentions *"…sand storms in Egypt and wildfires in the Permian Basin, extremes of cold in Horn River Basin… [and]…the mundane but preventable trip, slips and falls…Over the last five years, recordable injuries of … employees have declined by 63 percent and injuries…37 percent(sic)."* Process safety is not mentioned.[13]

These reductions in personal safety are creditable and to be commended and no doubt reflect a great deal of commitment and hard work on the part of the company concerned. But in an industry susceptible to low frequency but high consequence events, this statement suggests that more work may need to be done to explain why process safety needs particular focus so that both process safety and personal safety are given appropriate attention.

Recent Developments in Process Safety Indicators

The development of indicators more relevant to major incidents was given substantial impetus by the investigations into the BP Texas City refinery disaster in 2005 including the recommendation made by the US Chemical Safety Board (CSB) that API and the United Steelworkers International Union (USW) should work together to develop:

"…performance indicators for process safety in the refinery and petrochemical industries. Ensure that the standard identifies leading and lagging indicators for nationwide public reporting as well as indicators for use at individual facilities. Include methods for the development and use of performance indicators."[14]

However, it should be noted that work on developing alternative indicators predates this in the hydrocarbon industries. For example, two conferences held in 1994 and 1998 for the UK North Sea oil and gas industry, "Financial and Non-financial Performance Measures in the Oil and Gas Sector" and "Performance Indicators for a Step Change in Safety" both addressed in some detail the improvements needed. This latter conference, held 10 years after the Piper Alpha disaster, had an opening address from the UK industry's peak body, the United Kingdom Offshore Operators Association (UKOOA, now UK Oil and Gas). The speaker said, amongst other things, that the industry needed to come up,

[12] Personal communication to the author.
[13] Apache Corporation, "*Safety is in the hands of the employee*" *Rod Eicher, President and chief operating office,* http://www.apachecorp.com/News/Articles/View_Article.aspx?Article.ItemID=2361, accessed on 6 July 2012.
[14] US CSB 2007 "*BP Texas City Final Investigation Report*" page 212.

"… with indicators which we can all use and which provide meaningful data – information which does show us not only how we are doing statistically, but where the major weak points are in our safety management systems. In other words, we need to analyse and eliminate causes of accidents, not just look at the symptoms. Ideally we need to do this ahead of problems, so we need Leading Indicators to show us where the potential weak links are. By eliminating them we eliminate future accidents." [15]

In 2006 the UK HSE, working in collaboration with industry, finally gave us a credible way to do this. This innovative work integrated the concept of developing lead and lagging indicators into the barrier concept of accident causation. In essence the HSE work says that each barrier or risk control measure for a defined risk should have specific indicators of performance of the barrier, both leading and lagging. Arguably the most important part of this work is the emphasis on the methodology for identifying and developing the barriers and the indicators.

Let us "fast forward" now to 2011 and OGP's November 2011 "Process Safety – Recommended Practice on Key Performance Indicators, Report No.456." Texas City, and to a lesser extent the Buncefield oil terminal explosion in the UK in the same year, were seminal events in the development of our thinking on safety indicators. It is an unfortunate reality that change and improvement in the field of safety seem to depend in large measure on the energy created by disasters and the subsequent investigations. The years following the Texas City disaster in 2005 reflect this and we have seen the publication of a number of guidance documents on process safety indicators from the UK (HSE 2006), OECD (2008), CCPS (2007 and 2010), API (2010) of which the aforementioned OGP report is but the latest. Each one had the benefit of those going before it.

API Recommended Practice 754

Before discussing the OGP Recommended Practice, because it is so closely based on API Recommended Practice 754 (produced as a result of the CSB recommendation following the Texas City disaster) it is appropriate to briefly describe API 754.

API 754 identifies leading and lagging process safety indicators relevant to the refining and allied industries. There are four tiers of indicators presented in the form of a pyramid. At the top of the pyramid are losses of primary containment events of the greatest consequence. These are Tier 1 events. Tier 2 indicators are loss of containment events of less consequence than Tier 1s. Both are carefully defined and are intended for public reporting.

At the bottom of the pyramid are those managerial and operating aspects of operating a facility which, if successful, should contribute to a safe facility. There are potentially a large number of these measures which need to be appropriate to a given facility and which must be selected by the company; thus, they are not proscriptively defined in API 754. These are Tier 3 and 4 indicators and are intended for internal use at individual sites. API 754 recommends that leading indicators are appropriate for these topics. The OGP Recommended Practice discussed below and published in November 2011 closely follows the concepts and models set out in API RP 754.

[15] Javan Ottoson, Director, Gas Business Unit, Arco British Ltd, Speech notes for conference on performance measures to achieve a step change in safety, Thursday 15 October 1998.

OGP Recommended Practice on Key Performance Indicators, Report No.456. (OGP 456)

OGP 456 has the benefit of, and appropriately draws on, the work by the UK HSE with its focus on developing leading and lagging indicators for barriers to incidents as well as the other aforementioned reports. It is particularly important because it is the only document specifically aimed at the *upstream* oil and gas industry, including drilling. It is in this context that the following discussion on the OGP Recommended Practice takes place. Given the Deepwater Horizon incident, does the OGP Recommended Practice deliver for industry the guidance on indicators needed to support further improvements in upstream petroleum safety, especially offshore, where the risks are magnified by the marine environment? It is suggested that the answer to this is only in part.

There are three main reasons for this. First, the language and hence the concepts used are process operations focused. Second, the incidents selected for reporting for benchmarking purposes are consequence based losses of primary containment and suffer the same weaknesses of LTIFR based personal safety measures. Third, there is a potential methodological problem by starting off by collecting a narrow range of incidents for benchmarking rather than taking a broader approach and using that data to work out what is important to benchmark and then narrowing down the focus.

Language and Concepts

The OGP Recommended Practice represents only a very modest advance over API 754 on which it is substantially based. API 754 is written specifically with the refining and petrochemical industries in mind. In other words, the focus on API was on *process plant* risks. This is of course what they were asked to do following Texas City. Whilst there are strong parallels between these industries and upstream production activities, they are not identical. OGP recognised that more specific guidance was needed for the upstream oil and gas industry, but again their focus seems to be more on production related losses of containment, as opposed to the drilling sector. Although the OGP Recommended Practice is intended to apply to upstream industry the language and hence the concepts used such as “Process Safety Event” and “loss of *primary* containment” are redolent of the onshore oil refining and petrochemical industries. Refineries and terminals have secondary containment arrangements around bulk storage tanks, such as bunds, and where the risks come from the *processing* of the hydrocarbons.

Whilst there are obvious similarities to offshore production activities, the language translates less well to drilling where, unlike process operations, not all of the processing conditions are always as well-known as they should be in a refinery. Whatever remotely obtained data is available about the sub-surface formation, it is rarely perfect and it is not unusual to have to address unexpected circumstances associated with the natural variation of the strata. Do drillers see themselves as operating process plants?

Consequence based measures

It is questionable if the focus in API 754 and OGP 654, on a narrow category of higher consequence events - specifically, “Process Safety Events” – will give us enough detailed information needed to enable preventive activities to be effectively and quickly targeted. As discussed earlier it is the *causes* of the incidents we need to know about not just that an event has occurred which has had certain *consequences*. Personal safety measures such as LTIFR suffer from a similar weakness.

A Methodological Problem?

There is also a potential methodological problem. The OGP Recommended Practice defines, for comparability reasons, a small number of high level indicators such as "process safety events." This presupposes that these are what are important. No doubt they are for production operations but it is far from clear that this is the case for drilling. For example, a number of well-known topics which could form the basis of indicators have been proposed.[16] These include the precursors to well incidents (such as pit gains or losses), the drilling crew's response to these precursors of a well incident (which may be simulated by drills), the technical condition of key equipment such as the pit level monitoring devices, human and organisational factors such as crew competence, and finally indicators related to schedule and cost.[17]

Safety Indicators for Upstream Oil and Gas – What could we do?

The Skogdalen and Hopkins papers referred to above make a convincing case for having more drilling related indicators. The authors of both papers are academics. Is it practical to develop indicators for drilling safety based on the concept of identifying the barriers to or causes of a well related major incident? PTTEP AA have designed and implemented just such a system.

PTTEP AA's "Line of Sight" Tool[18]

An independent review[19] carried out on behalf of the Australian Government of the action plan prepared by PTTEP AA following the Montara blowout in 2009 found that it did not include action to implement effective monitoring by senior managers of its safety processes, including process safety and asset integrity. Partly in response to this finding, PTTEP AA developed its "Line of Sight" tool. Its goal, amongst other things, is to provide assurance of process safety management to senior personnel by demonstrating that frontline operational activities are being conducted in accordance with company policies, procedures and rules. In the case of Montara the issue of managerial oversight was powerfully raised in the Montara Commission of Inquiry as this exchange between the legal counsel assisting the Inquiry and the PTTEP AA Chief Operations Officer reveals[20] in his testimony:

Q. *You seem to be saying that, to your knowledge or understanding, no one in PTT would have credited at this time that people involved in well management and well control might have succumbed to any sort of corner cutting or inattention to proper procedures by virtue of the desire to achieve time and cost savings.*

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[16] See *Hopkins A, "Safety Indicators for Offshore Drilling: A working paper for the CSB inquiry into the Macondo blowout,"* www.csb.gov, 22 September 2011 p 3.

[17] For a useful discussion on safety indicators for drilling see *Skogdalen, J.E., Utne, I.B. & Vinnem, J.E. (2011) Looking back and forward: Could safety indicators have given early warnings about the Deepwater Horizon Accident?*

[18] Askew, P, *Line of Sight: Bringing MAE Prevention to Life*, Australian Petroleum Production and Exploration Association Conference 29th February 2012.

[19] Independent Review Report: Review of PTTEP Australasia's Response to the Montara Blowout ("Noetic Review"). http://www.ret.gov.au/Department/responses/montara/review-pttep-response/Pages/IndependentReviewReportReviewofPTTEPAustralalasia'sResponsetotheMontaraBlowout.aspx.

[20] Evidence to the Montara Inquiry 9 April 2010 by Andy Jacob pages 1784/5, http://www.ret.gov.au.

A. *Mmm-hmm, yes.*

Q. *I'm suggesting to you that the very fact that you are giving that evidence identifies a problem, namely, senior management did not properly recognise the plain fact of ordinary human nature and a known phenomenon, namely when you have lots of people applying themselves to achieving time and financial efficiencies, they can lose sight of the need to properly attend to processes.*

A*. On the basis that there weren't systems in place to ensure that the barriers, et cetera were identified as being in place and verified and that, yes, I can accept that.*

Q. *So if you like, senior management almost seem to have approached the matter on the basis that everyone could be relied upon to do a perfect job without investing time and effort into really monitoring what was happening and ensuring that their expectations about people doing their job properly were fulfilled?*

A. *That certainly would be a way of viewing it. Again, I don't believe there was any conscious decision not to do things. They had an expectation that people would be fulfilling their roles. I agree with you that the documentation and recording of those critical elements would be a far more satisfactory way of ensuring that they have been achieved.*

Q. *Yes but one failing, I am suggesting is a cultural or attitudinal notion that seems to have pervaded senior management with PTT to the effect that you just give people a job to do and let them go about doing that as efficiently as possible, and you need not worry after that, whether they are in fact doing everything they need to because you almost can't credit the alternative?*

A. *I think that's expanding it beyond the realms. I think in this particular case, as I said, I can agree that that's the way it appears but extrapolating that into a general statement is taking it a bit too far.*

Q. *Let's just analyse that quickly. There seems to have been a complete absence of effective quality assurance with respect to the installation of barriers in every single well.*

A. *Yes, based on the evidence we have heard, I agree.*

Q*. I want to suggest that a common denominator that explains all of that is a view by senior management that they really didn't need to closely monitor what was happening, because senior management just couldn't credit the possibility that corners might be cut in the pursuit of time and cost savings.*

A*. That's certainly one element of it, I would suggest, yes.*

Evidence to the Montara Inquiry 9 April 2010 by Andy Jacob pages 1784/5)

PTTEP AA has developed a tool to help ensure the situation described above would not happen again. The essence of the tool is that there is reporting by front line personnel (at a frequency relevant to the type of barrier) of the status of those barriers or controls, critical to preventing major accident events. The system is built upon the principles articulated by Professor James Reason and popularly referred to as the "Swiss Cheese Model." The barriers were identified by a range of front line personnel, technical line managers, safety specialists and senior management drawing on the formal safety analyses and Bow-Ties from the safety cases. Whilst it is relatively new and no doubt will be modified and improved, early indications and the personal observations by the author during offshore visits to the drilling operations strongly suggest it is providing much greater visibility of the major incident barriers and controls.

Underground Coal Mining: Trigger Action Response Plans

Underground coal mining has a long history around the world of major incidents. Roof falls, inundations from neighbouring workings and in particular fires and explosions associated with methane and coal dust have all killed large numbers of people (and continue to do so in some parts of the world). Queensland, Australia has not been immune from these sorts of events. In 1975, 13 were killed, in 1986 12 were killed, and in 1994 11 were killed, all near the town of Moura. Industry and regulators looked for more effective methods of preventing these major incidents. The approach adopted goes by the name "Trigger Action Response Plans, (TARPs)."

As part of the risk based approach to managing hazards in Queensland, mining companies are required to prepare TARPs as part of their Principal Hazard Management Plans. "Principal Hazards" are defined by legislation as those hazards which have the potential to cause multiple fatalities. The first point of interest is that, similar to the safety case type approach in use in the offshore oil and gas industry in the UK, Australia, and elsewhere in the world, there is an explicit focus on events which can cause multiple fatalities. Thus, the regulatory approach distinguishes between personal safety and what we know as process safety, but perhaps should be renamed major incident safety.

A TARP can be summarised as the minimum set of actions required by site personnel in response to a deviation in mine conditions from normality. This requires the development of indicators (or triggers) for specific hazards and the actions that site workers should take are defined by reference to these indicators. As explained by Hopkins and Wilkinson:

"The central philosophy behind these standards is that major accidents are usually preceded by indications of trouble. Plans must therefore identify these indications and specify appropriate action to be taken when they occur. For instance, the seepage of water at a coal face may foreshadow an inrush event. (Similarly, small leaks of gas on an offshore platform may be symptomatic of a corrosion problem)."

"In the language of the Queensland regulator, plans must identify trigger levels, or events, [or indicators] and action response plans, actions to be taken in response to trigger events. For each hazard, there are normally several trigger levels of increasing seriousness, with corresponding action plans, ranging up to withdrawal of all personnel from the mine."[21]

An interesting aspect of the TARPs is that they require specific indicators or triggers to be established which are relevant to the specific mine and working face. Although a degree of commonality exists across TARPs for specific hazards, such as gas concentrations in relation to

[21] Hopkins, Andrew and Peter Wilkinson, Working Paper 37: "*Safety Case Regulation for the Mining Industry,*" ANU July 2005, http://regnet.anu.edu.au/publications/wp-37-safety-case-regulation-mining-industry.

the fire and explosion risk in an underground coal mine, the particular characteristics of the mine, coal seam and its geology must be taken into account.

Similar principles could be usefully applied to drilling offshore oil and gas wells. At the heart of the TARPs process is the necessity to understand what normal looks like, and then the corresponding need to identify the indicators of what the triggers are, the appropriate action that should then be taken, and by whom. For example, at the drilling rig level at each stage of the well construction process, where it is foreseeable that there are significant risks, the well plan could identify what normal looks like in relation to those drilling parameters which, if not managed correctly, can lead to a "kick."[22] These include, amongst other things:

- Insufficient mud weight
- Gas cut mud
- Swabbing (more correctly a "swabbed show" – defined as formation fluid pulled into the well bore by pulling the drill string out of the hole too fast)
- Lost circulation
- Casing shoe/formation integrity failure[23]

A TARP, as well as identifying what normal looks like, importantly also identifies what action should be taken and by whom when a variation from what is 'normal' or expected is detected. The action to be taken typically involves graduated actions depending on the degree of variation from normal, based on the risk. A real example of a TARP appears in Annex 1.

This is an important aspect of the TARP concept. There are other benefits. One of these is to reduce the propensity we have as humans to "normalise evidence." Groups of people, when presented with indications that things are not going as planned, can be tempted to explain away the dissonant signals. This concept has been detected in serious incidents across a number of industries including the offshore oil and gas industry. Indeed there seems to have been evidence of this in relation to Deepwater Horizon, seen, for example, in relation to the results of the testing of the cement during the temporary abandonment procedure employed at the Macondo well.

To some degree, all people are proud of their work and reluctant to take lessons from elsewhere. This should not be viewed negatively. It is a sign of hard won experience and that people are rightly proud of what they have achieved. However, neither must we close our minds to other ideas. As a result, somebody could pilot the usage of the TARP concept to see if it would work. Undoubtedly there will be practical problems; there always are. But in working through the problems it is not inconceivable that other ideas may be generated and this is the value of taking new ideas seriously and trying them out – they tend to promote additional creativity and innovation, and who can deny the value of that?

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[22] A "kick" is usually defined as an inflow of fluids into a wellbore. See for example "*Blowout Prevention"* by Bell, T et al, 4th edition, published by PETEX, University of Texas, 2009, ISBN 0-88698-242-1.

[23] For a definition of these drilling terms see "*Blowout Prevention*" by Timothy Bell.

Summary - Where do we go from here?

Anybody who has experience of getting agreement via a committee to develop a document such as these Recommended Practices can only praise the work done by API and OGP. When one considers the international aspects of a venture along this lines, this is even more true.

These Recommended Practices represent real advances, drawing on the methodology developed by UK HSE in articulating the *process* for the development of indicators. Notwithstanding the fact that these Recommended Practices represent advances, the question is, are they sufficient? It appears the answer is no, especially in relation to upstream petroleum. They are insufficient because the measures which are being collected for comparison purposes are:

- consequence based and at too high a level to help understand the causes of the losses of containment;
- do not give enough emphasis to drilling and well related events;
- focused on one type of major incident event, namely losses of primary containment; and
- as a result, do not cover other types of major incidents which can occur in the offshore oil and gas industry.

This approach of recording events based on the consequences can leave us ignorant about the *causes* of the losses of containment. We need to know *why* they have happened to effectively direct preventive measures.

As has been remarked upon by others,[24] the problem is the lack of focus on wells and drilling. The evidence for this lies subtly in the language used but is nevertheless real enough. "Losses of primary containment," "pressure relief devices," "asset integrity" and even "process safety" itself are all terms used in the refinery and onshore petrochemicals business as well as offshore production processes. But they are much less used in the drilling world. They build wells and have the hazards presented by the sub-surface strata and what lies in the rock pores, unseen and only detected remotely or by inference from subtle changes in rate of penetration, increases or decreases in flows and pressures, sticking pipe and so on. It needs to be made more accessible to the drilling world. After all without drilling the refineries have little to process.

Finally, the focus on losses of containment, whilst obviously a very important class of incident, leaves out other types of major incidents which can occur. Are we a bit like an army fighting the last war? Do we need also to consider what other types of incidents are foreseeable and develop appropriate indicators? The semi-submersible accommodation barge, the Alexander Kielland was lost in the North Sea in 1980 with the loss of 123 lives following a structural failure; the Ocean Ranger semi-submersible drilling rig sank offshore the Maritime Provinces of Canada in 1982 with the loss of 84 lives following ballast control problems; and more recently the Kolskaya jack up was lost offshore Russia, also with substantial loss of life (apparently 53). None of these disasters involved a loss of containment.

[24] See for example *Skogdalen, J.E., Utne, I.B. & Vinnem, J.E. (2011) Looking back and forward: Could safety indicators have given early warnings about the Deepwater Horizon Accident?*

As the distribution of major incidents shows, the industry is international in scope. The problem solving needs to be approached with this in mind. As the Transportation Research Board comments:

"…many of the safety and environmental issues associated with offshore oil and gas operations are common worldwide, a data set compiled from all of these organizations would be invaluable. [They recommend that the]… *BSEE should create a task force with the industry, Petroleum Safety Authority Norway, the United Kingdom Health and Safety Executive, and other similar regulatory bodies worldwide to identify KPIs."*[25] This is surely the right approach.

Recommendations

1. Develop and implement a wider set of indicators based on the **major incidents** to which upstream petroleum is susceptible, including but not limited to drilling.
    a. These should focus on the causes of major incidents and not be solely consequence based.
    b. This should be done on an international basis.
    c. Communicate to senior executives the limitations of traditional personal safety lagging indicators
2. Remove the term *process safety* indicators and replace with Major Incident Indicators.
3. Develop managerial tools to provide senior leaders with information about the "health" of the barriers to a major incident, informed but not constrained by the PTTEP AA experience.
4. Promote a trial use or pilot project using the TARP concept in offshore drilling.

[25] Evaluating the Effectiveness of Offshore Safety and Environmental Management Systems, Transportation Research Board Special Report 309, National Academy of Sciences 2012, http://www.nap.edu/catalog.php?record_id=13434.

ANNEX 1

Example of a Trigger Action Response Plan (TARP) from the Queensland, Australia mining industry.

Underground Operations

Hazard: Highwall In-Stability

Trigger Action Response Plan

Objective:	Any change or deterioration in the physical condition of the Highwall may result in persons being exposed to unacceptable risk. This Trigger Action response Plan has been formed in consultation with affected mineworkers, and Open Cut Examiners. It is designed to prevent injury associated with the highwall. The Highwall has been exposed for more than 10 years. Normal additional weathering is expected over the life of the mine, and is more probable during or following heavy rain. The Highwall consists of different types of strata, which will weather at different rates. There are large sandstone bodies up to 20m thick, which overlie siltstone/shale beds. The siltstone/shales weather more rapidly when compared to the sandstone strata. This action may result in overhanging blocks of sandstone. The sandstone blocks are divided by joints, which cause smaller blocks that may eventually fall from the Highwall. The objective of this Trigger Action Response Plan (TARP) is to; • Identify any increase in the weathering process, or other instability, that could place persons at an unacceptable level of risk. • Provide additional controls (to protect persons) when entering Restricted Areas, or when instability has been identified.
Trigger Level:	A condition that is not normal. It must be able to be measured or observed and on being reached predetermined action must be taken.
TARP:	Trigger Action Response Plan (TARP) identifies the Normal State, and specifies the Trigger Levels and Actions to be taken, when a hazard is identified.
Highwall Support	The Highwall is draped with mesh, and bolted immediately above each portal. The draped mesh is designed to control the movement of rocks to the base of the Highwall. Steel portals extend to 7m from the base of the Highwall at each entry to the underground workings.

	In the Pit C area of the Mine, the Highwall is benched at an angle of X degrees (from the vertical) and a horizontal bench of approximately 10 metres provides a natural barrier from falling rocks that may fall from above that point.

Restricted Areas	**Base of Highwall** A restricted area barrier exists at the base of the high wall. Presently the barrier consists of a star picket and plastic tapes. It is planned to replace these barriers with more durable solid fencing. The barriers are placed adjacent to the un-meshed areas along the base of the Highwall. The barriers are normally placed at a location of approximately 10 metres from the base of the Highwall. The permanent barriers are designed to prevent rocks from bouncing into non-restricted areas. They are not designed to protect against a major slump of the highwall. The placement of barriers may be adjusted in accordance with this Standard Operating Procedure (TARP). Access into the Restricted Area is only allowed in accordance with this Standard Operating Procedure/ TARP. **Top of Highwall** Vehicular access to the top of the Highwall is restricted by a berm (placed in accordance to the direction of an Open Cut Examiner). The location of the berm is to consider possible failure of the Highwall, such that the berm would remain in place if the Highwall failed- and shall be in accordance with any relevant standard established at other Capcoal Mining Areas. Pedestrian access shall be restricted by a fence (consisting of steel pickets and wire/rope), with Restricted Access signage. Access into the Restricted Area shall only be in accordance with this Standard Operating Procedure/ TARP
Monitoring	Monitoring of Highwall forms a part of the Mine Inspection Scheme. It consists of; • Visual inspections by permanent employees • Visual inspections by ERZ Controllers and Open Cut Examiners- in accordance with the Mine Inspection Scheme • A survey (at pre-defined locations) by a registered survey at intervals of twice per year.

Reporting	Any deterioration, or safety concern resulting from the Highwall Stability, shall be recorded on the ERZ Controller statutory Report, and displayed on the district notice board.

Triggers

Persons Affected	Normal State	Level 1 Trigger	Level 2 Trigger	Level 3 Trigger
All Personnel employed in or adjacent to the Portal Entries	Highwall adjacent to the portals is drapped with mesh, and bolted. Portals extend to 7m from the base of the Highwall.	Rain Event Evidence of rock debris outside the 10m rill area New cracks observed A person requires access into a Restricted Area	Deterioration of the Highwall where unstable large overhangs are present or where keystone displacement is likely. Large rock fall and evidence of instability Open cracks noted at the top of the Highwall Mesh fallen or knocked down exposing unprotected Highwall	Major Highwall movement (slump)

Action Response Plans

Persons Affected	Normal State	Level 1 Response	Level 2 Response (in addition to Level 1)	Level 3 Response (in addition to Level 2)
Operator/Maintainer	Normal Activities Read Highwall Inspection Reports. Report any change to ETZ Controller Do not go within Restricted areas without authority	Report any change to ERZ Controller Read Highwall Inspection Reports and TARP Status Board at start of shift. Do not enter a Restricted Area without permission of the ERZ Controller	Obey all barriers and report evidence of change. Participate in corrective actions as directed	Cease normal activities in pit area and muster at the “Surface Emergency Muster Area” Participate in Emergency Response
CRO UG	Normal Activities. Read the outbye ERZ District Board.	Report any change to ERZ Controllers	Assist 1st Response and Participate in corrective actions as directed Raise awareness during mine familiarisations	

ERZ Controller	Conduct Inspections as per Mine Inspection Scheme Complete a Statutory Inspection Report. Report any change to the Open Cut Examiner. Record changes on the district board	Report any change to UMM and OCE Allow persons access into the Restricted Area, only after consultation with the Open Cut Examiner, and if it is safe to do so. An observer shall be used to confirm Highwall Stability	Maintain and Update Inspection District Board Ensure all barriers are obeyed and report evidence of change. Participate in formulation of Action Plan as required- Allow persons access into the Restricted Area, only after consultation with the Underground Mine Manager, and the Open Cut Examiner, and if it is safe to do so. Set up additional barriers, in the effected zone to restrict access where there is a risk to persons or plant	Cease normal activities in pit area and muster at the "Surface Emergency Muster Area" Participate in Emergency Response and/or Incident Management Team
Open Cut Examiner (OCE)	Normal Inspection regime-12 hourly Lodge Statutory Report at Open Cut Office, and	Communicate changes or concerns to the CRO. Only allow access into	Participate in formulation of Action Plan as required. Only allow access into the Restricted	Cease normal activities in pit area and muster at the "Surface Emergency Muster Area" Participate in Emergency Response and/or Incident Management Team

	update ERZC with any concerns.	the Restricted Area, if it is safe to do so. Contact and Strata Control Engineer (or Geologist) if continued deterioration is noted	Area, if it is safe to do so.	
Strata Control Engineer: Geologist or Delegate	Inspections as per the Mine Inspection Scheme	Inspect Highwall zone if required by the UMM, OCE or ERZ Controller	Participate in formulation of Action Plan in consultation with the OCE and ERZ Controller and others as deemed necessary	Participate in Incident Management Team
Manager Underground Operations	Inspections as per the Mine Inspection Scheme	Inspect Highwall zone if required by the OCE or ERZ Controller	Communicate with Site Senior Executive and consult with ERZ Controllers, OCE's and Site Safety and Health Representatives	Direct Incident Management Team; Report to Inspectorate and Industry Safety and Health Representative.