

## Measuring Human Performance: The next big challenge

Ian Travers, Principal Consultant, Process Safety, Leidos Innovations UK Ltd.

This paper explores the challenges and options for directly measuring the outcomes of competence management systems and the performance of safety critical tasks within major hazard organisations.

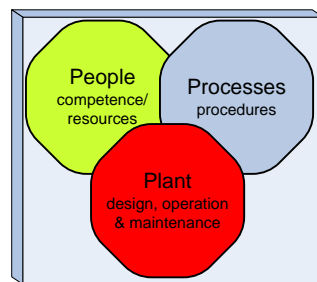
### Introduction

It's well acknowledged that a significant, if not the most prominent, underlying cause of major accidents and loss of containment incidents is human error<sup>1</sup>. Yet so few organisations have effective performance measures or KPIs to monitor this critical aspect of process safety. Few, if any, have effective leading indicators. As effective and reliable human performance is an outcome of a process safety management system then it's important that this aspect of risk management is monitored and measured. Succeeding in this aspect of risk management offers a real prospect of significant risk reduction and improvement in major hazard performance but, as yet there is not a standard way to achieve this goal.

This paper explores the challenges and options for directly measuring the outcomes of competence management systems and the performance of safety critical tasks within major hazard organisations. Many companies consider this as being too difficult and confrontational but positive options are available to measure human performance which can support and build on process safety behavioural safety programmes. I have drawn on my experience of investigating of major accidents and from my work with major hazard companies in developing targeted KPI programmes to underpin this approach. This paper proposes some general principles to apply to the collection of information and measurement of human performance.

### People do safety – and people also undo safety just as effectively

Regardless of whether we are considering the plant or the process or the person in the classic division of labour characterised in process safety management systems the reality is that people are responsible for all aspects of a process safety management. At all stages from hazard analysis, risk assessment through to plant design, commissioning, operation and maintenance people's competence and performance determines safety outcomes, whether immediately or sometime after an individual's input into the system.



**Figure 1:** People, process and plant aspects of process safety control systems.

There are few if any absolute certainties in process safety and it is not possible to eliminate human error. Whilst hardware and equipment and safeguarding systems have become more robust and reliable over the years humans have not had an equivalent upgrade in reliability. Great strides have been made through reliability analysis to rate the reliability of hardware and safety instrumented systems via the designation of Safety Integrity Levels (SILs). These categories do not readily translate into human performance. Imagine setting your recruitment and selection criteria to only select 'SIL 2 humans' for safety critical tasks and then proving human functional safety performance through the safety life cycle requirements of as set out for Safety Instrumented Systems in BS EN 61511<sup>2</sup>.

This then is the challenge for human performance in safety critical aspects of major hazard risk management. How do we emulate the reliability of hardware and control systems for people who form the core of process safety management?

### Process Safety - 5 Golden Questions

It have often reiterated the 5 key questions that organisations should constantly cycle through to ensure that process safety risks are properly understood and effectively managed:

1. What can go wrong?
2. Where and/or when can this failure occur?
3. What systems or control measures are in place to prevent the failure or mitigate the consequences?
4. Which of these control measures are the most important and the most vulnerable to failure?
5. What information is available to show that the control measures continue to operate as designed and continue to deliver the intended outcome?

## 1. What can go wrong? - Analysis of Human Performance

The first element of this analysis has been to understand the human failure modes:

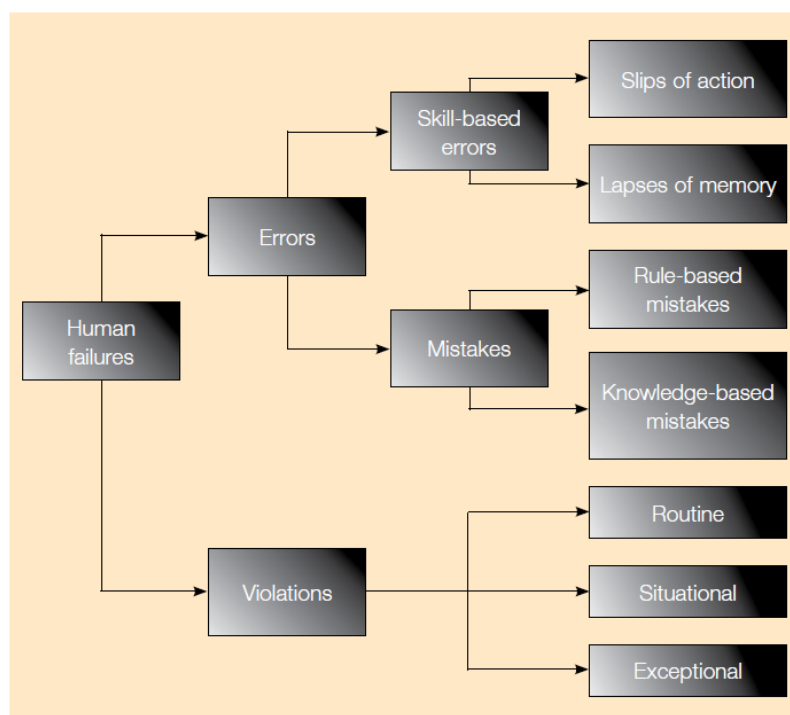
[errāre hūmānum est.](#)

(to err is human)

Alexander Pope, Essay on Criticism

So failure, or to make mistakes is a built in default condition for humans. Process safety management has seen a growth in the trend for assessing and analysing human performance including critical task analysis, human reliability studies and performance influencing factors.

The failure modes are well understood, described and categorised. HSE's guidance booklet HSG 48 reducing error and influencing behaviour<sup>3</sup> which sets this out clearly as shown in figure 1 below:



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**Figure 1:** Types of Human Failure – from HSE, HSG 48 reducing error and influencing behaviour

## 2. Where or when can failure occur?

HSG 48 also clearly establishes that these failure modes can be immediate or latent, made by people whose tasks are removed in time and space from operational activities, e.g. designers, decision makers and managers.

This throws up a further challenge when it comes to measuring human performance as latent failures will mainly only come to light sometime after the point at which the error or mistake was made. Although discovery of such faults can be measured as lagging indicators, influencing the correct behaviour to prevent a further occurrence may be impossible because those involved and the systems in place at that time may have long since changed. This therefore points to the need for measurement of effective control via leading indicators has to be undertaken at the time the task is undertaken.

### A moment on Leading and Lagging Indicators

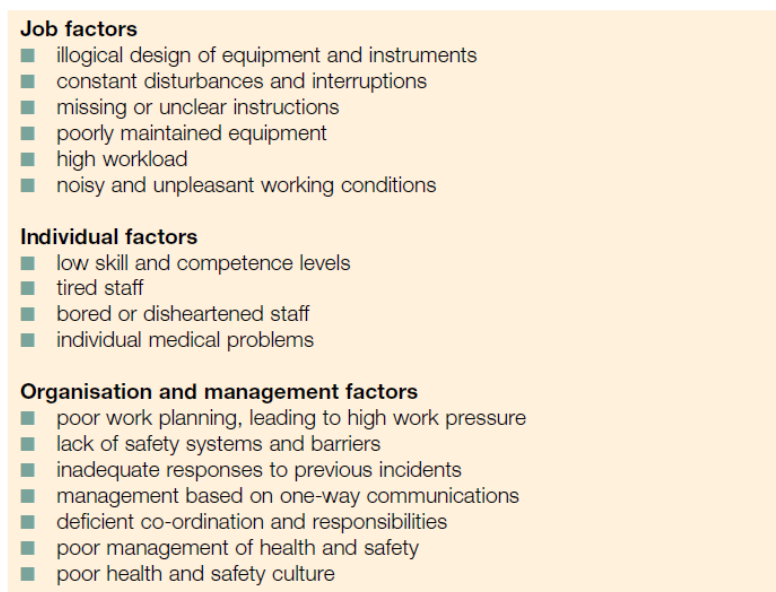
After more than 15 year's working in the field of performance measurement and KPIs I have not moved from my original position, as set out in HSG 254, 'Developing process safety indicators: A step-by-step guide for chemical and major hazard industries'<sup>4</sup>, that a lagging indicator measures the 'outcome' of the control measure or barrier in place to prevent an incident and a leading indicator is a measure of the performance of the 'input' into the control measure. This is why a 'near-miss' can never be a leading indicator as the 'miss' represents a failure to control the hazard and the lack of a harmful outcome was probably just down to chance.

### 3. What systems or controls are in place to prevent a major accident?

The analysis of human failure mechanisms is fundamental in then developing suitable control and mitigation measures. Such measures have to be tailored to the risk profile of the activities undertaken with the business. A 'one size' fits all approach is not adequate and designing and implementing effective human performance control measures or barriers requires a systematic approach.

#### Performance Influencing Factors

Understanding what needs to be right to decrease the likelihood of human error being made during work activities is essential in designing and implementing effective controls. Once more HSE 48 sets these out in terms of 'the job', 'the individual' and 'the organisation'. Whilst being helpful this division is somewhat academic in so far as jobs are designed by individuals and organisations consist of collections of individuals and in each there is capacity for error. In more practical terms performance influencing factors are sub-divided into examples of these factors as shown in figure 2.



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**Figure 2:** performance influencing factors from HSE, HSG 48 reducing error and influencing behaviour

These factors now start to provide some insights into effective measurement of human performance or at least gaining intelligence which can point to improvements in the management of this risk.

Every aspect of a process safety management system from risk assessment, to operational control and maintenance will involve a human input so human factors will be a feature of each and every control measure or barrier within a process safety management system.

### 4. Which control measures are the most important and most vulnerable to failure?

Importance in this context is the contribution made by the control measure to preventing a major accident. Whilst all aspects of process safety management can be considered important some elements are much more important than others based on their relative contribution to prevention of a major incident. These 'high criticality' barriers can be viewed as being essential in preventing an incident. In other words if they fail then it would most likely lead to a major accident. For hardware and say instrumented control systems the importance of human input can be considered to be mainly related to:

- System design and selection and
- Installation, testing, validation and commissioning.

All predicated on effective risk assessment which of course is a human process.

For day to day operations then the most important aspects are related to the performance of critical tasks associated with maintaining operations within safe operating parameters, inspection testing and maintenance activities, fault detection and emergency response.

Vulnerability of a control measure or barrier is based on:

- The nature of its failure mode,
- How predictable these are in order to allow for effective pre-failure intervention, and
- Whether there is opportunity for recovery to regain control or at least to limit the consequences.

Ideally, systems should fail:

- Predictably,
- Steadily,
- According to engineering calculations and design lives,
- Provide early warning of failure, and
- Allow for recovery.

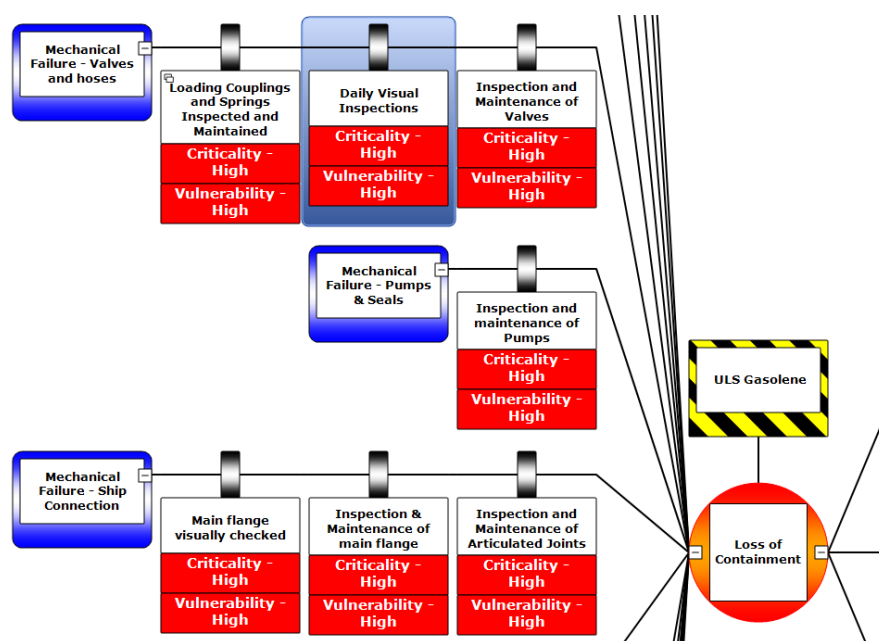
Less helpful failure modes are:

- Erratic,
- Without warning or previous mal-function,
- Early within the life cycle of a system, or
- Allowing for no recovery.

Unfortunately human failure falls within these later unhelpful modes.

So when it comes to measuring human performance the focus should be on those activities or system components which provide the greatest contribution to the prevention of a major incident in combination with those which show the characteristics of unhelpful failure. A further consideration of selection for measurement is whether the control measure is the last in line using a bow-tie analysis of control measures. A classic example of such a human failure was the installation and maintenance of the independent high level shutdown, IHLS, system fitted to gasoline tank 912 at the Buncefield Fuel Storage depot, Hemel Hempstead, UK<sup>7</sup>. This last in line barrier to control the gasoline tank from overflowing failed because the IHLS needed a padlock to retain its check lever in a working position. However, the switch supplier did not communicate this critical point to the installer and maintenance contractor or the site operator. Because of this lack of understanding, the padlock was not fitted. It gave no early warning that it would not function if needed and so on the 10<sup>th</sup> December 2005 when the tank was overfilled it failed to operate when needed resulting in a large scale explosion and fire.

The use of bow-tie analysis of control and mitigation measures (barriers) mapped against each major hazard scenario is one way to identify the high criticality and high vulnerability barriers. Those associated with high criticality tasks where the barrier is considered to be vulnerable to failure (as set out above) would form the first set of target control measures to include in a human performance monitoring and measuring programme. This approach was set out in Hazards 26 paper 'How to Focus on the Right Things in Complex Process Safety Systems'<sup>6c</sup>.



**Figure 3:** Snap shot of a bow-tie showing high criticality and high vulnerability control measures associated with off-loading gasoline from a ship to on-shore bulk storage.

From the bow-tie analysis for a bulk storage terminal an example of a safety critical task that is last in line and where failure to undertake the task could lead to a major loss of containment with no opportunity for recovery involves the daily visual checks of the integrity of the flexible hoses connecting the ship to the incoming pipeline. This was just routine and undertaken by a range of terminal staff. Instructions such as check for damage or abrasion did not give any indication of the range of defects which were either acceptable or which should lead to hose replacement. Time pressures on the ship's turnaround meant that the checks could be quite superficial and replacing a hose with borderline damage would cause delays. Yet a hose failure would lead to a catastrophic incident.

## What to measure and monitor?

In summary, the most important aspects of human performance to measure and monitor to prevent a latent failure are those associated with:

- Risk assessment leading to the:
  - design,
  - selection,
  - installation,
  - commissioning, and
  - change

of plant, equipment or tasks.

To prevent immediate human failures the most important aspect of human performance to measure and monitor are those associated with:

- Maintaining processes within safe operational limits,
- Identifying and dealing with abnormal conditions and responding to emergencies, and
- Inspection, testing and maintenance, including interfaces with hazards via permit to work controls.

## Demonstrating Reliability

The importance of these approaches to better understanding and management human performance is highlighted in the recent publication of the ‘COMAH Competent Authority Delivery Guide: Inspecting Human Factors at COMAH Establishments’<sup>7</sup>, which sets out what HSE and Environment Agencies will be verifying during regulation of UK Seveso sites. The HSE has said that:

*“Where reliance is placed on people as part of those necessary measures, human factors and human reliability should be addressed with the same rigour as technical and engineering measures “.*

As companies are required to demonstrate that this aspect of major hazard risk management meets the requirements of COMAH and is included within a Safety Report then measuring and reporting on human performance is a key aspect of this demonstration. It not sufficient simply to undertake the required human factors analysis and implement improvements where required. Measuring and reporting human performance is pre-requisite to assuring that risks are effectively controlled and the process set out in this paper will assist in meeting this requirement.

## 5. What information is available to show that the control measures deliver the intended outcome? How to Monitor and Measure Human Performance

My experience in this area shows that the most frequently measured aspects of human performance are either a focus on the process or activity designed to deliver competence – e.g. measuring training provided, or skill and experience levels and qualifications held by those involved in critical tasks. The second most common type measurement is the measurement of failures which are identified through incident investigation.

It is self-evident that measuring the process of achieving competence is less effective than measuring the outcome itself. For instance, we all know that measuring say driver safety by counting how many drivers have passed a driving test is not a good indicator of whether road users are operating safely. A better measure is to check and monitor how well an individual drives on a day to day basis. Recent improvements in vehicle technology and telemetry has allowed for remote tracking of vehicle speeds and braking and many employers now routinely re-examine driver’s performance by periodic safe driver courses and feedback.

This form of active monitoring of human has enormous benefits for process safety. I’m not suggesting that workers should be fitted with tracking devices or even video cameras (although some police forces have adopted this approach for law enforcement). But rather a much greater emphasis should be given to routinely checking and reviewing how critical tasks are actually performed.

There are opportunities to do this by incorporating process safety into behavioural safety programmes which traditionally focus on personal safety (holding the hand rails and wearing the correct PPE). Many organisations set targets for managers and supervisors to conduct safety tours at workplaces. The problem I have encountered with this proposition is that whilst many managers feel confident to assess personal safety because safe behaviour in this is context is visible and can be detected just by simple observation the same is not always true for process safety. Few managers who are not process safety professionals feel comfortable with this type of behavioural safety monitoring.

To address this lack of confidence or even competence in measuring human performance by observation and engagement I have developed a series process safety guide questions which can be asked. For instance whether:

- The person meets the designated competence standard (where one exists),
- The person fully understands the task to be undertaken and its significance in controlling major hazard risk,
- The activity follows the documented procedure (where one exists),
- The plant / process design facilitates the task being undertaken in accordance with the documented procedure,
- The person has been provided with sufficient resources (including time) to undertake the task.

These were first published by HSE in the 'COMAH Competent Authority - Inspection of Competence Management Systems at COMAH Establishments (Operational Delivery Guide)<sup>8</sup>.

In addition I have also used a series of supplementary questions to ask of those involved in safety critical tasks:

- What shortcuts do people take?
- What do they find confusing?
- What do they find conflicting?
- What could be improved?
- What's gone wrong recently but has not been reported?

It is important to ask these questions in an open and constructive manner and to make no immediate negative conclusions to those involved which may lead to a reluctance to share information in the future or to give honest answers at the time of the review.

The most common concerns raised about this type of monitoring of human performance is that when being observed or questioned as to the way a task is performed people are bound to undertake the task correctly and this may not be the way the work is done when no one is looking. There are two responses to this concern. Firstly, is that most employees do not deliberately work unsafely but rather make mistakes or errors because of a lack of an effective understanding of the risks to a degree which would influence the way and diligence with which someone performs a task or that there is in built conflict and miss match between the way the task was designed and the way it can practically be performed. So discovery of these system failures is a critical aspect of monitoring. Imagine for instance, a KPI that revealed that 20% of safety critical tasks within an organisation could not be performed safely because of a disparity between the documented procedure and the way the job was configured in practice. Such failing are normally only revealed following an incident where an investigation uncovers this sort of problem.

The second response to a concern about false performance during task observation is that it presents a valuable opportunity for a discussion and reinforcement of why the task is safety critical and should be performed the way it was designed, with no tolerance of deviation. Routine reinforcement of safety factors with those directly involved in the task is a way of reducing the natural human tendency for deviation, especially where a minor modification in the way the work is conducted does not lead to any immediate adverse harm.

I have often had reported to me that by undertaking routine task analysis and observation somehow undermines the trust an organisation places on those allocated responsibility for those tasks. However, comparison with say safety briefings a checks performed by pilots and aircrew prior to take off shows that this is a false premise where the potential impact from an error could have catastrophic consequences. For all major hazard activities this is exactly the same. My experience of this reluctance to actively engage with those involved in safety critical tasks is that it's probably a reflection of a lack of confidence by the observers to deal with the answers and to probe deeper where there is some uncertainty or ambiguity from a first response.

## Handling adverse results

Process safety task assessments and observations should always be handled in a positive and supportive way. The moment any adverse outcome or admonishment is imposed or implied then the goodwill and trust of employees to share honest and open information about the way safety critical tasks are performed will be removed.

## Developing Key Leading Performance Indicators

My focus here is on leading indicators as measuring failures in human performance following an incident or accident is a well-established practice and is embodied in process safety incidence rates as outlined in indices such as American Petroleum Institute API 754 - Process Safety Performance Indicators for the Refining & Petrochemical Industries<sup>9</sup>. My only caveat is that above where a near miss which results from human error should be counted as a lagging indicator.

Leading indicators measure and monitor the activities or inputs into a system that give rise to the intended outcome. An example to illustrate this comes from a company who wanted to measure the success of its shift handover procedure. This was seen as a very important aspect of major hazard risk management within the organisation. Up to this point shift handover was measured by ensuring the handover was recorded in the control room log. So this was a 'completed and completed to time' type of KPI.

The term 'Shift Handover' has a noun 'shift' and a verb 'handover'. So the active part is the verb and it was important to understand the process safety purpose of the action of handing over. The first aspect was to hand over control of the site to a new crew. The second part was to hand over information about the status of the site any ongoing issues such as plant or system isolations, process deviations, ongoing maintenance activities and outstanding permits to work. The aim was to ensure the new shift were fully informed and understood the current safety status of the site so they could take account of these factors when running their shift. So the essential element was the handover and comprehension of this information exchange. Measuring this by reviewing the log to see that the correct information was recorded was one way to do this but was less effective than actually speaking to the new crew members to ascertain what intelligence they had gained from the handover. After all they may not have actually read the log or been present in the control room when the departing supervisor handed over to the oncoming supervisor.

So the metric for shift handover became the percentage of shift handovers where the new crew could verbally repeat the safety information in the shift log. The point of measurement was always some time into the shift following the shift

handover. The measurement frequency was set to ensure that each member of every shift team was tested on the handover within a 12 month period.

### Conclusions and principles of measuring human performance.

Monitoring and measuring human performance is the next big challenge in effective process safety management. Simply monitoring and measuring the performance of plant and equipment leaves an organisation blind to a majority of the factors which give rise to a major accident. Whereas data can easily be recorded and extracted from electronic management systems such as SAP there is no such equivalent for human performance. To make matters worse the failure mechanisms and modes of humans are much less predictable than those relating to plant and equipment because humans fail irrationally and without prior warning. Unlike say valves and pumps people generally don't leak, squeak, overheat or vibrate prior to failing catastrophically. What's more correct human action is often the last in line in a safety system and will offer no opportunity for recovery once a failed action has occurred.

In meeting this challenge of measuring human performance it is important to focus on the most important aspects of the control system and to measure performance that can lead to latent defects as well as immediate issues of operational control. So measuring risk assessments, plant design and commissioning becomes just as important as measuring day to day routine operational tasks. Barrier analysis as shown in Figure 4 above can help with this. Where this leads to an excessive number of safety critical tasks then further sampling regimes should be adopted to keep the number of checks manageable. Essentially the results of these checks can be rolled up into KPI's covering the two areas outlined in Table 1 below.

Human performance leading KPIs monitoring latent defects	Human performance leading KPIs monitoring immediate threats
<p><b>Critical tasks covering:</b></p> <ul style="list-style-type: none"> <li>• design,</li> <li>• selection,</li> <li>• installation,</li> <li>• commissioning, and</li> <li>• change</li> </ul> <p>of plant, equipment or tasks.</p>	<p><b>Critical tasks covering:</b></p> <ul style="list-style-type: none"> <li>• Maintaining processes within safe operational limits,</li> <li>• Identifying and dealing with abnormal conditions and responding to emergencies, and</li> <li>• Inspection, testing and maintenance, including interfaces with hazards via permit to work controls.</li> </ul>

**Table 1:** Categories of KPIs to monitor human performance

Measurement of human performance requires a balanced open minded and engaging approach and is best done as an interaction and task observation with those directly involved. Such measurements can readily be incorporated within safety behavioural programmes and can form part of safety tours and checks allocated to senior managers provide that basic process safety management training and support is available to them.

It's important to involve employees in the design of a human performance monitoring programme so that there is a full understanding of the purpose and the process. Any indication of punishment or retribution associated with the discovery of a problem or deviation in performance is likely to hamper or even prevent future honest and open dialogue and disclosure.

Measurement does not have to be continuous but can easily be undertaken on a sample basis providing that the sample includes all or the majority of those involved in safety critical tasks, including contractors and third parties.

These factors therefore give rise to the following principles of measurement of human performance:

- Actively monitor and measure process safety critical tasks,
- Focus on the most important and vulnerable control measures,
- Go beyond measuring whether a task have been completed to schedule to monitoring and measuring how it was undertaken,
- Engage employees in the design of the KPIs,
- Measure performance during risk assessment and process and plant design, maintenance and change as well as front line operational tasks,
- Measure on a repeat sample basis,
- Set the measurement frequency based on the opportunity for drift and deviation,
- Over a measurement cycle wherever possible include each person who performs the task and include contractors and third party employees where critical process safety outcomes relies upon their actions,
- Ensure measurement reinforces the desired outcome from the control measure,
- Avoid negative or punitive action where the findings do not match expectations,
- Integrate measurement of human performance in process safety into behavioural safety programmes, and
- Review the findings alongside other KPIs

Ian Travers

Principal Consultant, Process Safety

Leidos Innovations UK Ltd.

[ian.travers@leidos.com](mailto:ian.travers@leidos.com)

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