

“KEY PERFORMANCE MEASURES FOR HUMAN FACTORS IN MAJOR HAZARD INDUSTRIES”

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Following the Texas City incident, there has been a significant increase in the amount of attention paid to performance indicators for process safety, with authoritative guidance being published in both the UK and US. The focus on Human Factors influences on process safety has also grown significantly over this time. However, while measurement of the technical aspects of process safety is well covered by the available guidance, there is little information available with regard to how Human Factors performance might be measured.

Lloyd's Register EMEA (LR), Energy Institute (EI) and the UK Health and Safety Executive (HSE), working within a joint industry research project framework, and taking formal input from operating companies in the major hazards industries, have developed a proposed approach to setting performance measures for human factors. The approach is aligned to the Human Factors “Key Topics” framework established by HSE and used by HSE to support site inspections, and is presented in detail in a recent EI research report¹.

This paper provides an overview of the proposed approach, the supporting materials that have been developed, and industry views on requirements in the area.

INTRODUCTION BACKGROUND

The measurement of safety performance using retrospective (“lagging”) indicators such as incident and accident rates is a long-standing requirement in most developed economies. Similarly, the use of “leading” indicators to monitor the precursors to individual accidents (so-called “slips, trips and falls”) is usual in many industries, particularly where behavioural safety systems have been implemented. The adoption and use of leading and lagging indicators to monitor and manage major accident hazards (MAH) safety performance is however still a developing area.

Recent major accidents at Texas City in the USA, and at Buncefield in the UK, have brought into focus the need for industry to monitor the safety of major hazards operations in a different, more consistent and more proactive way, to allow improvements to be identified and implemented before major accidents occur. As part of the growing attention paid to measurement of process safety, recognition of the significance of the human contribution to process safety has also been growing. The UK Health and Safety Executive (HSE) has condensed its experience of shortcomings in the human aspects of management of major accident hazards into a set of Human Factors “Key Topics”. These “Key Topics” cover the breadth of human involvement in process safety, from culture to staffing levels and from incident investigation to organisational change. Whilst the

“Key Topics” are generally easy to understand, there are few established metrics available to help an organisation judge whether it is managing them well.

Lloyd's Register EMEA (LR), Energy Institute (EI) and the UK Health and Safety Executive (HSE), working within a joint industry research project framework, have developed a proposed approach to setting performance measures (or indicators) for the “Key Topics”. As part of the development process, measurement needs and current measurement practices of operating companies were captured by means of a “Performance Indicators Workshop” attended by representatives from the major hazard energy and related process industry sectors and the Regulator. The proposed approach presented in this paper has also been reviewed by these representatives.

The main objective of this paper is to present the proposed approach and supporting materials that have been developed, and to highlight additional findings from the research programme completed under the joint industry project.

HSE HUMAN FACTORS “KEY TOPICS”

The HSE Human Factors “Key Topics” are set out in Table 1. Some of these “Key Topics” are divided into further sub-topics. Whilst numbered, the “Key Topics” are not in priority order. The issues are similar in the onshore and offshore major hazard sectors.

The “Key Topics” reflect HSE experience of shortcomings in Human Factors management at major hazards sites, and are used by HSE to support site inspections.

For further information, see the HSE website at www.hse.gov.uk/humanfactors/topics/index.htm.

¹Research report: Human factors performance indicators for the energy and related process industries, 1st Edition, December 2010.

Table 1. HSE human factors “key topics”

1. Managing Human Failures (including Human errors, incident investigation).
2. Procedures.
3. Training and Competence.
4. Staffing (including Staffing Levels, Workload, Supervision, Contractors).
5. Organisational Change.
6. Safety Critical Communications (including Shift handover, Permit to work (PtW)).
7. Human Factors in Design (including Control rooms, Human/computer interfaces (HCI), Alarm management, Lighting, thermal comfort, noise and vibration).
8. Fatigue and Shiftwork.
9. Organisational Culture (including Behavioural safety, Learning organisations).
10. Maintenance, Inspection and Testing (including Maintenance error, Intelligent customers).

A concise description of the content of each “Key Topic” is contained in Step Change in Safety (2010).

CURRENT SITUATION

AVAILABLE GUIDANCE

There is an extensive literature related to process safety performance measurement, and relevant guidance for the process industries has been published by HSE (2006), CCPS² (2008), OECD³ (2008) and API⁴ (2010). These documents all aim to cover technical and Human Factors aspects of process safety.

HSE (2006) provides a process for selecting and using process safety performance indicators, and incorporates Human Factors within its framework, but offers few candidate metrics for Human Factors performance. CCPS (2008) aims to establish a basis for industry process safety benchmarking and offers a limited set of metrics related to Human Factors. Although OECD (2008) identifies an extensive list of organisational factors, assessment is biased towards audit-type questions rather than continuous indicators. API (2010) aims to build on the documents identified above; it addresses the requirement for a process, combining this with the four tier indicator structure of CCPS (2008), and including a limited set of possible metrics.

The overall scope of these documents is summarised in Table 2.

The amount of guidance available specifically for Human Factors performance measurement in the energy and related process sectors is rather limited. In particular, there is no single source of guidance that provides both a process for determining where indicators are needed and advising what these indicators might be. The view of participants in the Performance Indicators Workshop held as part of this research programme is that clearer recommendations on appropriate performance indicators would be

welcomed by industry. However, industry does not see benefit in adopting a standard set of indicators across the sector, and so a process for selecting appropriate indicators is also required.

IMPLEMENTATION IN THE ENERGY AND RELATED PROCESS INDUSTRY SECTORS

As indicated in Section 1.1, a Performance Indicators Workshop was held as part of the research programme. The workshop included representatives from the chemicals, oil & gas and nuclear industries, and from the Regulator, and was designed to help:

- Determine what use is made of Human Factors indicators currently within the energy and related process industry sectors.
- Develop proposals for indicators for the HSE Human Factors “Key Topics”.

Both existing and potential indicators were recorded and mapped to the HSE Human Factors “Key Topics”.

Information from workshop participants indicated a broad range of maturity with regard to awareness and monitoring of Human Factors performance in industry. Most energy and related process industry organisations have developed process safety indicator systems of some sort. In general, these do not explicitly reference all of the HSE Human Factors “Key Topics”, although they may address those Human Factors topics recognised and considered critical by the operating company. Common issues that are incorporated in indicator systems include compliance with procedures, training currency and staffing levels.

Many organisations have implemented systems for managing some of the “Key Topics”, although formal performance indicators may not be part of these systems. Examples of “Key Topics” that are recognised, but not typically monitored with a formal performance indicator, include “organisational culture”, “Human Factors in design” and “managing human failure”.

The more advanced companies (typically larger and more international organisations) have implemented

²Center for Chemical Process Safety of the American Institute of Chemical Engineers.

³Organisation for Economic Co-operation and Development.

⁴American Petroleum Institute.

Table 2. Scope of guidance documents related to process safety performance measurement

Guidance reference	Process approach?	Human and organisational factors included?	List of proposed human factors metrics?
OECD (2008)	Yes [cross-reference to HSE (2006)]	Yes	Yes, with bias to audit-type questions.
HSE (2006)	Yes	Yes	No
CCPS (2008)	Implicit	Partial	Limited
API (2010)	Yes	Partial	Limited

performance dashboards to provide a high level diagnostic of current performance. At least one UK operator has implemented a process safety “dashboard”, which provides for presentation of live process safety performance indicator data on the company intranet.

INDICATOR SELECTION

Participants at the Performance Indicators Workshop were asked to comment on their experience of indicator systems, and their likely future use of Human Factors performance indicators. The key points that were raised are summarised below:

- The performance indicators to be used should not be prescribed by external organisations for use by operating companies/duty holders; they should relate to the organisation’s own understanding of its hazards and risks.
- Performance indicators need not be implemented for all the Human Factors “Key Topics”.
- Lagging indicators tend to be relatively permanent within an organisation.
- Leading indicators are relatively transient; they are used to drive improvement, and are replaced once improvement is embedded.
- Replacement of performance indicators is partly to reflect changing needs within the organisation, but partly also to mitigate the risk of unintended consequences arising as personnel seek to manage the performance indicator rather than the underlying safety input or activity.
- Organisations need to distinguish between tools for managing issues (i.e. which imply action), and metrics for reporting issues (i.e. measures of system outputs).
- Organisations can benefit from both audit-type measures (e.g. the presence or absence of a system) and continuous performance indicators.

EI (2010b) also notes that indicators are not permanent but may need to change as the organisation changes, while for the nuclear sector INSAG (1999) emphasises the need for indicators to change to reflect the evolution of the organisation and its changing needs.

In the course of developing the proposed approach, desirable attributes of safety performance indicators

have been identified (Energy Institute, 2010a). Attributes to be considered when choosing what to measure, and how, include:

- The indicator should match the cultural maturity of the organisation; i.e. the organisation should be able to acknowledge and accept the significance of the message contained in the indicator, and should be able to act on it without damaging workforce engagement.
- The person responsible for the indicator should be in a position to take action if the indicator suggests that that is what is required.
- A true indicator should provide continuous indication, i.e. it should do more than prompt a yes/no response (if it prompts a simple yes/no then it resembles an audit-type question, and whilst such information is useful, it does not provide a continuous measure of degree of performance).
- Indicators should collectively provide broad coverage whilst being individually reasonably specific.
- Indicators should be monitored (i.e. data should be renewed) at a frequency that will detect changes in time for action.
- Thresholds or tolerances should be specified beyond which deviations in performance should be flagged for action.

THE PROPOSED APPROACH TO SETTING HUMAN FACTORS PERFORMANCE MEASURES HUMAN FACTORS KEY TOPICS AND RISK CONTROL SYSTEMS

Three main components can be distinguished that need to be addressed:

1. The process for identifying what needs to be monitored (i.e. which safety inputs/outputs are to be monitored).
2. The selection of the indicators themselves.
3. The implementation of a suitable process for collecting, monitoring, and acting upon information derived from the indicators.

In the UK, the principal guidance for process safety performance measurement is contained in HSG 254 (HSE, 2006), and the proposed approach set out here is intended to align with that of HSG 254 for establishing

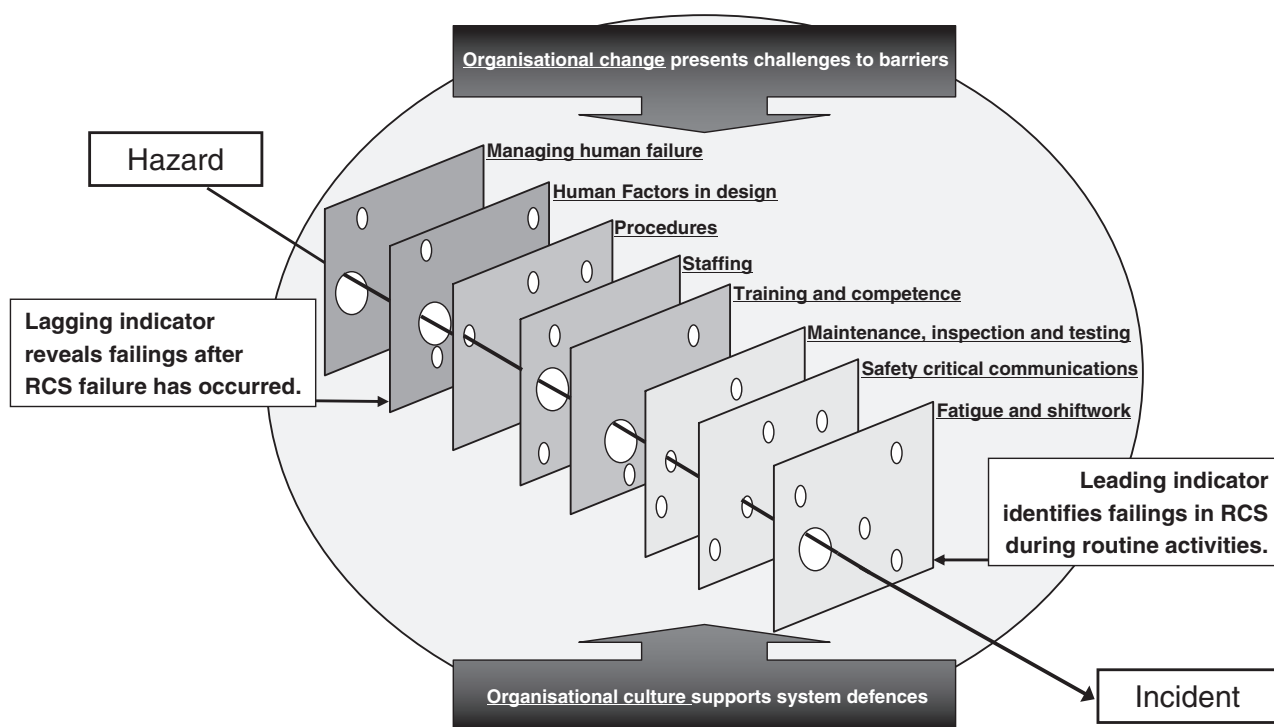


Figure 1. "Swiss Cheese" accident trajectory model

leading and lagging "Process Safety Performance Indicators".

The term Risk Control System (RCS) is used in HSG 254 to describe a barrier or a safeguard within a process safety management system that focuses on a specific risk or activity (e.g. plant and process change, permit to work, inspection and maintenance, etc). The use of leading and lagging indicators can be visualised using the "Swiss cheese" accident trajectory model of Reason (1997), shown in Figure 1, in which major accidents are considered to result from concurrent failings within several Risk Control Systems (RCSs). For each RCS (see HSL, 2006; HSE, 2006):

- Leading indicators identify failings or "holes" in processes or inputs essential to maintain critical aspects of the RCS (i.e. to deliver the desired safety outcomes).
- Lagging indicators reveal failings or "holes" in that barrier discovered following an incident or adverse event. The incident does not necessarily have to result in injury or environmental damage and can be a near miss, precursor event or undesired outcome attributable to a failing in that RCS.

It is proposed (Energy Institute, 2010a) that each HSE Human Factors "Key Topic" potentially constitutes a RCS, or contributor to a larger RCS, associated with a speci-

fic scenario. As such, the "Key Topics" can be mapped to an accident trajectory model⁵ as shown in Figure 1. (Note that Organisational Change and Organisational Culture exert an influence across all the "Key Topics").

The challenge to organisations seeking to implement Human Factors performance indicators is then to answer the questions:

- Which HSE Human Factors "Key Topics" should be monitored and what are appropriate indicators to use?
- What should be the process for collecting and monitoring indicators, and for acting upon information derived from the indicators?

The proposed approach is outlined in the next section, and further considerations for design of indicator systems are given in the following section.

PROPOSED APPROACH

Main Elements

The process laid out in HSG 254 (HSE, 2006) involves identifying the main process safety hazard scenarios and relevant Risk Control Systems, and setting leading and lagging indicators for these Risk Control Systems. The

⁵Note that, with the exception of Organisational Change and Organisational Culture, the key topics are loosely mapped in the diagram against the asset lifecycle.

approach presented here follows the same process, and leads to identification of leading and lagging indicators relevant to the Human Factors “Key Topics”.

There are three main elements to the proposed approach:

1. The overall process, aligned to HG 254, set out below.
2. The use of Key Topics tables that define the critical aspects of each Key Topic, provide audit type “health check” questions, and propose potential leading and lagging indicators (See Supporting Materials).
3. An organisational maturity assessment, intended to support selection of indicators that are appropriate for the organisation.

Process

In line with HSG 254 (HSE, 2006) it is proposed that the following steps to setting indicators for Human Factors performance are followed:

1. Identify the main **process safety hazard scenarios** (i.e. what can go wrong).
2. Identify the associated **Risk Control Systems** to control these hazards.
3. Describe the **required safety outcome** for each Risk Control System (what does success look like?).
4. Identify the **Human Factors aspects of the Risk Control Systems**.
5. Decide on the **organisation’s maturity with regard to Human Factors**. If the Risk Control System relates to one of the HSE Human Factors “Key Topics” then the user should consider their *Human Factors maturity* and their readiness to report Human Factors issues and failings (See Organisational Maturity).
 - a. If the organisation is *less mature*, then it should start by reviewing the organisation’s performance or status against the “Health Check” questions (See Section on Supporting Materials). They may then implement systems and processes to address the requirements identified.
 - b. *Mature* organisations may choose to select and implement leading and lagging indicators that are already in use within other organisations, to monitor relevant Human Factors “Key Topics” (See Supporting Materials).
 - c. *More mature* organisations may choose to consider the “proposed” metrics contained in the tables (See Supporting Materials).
6. For each Risk Control System, set a **lagging indicator** to show whether the required safety outcome is achieved. Set a range of **tolerance**.
7. Identify the **critical elements** of each Risk Control System and set **leading indicators** to monitor effectiveness of critical elements of the Risk Control System to show controls are working as intended. Set the range of **tolerance** for each indicator.
8. Establish the **data collection and reporting system**.
9. **Review** the performance of the system, including scope of indicators and tolerances.

Bow-tie or other analysis can be used to identify the RCSs associated with a specific hazard scenario, and help draw out the relevant Human Factors Key Topics and critical elements.

It is strongly recommended that indicator systems are designed with input from the workforce and those who will be charged with operating and maintaining the indicator systems.

Supporting Materials

To support the selection process outlined, the following supporting materials have been developed (Energy Institute, 2010a):

- A Human Factors organisational maturity assessment tool.
- A Human Factors Performance Indicator Template.
- A set of tables covering each of the HSE Human Factors “Key Topics” and identifying potential leading and lagging metrics.

Each “Key Topics” table contains the following:

- Summary of HSE Human Factors “Key Topic” drawn from Step Change in Safety (2010).
- Desired Safety Outcome: the impact that effective management of the Topic would have.
- Critical Elements: the processes or inputs that need to be in place to ensure the safety outcome.
- “Health-Check” Questions: audit-type questions to determine if necessary systems and approaches are in place. These draw on the “HSE Safety Report Assessment Guide: Human Factors” (HSE, 2009) in particular.
- Leading Indicators: established (i.e. in use) and proposed (i.e. untested) leading indicators.
- Lagging indicators: established (i.e. in use) and proposed (i.e. untested) lagging indicators.

The information contained in each table is drawn from various sources, including:

- HSG 254 (HSE, 2006).
- HSE Human Factors web pages (HSE, 2010).
- HSE Safety Report Assessment Guide: Human Factors (HSE, 2009).
- OECD guidance (OECD, 2008).

as well as output from the cross-industry Performance Indicators Workshop that formed part of the joint industry research project.

As an example, the “Key Topic” table developed for the risk assessment element of the Key Topic “Managing Human Failure” is shown in Table 3. The Human Factors Performance Indicator Template is shown in Table 4.

FURTHER CONSIDERATIONS

Scope of Indicator System

If they are to be sustained by an organisation, indicators need to be useful to the organisation and the individuals within it. In addition to helping demonstrate to external

Table 3. Key topic table: risk assessment element of “managing human failure”**RCS/HSE Key Topic in Human Factors****Managing Human Failures:**

Managing Human Failures is about predicting how people may fail through errors or intentional behaviours. If you are relying on people to prevent a serious accident, what would happen if they missed a step in a procedure? What would happen if they missed an alarm, or pressed the wrong button? If the consequences are serious then it is something you should manage.

Risk assessments need to recognise the limits of what humans can and can't do and take into account the impact of job, personal and organisational factors when deciding on control measures.

Incident investigations need to dig down to establish the conditions that allowed human failures to occur. The investigation needs to take account of all aspects of human factors that may have contributed to the incident.

Risk Assessments**Desired Safety Outcomes**

- Controls reflect limitations of human beings and take into account job, personal and organisational factors.
- Systems and processes are designed to be tolerant of human performance failings.

“Health check” Questions

- Are you following HSE’s 7 step risk assessment process for managing human failures?
- Have you identified safety critical tasks and roles, clearly linked to major hazard scenarios in the safety case/report?
- Have routine and non-routine tasks been considered?
- Is human failure analysis undertaken for each critical task step; for example, are human HAZOP^a techniques and guide words used?
- Can you demonstrate that Human Factors Performance Shaping Factors^b are being systematically considered in relation to human failure likelihood?
- Are potential human failures actively managed according to the hierarchy of controls? Are improvement plans in place?
- Is error recovery managed? (via detection, diagnosis and correction).
- Is there a suitable plan in place on site for managing Human Performance related risks?

Potential Lagging Indicators**Measures in Use**

- Number or % of incidents, accidents or root cause investigations in which human failure identified as being a contributory or causal factor.
- Total number per year of recommendations made in response to identified Human Factors related failures.

Proposed Measures

- Number of API RP 754 loss of containment incidents at each level with associated human factors root causes.
- Number or % of incidents involving human failures in which potential for failure was previously identified via risk assessment, HAZID or HAZOP process but not sufficiently mitigated.

Critical Elements (Process assurance)

- Implications of human failure are adequately understood and recognised in risk assessment, and appropriate controls are defined.

Potential Leading Indicators**Measures in Use**

- Number or % of risk assessments/HAZOPs that include assessment of potential human failure.
- Number or % of risk assessments/HAZOPs/HAZIDs with defined team competencies including Human Factors specialist competence/capability.
- Number or % of plants/sites in the organisation that have designated Champion to help manage Human Performance risk.

Proposed Measures

- Number or % of projects in the organisation for which Human Factors Manager has been appointed.
- Number of safety critical task assessments (Human Reliability Assessment, Human Error Analysis) completed vs number planned.

^aA Human HAZOP is a group-based approach to human hazard identification based on the HAZOP study method.

^bPerformance Shaping (or Influencing) Factors (PSFs) are factors that influence human failure rate. Typical PSFs include level of training, time pressure, quality/availability of procedures etc.

stakeholders (e.g. the Regulator) that the organisation is in control of its operations, indicators can help:

- Improve hazard awareness and understanding (and hence performance) amongst the workforce and management at the installation.
- Support sharing best practice between locations.

- Assess actual performance of risk control systems and target improvement.
- Communicate concisely the status of risk control systems to senior management.
- Provide a means of demonstrating to senior management the need for, and benefits of, investment.

Table 4. Human factors performance indicator template

Asset	Date
Team Members	
Include process safety, operations management and workforce representatives.	
Process Safety Hazard Scenario	
What is the scenario of concern?	
Risk Control Systems	
What risk control systems are in place?	
Desired Safety Outcome	Critical Elements
What is the required safety outcome that each risk control system is designed to deliver? What does success look like?	What are the critical elements that need to be in place to deliver the desired safety outcomes?
<ul style="list-style-type: none"> The team should define this outcome in its own words. 	
Health Check	
Review the “Health Check” Questions.	
<ul style="list-style-type: none"> Are all the elements in place? Should new elements be implemented? 	
Human Factors Cultural Maturity	
How mature is the organisation with regard to Human Factors?.	
Are there barriers which affect implementation of performance indicators?	
<ul style="list-style-type: none"> Are data available? Is there the required level of trust between management and workforce? Is there enough appreciation of Human Factors to be able to implement helpful performance indicators? 	
Potential Lagging Indicators	Potential Leading Indicators
<i>Less mature organisations:</i>	<i>Less mature organisations:</i>
<ul style="list-style-type: none"> Review the organisation’s performance or status against the “Health Check” questions. 	<ul style="list-style-type: none"> Review the organisation’s performance or status against the “Health Check” questions.
<i>Mature organisations:</i>	<i>Mature organisations:</i>
<ul style="list-style-type: none"> Select and implement lagging indicators that are already in use with other organisations. Set a tolerance for each indicator. 	<ul style="list-style-type: none"> Select and implement leading indicators that are already in use with other organisations. Set a tolerance for each indicator.
<i>More mature organisations:</i>	<i>More mature organisations:</i>
<ul style="list-style-type: none"> Use Energy Institute (2010a) to promote new thinking in performance measurement. Or consider the “untested” metrics contained in the tables of the report. 	<ul style="list-style-type: none"> Use Energy Institute (2010a) to promote new thinking in performance measurement. Or consider the “untested” metrics contained in the tables of the report.
Indicator Requirements	
<ul style="list-style-type: none"> Are the required data available? How often does the indicator need to be calculated/reviewed? What tolerance should be set on the indicator? What action will be taken when the indicator goes out of tolerance? (if it never goes out of tolerance it is probably not useful). 	
Implementation Plan	
<i>Performance Indicator Ownership:</i> Who is the customer for the indicator (who will review it?), who is accountable and who is responsible for providing it?	
<i>Resources:</i> Who needs to be involved, how much effort needed, what data are required?	
<i>Review:</i> How often will the indicator’s operation be reviewed?	

HSG 254 (HSE, 2006a) provides useful pointers to the design of systems for collecting and reporting indicators. Issues that are considered include:

- Reporting level; are the indicators to apply to the whole organisation, a group of sites, or an individual installation?

- Reporting structure; for complex sites, reporting can be based on a hierarchical approach with installation level indicators feeding to more generic site level and organisation level indicators. Within this, a large number of installation level indicators will typically be aggregated for reporting at organisation level, so rules for upward

reporting need to be designed and established carefully to ensure visibility of installation level information regarding non-conformities.

- The number of indicators to be collected; HSE recommends focusing on a few risk control systems.

In selecting indicators, the system designer should consider what action the indicator is intended to inspire, and whether this action will be taken by operators, by supervisors, by departmental or senior managers? The reporting level, content, and implied action contained in the indicator should be appropriate to the recipient and their “span of control”; i.e. the “owner” of the indicator should both understand the meaning of the measurements, and be able to take appropriate action. Indicators for use at plant level are likely to be specific and detailed, while indicators for senior managers are likely to address generic issues and inform investment and higher-level decision making.

Organisational Maturity

Success or failure of measurement initiatives has been linked to organisational culture. If disincentives are present then required information may not be collected or may not be acted upon. The designer of a performance indicator system needs to consider the capacity of the organisation to operate and accept the outputs of a performance indicator system, and then design a system that is compatible with this capacity. Indicators for Human Factors “Key Topics” may simply not be appropriate to organisations that are in the early stages of embedding safety management processes. Other organisations, that have well-developed management systems, may nonetheless be poorly equipped with regards to safety culture and unable to rely on honest and open reporting of perceived problems. On the other hand, the most mature organisations, aspiring to be high reliability organisations (HROs), will seek out opportunities to implement appropriate performance indicators, and will be responsive even to weak warning signals from these indicators.

DISCUSSION AND CONCLUSIONS

Systems for monitoring the technical contributors to process safety performance are becoming established, driven by learning from incidents, the publication of formal guidance, and emerging regulatory requirements. The importance of Human Factors to major accident hazard safety performance is increasingly recognised, but indicators for human factors performance are less well developed than they are for technical process safety.

This paper has outlined a process for selecting Human Factors performance indicators. The process presented has the advantage of being consistent with guidance published by HSE in the UK (HSE, 2006) and with the approach of HSE to Human Factors via the “Key Topics”.

The proposed process also draws on the experience of high hazard industries in implementing and using performance indicator systems.

Although consistent with established approaches for technical safety performance measurement, and with “lessons learned” in industry, the process has not yet been tested in practice, and it is therefore offered as a proposed approach. The partners of this joint industry project foresee that there may be value in establishing a user group to review industry experience with the approach, and to facilitate its development in the future.

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