RESEARCH REPORT

HUMAN FACTORS PERFORMANCE INDICATORS FOR THE ENERGY AND RELATED PROCESS INDUSTRIES

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FOREWORD

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 (performance indicators (PIs)) to monitor and manage major accident hazards safety performance is, however, still a developing area. In general, the literature that does exist in this area covers technical aspects of process safety, but not human factors.

This research report is intended for senior management and specialists charged with designing and implementing indicators for major accident hazards safety, or responsible for operating such systems. The report provides an introduction to the HSE human factors key topics, and proposes ways in which these might be measured. It also sets out a process for identifying relevant PIs. The research report incorporates findings related to current thinking on safety PIs, in particular for human factors, how organisations currently monitor human factors in practice, and what processes are used to ensure appropriate indicators are selected.

The research on which this report is based involved:

- An assessment of the literature regarding PIs.
- Discussions held with representatives of organisations active in the development of process safety performance measurement systems.
- A workshop with energy industry and related process industries' representatives to determine what use is made of human factors indicators currently within onshore and offshore energy and related process industry sectors, and to develop proposals for indicators for the HSE human factors key topics.
- Finally preparation of guidance in consultation with users.

This is an emerging area, and so it should be noted that rather than representing mature guidance, this is a research report that contains proposals for potential indicators, and a process for their selection. Further information is available from the EI website **www.energyinst.org/hofpi**.

This publication may be reviewed from time to time and it would be of considerable assistance for any future revision if users would send comments or suggestions for improvements to:

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1 INTRODUCTION

1.1 BACKGROUND TO THE RESEARCH

Lord Kelvin observed that "when you can measure what you are speaking about, and express it in numbers, you know something about it".

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 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. This area is one in which active development is underway and one to which this research report is intended to contribute.

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 (MAHs) into a set of human factors key topics[1]. These key topics cover the breadth of human involvement, 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 indicators available to help an organisation judge whether it is managing them well, and there is consequently a need for industry guidance in this area. The main objective of this research report is to propose specific leading and lagging indicators for the key topics, along with a structured process for their appropriate selection.

1.2 THE RESEARCH PROGRAMME

This research report was prepared by Lloyd's Register EMEA (LR) over the period of March to September 2010, under the guidance of a steering team comprising representatives from the Energy Institute (EI), HSE and LR.

The EI took the lead role in coordinating industry input, with its Human and Organisational Factors Committee providing the vehicle for industry consultation. HSE's Offshore Division and LR provided specialist technical input to the project, which was delivered by LR consulting personnel. The EI was responsible for final publication of the report.

The research programme involved:

1. Information gathering: the available literature was assessed, and discussions held with representatives of organisations active in the development of process safety performance measurement systems.
2. A workshop: a performance indicators workshop was held with representatives of onshore and offshore high hazard industry, from the energy and related process industries to:

1 See section 2.2

   – determine what use is made of human factors indicators currently within these sectors, and
   – develop proposals for indicators for the HSE human factors key topics introduced in 1.1.
3. Preparation of guidance and consultation with users: the outputs of the literature assessment and workshop were developed and a draft report prepared. Industry users were consulted over the period mid-August to mid-September 2010, and additional input consolidated in this final research report.

As indicated in 1.1, the main objective of the research reported here was to propose specific leading and lagging indicators for the key topics, along with a structured process for their appropriate selection. In support of this, an important secondary aim was to access current practices in industry, which are not necessarily reported in the literature, and the delivery of the performance indicators workshop was central to meeting this objective.

The volume of material related to performance indicators (PIs) is significant, and it was not feasible to complete an in-depth literature review. Therefore only the most relevant literature was identified, and this is introduced in Section 3 and in Annex D.

1.3 THIS REPORT

1.3.1 Structure and readership

The intended readership of this research report is senior management and specialists charged with designing and implementing indicators for major accident hazards (MAH) safety, or responsible for operating such systems.

The research report is divided into Part I, which (in conjunction with Annex D) provides the technical background to the area, and Part II which contains the proposed approach to developing PIs, and associated supporting information.

In parallel with the work reported here, the EI has also prepared a human factors briefing note on PIs (EI, 2011a) and the reader is referred to this for an overview of the topic area.

1.3.2 Scope

This research report is concerned with human and organisational factors, as they are defined by the HSE human factors key topics. In general, the literature that exists provides detailed coverage of technical matters, but does not include human factors in any depth. Further, whilst the indicators proposed in the literature might provide broad coverage of the various technical challenges to process safety, the process for selecting an appropriate set of indicators is not always well defined.

This research report is intended to propose possible indicators specifically for the HSE human factors key topics and - as importantly - a process for selecting relevant indicators.

Part I of the research report incorporates findings related to:

– current thinking on safety PIs, and in particular indicators for human factors;
– how organisations monitor human factors in practice, and
– what processes are used to ensure that appropriate indicators are selected.

Part II of the research report:

- provides an introduction to the HSE human factors key topics;
- proposes ways in which these might be measured, and
- sets out a process for identifying relevant indicators.

Part II also contains more general guidance for successful indicator implementation, including consideration of the reporting structure and cultural aspects.

This is an emerging area, and so it should be noted that rather than representing mature guidance, this is a research report only.

2 HUMAN FACTORS AND MAJOR ACCIDENT HAZARDS

2.1 HSE HUMAN FACTORS FRAMEWORK

Reducing error and influencing behaviour (HSG48, HSE, 1999) is the key document in understanding HSE's approach to human factors. It gives a simple introduction to generic industry guidance on human factors, which it defines in the following way:

"Human factors refer to environmental, organisational and job factors, and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety".

This definition includes three interrelated aspects that must be considered: the job, the individual and the organisation.

The job: including areas such as the nature of the task, workload, the working environment, the design of displays and controls, and the role of procedures. Tasks should be designed in accordance with ergonomic principles to take account of both human limitations and strengths. This includes matching the job to the physical and mental strengths and limitations of people. Mental aspects would include perceptual, attention and decision-making requirements.

THE HUMAN CONTRIBUTION TO MAJOR ACCIDENT HAZARDS SAFETY

Piper Alpha

On 6 July 1988, an explosion occurred on the Piper Alpha platform, an oil and gas production facility in the North Sea, following a release from equipment undergoing maintenance. In the subsequent fire, the platform itself was destroyed and 167 persons lost their lives in what was the world's worst offshore accident.

Some of the human factors issues subsequently highlighted included:

- Procedures: adequacy of permit to work (PTW) procedures, and those related to emergency response.
- Safety critical communication: failures in shift handover (PTW).
- Training and competence: specifically safety training and emergency response.
- Organisational culture: management attitude to safety, not addressing findings of safety audits, and focus on production rather than safety.

The individual: including competence, skills, personality, attitude, and risk perception. Individual characteristics influence behaviour in complex ways. Some characteristics such as personality are fixed; others, such as skills and attitudes, may be changed or enhanced.

The organisation: including work patterns, the culture of the workplace, resources, communications, leadership and so on. Such factors are often overlooked during the design of jobs but have a significant influence on individual and group behaviour.

In other words, human factors is concerned with what people are being asked to do (the task and its characteristics), who is doing it (the individual and their competence) and where they are working (the organisation and its attributes), all of which are influenced by the wider societal concern, both local and national. People are involved in the working system because of a number of strengths: for example, versatility in providing a link between a number of tasks, knowledge and judgement, and ease of communicating with others and eliciting a response. Hence, human acts and omissions can play a role in the initiation, mitigation, escalation and recovery phases of an incident (HSE, 2005a).

2.2 THE HSE HUMAN FACTORS KEY TOPICS

The UK HSE has condensed its experience of shortcomings in the human aspects of management of onshore MAHs into a set of human factors key topics. Some of these key topics are sub-divided into further issues. Whilst numbered, the key topics are not in priority order. The issues are similar in the offshore major hazard sector.

The key topics identified by HSE (see HSE website: www.hse.gov.uk/humanfactors/index.htm), are:

1. Managing human failures:
   - human errors, and
   - incident investigation.
2. Procedures.
3. Training and competence.
4. Staffing:
   - staffing levels;
   - workload;
   - supervision, and
   - contractors.
5. Organisational change.
6. Safety critical communications:
   - shift handover, and
   - permit to work (PTW).
7. Human factors in design:
   - control rooms;
   - human/computer interfaces (HCI);
   - alarm management, and
   - lighting, thermal comfort, noise and vibration.
8. Fatigue and shiftwork.
9. Organisational culture:
   - behavioural safety, and
   - learning organisations.
10. Maintenance, inspection and testing:
    - maintenance error, and
    - intelligent customers.

These key topics are expanded in Annex E, and in the key topics panels of Section 5, using the concise topic descriptions provided by Step Change in Safety (Step Change 2010) supplemented by HSE material where appropriate.

The reader is referred to the HSE website (**http://www.hse.gov.uk/humanfactors/topics/index.htm**) for the latest information on these topics.

THE HUMAN CONTRIBUTION TO MAJOR ACCIDENT HAZARDS SAFETY

Longford

On 25 September 1998, a vessel at the Longford Gas Plant 1 fractured following incorrect operation of equipment, releasing hydrocarbon vapours and liquid. Explosions and a fire followed. Two employees were killed and eight others were injured. Supplies of natural gas to domestic and industrial users were halted.

Some of the human factors issues subsequently highlighted included:

- Training and competence: operator training was inadequate as it did not demand a true understanding of the process.
- Organisational change: removal of engineering support from the plant to a remote head office deprived operators of the engineering expertise and knowledge they required; in addition, the engineers also lost awareness and knowledge of plant activities.
- Procedures: procedures were not followed and workers developed their own set of informal work practices.
- Communication: problems were not passed on to the right personnel and critical information was unrecognised, ignored or suppressed.

Texas City Refinery

On 23 March 2005, the Texas City Refinery experienced one of the worst industrial safety incidents in recent U.S. history following overfill of a tower on start-up. Explosions and fires killed 15 people and injured another 180, and resulted in financial losses exceeding $1.5 billion.

Some of the human factors issues subsequently highlighted included:

- Training and competence: lack of supervisory and technically trained personnel during unit start-up.
- Communication: poor communication of critical information regarding start-up during shift changeover between operators and supervisors, miscommunication during tower start-up.
- Human factors in design: malfunctioning instrumentation did not alert operators to the actual condition of the unit, and a poorly designed computerised system hindered operators’ ability to determine if the tower was overfilling.
- Organisational change: high turnover of refinery plant managers resulting in negative impact on process safety leadership.

PART I - TECHNICAL BACKGROUND

3 CURRENT PRACTICES IN PROCESS SAFETY PERFORMANCE MEASUREMENT

The prime purpose of this section is to address the questions:

- What are indicators and what are PIs (3.1)?
- What is considered current good practice in indicator selection and system design, and what information is available on PIs for human factors issues (3.2)?
- What use is made of PIs for human factors currently in the process sector (3.3)?

The section opens with an introduction to process safety performance measurement and indicator terminology (3.1). Findings from an assessment of the literature are presented in 3.2, and the findings from discussions with operating businesses are presented in 3.3. Technical information relating to the literature assessment is contained in Annex D.

3.1 WHAT ARE INDICATORS?

Management scientists have placed considerable emphasis on performance measurement, and there is an extensive literature on the subject. In the process safety field, partly as a result of the recommendations arising from the Texas City incident, we now encounter the terms key performance indicators (KPIs), PIs, process safety performance indicators (PSPIs), leading and lagging indicators, activities indicators and outcome indicators. Do these terms all mean the same thing, and if not then how are they different?

Some of the general thinking behind PIs in general, and PSPIs in particular, is introduced below.

3.1.1 Key performance indicators (KPIs)

It is common to hear the terms KPI and PI used interchangeably to describe some measurement of a process input, output or state. Research carried out under this project has suggested that there may be advantages to distinguishing more precisely between different types of indicator. Parmenter (2010), for example, draws a distinction between KPIs and key results indicators (KRIs). As defined by Parmenter, KPIs are inputs to systems, and KRIs are outputs. In a business context, typical KRIs might be customer satisfaction or return on capital employed (ROCE). In process safety, a KRI could be the total count of process safety incidents (PSIC[2]) recommended by CCPS[3] (2008). The distinction can be useful because KRIs typically represent the outcome or results of many actions, but they do not tell you what you need to do to change the outcome or results; so for example a high or low value of PSIC provides information, but it does not allow improvement action to be directed at a specific issue.

Parmenter (2010) defines KPIs as those measures that focus on the aspects of organisational performance that are the most critical for the current and future success of the organisation. A number of characteristics of KPIs are identified, including that they:

- are measured frequently (e.g. daily);

2 From Process Safety Incident Count
3 The Center for Chemical Process Safety of the American Institute of Chemical Engineers

– are acted on by the senior management team;
– indicate what action is required by staff;
– have a significant impact (by affecting one or more critical success factors and more than one high level goal), and
– establish who is responsible for taking action.

In other words, KPIs are defined as measures of system inputs that can be controlled to give significant positive impact. This research report is concerned with performance measurement in a broader sense, so the term PI (rather than KPI) is used throughout, noting of course that organisations may choose to adopt some of the indicators presented as KPIs.

Kaplan and Norton (1996) recommend that organisations adopt no more than 20 KPIs, and other writers suggest fewer than 10. Parmenter indicates that between KPIs and KRIs there may be up to 80 performance and results indicators owned and managed by individuals within the organisation.

3.1.2 Process safety performance indicators (PSPIs)

Following the Texas City incident of 2005, the Baker Panel (Baker, 2007) recommended that BP implement "a reasonable set of integrated performance indicators". In the wake of this, guidance has been published both in the US and UK (CCPS, 2008; API, 2010; HSE, 2006a) to help organisations develop, implement, maintain and update integrated leading and lagging PIs for process safety.

In the UK, HSE guidance contained in HSG 254 (HSE, 2006a) recommends the use of a dual assurance system of paired leading and lagging indicators for process safety performance. The indicators are related to specific risk control systems (RCSs) associated with specific major accident hazard scenarios; HSE terms these indicators PSPIs. HSE has set a deadline for all UK onshore high hazard sites (i.e. those subject to the Control of Major Accident Hazard (COMAH) Regulations) to have implemented effective process safety PIs by April 2011.

In the US, CCPS has promoted a rather different approach to that of HSE, recommending indicators that tend to target generic system requirements for safe process operation (e.g. mechanical integrity, or personnel competency). The approaches of HSE and CCPS are of course complementary, but while the HSE approach may lead to selection of indicators identified by CCPS, the CCPS approach cannot generate indicators that are tailored to a particular process - which is the intent of the methodology contained in HSG 254 (HSE, 2006a).

API (2010) guidance sets out to integrate elements of other guidance, including HSE (2006a) and CCPS (2008). The document classifies process safety indicators into four tiers of leading and lagging indicators. Tiers 1 and 2 are intended for public reporting and Tiers 3 and 4 are intended for internal use at individual sites. Guidance on methods for development and use of PIs is provided in the document. The International Petroleum Industry Environmental Conservation Association (IPIECA), API and the International Association of Oil and Gas Producers (OGP) will shortly publish a revision to the IPIECA/OGP/API 2005 *Oil and gas industry guidance on voluntary sustainability reporting* (IPIECA, 2005), to include reporting of process safety and asset integrity in a framework aligned to API (2010) guidance.

OECD (2008) guidance on developing PIs draws on the process presented in HSE, 2006a to present a similar approach for identifying leading indicators (which it terms activities indicators) and lagging indicators (which it terms outcome indicators).

A leading PSPI (as defined in HSG 254, [HSE, 2006a]), or an 'activities indicator' (as defined in OECD, 2008) would constitute one of Parmenter's PIs. A lagging PSPI (as defined in HSG 254, [HSE, 2006a]), or an 'outcome indicator' (as defined in OECD, 2008) would constitute one of Parmenter's results indicators.

The correspondence between these indicators is shown in Table 1.

Table 1 Correspondence of indicators between organisations

Parmenter (2010)	HSE (2006a)	CCPS (2008)	API (2010)	OECD (2008)
PI	Leading PSPI	Leading indicator	Leading PI	Activities indicator
Results indicator	Lagging PSPI	Lagging indicator	Lagging PI	Outcome indicator

Within this research report we will follow the leading/lagging indicator terminology of HSG 254 (HSE, 2006a), and draw also on HSL, 2006 to define leading and lagging indicators as follows:

- 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).
- The lagging indicator reveals 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.

3.2 TECHNICAL REVIEW: FINDINGS FROM LITERATURE ASSESSMENT

Technical information relating to the literature assessment is contained in Annex D. This section provides an overview of the main findings from the literature assessment.

3.2.1 Indicators for safety

The idea of indicators for safety performance is firmly established. The uses to which such indicators can be put include:

- Tools for authorities to define their regulatory requirements and goals and assess the degree to which these are met.
- Ways to communicate safety issues to the general public.
- A means for industry to monitor its own performance and drive improvement.

Within the scope of this report, it is the last of these that is the primary interest.

3.2.2 Attributes of safety PIs

With regard specifically to industry performance monitoring, the research reported here has identified a number of attributes of safety PIs that should be considered when choosing what to measure, and how to measure it:

- Relation to safety; it may appear obvious, but an indicator needs to be related to safety in a way that can be understood if it is to inspire action.
- The indicator should match the cultural maturity of the organisation; i.e. the organisation should be able to acknowledge the message contained.
- 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 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.

Feedback from operating businesses with regard to their current or potential use of human factors PIs is that:

- The PIs to be used by operating companies/duty holders should not be prescribed by external organisations; they should relate to the organisation's own understanding of its hazards and risks.
- PIs may not need to 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 PIs 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 PI rather than the underlying safety input or activity.
- Organisations need to distinguish between tools for managing issues (i.e. which imply action), and indicators 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 or process) and continuous PIs (including traffic light systems).

3.2.3 Process safety performance indicators (PSPIs)

There is an extensive literature related to process safety PIs, and for the process industries we draw attention particularly to the guidance published by HSE (2006a), CCPS, (2008), OECD, (2008) and API, (2010) introduced in 3.1.2.

In general, publications focus on what might be measured, rather than the process of choosing what to measure. HSE (2006a) provides process-based guidance on the selection and use of indicators, i.e. it is focused on how to identify relevant indicators, and the design of an indicator system. Industry feedback is that clearer recommendations on which indicators to use would also be welcomed. OECD, CCPS, API and others provide 'menus' of possible indicators, with a lesser emphasis on the selection process.

3.2.4 Indicators for human factors

If one turns specifically to indicators for human factors, then the amount of guidance for the process sector is rather limited. In particular, there is no single source of guidance that provides both a process for determining where indicators are needed and suggested indicators.

HSE (2006a) incorporates human factors within its process-based framework, but offers few candidate indicators for human factors performance. CCPS (2008) offers a rather small number of indicators related to human factors, and OECD (2008) provides an extensive list of organisational factors, though in the form of audit-type questions rather than continuous indicators. API (2010) addresses the requirement for a process and combines this with thinking from CCPS (2008).

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

Table 2 Scope of documents

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

Within the nuclear industry, measurement of human factors performance is more firmly established, and there is guidance on the use of appropriate indicators. This tends to be prescriptive, i.e. it lacks a process-based approach to indicator selection. However there are many common issues within the sector, and where international comparisons are sought, there are clearly benefits to adopting standard measures.

Approaches in the nuclear sector are hierarchical and tend to involve identifying high level organisational attributes, e.g. (positive) attitude to safety, developing strategic measures of this (e.g. human performance) and then establishing specific safety performance indicators (SPIs), (e.g. number of events due to training deficiencies) etc. Aspects of this approach have been adopted by the more mature operating companies in the process sector as discussed in 3.3.

3.2.5 Reporting system - structure and communication

The preferred structure for reporting indicators appears still to be an emerging area in the process industries. CCPS (2008) offers recommendations on what should be measured, but not the process for capturing the information, while OECD (2008) refers to HSE guidance. HSE (2006a) does provide information regarding reporting structures, and advances a hierarchical indicator structure, in which plant or facility indicators are aggregated and fed up to organisational level. This aligns with practices and recommendations from the nuclear industry, which appears to have developed the most mature indicator systems. The European Commission (2009) notes:

– Safety performance measurement systems for operating plant in the nuclear industry should have a hierarchical structure. Lower level indicators can be used to measure different aspects of plant performance, while higher level indicators can inform the regulatory process, including supporting the definition of goals and standards.
– The use of a hierarchical structure with several layers provides for flexibility; aggregated measures can provide an integrated and high-level view of plant safety performance but the level of aggregation can be adjusted to suit the needs of a particular stakeholder. At the same time, detailed information is retained and can be interrogated if specific aspects of plant performance need to be understood.

It is considered that the same holds true in the process sector, and that a hierarchical approach to indicators is to be preferred.

Discussions with selected operators, completed as part of this research project, have confirmed that the more mature indicator systems are hierarchical.

In addition to the reporting structure, the way in which the indicators are to be communicated should also be considered. Many organisations elect to use 'traffic light' systems to show the status of their systems and performance, in which the traffic light changes according to the value of some underlying indicator (which may be quantitative or qualitative). The advantage of the traffic light approach is that the system status can be quickly understood by personnel lacking detailed technical knowledge of what is being monitored, which facilitates communication. Where the traffic light indicator is derived from complex information, the underlying data should of course be retained to support problem-solving if the traffic light changes to red or amber.

3.2.6 Leading and lagging indicators

The literature assessment has demonstrated that there is awareness of the benefits of employing both leading and lagging indicators for safety in industry, although the precise definition of leading and lagging continues to be a source of discussion. From a practical viewpoint this is not a major consideration; organisations require indicators to monitor the results of failures (e.g. accidents, incidents) and indicators of precursors to these accidents and incidents, which might be used to prompt corrective action before these accidents and incidents are realised.

A potentially useful distinction has emerged (SSM, 2010) between drive indicators (that represent inputs to the safety management process and correspond closely to leading or activity indicators), monitor indicators (that represent the current level of safety in the organisation) and feedback indicators (that correspond closely to lagging or outcome indicators). This distinction is not pursued in this research report but is something of which readers may wish to be aware.

3.3 FINDINGS FROM INDUSTRY CONSULTATION

Discussions with representatives of organisations active in the development of process safety performance measurement systems are summarised in this section.

Organisational maturity with regard to the monitoring and awareness of human factors issues varies widely across the process sector. Discussions with representatives of operating companies have established that most organisations have developed process safety indicator systems of some sort. In general, these do not explicitly reference all HSE's human factors key topics, but they may address those human factors topics recognised and considered critical by the operating company. Common issues that are included are compliance with procedures, training currency and staffing levels.

Many organisations have implemented systems for managing some of the key topics, although formal PIs may not be part of these systems. Examples of key topics that are recognised, but not typically monitored with a formal PI, include organisational culture, human factors in design and managing human failure.

The more advanced companies (typically the larger and more international organisations) have implemented performance 'dashboards' to provide a high level diagnostic of current performance. One North Sea operator has implemented a process safety dashboard, which provides for presentation of live PI data on the company intranet using a traffic light system. Eight high level process safety indicators are used:

1. emergency management;
2. SSoW[4] and job planning;

4 Safe system of work

3. project management;
4. change management;
5. offshore crew competence;
6. integrity;
7. compliance, and
8. maintenance.

A hierarchical approach is taken in which each high level indicator is broken down into a number of component leading and lagging indicators; the data input to each indicator is managed by a nominated owner. Thus SSoW and job planning (for example) is broken down into indicators that include:

- monitoring reviews completed (lead);
- actions arising from PTW audits closed (lead);
- incidents relating to failings of PTW system (lag), and
- long-term isolations and inhibits (lag).

Different approaches to constructing such dashboards have been noted, with a top-down approach (i.e. driven by technical management understanding of the requirements to deliver high level process safety goals) being the most usual. Some organisations have taken a bottom-up approach, recruiting the workforce to the process of identifying the most relevant front-line PI. In practice, a combination of both approaches is probably required. Such dashboards do require long-term commitment of resource, and high-level sponsorship of such systems is usually required, noting that failure to maintain currency of the information will tend to undermine the credibility of the system.

PART II - ESTABLISHING INDICATORS FOR HUMAN FACTORS PERFORMANCE

4 AN APPROACH TO DEVELOPING PERFORMANCE INDICATORS FOR HUMAN FACTORS

4.1 INTRODUCTION

The term 'risk control system' is used (HSE, 2006a) 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, PTW, inspection and maintenance, etc.). RCSs provide the means for controlling challenges to plant integrity, and a process for their identification is set out in HSG 254 (HSE, 2006a).

One way in which the relationship between RCSs, the human factors key topics, and leading and lagging indicators can be visualised is by using the 'Swiss cheese' accident trajectory model developed by Reason (1997). In this model, major accidents are considered to result from concurrent failings within several RCSs. For each RCS (see HSL, 2006, HSE, 2006a):

– 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.

Each HSE human factors key topic potentially constitutes a RCS, or contributor to a larger RCS, associated with a specific incident. As such, the key topics can be mapped to an accident trajectory model[5] as shown in Figure 1. Note that organisational change and organisational culture cut across all the key topics.

5 Note that, with the exception of organisational change and organisational culture, the key topics are loosely mapped in the diagram against the asset lifecycle.

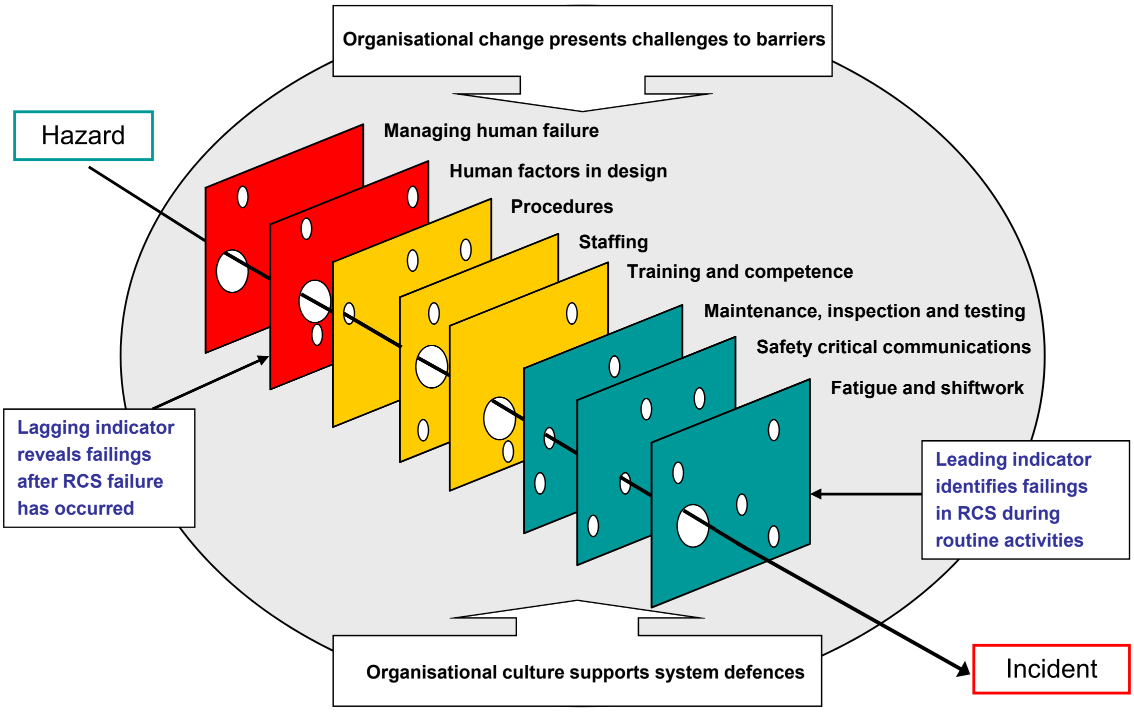

Figure 1 Accident trajectory model (Swiss cheese model)

Within this model, the role of the operator both in initiating and mitigating the consequences of an event is included.

The human contribution to the RCSs associated with specific hazard scenarios can also be drawn out effectively using 'bow-tie' diagrams. An example of this is shown in Figure 2, which represents a high-level schematic bow-tie for the two initiating events of 'tanker drive-away' and 'hose failure', leading to hose rupture on a hydrocarbon tanker loading system.

This bow-tie analysis emphasises the human role in prevention and mitigation of an incident through compliance with procedures, and the consequent importance of the HSE human factors key topics procedures and training and competence. The key topics: maintenance, inspection and testing (of leak detection equipment and the loading hose), human factors in design (e.g. design of interlock system), fatigue and shiftwork are also particularly relevant.

It should be noted that the HSE human factors key topics appear both as discrete RCSs (e.g. procedures) and as contributors to larger RSCs (e.g. human factors in design contribution to loading station interlock).

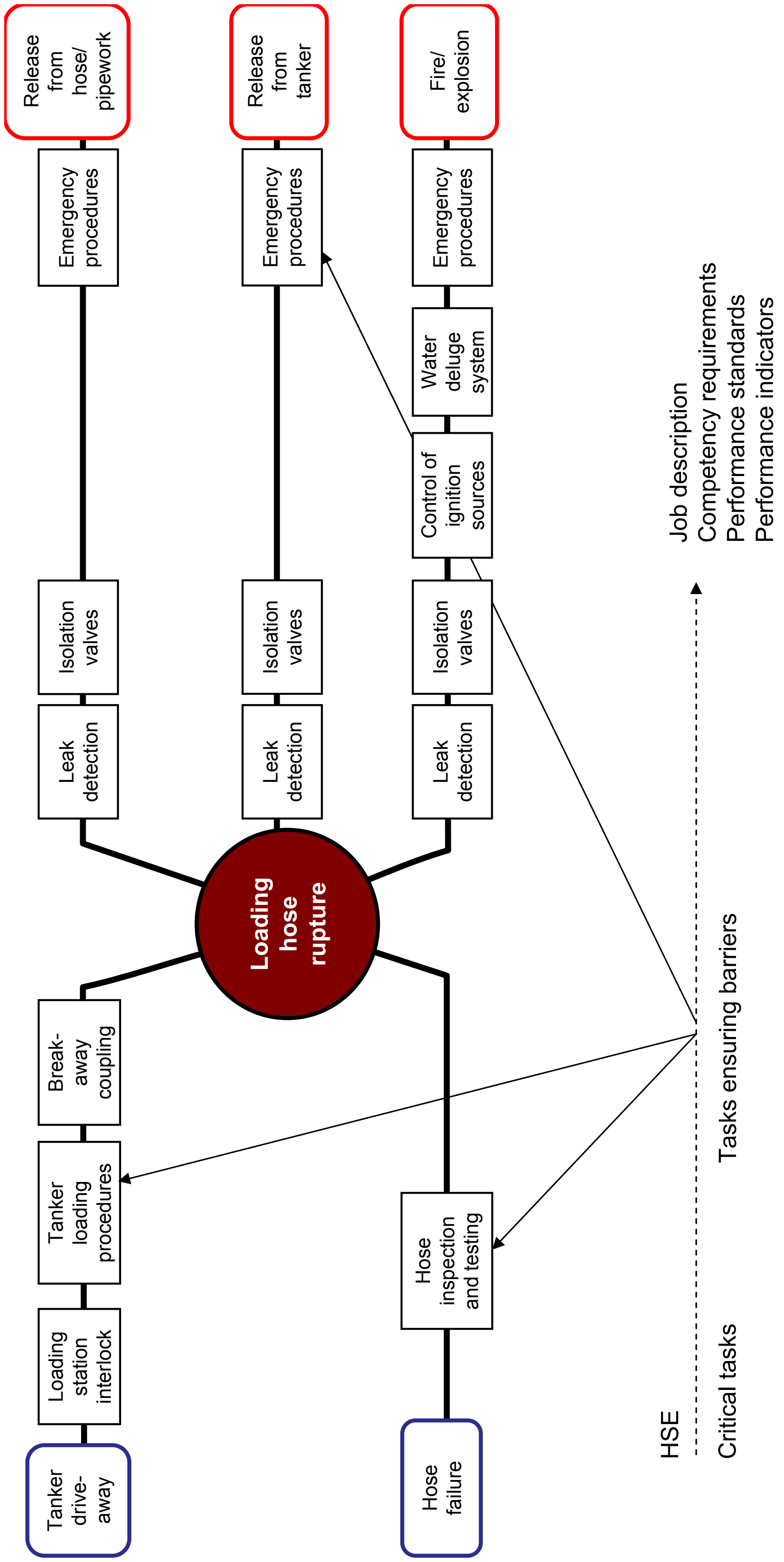

Figure 2 Bow-tie diagram

The challenge to organisations seeking to implement human factors PIs is to answer the questions:

1. Which HSE human factors key topics should be monitored and what are appropriate indicators to use?
2. What should be the process for collecting and monitoring indicators, and for acting upon information derived from the indicators?

4.2 WHICH HSE HUMAN FACTORS KEY TOPICS SHOULD BE MONITORED AND WHAT INDICATORS ARE APPROPRIATE?

4.2.1 Key topics

HSE (2006a) provides a methodology for identifying and implementing appropriate PSPIs that includes the following steps[6]:

- identifying the main process safety hazard scenarios (i.e. what can go wrong);
- identifying the associated RCSs to control these hazards;
- describing the required safety outcome for each RCS (what does success look like?);
- setting a lagging indicator to show whether this outcome is achieved;
- identifying the critical elements of each RCS;
- setting leading indicators to monitor effectiveness of critical elements of the RCS to show controls are working as intended;
- setting the range of tolerance for each indicator;
- ensuring required information is available, and
- reviewing the performance of the system.

The RCSs that are identified using this methodology may include human factors key topics. Where these human factors key topics either constitute the RCS, or are a major contributor to the overall integrity of a larger RCS (as discussed in 4.1), the organisation should consider setting leading and lagging indicators for associated human factors critical elements. The prime requirement is clearly to monitor human factors aspects that are relevant to the hazard scenario of interest. 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.

In broad terms, the key topics to be monitored should:

- be relevant;
- be controllable, and
- have a defined (significant) impact on the required outcome that is measurable within a relatively short timescale.

4.2.2 Critical elements and PIs

The human factors critical elements that are to be monitored should preferably be under management control, i.e. it should be possible to use the information generated from the measurement process to improve the status of the critical element within a useful timescale. This requires that the means to influence a critical element are known, and that it is possible to influence that element consistently and predictably.

A strong coupling between the chosen PI, the associated critical element and the required safety outcome is generally preferred to a loose coupling. In other words, the PI

6 Note that these steps are only part of the total process presented by HSE.

should provide a direct measure of the status of the critical element which should in turn have a rapid, significant and predictable influence on the required safety outcome.

So, for example if an organisation identified that safe operation depended on the correct performance of a particular manual task, it might consider implementing indicators for competence (key topic training and competence), currency of procedures (key topic procedures) or behaviour (key topic organisational culture) for that task. All these key topics are relevant, but the business might argue that demonstrated competence in the workplace was the most strongly linked to delivery of the required outcome, and it might therefore choose to implement a specific (leading) indicator directly for competent task execution (for example, derived from observation of the particular task). It might also choose to implement a more generic measure for currency of procedures across all safety critical tasks.

Critical elements and possible PIs for this example are shown in Table 3, drawing on the information which will be introduced in more detail in Section 5.

Table 3 Example critical elements and PIs

Required high-level safety outcome	**Task performed correctly**		
	Procedures	**Training and competence**	**Organisational culture**
Relevant RCSs/ human factors key topics, and associated required safety outcomes	Procedures are technically correct, appropriately maintained, and easy to access.	People have the necessary skills, knowledge and experience to perform the task to the required standard.	The culture supports compliant working, i.e. people seek to comply with requirements for safe working.
Critical element	Procedures are up-to-date.	Staff can demonstrate task/role competence in a way that can be validated.	Workforce is empowered to act safely.
PI	Percentage of procedures current (i.e. within review date). (Leading indicator)	Percentage of training records complete/up-to-date. **Number or percentage of safety critical staff assessed to be competent in their roles (based on competency assessment programme).** **This (leading) indicator is selected for implementation.**	Safety climate measurement (Leading indicator)

As noted in Annex D, whether a particular PI is categorised as leading or lagging may not be significant. What is important is that an indicator provides an early warning enabling management to act in good time to address any problems before they become too serious.

4.3 HOW SHOULD INDICATORS BE COLLECTED AND MANAGED?

4.3.1 Reporting level, structure and frequency

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 stakeholders (for example, 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 RCSs and target improvement.
- Communicate concisely the status of RCSs to senior management.
- Provide a means of demonstrating to senior management the need for, and benefits of, investment.

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 into 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 the visibility of installation level information regarding non-conformities.
- The number of indicators to be collected; HSE recommends focusing on a few RCSs.

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, or 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. Associated with this is also the question of reporting frequency; indicators that change frequently and may prompt urgent action should be reported frequently. The design of an indicator system is likely to align with an organisation's existing reporting structure (for example, plant daily and weekly meetings, monthly production meetings, quarterly reviews, etc).

Possible indicators, mapped against the HSE human factors key topics are presented in Section 5.

4.3.2 Organisational maturity

In addition to the technical suitability of indicators, an organisation's ability and preparedness to respond to a signal contained in an indicator should also be considered.

Indicators for human factors key topics may simply not be appropriate to organisations that are in the early stages of embedding safety management processes, and 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. For the former organisation, the focus is likely to be on investing further in embedding the safety management processes before embracing human factors indicators, while for the latter organisation the challenge is to find indicators that will be supported and maintained by operating personnel. On the other hand, the most mature organisations, aspiring to be high reliability organisations (HROs), will seek out opportunities to implement appropriate PIs, and will be responsive even to weak warning signals from these indicators.

As an example, if staff competence is a critical element of a RCS then it may appear that a measure of competent task execution would be an appropriate indicator. But, how can this be measured, and will observers be prepared (or allowed) to report their observations? While more developed organisations might feel that the culture permitted this type of indicator to be implemented, many might choose to focus instead on currency of training records.

4.3.3 Unintended consequences

It is often observed that "what gets measured gets done". PIs can drive appropriate behaviours, but depending upon how performance is rewarded, they can also drive inappropriate behaviours. Building on the discussion in 4.3.2, for example, if disincentives are present then required information may not be collected or may not be acted upon; if personnel expect to be penalised for exceeding a target value of a particular PI, then they might choose not to report certain information, or instead to report information under other lower consequence categories. Success or failure of measurement initiatives is therefore linked to organisational culture and particularly to reward structures within the organisation. The designer of a PI system should bear in mind the capacity of the organisation to operate and accept the outputs of a PI system, and design the system so that it is compatible with this capacity.

Stages of maturity of some relevant aspects of organisational culture are set in the tables of Annex F, with the aim of helping users of this research report to determine what types of indicator will work best within their own organisations.

5 PERFORMANCE INDICATORS (PIS) FOR HSE HUMAN FACTORS KEY TOPICS

5.1 INTRODUCTION

The following pages provide suggestions for the assessment of organisational performance against the HSE human factors key topics. The information presented is drawn from various publications, including:

– HSG 254 (HSE, 2006a);
– HSE human factors web pages (HSE, 2010);
– HSE Safety report assessment guide: human factors (HSE, 2009a);
– OECD guidance (OECD, 2008), and
– output from the cross-industry workshop on human factors performance indicators that formed part of this project.

The following information is contained in the key topic sheets of 5.2:

– Summary of HSE human factors key topics drawn from Step Change (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 (as identified from a safety critical task analysis; see also section 4.1).
– 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* in particular.
– Leading indicators: established (in bold type) and proposed (i.e. untested, in black type) leading indicators. 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), and provide early indication of potential problems.
– Lagging indicators: established (in bold type) and proposed (i.e. untested, in black type) lagging indicators. Lagging indicators reveal failings or holes in the RCS following an incident or adverse event.

The distinction between a KPI and a PI has been set out in section 3.1.1. KPIs are, strictly, measures of system inputs that can be controlled to give significant positive impact. This report is concerned with performance measurement in a broader sense, so the term PI is used throughout, noting of course that organisations may choose to adopt some of the indicators set out in the key topics sheets as KPIs.

5.2 HOW TO USE THE INFORMATION IN THIS SECTION

In line with HSG 254 (HSE, 2006a) it is proposed that users of this research report take the following steps to setting indicators for human factors performance:

1. Identify the main process safety hazard scenarios (i.e. what can go wrong).
2. Identify the associated RCSs to control these hazards.
3. Describe the required safety outcome for each RCS (what does success look like?).
4. Identify the human factors aspects of the RCSs.
5. Decide on the organisation's maturity with regard to human factors (see Annex F and section 4.3.2).

   a. If the RCS 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.
   b. If the organisation is less mature, then it should start by reviewing the organisation's performance or status against the health check questions (5.2.1 onwards). They may then implement systems and processes to address the requirements identified.
   c. Mature organisations may choose to select and implement leading and lagging indicators that are already in use within other organisations (bold text), to monitor relevant human factors key topics (5.2.1 onwards).
   d. More mature organisations may choose to consider the proposed indicators contained in the tables (black text, 5.2.1 onwards).
6. For each RCS, 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 RCS and set leading indicators to monitor their effectiveness and 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.

A flow chart is provided in Figure 3. Note that the key topics are at different stages of development, and so some have significantly more information available for consideration than do others.

Indicator systems should be designed with input from the workforce and those charged with operating and maintaining the indicator systems. The maturity model contained in Annex F may be used to help determine what type of workforce involvement should be sought.

A template to support design of human factors indicators for implementation in a business is contained in Annex C, along with a worked example.

How to use this information:

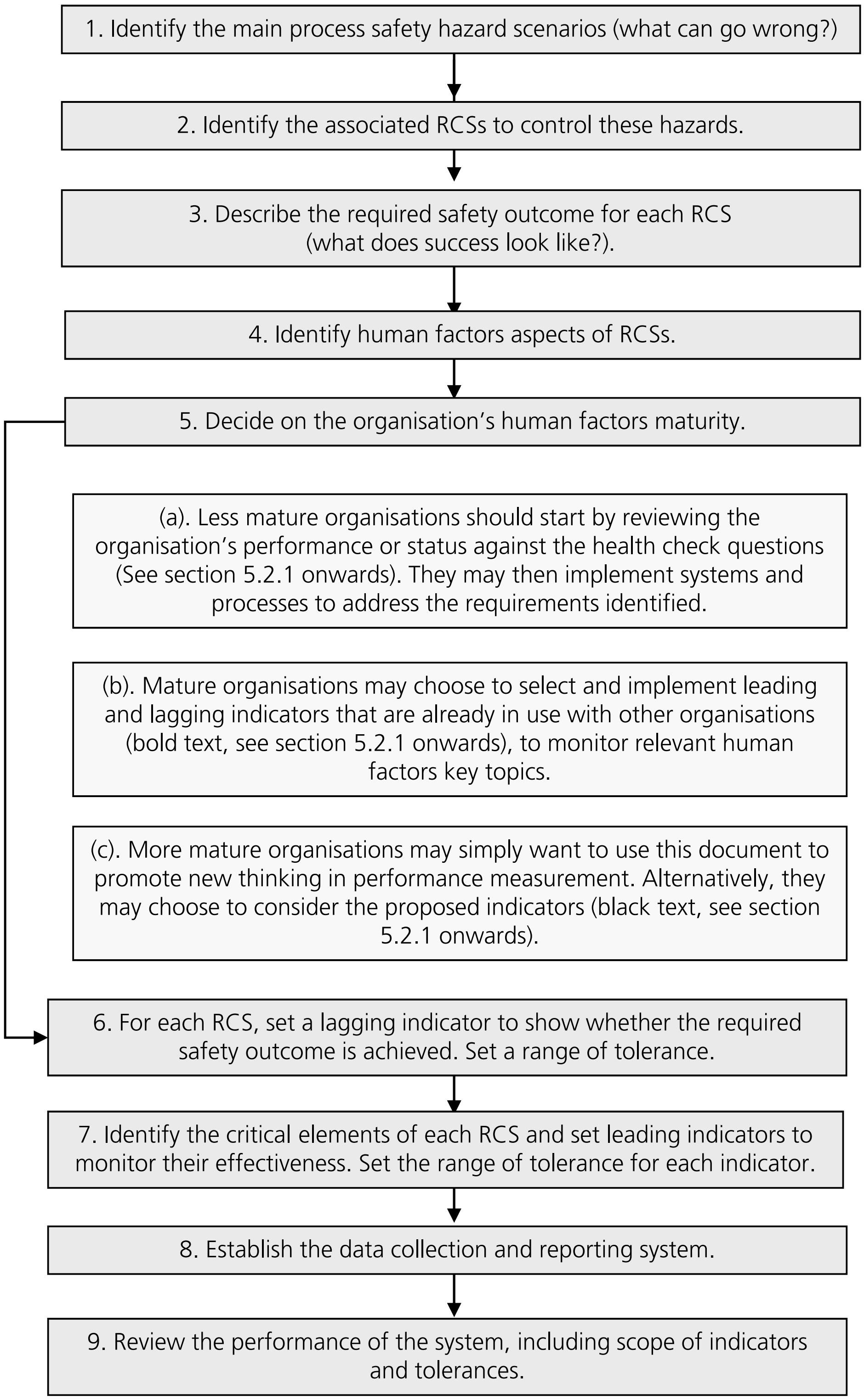

Figure 3 'How to use this information' flow diagram

5.2.1 Managing human failures

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. – Performance shaping factors (PSFs)[8] are optimised.	**Critical elements (process assurance)** – Human failure, its implications, and associated PSFs are adequately understood and recognised in risk assessment. Appropriate controls are defined.
'Health check' questions – Are you following HSE's 7 step risk assessment process for managing human failures (see HSE (2005b) *Core topic 3: identifying 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 hazard and operability study (HAZOP[7]) techniques and guide words used? – Can you demonstrate that human factors PSFs 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? – Are operators involved in the assessment of the safety critical tasks they perform?	

7 A human HAZOP is a group-based approach to human hazard identification based on the HAZOP study method.

8 Performance 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.

<table>
<tr><td>Potential lagging indicators
– Number or percentage 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.
– Number or percentage of API RP 754 loss of containment incidents at each level with associated human factors root causes.
– Number or percentage of incidents involving human failures in which potential for failure was previously identified via risk assessment, hazard identification study (HAZID) or HAZOP process but not sufficiently mitigated.</td><td>Potential leading indicators
– Number or percentage of risk assessments/HAZOPs that include assessment of potential human failure.
– Number or percentage of risk assessments/HAZOPs/HAZIDs with defined team competencies including human factors specialist competence/capability.
– Number or percentage of plants/ sites in the organisation that have a designated champion to help manage human performance risk.
– Number or percentage of projects in the organisation for which a 'human factors manager' has been appointed.
– Number or percentage of safety critical task assessments (human reliability assessment, human error analysis) completed vs. number planned.</td></tr>
<tr><td colspan="2">Incident investigations</td></tr>
<tr><td>Desired safety outcomes
– Incident investigations establish the conditions that allowed human failings to occur, and system failings are corrected.
– Systems are tolerant of human performance failings.</td><td>Critical elements
– Incident investigations enable human performance failings to be identified, and allow root causes to be addressed.</td></tr>
<tr><td colspan="2">Health check questions
– Is consideration of human factors included within the formal incident investigation process?
– Is the process systematic, and is it documented?
– Does the process encourage investigators to find out why human failures occur?
– Do your incident investigations assess immediate causes behind an incident (active failures) and contributing factors (latent conditions) at the job, individual and organisational levels?
– Do your incident investigations typically recommend retraining of operators?
– Are operational staff able to explain the difference between errors, failures and violations?
– Do investigations recognise that there are different types of human failure and do they lead to appropriate remedial action?</td></tr>
<tr><td>Potential lagging indicators
– Number or percentage of incidents, accidents or root cause investigations in which human failure identified as being a contributory or causal factor.
– Total number/year of recommendations made in response to identified human factors-related failures.</td><td>Potential leading indicators
– Number or percentage of incident investigations that include systematic assessment of potential human failure.
– Number or percentage of incident investigations with defined team competencies including human factors specialist knowledge.</td></tr>
</table>

5.2.2 Procedures

<table>
<tr><td colspan="2">RCS/HSE key topic in human factors: Procedures
Procedures include method statements, work instructions, PTWs etc. Incomplete, incorrect, unclear or outdated procedures can lead to short cuts and human failures. Procedures should be managed and use a format, style and level of detail appropriate to the user, task and consequences of failure.</td></tr>
<tr><td>Desired safety outcomes
– Procedures are implemented where they are needed (and contain correct scope - actions and tasks, including emergency actions - and sufficient detail).
– Tasks are executed safely and consistent with the design intent of the procedure.</td><td>Critical elements
– Procedures are linked to safety critical tasks.
– End users are involved in design of procedures.
– Procedures are selected, designed and managed so as to promote human reliability.
– Procedures are easy to understand.
– Procedures are up-to-date.
– Procedures are easy to access.</td></tr>
<tr><td colspan="2">Health check questions
– Are procedures readily accessible in the working environment?
– Is the content of procedures informed by task and human failure analysis?
– Is your workforce involved in drafting procedures?
– Do you have a robust process for regularly reviewing and updating procedures in line with process changes?
– Are there any current procedures that cannot be followed?
– Do procedures exist for safety-critical tasks across the full range of activities (start-up/shut-down; commissioning; maintenance; upset and abnormal conditions; emergencies)?
– Is there is a clear link between procedures and competence (see training and competence)?
– Is an efficient process in place to monitor compliance with rules and procedures?
– Do measures exist to ensure compliance with procedures (including user involvement and job design)?
– Do you have a procedure for managing procedures that addresses:
    – which tasks require procedures?
    – the level of procedural support/detail required (background information only, training aid, step-by-step written instructions, job aid, decision table, checklist etc)?
    – guidance on style and consistency?
    – robust approvals process (including arrangements to verify technical accuracy)?
    – arrangements for regular review and update?</td></tr>
</table>

Potential lagging Indicators	Potential leading Indicators
– **Number or percentage of incidents, accidents or root cause investigations in which inadequate procedures identified as being a causal factor[9].** – Number or percentage of incidents related to failure to follow procedures. – **Number or percentage of non-compliances/violations in following procedures.**	– Number or percentage of safety critical tasks for which procedures are in place[10]. – **Number or percentage of procedures documented/up-to-date/within scheduled review date, or as compared with total number of procedures.** – **Number or percentage of procedures meeting quality criteria/number of errors found in procedures (based on procedural 'walkthroughs' undertaken by managers and operators to confirm appropriateness).** – **Number or percentage of errors found in procedures.** – **Number or percentage of safety critical tasks for which appropriate (scope, critical tasks, emergency actions) procedures are in place.** – **Number or percentage of PTWs reviewed and considered fit-for-purpose.**

5.2.3 Training and competence

RCS/HSE key topic in human factors: Training and competence	
Competence is a combination of practical thinking skills, knowledge and experience[11]. Training provides people with new knowledge and skills, but people need to apply and practise these to become competent. Training and competence can help reduce human failures caused by lack of knowledge, and teach people behaviours that will keep them safe. This is not a universal safeguard though. Even the most experienced and competent individuals can fail.	
Desired safety outcomes	**Critical elements**
– Personnel are able to perform safety critical tasks consistently to the required standard (no deviations). This includes the ability of personnel to fulfil requirements for effective emergency response.	– Staff have the requisite knowledge required for their roles, including technical knowledge, knowledge of site hazards, knowledge of site rules and processes. – Staff can demonstrate competence for routine and non-routine (emergency) activities. – Staff are able to demonstrate task/role competence in a way that can be validated.

9 NB: Procedural inadequacies are frequently cited as a contributory factor to incidents. In order to be a meaningful measure, focused investigation is needed to determine whether procedural failings are truly a causal factor.

10 This indicator will be appropriate for less mature organisations. For more mature organisations with procedures in place, the indicator should be concerned with assessing the adequacy of procedures.

11 That together provide 'the ability to carry out a task to the required standard'.

Health check questions	
– Is an effective competence management system in place? – Have safety critical roles been defined? Have safety critical competence requirements been identified for, and mapped against, specific safety critical tasks and roles? – Are appropriate processes in place for recruitment, selection, training and periodic assessment of staff? – Are there triggers in place to ensure that competence requirements are re-evaluated and training provided if necessary following process changes etc.? – Are training programmes updated to reflect lessons learned from incidents etc.? What is the process for ensuring this? – Do systems exist to establish and maintain levels of competency for all those involved in safety critical activities (including managers, trainers, assessors, contractors etc.)? – Are NVQs aligned with site-specific major hazards? – Is on-the-job training structured (with specific learning objectives) and supported by other modes of training (e.g. control room simulators)? Are trainees assessed by suitable means (tests with pre-set marks; on-the-job assessment etc.)? – Is structured refresher training conducted for safety-critical and infrequent safety-related tasks? – Is training validated (did it deliver what it was supposed to?) and evaluated (is this the right kind of training for our needs?); are suitable records maintained? – Does risk assessment include consideration of competence? – Do systems exist to establish and maintain 'trainer' competency? – Does the training department have sufficient resources?	
Potential lagging indicators	**Potential leading indicators**
– **Number or percentage of incidents, accidents or root cause investigations in which lack of competence identified as being a causal factor.** – Feedback on staff competence from third party body (based on annual audits).	– **Number or percentage of employees trained per period as compared with schedule[12].** – **Number or percentage of training records complete/up-to-date.** – **Number or percentage of staff satisfactorily completing refresher training as compared with schedule[13].** – **Number or percentage of safety critical staff assessed to be competent in their roles (based on competency assessment programme/use of simulator re-assessment).** – Number or percentage of safety critical roles filled versus unfilled[14]. – Frequency with which supervisors actively check staff competence (based on audit interviews with supervisors). – Number or percentage of staff 'acting up' (temporarily filling more senior roles), based on spot check audits. – Number or percentage of training not given on request. – Number or percentage of technical specialists available versus required number (cf Longford. See also 5.2.4, staffing levels).

12 Indicators can be developed if necessary for % of employees successfully completing: general safety awareness training, emergency response training/drill, technical training, etc.

13 NB: this is not the same as competence. Also, the number of non-attendees may indicate staffing pressures.

14 Note this requires safety critical roles to be defined, so likely to be useful for mature and more mature organisations.

5.2.4 Staffing (staffing levels and workload, supervision, contractors)

<table>
<tr><td colspan="2">RCS/HSE key topic in human factors: Staffing
Changes in staffing levels and increase/decrease of workload[15] often occur as part of organisational change. It is important to consider the impact of this change on the control of hazards.
Effective supervision has a significant positive impact on a range of human factors such as compliance with procedures, training and competence, safety critical communication, staffing levels and workload, fatigue and risk assessment.
Contractors (including suppliers and third parties) face the same human factors issues as their clients. Some of these issues are critical at the client-contractor interface, e.g. communication, supervision, organisational culture, competence.
(Note that all the HSE human factors key topics are relevant to contractors, and that the précis above relates to the client/contractor interface only).</td></tr>
<tr><td colspan="2">Staffing levels and workload</td></tr>
<tr><td>Desired safety outcomes
– There are a sufficient number or percentage of competent personnel to deliver routine and non-routine (including abnormal or emergency) activities safely.
– Personnel are not subject to excessive stress or fatigue.</td><td>Critical elements
– Structured assessment of required staffing level.</td></tr>
<tr><td colspan="2">Health check questions
– Has a structured analysis been completed to determine adequate staffing levels (e.g. using HSE Contract research report CRR 348/2001 (HSE, 2001a) and EI Safe Staffing arrangements - user guide for CRR348/2001 methodology (EI, 2004).
– Is a suitable staffing plan in place (i.e. are there arrangements to ensure the right number or percentage of competent people are in the right place at the right time, especially during abnormal and emergency conditions)?
– Has a workload assessment been carried out?
– Are there suitable arrangements in place to ensure that workload is managed proactively?
– What is the policy for 'no-shows' - i.e. operators not available to run the plant?
– Where roles and responsibilities are outsourced, is intelligent customer capability retained (see 5.2.10)?
– Are there arrangements to set, record, monitor and enforce limits and standards for working hours, overtime, on-call working, shift swapping etc. (see also 5.2.8)?</td></tr>
</table>

15 Note that workload is related (inversely) to competence.

<table>
<tr><td>Potential lagging indicators
– Number or percentage of incidents, accidents or root cause investigations in which workload/ staff shortages identified as being a causal factor.
– Average hours worked/ overtime worked (taken from timesheet analysis).
– Number or percentage of times work stopped because of lack of personnel.
– Number or percentage of staff off work because of stress.
– Number or percentage of identified skills shortages.
– Staff turnover.</td><td>Potential leading indicators[16]
– Staff workload assessment[17].
– Maintenance backlog.
– Percentage of optimum staffing level achieved, or degree to which required percentage staffing levels are being met (e.g. for emergency requirements).
– Team availability (number or percentage of personnel available on each shift who are fully trained).
– Number or percentage of tasks carried over to next shift and/or that exceed programmed time.
– Number or percentage of people available/trained to cover required signing authority roles versus target (PTW issuer, receiver).</td></tr>
<tr><td colspan="2">Supervision</td></tr>
<tr><td>Desired safety outcomes
– Supervisors' roles in routine and non-routine situations are appropriately defined (particularly in relation to safety critical activities).
– Effective supervisory arrangements are in place.
– Supervisors' roles support requirements for safe working.</td><td>Critical elements
– Supervisors' roles are clearly defined and communicated.</td></tr>
<tr><td colspan="2">Health check questions
– Are supervisor roles clearly defined and realistic in the context of major hazards?
– Are the limitations of self-managed teams and 'flatter' management structures addressed?
– Does on-site supervision involve/ensure leadership, compliance with procedures, planning and allocation of work, communication and teamwork, workforce involvement, fatigue management?
– Can managers describe why supervisors are there and what their role is?</td></tr>
<tr><td>Potential lagging indicators
– Number or percentage of accidents, incidents or root cause investigations in which lack of or poor supervision identified as being a causal factor.</td><td>Potential leading indicators
– Ratio of supervisors to staff reporting to them.
– Supervisor time on plant against time in office versus target (hours)[18].
– Number or percentage use of upward appraisal and 360 degree feedback.</td></tr>
</table>

16 Measures can be indicative of resource/workload problems, but careful interpretation of the data is required.
17 Workload assessment is particularly important for safety critical tasks.
18 Can be useful, but depends on site context.

Contractors	
Desired safety outcomes – Risks associated with contractor personnel and activities are managed consistently with those of organisation's own activities and personnel. – Contractors are managed effectively.	**Critical elements** – Effective contractor management processes in place.
Health check questions – Does the organisation have a clear policy and rationale for use of contractors? – Is there a process for contractor selection and management? – Are there arrangements to capture and monitor relevant data for contractors? – Can the organisation demonstrate that it remains in control of work undertaken by contractors? – Where contracting out introduces additional risk, how are these risks managed? – How does the organisation ensure adequate authorisation, oversight and assurance of contractors' work? – Can the organisation demonstrate that the contractor is suitable for the specific task? – Does the organisation have a process for taking action where performance is less than adequate? – How does the organisation ensure that there is continuity through the hand-back process to the organisation or further contractor?	
Potential lagging indicators – **Number or percentage of incidents, accidents or root cause investigations in which poor management of contractors identified as being a causal factor.**	**Potential leading indicators** – Number or percentage of risk assessments relating to contractor activities that involve contractor personnel. – Number or percentage of audits that are undertaken for contractor activities, versus target.

5.2.5 Organisational change

RCS/HSE key topic in human factors: Organisational change	
Organisational change covers a range of issues, e.g. staffing levels, use of contractors or outsourcing, combining departments, changes to roles and responsibilities etc. Similar to plant or process change, organisational change can have direct and indirect effects on the control of hazards. Organisational changes need to be planned and assessed.	
Desired safety outcomes – Organisational changes are made in an informed way such that any impacts on safety are understood and managed.	**Critical elements** – Management of change (MoC) process is in place. – All organisational changes are subject to the MoC process. – The MoC process is completed by competent personnel with appropriate involvement. – Recommendations arising from MoC are acted upon.

<table>
<tr><td colspan="2">Health check questions
– Is an appropriate MoC process in place?
– Does the scope of the MoC process include robust arrangements to manage organisational change? Is the process triggered by an organisational change as well as an engineering change?
– Are human factors implications of change recognised (e.g. staffing levels and workload, team work, communications)?
– Are all changes planned and staggered (to avoid too many simultaneous changes)?
– Do personnel and contractors actively participate before, during and after the change?
– Are all safety-critical tasks and key major hazard responsibilities identified and successfully transferred to the new organisational structure?
– Is a full review undertaken prior to go-live, and is performance monitored post-change?
– Is training, support and supervision for staff with new or changed roles provided (and is there adequate planning for competent cover during the training period)?</td></tr>
<tr><td>Potential lagging indicators
– Number or percentage of incidents, accidents or root cause investigations in which failures in the MoC process identified as a causal factor.
– Number or percentage of issues arising from failure in MoC process (e.g. delays, impact on operations etc).</td><td>Potential leading indicators
– Number or percentage of engineering, and organisational, changes that are risk assessed as part of MoC process.
– Number or percentage of MoC requests closed out or signed off versus number remaining live (for period/against targets).
– Number or percentage adherence to MoC procedures, based on spot check audits.</td></tr>
</table>

5.2.6 Safety critical communications (including permits and shift handover)

<table>
<tr><td colspan="2">RCS/HSE key topic in human factors: Safety critical communications
Frequent and clear two-way communication (spoken and written) is essential for safety in any task. The methods of communication, language, timing and content are all important factors in effective communication. Checking understanding is also critical.
Permits are effectively a means of communication between site management, plant supervisors and operators, and those who carry out the work. The goal of shift handover is the accurate reliable communication of task-relevant information across shift changes or between teams thereby ensuring continuity of safe and effective working (HSE, 2010).</td></tr>
<tr><td colspan="2">Communications</td></tr>
<tr><td>Desired safety outcomes
– All relevant parties communicate clearly such that personnel understand what is required of them during execution of safety critical tasks.</td><td>Critical elements
– Identify who needs to communicate, what their communication needs are, and how communication will be achieved (e.g. using common equipment). This could be identified during risk assessment.
– Consider timings of key communications e.g. draw attention to hazards before people are required to carry out tasks.
– Language should be appropriate to the workforce (consider literacy, first language) and use appropriate terminology.
– Highlight safety critical steps in procedures and draw attention to them in training.</td></tr>
<tr><td colspan="2">Health check questions
– Is information about major hazards and associated control measures clearly communicated across all levels of the organisation (especially lessons learned from near misses and incidents)?
– Do adequate communication channels exist between different sub-groups (operations and maintenance personnel, employees and contractors, incoming and outgoing shifts, suppliers and recipients of products (cf Buncefield/Piper Alpha) etc.?
– Are communication protocols established?
– Do safety critical procedures utilise more than one means of communication (redundancy in communication)?
– Is remote communication equipment (radios, intercoms, PAs, intranet) suitable and reliable?
– Do robust communication channels exist for emergencies?
– Is suitable support equipment provided (logs; computer displays etc.)?
– Is there diversity between shifts with respect to task execution? (Do different shifts do things differently?)</td></tr>
</table>

<table>
<tr><td>Potential lagging indicators
– Number or percentage of incidents, accidents or root cause investigations in which failures in communication identified as a causal factor.</td><td>Potential leading indicators
– Number or percentage compliance with communication protocols (based on spot check/sampling audits).
– Correct use of communications proformas (identify number or percentage non-compliance via sampling).</td></tr>
<tr><td colspan="2">Permits</td></tr>
<tr><td>Desired safety outcomes
– Work is carried out under an appropriate and compliant permit.</td><td>Critical elements
– An appropriate permit system is in place.
– Personnel are competent to use the permit system.
– Permit system is operated correctly.
– Equipment/plant conditions are correctly identified.</td></tr>
<tr><td colspan="2">Health check questions
– Is a clearly defined fit-for-purpose permit (including PTW) system in place?
– How do you ensure personnel are competent to operate the permit system?
– How do you ensure that work locations are correctly identified, and necessary isolations made?
– How do you manage carryover of permits from shift to shift?
– Where possible, is maintenance work scheduled to finish within one shift?
– Is there evidence of permit copying?</td></tr>
<tr><td>Potential lagging indicators
– Number or percentage of incidents, accidents or root cause investigations in which failures in permits identified as a causal factor.</td><td>Potential leading indicators
– Number or percentage adherence to correct permit process (quality checks based on sample auditing).
– Competence of permit issuers/ receivers.</td></tr>
<tr><td colspan="2">Shift handover</td></tr>
<tr><td>Desired safety outcomes
– Plant is handed over in a known (safe) state to incoming team.</td><td>Critical elements
– Clear identification and communication of critical plant parameters, including temporary measures/situations (PTW or other permits to be carried across shifts, degraded equipment etc.).</td></tr>
<tr><td colspan="2">Health check questions
– Is shift handover recognised as a crucial element of safety-critical communication and is it managed accordingly?
– Is time scheduled for handover?
– Is there a handover proforma/log?
– Is there an effective shift handover procedure?
– Do incoming and outgoing shifts discuss plant status face-to-face?</td></tr>
</table>

Potential lagging indicators	**Potential leading indicators**
– **Number or percentage of incidents, accidents or root cause investigations in which failures in shift handover process identified as a causal factor.** – **Number or percentage of reported end-of-tour or shift handover problems.**	– **Number or percentage of shift handovers meeting required criteria[19]/number or percentage of errors found in handover process (quality checks based on sample auditing of handover process and review of logs).**

5.2.7 Human factors in design (control rooms; human/computer interfaces (HCI); alarm management; lighting, thermal comfort, noise and vibration)

RCS/HSE key topic in human factors: Human factors in design	
The design of control rooms, alarm systems, plant and equipment can have a huge impact on human performance. The work environment (lighting, thermal comfort, working space, noise and vibration) also impacts human performance in unexpected ways. Designing tasks, equipment, processes and the work environment to suit the user can reduce human failure, accidents and ill-health. Human-system interactions have frequently been identified as major contributors to poor operator performance (HSE, 2010).	
Human factors in design	
Desired safety outcomes	**Critical elements**
– Task design, the human/machine interface and the work environment support safe error-free operation and maintenance.	– Equipment and control rooms should be designed in accordance with relevant ergonomics standards. – Users should be involved in the design process. – Plant and processes should be designed for operability and maintainability and other elements of the life cycle should not be neglected e.g. decommissioning. – Consideration should be given to all foreseeable operating conditions including abnormal operations, upsets and emergencies.

19 Checks to include correct completion of handover documentation, quality of spoken handover, and acceptance of handover by incoming team.

<table>
<tr><td colspan="2">Health check questions
– Is there a human factors integration plan in place (for a new project, including decommissioning projects)?
– Are appropriate human factors design standards identified and are they being followed?
– Have a human factors integration manager and human factors delivery manager been appointed or are there arrangements for appropriate human factors integration?
– Are plant, equipment, workstations and control systems designed with human performance in mind?
– Are human factors principles integrated into system design and development?
– Are human factors considered throughout the development lifecycle?
– Are relevant front-line personnel actively involved in the design process; is usability/operability assessed?
– Does the design process identify the procedural and training needs of relevant users?
– Are relevant general design standards applied on site?
– Are the results from safety critical task analysis used to inform system design?
– Are the results from safety critical task analysis used to inform development of safety critical procedures and associated training programmes?</td></tr>
<tr><td>Potential lagging indicators
– Number or percentage of incidents, accidents or root cause investigations in which human factors design failings identified as a causal factor.
– Number or percentage of items not accessible for maintenance (ergonomic considerations for accessibility have not been addressed).
– Number or percentage of installations requiring re-work (revealed by commissioning/decommissioning).</td><td>Potential leading indicators
– Compliance with human factors integration plan, based on review of site activities, interviews, documentation.
– Number or percentage of ergonomic design issues raised during ergonomic walkabout reviews/audits.
– Number or percentage of items of equipment non-compliant with ergonomic standards (based on spot check sampling audits/review of ergonomic assurance evidence).
– Number or percentage of design reviews with defined team competencies including human factors/ergonomics specialist knowledge.
– Number or percentage of workarounds found related to design problems (based on audit sampling).
– Subjective operator views on equipment usability, obtained via interviews/sampling audit.
– Compliance of workplaces with ergonomic environmental design requirements (lighting, noise, etc.) based on sample audits.</td></tr>
</table>

Control room and interface design	
Desired safety outcomes – The control room design, human/machine interface and the work environment support safe error-free operation.	**Critical elements** – Equipment should be designed in accordance with key ergonomics standards. – Control rooms should be designed in accordance with key ergonomics standards (e.g. ISO 11064).

Health check questions
– Is there is a clear, applied policy regarding centralisation or in-field location of control rooms?
– Do design criteria encompass control room arrangements and layout, panel workstations, displays and controls, environmental conditions (lighting, acoustics, ventilation, temperature etc.)?
– Are relevant standards/good practice applied during upgrades and modifications of existing control room interfaces, as well as in the design of new control systems?
– Is the experience of operators and maintenance personnel captured and fed back into the upgrade process?
– Does distributed control system (DCS) and safety instrumented system (SIS) training cover specific operational aspects (local use as installed), as well as generic familiarisation with the interface and system operating manuals?
– Have relevant standards been applied? (See, for example, list below):
    – BS EN ISO 11064 *Ergonomic design of control centres.*
    – BS EN ISO 9241-400:2007 *Ergonomics of human-system interaction - input devices.*
    – EEMUA 201:2002 *Process plant control desks utilising human-computer interface.*
    – NUREG-0700 *Human-system interface design review guidelines.*
    – HSE CRR 432/2002 *Human factors aspects of remote operation in process plants.*	

Potential lagging indicators – **Number or percentage of incidents, accidents or root cause investigations in which design factors/ergonomics failures identified as a causal factor.** – Number or percentage of repeat incidents associated with specific equipment (NB: repeated problems may be indicative of a problem in the design). – Number or percentage of design issues raised on Issues Register.	**Potential leading indicators** – Compliance of equipment/workplace with requirements of ergonomic standards, based on sample audits.

Alarm systems	
Desired safety outcomes – Alarm design and alarm handling support safe error-free operation.	**Critical elements** – Equipment should be designed in accordance with key ergonomics standards. – Control rooms should be designed in accordance with key ergonomics standards including EN11064, EEMUA 191 and EEMUA 201.

Health check questions
– Is there a clear link between major hazard risk assessment and the on-site alarm philosophy, such that all alarms can be justified and are suitably prioritised?
– Is alarm handling fully integrated into the design process and considered at the outset?
– Does the design process acknowledge and accommodate human capabilities and limitations (including operator availability to respond, time to respond, the potential for alarm flooding etc.)?
– Are alarms useful and relevant? Is it clear how alarm systems alert, inform and guide required operator action (including a defined, documented response for each safety-critical alarm, supported by training)?
– Are alarm systems subject to continuous improvement (for example, is there a clear link between process change and alarm system upgrade)?
– Are relevant performance measures defined and monitored (average alarm rate, average number or percentage of standing alarms etc.)?
– Are specific examples included within the safety case/report to show how relevant standards and good practice (see, for example, below) have been applied on site?
    – EEMUA 191: 2007 *Alarm systems: a guide to design, management and procurement*
    – HSE CRR 166/1998 *The management of alarm systems*	

Potential lagging indicators – Number or percentage of incidents in which alarms issues/failures identified as a causal factor.	**Potential leading indicators** – **Number or percentage of alarms that operators fail to acknowledge per shift.** – **Compliance with EEMUA guidance on human/machine interfaces and alarm handling. Possible indicators include counts of overall alarm frequency, number or percentage of standing alarms, number or percentage of alarms failing to initiate, number or percentage of false alarms etc.** – **Evaluation of alarm follow-up actions (e.g. accepted/disabled) and standing alarm reviews, based on sampling.**

5.2.8 Fatigue and shiftwork

<table>
<tr><td colspan="2">RCS/HSE key topic in human factors: Fatigue and shiftwork
Fatigue refers to the issues that arise from excessive working time or poorly designed shift patterns. It can lead to human failures, slower reaction times, reduced ability to process information, memory lapses, absent-mindedness, and losing attention.</td></tr>
<tr><td>Desired safety outcomes
– Shift-working arrangements and working hours are designed to balance the demands of work with time for rest and recovery so that personnel are alert when working.</td><td>Critical elements
– Shift patterns and working hours are designed and managed to control workforce fatigue levels.
– The workforce is aware of fatigue, and time away from work is utilised effectively to get the required restorative sleep.
– Fatigue of individuals is monitored and managed such that system safety is not compromised.</td></tr>
<tr><td colspan="2">Health check questions
– Has an appropriate shift schedule been put in place, in accordance with recognised good practice?
– Is there a clear framework for managing fatigue using appropriate standards and good practice (e.g. HSG256 Managing shiftwork [HSE, 2006b])?
– Has a fatigue risk index assessment of shift systems been completed (and does it indicate arrangements are acceptable)? Is there a systematic assessment of any changes to working hours and shift patterns using a MoC type process?
– Does shift roster design take account of shift types, shift length, rest periods, rotation and social factors etc.?
– Has a competency based fatigue training programme been adopted to train identified employees on fatigue and its management?
– Are employees who are about to be deployed to shift work offered a pre-placement health check?
– Do accident investigations consider whether or not fatigue was a root cause or significant contributing factor?</td></tr>
<tr><td>Potential lagging indicators
– Number or percentage of incidents, accidents or root cause investigations in which fatigue issues or shift scheduling identified as a causal factor.
– Number or percentage of near-misses arising from shiftwork/fatigue issues.
– Levels of sickness absence[20].
– Reported and observed cases of fatigue.</td><td>Potential leading indicators
– Average number of hours worked (or percentage overtime worked) from timesheet analysis[21].
– Number or percentage of open shifts.
– Number or percentage of consecutive shifts worked by individuals.
– Number or percentage work breaks missed (sampling/interview).
– Number or percentage of non-compliances with documented shift pattern.
– Number or percentage of exceptions (breaches of company policy), including staff working non-compliant working hours.
– Scheduled versus actual hours worked.</td></tr>
</table>

20 May be indicative of fatigue issues if sickness absence is a means to avoid working a shift. Care is required in interpretation.
21 NB: a trend towards more overtime might suggest increased potential for fatigue/reduced alertness.

5.2.9 Organisational culture (leadership, behavioural safety, learning organisations)

RCS/HSE key topic in human factors: Organisational culture

HSE identifies 'behavioural safety' and the 'learning organisation' as two critical aspects of safety culture, and Step Change has added 'leadership' to these. The Step Change definitions are provided below:

Setting of expectations, leading by example and decision making that takes safety into consideration are essential in creating a strong safety culture. This means taking personal responsibility for safety.

A learning organisation values and encourages learning from its own and other organisations' experiences. Learning is linked to 'corporate memory', which must withstand organisational changes. Learning organisations are characterised by 'constant vigilance' and seek out bad news as well as good. Understanding human factors can turn organisational learning into preventative solutions.

Behavioural safety is an approach which tries to promote safe behaviours and eliminate unsafe behaviours. Behavioural safety programmes typically involve observation of workplace practices followed-up by individual feedback and reinforcement of good practices.

Because of the complexity of organisational culture, the text below is not restricted to treatment of the three major headings given here.

Desired safety outcomes	Critical elements
– Organisational culture supports safe working.	– Management of major hazards safety is consistent within the business. – Production/safety conflicts are managed responsibly. – Risks are understood across the business. – Workforce is empowered to act safely.

Health check questions

An evaluation of the culture of an organisation is a complex process, and will require formal safety climate assessment. The questions listed below do not constitute a comprehensive set but do address some of the requirements for a positive culture.

- Are appropriate organisational arrangements in place to ensure optimal organisational culture?
- Is there strong, visible leadership and an unambiguous commitment to actively manage major hazards (e.g. no bias towards production over safety, evidence of mid- to long-term investment (rather than inadequate, short-term fixes), good balance between active and reactive measures to manage major hazards, commitment to keep pace with new ideas and technology)?
- Is there evidence of a previous and/or regular toleration of 'short cuts' by management?
- Is there evidence of a just rather than a blame culture?
- How sophisticated is the root cause investigation process? Do incident investigations typically conclude with human error or violations (non-compliances) or do they drill deeper? Do they seek to assign individual blame, or to identify organisational failings? Are individuals named in incident investigations (indicative of blame culture)?

<table>
<tr><th colspan="2">Health check questions (cont.)</th></tr>
<tr><td colspan="2">– Does employee and contractor involvement in major hazards equate to active participation, not passive consultation (i.e. active participation in task analysis, major hazard risk assessment, development of procedures, design for usability and maintainability, incident investigations etc.)?
– Do arrangements exist to ensure the empowerment of employees (e.g. to stop work if not safe)?
– Do mechanisms exist to feed back the findings of incident and near-miss investigations?
– Is the organisation's relationship with the regulator positive or negative?
– What level of access is provided to the workforce?
– Is critical documentation available and complete?
– Is culture viewed as more than the inclination of employees to follow rules?</td></tr>
<tr><th>Potential lagging indicators</th><th>Potential leading indicators</th></tr>
<tr><td>Reporting and incident investigation
– Number or percentage of reported near-misses (should not be zero).
– Number or percentage of incidents, accidents or root cause investigations in which organisational culture/safety culture identified as being a causal factor.

Continuous improvement
– Number or percentage of incidents/accidents that are repeat incidents/accidents (measure of how well the organisation is learning from incident investigations).

Safety climate and culture
– Breaches of company policy.</td><td>Leadership
– Measure of visibility of senior executives in the workplace (number of site visits, etc).
– Number or percentage of safety tours undertaken by managers and middle managers.
– Number or percentage of task observations undertaken by leaders (behavioural safety measure).
– Outcomes of upward/360 appraisals.

Provision of resources
– Number or percentage of items of equipment requested but not provided.

Communication and risk awareness
– Feedback on adequacy of regular toolbox talks.
– Number or percentage of working groups (including employee representation).

Reporting and incident investigation
– Number or percentage of incidents reported upwards through the reporting chain.
– Effectiveness of incident investigation process, including:
  – circulation of incident investigation reports;
  – adherence to planned timeframes for incident investigation;
  – effectiveness of interventions, and
  – adherence to timescales for remedial actions (number or percentage of actions closed out by target dates).</td></tr>
</table>

Potential lagging indicators (cont.)	Potential leading indicators (cont.)
	Continuous improvement – Number or percentage of issues reported in timely fashion by workforce. NB: non-reporting or delay in reporting might be indicative of undesirable cultural issues. Safety climate and culture – **Results from HSE safety climate surveys (or other safety culture/ climate surveys or external audits), undertaken every 12 or 18 months, involving questionnaires, team interviews and individual interviews. Provide a snapshot of the organisation's culture (compare results against industry benchmark/ changes over time).** – Employee attitude and perception survey (including management, supervisors and workforce), results benchmarked against industry. – Number or percentage of actions identified from previous safety culture/ climate audits that have been closed, against prioritised targets. – Evaluation of working culture: completeness and adequacy of work undertaken versus 'tick-box' mentality (determined via spot check audits). Major accident hazards/behavioural safety focus – Number or percentage of reported events that are process safety related versus behavioural safety related.

5.2.10 Maintenance, inspection and testing (maintenance error, intelligent customers)

RCS/HSE key topic in human factors: Maintenance, inspection and testing

Maintenance is heavily reliant on human activity. The actions and decisions of maintenance personnel should not leave equipment or systems in an unsafe state. Even experienced, highly-trained, well-motivated technicians can fail to perform as required, potentially causing an incident. Human error in maintenance is largely predictable and therefore can be identified and managed.

Intelligent customer capability can be defined as "the capability of the organisation to have a clear understanding and knowledge of the product or service being supplied" (HSE, 2010).

Maintenance error

Desired safety outcomes	**Critical elements**
– Maintenance activities are delivered without compromising safety.	– Potential for human failure is understood and managed. – Maintenance work is controlled and delivered by competent personnel working to approved systems and procedures. – Work is appropriately scheduled. – Maintenance requirements and plans are effectively and reliably communicated. – Key work practices are monitored (e.g. by supervisors).

Health check questions

- Is the potential for human error during maintenance activities clearly acknowledged?
- Are plant and equipment designed for maintainability, to reduce the likelihood of maintenance error? (See also 5.2.7 Human factors in design).
- Has human error analysis been undertaken on safety-critical maintenance tasks?
- Are maintenance tasks well designed (work is interesting and challenging, diagnostic tools are provided, adequate time is available, distractions are minimised, PPE is realistic etc.)?
- Do up-to-date procedures exist for safety-critical maintenance tasks?
- Does the organisation have a process to determine and ensure competence for maintenance/inspection?
- Are supporting resources readily available (P&IDs, schematics, job-aids, tools and spares etc.)?
- Are in-house and contractor maintenance activities well supervised and controlled (effective PTW, robust isolation procedures, systematic hand-back, independent cross-checks etc)? (See also 5.2.2 Procedures and 5.2.4 Staffing).
- Do effective communication channels exist between shifts, and between operations, maintenance and contractor personnel? (See also 5.2.6 Safety critical communications).
- Is maintenance performance monitored and reviewed (backlogs, excessive repair times etc.)?

Potential lagging indicators	**Potential leading indicators**
– Number or percentage of incidents, accidents or root cause investigations in which failures in maintenance, inspection or testing identified as being a causal factor, including maintenance-induced latent failures. – Number or percentage of loss control reports/reported failures, including key component failures, attributable to lack of maintenance. – Number or percentage of reported maintenance errors/ number of tasks requiring re-work. – Number or percentage of times issues reported with equipment that has been maintained or repaired (i.e. maintenance incorrectly performed leading to latent defects/maintenance-induced failure).	– **Relative number or percentage of reactive (corrective) versus proactive (planned) maintenance.** – Maintenance backlog (number or percentage of equipment not maintained against prioritised targets). – Number or percentage of equipment inspections/tests undertaken against target schedule. – Completeness and accuracy of maintenance records (based on sampling review). – **Timescale for closure of work orders, against targets.** – Availability of critical spares. – Number or percentage of workarounds (temporary modifications) in place because of failed/degraded equipment. – Evaluation of effectiveness of maintenance against procedure/process (based on regular review of maintenance reports/job notes). – Number or percentage of plant alarms not available/not calibrated at plant start-up.

Intelligent customer

Desired safety outcomes	**Critical elements**
– Sub-contracted activities meet the organisation's quality and safety requirements.	– The organisation has sufficient technical knowledge and management processes to ensure compliant delivery by subcontractors (see also HSE, 2009b).

Health check questions

- Where activities are out-sourced, does the plant retain an intelligent customer capability (i.e. retain adequate technical competence to judge whether, and ensure that, work is done to the required quality and safety standards)?
- Has the organisation a process for identifying all core competencies it requires? Is there a process for identifying required intelligent customer capability?
- Can the organisation show how it selects and appoints individuals to deliver this capability?
- Can the organisation demonstrate that it has contingency plans in place for loss of staff/intelligent customer capability?
- Can the organisation demonstrate that it has succession plans and training/ recruitment plans where necessary?
- Can the plant show it understands the relevance of any given work carried out by contractors to the safety case?
- Can the plant show how the specification for contracted work was derived, how it assessed the technical quality of tenders and explain how the contractor selected was suitable for the task?
- Can the plant explain how it evaluated the product and/or work produced and decided it was of the appropriate quality?

Potential lagging indicators	**Potential leading indicators**
– Number or percentage of incidents, accidents or root cause investigations in which failures related to outsourcing identified as being a causal factor.	– Number or percentage of nominated 'intelligent customer' resources within the organisation. – Number or percentage of defined 'intelligent customer' competence profiles within the organisation. – Number or percentage of contracts requiring 'intelligent customer' management.

ANNEX A
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ANNEX B ABBREVIATIONS

AIChE	American Institute of Chemical Engineers
API	American Petroleum Institute
CCPS	Center for Chemical Process Safety of the American Institute of Chemical Engineers
COMAH	Control of Major Accident Hazards [Regulations]
CSB	Chemical Safety Board
DCS	distributed control system
FCCU	fluidised catalytic cracker unit
HAZID	hazard identification study
HAZOP	hazard and operability study
HCI	human/computer interface
HRO	high reliability organisation
HSE	Health and Safety Executive
INES	international nuclear and radiological event scale
IPIECA	International Petroleum Industry Environmental Conservation Association
KPI	key performance indicator
KRI	key results indicator
LOPC	loss of primary containment
LTI	lost time incident
MAH	major accident hazard
MoC	management of change
MP	medium pressure
OECD	Organisation for Economic Co-Operation and Development
OGP	International Association of Oil and Gas Producers
PA	public address (system)
PI	performance indicator
PSE	process safety event
PSF	performance shaping factor
PSIC	total count of process safety incidents (process safety incident count)
PSM	process safety management
PSPI	process safety performance indicator
PSSR	pre start-up safety review
RCS	risk control system
ROCE	return on capital employed
SCRAM	emergency reactor shutdown (note: this is not a formal abbreviation)
SIL	safety integrity level

SIS	safety instrumented system
SMS	safety management system
SPI	safety performance indicators
SSM	Stral Sakerhets Myndigheten (Swedish Radiation Authority)
SSoW	safe system of work

ANNEX C
HUMAN FACTORS PERFORMANCE INDICATOR (PI) TEMPLATE AND COMPLETED EXAMPLE

C.1 HUMAN FACTORS PERFORMANCE INDICATOR (PI) TEMPLATE

<table>
<tr><td>Asset:</td><td>Date:</td></tr>
<tr><td colspan="2">Team members
Include process safety, operations management and workforce representatives.</td></tr>
<tr><td colspan="2">Process safety hazard scenario
What is the scenario of concern?</td></tr>
<tr><td colspan="2">RCS
What RCSs are in place?</td></tr>
<tr><td>Desired safety outcome
What is the required safety outcome that each RCS is designed to deliver? What does success look like?
The team should define this outcome in its own words, drawing on Section 5 as required.</td><td>Critical elements
What are the critical elements that need to be in place to deliver the desired safety outcomes?</td></tr>
<tr><td colspan="2">Health check
Review the health check questions (Section 5).
– Are all the elements in place?
– Should new elements be implemented?</td></tr>
<tr><td colspan="2">Human factors cultural maturity
How mature is the organisation with regard to human factors (section 4.3.2)?
Are there barriers which affect implementation of PIs?
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 PIs?</td></tr>
<tr><td>Potential lagging indicators
Less mature organisations:
– Review the organisation's performance or status against the health check questions (section 5.2.1 onwards).
Mature organisations:
– Select and implement lagging indicators (section 5.2.1 onwards) that are already in use with other organisations (bold text). Set a tolerance for each indicator.
More mature organisations:
– Use this report to promote new thinking in performance measurement. Or consider the untested indicators contained in the tables (black text, section 5.2.1 onwards).</td><td>Potential leading indicators
Less mature organisations:
– Review the organisation's performance or status against the health check questions (section 5.2.1 onwards).
Mature organisations:
– Select and implement leading indicators (section 5.2.1 onwards) that are already in use with other organisations (bold text). Set a tolerance for each indicator.
More mature organisations:
– Use this report to promote new thinking in performance measurement. Or consider the untested indicators contained in the tables (black text, section 5.2.1 onwards).</td></tr>
</table>

Indicator requirements – 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 **PI ownership**: Who is the customer for the indicator (who will review it?), who is accountable and who is responsible for providing it?
Resources: Who needs to be involved, how much effort needed, what data are required?
Review: How often will the indicator's operation be reviewed?

C.2 HUMAN PERFORMANCE INDICATORS (PIS) TEMPLATE: COMPLETED EXAMPLE

Asset: *Isomerisation Unit*	**Date:** *23 March 2010*
Team members *Process Safety Engineer. Area Operations Manager. Process Operator. Training Department Representative.*	
Process safety hazard scenario – Safety critical task: safe isolation of plant and equipment for maintenance. – Hazard scenario: potential operator human failure in isolation for maintenance, leading to incorrect pipeline isolation and potential loss of containment of hydrocarbons on break-in. *Note: many sites will have documentation available to support this stage of the analysis. For example MAH safety reports and risk assessments may provide:* – *HAZOP tables identifying operational and maintenance task failures as causal factors of MAHs.* – *Fault trees showing task failures as contributors to MAH top events.* – *Safety integrity level (SIL) assessments of emergency shutdown and safety control systems. These are required by the relevant standards (IEC 61508 and 61511) to include the contribution of human error. SIL determination may be based on quantitative or semi-quantitative methods such as fault tree analysis or layers of protection analysis (LOPA). Underlying such methods will be the identification of relevant safety critical tasks.* – *Bow-tie diagrams showing human factors contributions to hazard initiation and escalation.* *The consequences should be quantified where possible.*	
RCSs Operator competence in carrying out preparation for maintenance. *Note: there are likely to be a number of RCSs in place to help minimise the potential for error in task operation, including technological safeguards and clearly defined procedures, job aids, etc. For the purposes of this worked example, consideration of RCSs has been limited to operator training and competence only.*	

Desired safety outcome	**Critical elements**
Process operators should have skills and knowledge required to execute maintenance isolations with no mistakes or violations.	– Competence management system. – Risk-based competence profile for operator role. – Validated operator basic training. – Three-yearly validated refresher training for operators.

Health check

See Training and competence, section 5.2.3.

- Is an effective competence management system in place? *YES*
- Have safety critical roles been defined? Have safety critical competence requirements been identified for, and mapped against, specific safety critical tasks and roles? *YES*
- Are appropriate processes in place for recruitment, selection, training and periodic assessment of staff? *CHECK*
- Are there triggers in place to ensure that competence requirements are re-evaluated and training provided if necessary following process changes etc? *CHECK*
- Are training programmes updated to reflect lessons learned from incidents etc. and is there a process for ensuring this? *YES*
- Do systems exist to establish and maintain levels of competency for all those involved in safety critical activities (including managers, trainers, assessors, contractors etc.)? *NO*
- Are NVQs aligned with site-specific major hazards? *NO*
- Is on-the-job training structured (with specific learning objectives) and supported by other modes of training (e.g. control room simulators)? *YES*
- Are trainees assessed by suitable means (tests with pre-set marks; on-the-job assessment etc.)? *YES*
- Is structured refresher training conducted for safety-critical and infrequent safety-related tasks? *YES*
- Is training validated (did it deliver what it was supposed to?) and evaluated (is this the right kind of training for our needs?); are suitable records maintained? *YES*
- Does risk assessment include consideration of competence? *NO*
- Do systems exist to establish and maintain trainer competency? *YES*
- Has the training department sufficient resources? *YES*

Human factors cultural maturity

The business has a nominated human factors champion based on site.
The workforce has good awareness of the human contribution to safety.
Competence management records are available.
The workforce indicates that competence is not a contentious issue with management.
Based on the above, the assessment team considers the organisation to be mature with regard to human factors appreciation.

Potential lagging indicators	**Potential leading indicators**
See Training and competence (section 5.2.3). *Incident/near-miss reporting system generates good quality and reliable information, and therefore the team selects the following indicator:* – *Number or percentage of near-misses, incidents or accidents connected with isolations for maintenance.*	See Training and competence (section 5.2.3). *The organisation has a well-developed competence management system, and therefore the team selects the following indicator:* – *Number or percentage of process operators assessed to be competent in their roles (based on competency assessment programme).*

Indicator requirements

– Are the required data available? *YES*

– How often does the indicator need to be calculated/reviewed?
The team determines that the leading and lagging indicators should be calculated and reviewed quarterly, to reflect the timing of periodic competence assessment.

– What tolerance should be set on the indicator?
The indicators are not already in use. The current values have been calculated; no incidents have been reported in the past 12 months (lagging indicator), and 85% of personnel are assessed as competent (leading indicator). A tolerance of zero will be set on the lagging indicator. The team does not expect that the leading indicator will show 100% competence, and will monitor the indicator value monthly for the coming quarter to see what variation there is. A tolerance will be set reflecting the learning from this, and a review of competence-related incident reports.

– What action will be taken when the indicator goes out of tolerance? (If it never goes out of tolerance it is probably not useful).
When the lagging indicator goes out of tolerance (i.e. when there is a near-miss, incident or accident) there will be a root cause investigation.
When the leading indicator goes out of tolerance, immediate re-training and re-assessment of the relevant personnel will be actioned. In the interim, their role will be covered by other competent personnel (NB: impact on workload of these personnel will need to be considered).

Implementation plan

PI ownership:

Who is the customer for the indicator (who will review it?), who is accountable and who is responsible for providing it?
The Area Operations Manager will be accountable for reporting all indicators for his/her area to the Site Manager, and to the HSE Manager, for communication to other departments including Human Resources and Training Department. The indicators will be reviewed quarterly with the Site Manager. Required actions will be agreed with the Site Manager.

Resources:

Who needs to be involved, how much effort needed, what data are required?
Data will be collected by the Area Operations Manager's nominee.

Review:

How often will the indicator's operation be reviewed?
The indicators' operation will be reviewed at the site annual PIs review meeting.

ANNEX D
TECHNICAL REVIEW

D.1 LITERATURE ASSESSMENT

There is a significant body of literature related to process safety performance measurement, and it is not practical to review it in detail here. Rather, the function of this Annex is to identify and position relevant industry material so that the reader can explore further if required. In preparing this section we have sought to bring out coverage of human factors issues, and approaches to identifying suitable indicators. D.1 provides a general overview, D.2 contains a review of key texts, and critical success factors for implementation are reviewed in D.3.

A high level review of safety performance measurement in the nuclear and related industries is contained in D.1.2.

D.1.1 Indicators for process safety in the process industries

D.1.1.1 Recognition of the need

Recognition of the need for process safety performance measurement can be traced to HSE's report (HSE, 2003) into three incidents that occurred at the Grangemouth Complex (UK) between 29 May 2000 and 10 June 2000 (a power distribution failure, MP steam main rupture, and an FCCU fire). One of the key lessons HSE identified was that companies should develop KPIs for major hazards and ensure process safety performance is monitored and reported against these parameters.

HSE subsequently published guidance on process safety indicators, HSG 254 (HSE, 2006a). This is a major source of guidance on process safety performance measurement, and because of this it is reviewed in some detail in D.2, along with other documents having similar stature within the industry sector. One of the most significant ideas contained in this document is that of dual assurance, in which leading and lagging indicators are set in a structured and systematic way for each critical RCS within the whole process safety management system.

The Organisation for Economic Co-operation and Development (OECD) published its guidance to safety PIs for chemical accidents (OECD, 2008) in 2008. This built on earlier guidance from OECD (2003b) and incorporated the process presented by HSE (2006a) for identifying leading and lagging indicators.

Following the Texas City incident in 2005, the Baker Panel investigation and Chemical Safety Board (CSB) separately recommended the use of leading and lagging process safety indicators. The CSB report (CSB, 2007) commented that reliance on the low personal injury rate at Texas City as a safety indicator failed to provide a true picture of process safety performance and the health of the safety culture. The American Institute of Chemical Engineers' Center for Chemical Process Safety published its own guidance to process safety measurement in 2008 (CCPS, 2008), and the American Petroleum Institute has recently issued guidance for the refining and petrochemical industries (API, 2010).

CCPS guidance focuses almost exclusively on technical issues, and does not provide any volume of material explicitly for human factors performance measurement. OECD and HSE do give consideration to organisational issues. However, neither offers detailed indicators for human factors performance to cover the entirety of the HSE human factors key topics.

The International Petroleum Industry Environmental Conservation Association (IPIECA), API and the International Association of Oil and Gas Producers (OGP) will shortly publish a revision to the IPIECA/OGP/API 2005 *Oil and gas industry guidance on voluntary sustainability reporting* (IPIECA, 2005) to include reporting of process safety and asset integrity in a framework aligned to API (2010) guidance. This makes reference to human factors topics such as training and competency, leadership/management, culture etc.

We note that there is no conflict between the published guidance documents (HSE, 2006a; CCPS, 2008; OECD, 2008; API, 2010; IPIECA, 2010), indeed, there is significant overlap between them, and recognition within them of their collective value. The HSE, OECD, CCPS and API documents are reviewed in detail in D.2.

D.1.1.2 Leading and lagging

There continues to be discussion regarding the precise meaning of leading or lagging, and for completeness we include some of this here.

Andrew Hopkins (2007) has provided a commentary on the HSE guidance (HSE, 2006a), and the Baker Panel's own observations regarding application of leading and lagging indicators for process safety. He identifies three types of indicator, noting that leading indicators relate directly to safety-management activities and can be measures of those activities themselves (type A) or of the results of those activities (type B). Lagging indicators are defined as measures of unexpected failures occurring in normal operations (type C).

API (2010) seeks to simplify the definition of leading indicators by saying that they are designed to give an indication of potential problems or deterioration in key safety systems early enough that corrective actions may be taken. Lagging indicators are retrospective and focused on outcomes; they describe events that have already occurred and may indicate potential recurring problems, and they can include fires, releases, and explosions. Leading indicators indicate the performance of critical work processes or protective layers that prevent incidents. API does not consider classification of indicators as lagging or leading to be important; the important point is to capture information that can be acted upon to prevent a severe event, to identify lessons learned, and to ensure this knowledge is communicated so as to avoid recurrence or occurrence elsewhere.

Mearns (2009) indicates that it may be helpful to move away from the concept of leading and lagging indicators and focus instead on KPIs for safety. Such KPIs should be based on an understanding of the links between leading (or activities) indicators such as safety climate and outcome measures such as lost-time injury rates.

Hopkins (2007) observes that the most important point to emerge from the HSE guidance (HSE, 2006a) is that process safety indicators must be chosen so as to measure the effectiveness of the controls upon which the RCS relies. He notes that whether they are described as leading or lagging is less important and that safety indicators are only worth developing if they are used to drive improvement. We note that whether an indicator is leading or lagging depends on what system failure it is intended to monitor, and that a leading indicator for one system can be a lagging indicator for another.

D.1.2 Indicators for process safety in the nuclear and related sectors

A significant body of work exists for the nuclear sector, and provides a source of potential human factors performance indicators as well as information on approaches to measurement. A selection of texts is introduced below.

All nuclear utilities participate in the WANO PI system (EPRI, 2001). This was introduced in the mid-1980s to provide a basis for comparison among utilities, and the PI approach has now been adopted worldwide. The indicators that are recorded focus on engineering aspects of plant performance; industry-wide goals are set every five years, individual plant data are collected and the system provides a basis for comparison among utility executives.

The results of a review of nuclear PIs used in the industry are reported in European Commission, 2009. This includes a list of 69 high level nuclear safety PIs, including strategic indicators for operator preparedness , emergency preparedness, attitude toward procedures, policies and rules, human performance and safety awareness that relate directly to human factors aspects.

Conclusions are also presented in European Commission, 2009 regarding the preferred structure of safety PI systems, the main findings being that:

– Safety performance measurement systems for operating plant in the nuclear industry should have a hierarchical structure. Lower level indicators can be used to measure different aspects of plant performance, while higher level indicators can inform the regulatory process, including supporting the definition of goals and standards.
– The use of a hierarchical structure with several layers provides for flexibility; aggregated measures can provide an integrated and high-level view of plant safety performance but the level of aggregation can be adjusted to suit the needs of a particular stakeholder. At the same time, detailed information is retained and can be interrogated if specific aspects of plant performance need to be understood.

In this review of use of safety performance indicators (SPI), by nuclear operators and regulators in the EU Member States (European Commission, 2009) the following attributes were identified as important to a SPI system:

– Coverage of a broad range of areas having an impact on safety.
– Independence of individual indicators.
– Use of a combination of leading and lagging indicators.

INSAG (1999) provides a useful set of safety management indicators (albeit these take the form of audit type questions). INSAG notes that most conventional quantitative indicators measure historical performance (i.e. they are lagging indicators) and that forward looking indicators (i.e. leading indicators) are particularly valuable, although they can be more difficult to measure objectively. INSAG also observes that measures of personnel behaviour and attitudes can be particularly useful in assessing safety performance; such information can be difficult to interpret but it provides direct feedback from operational staff and can allow emerging safety issues and early signs of deteriorating performance to be identified. INSAG cites the reporting of 'near misses', the number of safety inspections and the provision of safety training as potential input measures.

INSAG indicates that use of a fixed set of indicators should be avoided. Rather, it considers that indicators should be periodically reviewed, and that their relative importance may change with time. INSAG proposes the following specific indicators to complement those monitored by WANO:

– Repeat events that have taken place on the plant; these provide a measure of the failure to implement effective corrective actions.
– Events that are similar to those identified at other nuclear plants; in this case, the organisation may not have learned sufficiently from the experience of others.
– Events arising from particular types of deficiency (e.g. failure to comply with technical specifications or near misses related to human factors).

Harms-Ringdahl (2009) presents a summary of indicators used in the Swedish nuclear industry, including the following indicators for human factors aspects:

– Unattended issues from safety committee.
– Time for correction of safety related failures.
– Recurrence of failures and errors.
– Employees' attitude to safety issues.
– Relationship between technical and human/organisational failures.

The Nuclear Energy Agency of OECD (OECD NEA, 2006) sets out a more detailed set of indicators related to safety management/safety-related processes, including:

– human performance;
– compliance/attitude;
– operational preparedness;
– emergency preparedness;
– management of plant modifications;
– maintenance;
– self-assessment;
– operating experience feedback, and
– backlog of safety issues.

The Swedish Radiation Safety Authority (SSM, 2010) recommends that leading indicators should be established to monitor the effects of proactive safety work. Indicators should relate to organisational practices and processes that precede changes in the safety performance of the organisation.

SSM categorises indicators into three types; feedback, monitor and drive indicators. The feedback and drive indicators correspond closely with outcome and activity indicators (cf OECD, 2008), respectively. The monitor indicators indicate the current level of safety in the organisation, that is, they indicate the capacity of the organisation to perform safely by monitoring the functioning of the system including the effectiveness of the control measures.

Table D.1 which draws on SSM, 2010 provides further information.

Table D.1 Indicator types

	Lagging - feedback	**Leading - monitor**	**Leading - drive**
Technology	– Unavailability of safety systems. – Unplanned emergency shutdowns. – INES[22] rated incidents.	– The current condition of safety systems.	
Organisation	– Near misses. – Incident reports. – Corrective actions.	– Current safety management practices.	– Quality of change management, risk management, leadership, hazard identification etc.
Personnel	– Occupational accidents and injuries.	– Personnel responsibility and hazard understanding.	

Energy Institute (2010) has recently published guidance on managing human and organisational factors in decommissioning of process plants. The use of human performance and human factors data to indicate the possibility of future failures is included within the scope of the guidance. Guidance provided in the document includes:

– Consider legal requirement and duties - put in place programmes for meeting (or exceeding) these requirements - the leading indicators would include: number of

22 INES = International nuclear and radiological event scale.

inspections/audits/reviews conducted of compliance with those legal requirements against those planned; amount of training provided to employees to help them meet legal requirements etc.
- Use safety management/culture audits to provide information – many of the issues explored as part of this type of auditing are relevant: management commitment, number of risk assessments completed, number of safety audit recommendations closed out on schedule.
- Develop local indicators – involve the workforce in developing indicators; note that indicators relevant to one site/department may differ from those relevant to another as a result of local conditions. Examples include: percentage of planned equipment tests meeting performance criteria; number of critical procedures awaiting updating; number of safety improvements made per site inspection.

Energy Institute (2010) indicates that irrespective of the cultural maturity level of the organisation, the principles for identifying leading indicators include the following, that:
- There is a direct relationship between the indicator and performance.
- The indicators are clear, easy to understand and unambiguous.
- They can be 'measured' – subjective measures are possible.
- Criteria for measurement and data can be generated.
- Good performance against an indicator is not easy to 'fake'.
- They are sufficient in number and type to give a spread of measurements of performance.
- Actions clearly follow from the findings generated.
- Indicators are not permanent but may need to change as the organisation changes.

Indicators should be continually reviewed and updated, for example, to focus on safety issues related to construction/demolition site working rather than operational safety issues.

The guidance sounds the following cautionary notes:
- It is a complex field: choosing the wrong leading indicators can mislead managers into either a false sense of security or to attend to matters that do not have any bearing on safety.
- It is possible to become complacent using leading indicators and to lose sight of the fact that other complementary initiatives should continue – inspections, audits, QA, self assessment surveys etc.
- Good scores do not necessarily improve performance.

D.2 KEY TEXTS: PROCESS SAFETY INDICATORS

Four of the most significant guidance documents have been identified in D.1.1. Because of their role in shaping operating companies' responses to requirements, they are reviewed briefly below.

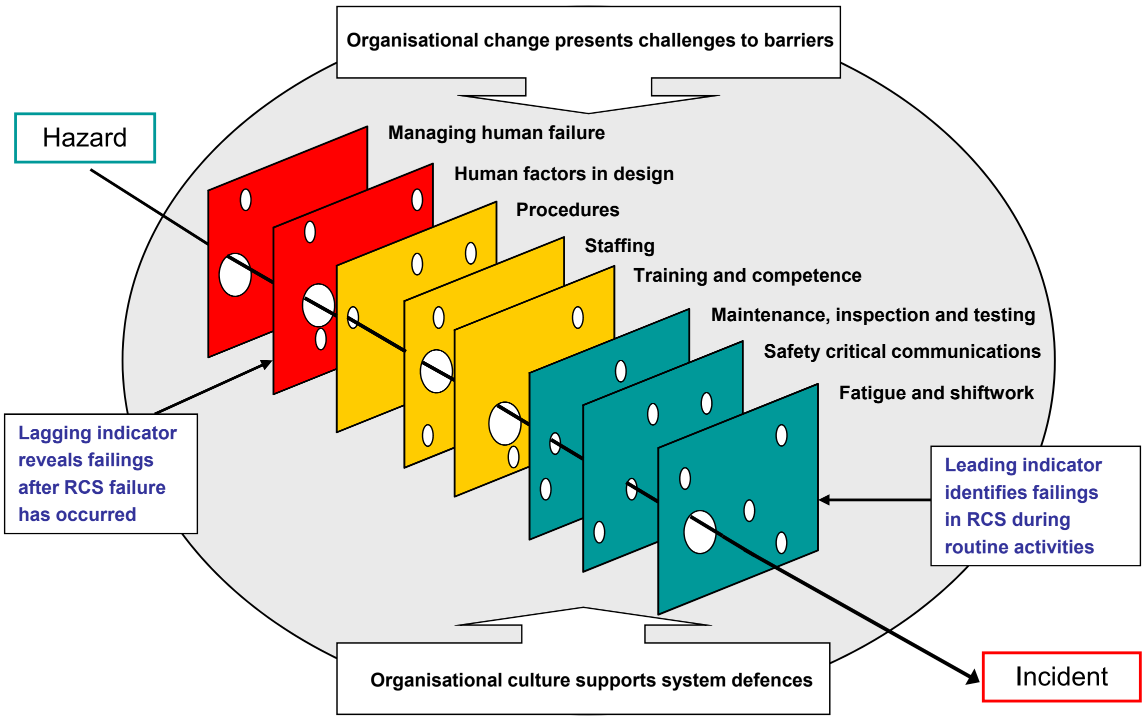
D.2.1 Developing process safety indicators (HSE, 2006a)

Guidance published by HSE (HSG 254, HSE, 2006a) has emerged as one of the most influential documents in the area of process safety measurement. It advances two key principles:
- A process-based approach to identifying relevant indicators for process safety (as distinct from offering a menu of possible indicators), linked to site-specific MAH scenarios.

– The concept of dual assurance, that is, the use of paired leading and lagging indicators for each critical RCS within the process safety management system. In tandem, these indicators confirm that the RCS is operating as intended, or provide warning that problems are present.

The use of leading and lagging indicators can be visualised using the 'Swiss cheese' accident trajectory model of Reason (1997), shown in Figure D.1, in which major accidents are considered to result from concurrent failings within several RCSs.

Figure D.1 Accident trajectory model (Swiss cheese)



HSE (2006a) defines leading and lagging indicators for each RCS as follows:

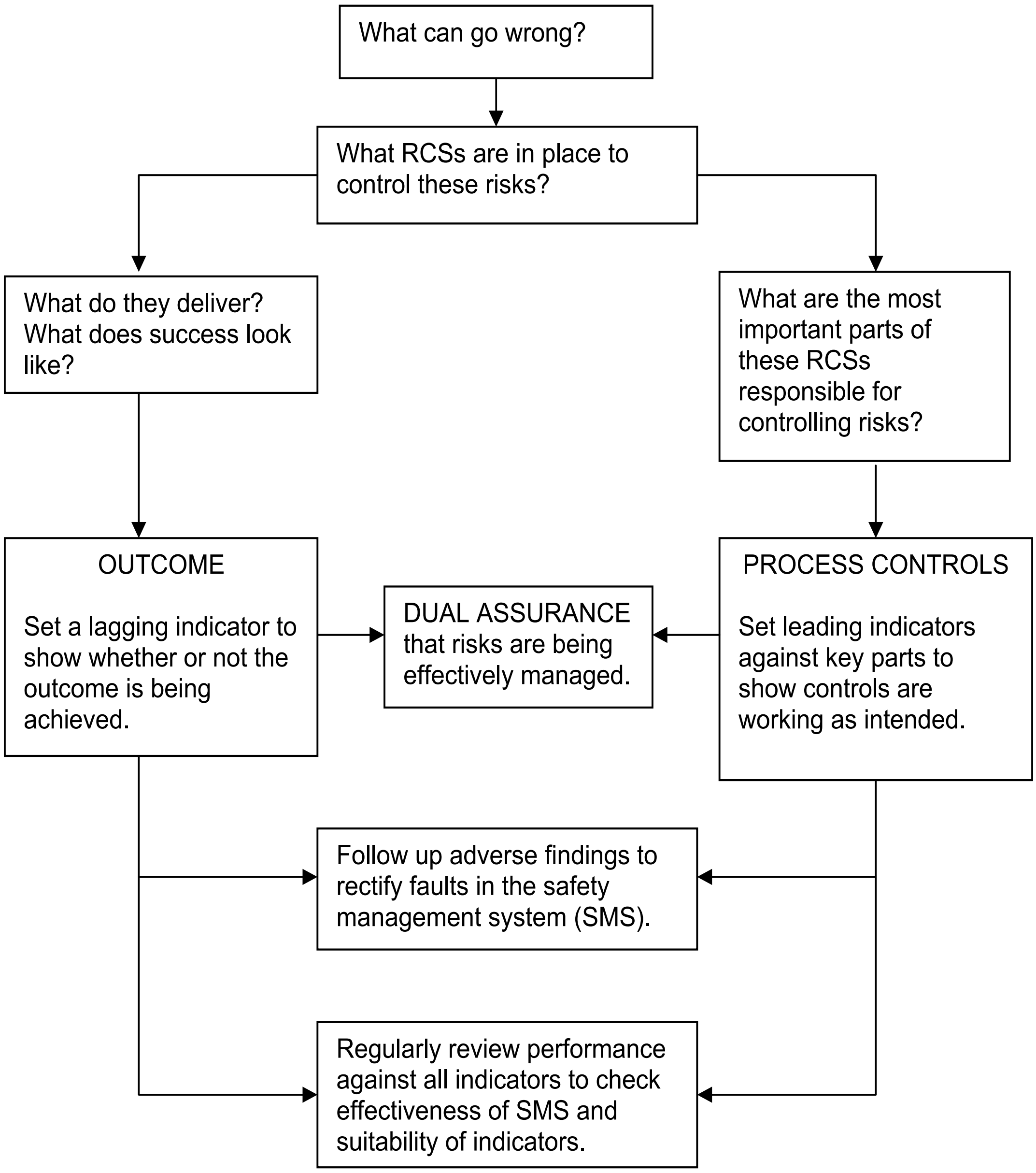
– The leading indicator identifies failings or holes in vital aspects of the RCS discovered during routine checks on the operation of the critical activity within the RCS.

– The lagging indicator reveals 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.

In a review of indicators in the major hazards sector (HSL, 2006), HSL notes that leading indicators can be considered as measures of process or inputs essential to deliver the desired safety outcomes, which is somewhat broader than the definition in HSG 254 and has been adopted in this report. HSL defined lagging indicators as showing when a desired safety outcome has failed or has not been achieved.

HSE's guidance is designed for organisations with appropriate safety management systems already in place and utilises a six-stage process for the implementation of indicators (shown schematically in Figure D.2).

Figure D.2 Schematic for implementation of indicators



The steps are:

- Step 1: Establish the organisation to implement indicators.
- Step 2: Decide on the scope of the indicators.
- Step 3: Identify the outcome for each relevant RCS.
- Step 4: Identify critical elements of each RCS.
- Step 5: Establish data collection and reporting system.
- Step 6: Review.

RCSs relevant to the HSE human factors key topics that are identified in HSG 254 include staff competence, operational procedures, communication and PTW; leading and lagging indicators are identified for these.

D.2.2 *Guidance on developing safety performance indicators related to chemical accident prevention, preparedness and response* (OECD, 2008)

In its *Guiding principles* (OECD, 2003a) OECD articulates a golden rule that owners/managers of hazardous installations should:

- Know what risks exist at their hazardous installations.
- Promote a 'safety culture', which is known and accepted throughout the enterprise.
- Implement a safety management system, which is regularly reviewed and updated.
- Prepare for any accident that might occur.

OECD's 2008 guidance on developing performance indicators (OECD, 2008) serves as a companion document to the *Guiding principles* and draws on the process presented in HSE's 2006 guidance (HSE, 2006a) to present a similar approach for identifying lagging indicators (which it terms outcome indicators) and leading indicators (which it terms activities indicators).

OECD states that outcome indicators are designed to help assess whether safety-related actions (e.g. policies and procedures) are achieving their desired results and whether such actions are reducing the likelihood of an accident occurring. Outcome indicators are reactive, and often measure change in safety performance over time, or failure of performance. Outcome indicators tell you whether you have achieved a desired result but do not indicate why the result was achieved or why it was not. Outcome indicators correspond broadly to lagging indicators.

Activities indicators are designed to help identify whether organisations are doing what is considered necessary to improve safety performance (e.g. the activities set out in the *Guiding principles*). Activities indicators are proactive measures. They often measure safety performance against a tolerance level that shows deviations from safety expectations at a specific point in time and can therefore highlight the need for action. Activities indicators are similar to leading indicators.

Activities indicators provide organisations with a way of checking whether they are implementing their priority actions in the way they were intended. Activities indicators can help explain why a result (e.g. measured by an outcome indicator) has been achieved or not.

OECD's guidance does not specify which indicators should be applied by an individual organisation. Rather, it focuses on the process of establishing an SPI programme and then provides a menu of outcome indicators and activities indicators to help organisations choose and/or create indicators that are appropriate to their organisation. The document notes that it is for the user to decide whether to focus on a single process or hazard, or to focus on site-level policies, procedures and practices covering multiple hazardous processes.

As with earlier OECD guidance (see HSL, 2006), the lagging indicators tend to lend themselves to measurement on a numeric scale whereas the leading indicators take the binary (yes/no) format typical of audit systems.

A useful selection of indicators is presented in Section 3 of OECD, 2008, choosing targets and indicators, for example under human resources:

- Extent employees have been trained in accordance with the planned training programme.
- Extent employees (including contractors and others) pass periodic assessments of competence.
- Extent to which the workforce performed consistent with safety objectives (i.e. appropriate procedures being followed) during normal operations.
- Extent to which the workforce performed during emergency situations (based on tests or actual situations).
- Extent of incidents attributed to problems related to human resources as a root or intermediate cause (e.g. staffing levels, training, competency).
- Extent to which employees believe that they have sufficient resources (including staff, materials, resources) for safety critical tasks.
- Number of safety proposals per employee (high number shows commitment).
- Extent employees are satisfied with the safety situation in the enterprise.

While OECD has categorised all these as outcome indicators (i.e. outcomes of processes, practices etc.), we note that many could usefully serve as human factors leading indicators.

Some of the associated activities indicators include:

- Do employees receive adequate safety-related information, and understand this information?
- Do employees use/apply safety information (e.g. based on an independent review of day-to-day activities)?
- Is there enough specialist competence related to safety?
- Is there an independent safety function and does it have the mandate, position and qualifications to exercise influence?
- Is there competence in all fields of safety (e.g. process safety, industrial hygiene)?
- Is there an adequate recruitment procedure?
- Are adequate job requirement profiles established?

This reinforces HSL's observation (HSL, 2006) that many activities indicators take the form of audit questions.

D.2.3 *Process safety leading and lagging metrics: you don't improve what you don't measure* (CCPS, 2008)

Following publication of the BP *US Refineries Independent Safety Review Panel* ('Baker Panel') and US Chemical Safety Board reports into the Texas City incident, CCPS prepared a detailed guidance document on leading and lagging indicators. In doing this, it aimed to help industry drive performance improvement, facilitate benchmarking in process safety, and help provide leading indicators of process safety issues which could lead to a major accident.

CCPS recommended that all companies adopt and implement leading process safety indicators, including a measurement of process safety culture. CCPS did not propose a process for selecting leading process safety indicators, but advanced proposals based on the experience of the contributors to the guidance. The indicators are generic, and the reader is advised by CCPS to select those that are relevant to his operations.

The safety systems that leading indicators have been developed for are:

- maintenance of mechanical integrity;
- action items follow-up;
- MoC, and
- process safety training and competency (and training competency assessment).

The proposed leading indicators are:

- Maintenance of mechanical integrity:
  - Inspections done/inspections due (%).
  - Time safety critical equipment in failed state/total operating time (%).
- Action items follow-up:
  - Number of past-due action items/total action items (%).
- MoC:
  - Percentage of MoCs satisfying MoC procedure.
  - Percentage of audited changes that used the site's MoC procedure prior to making the change.
  - Percentage of start-ups following plant changes where no safety problems related to the changes were encountered during re-commissioning or start-up.
- Operator competency (PSM training):
  - Number of individuals who completed a planned PSM training session on-time/total number of individual PSM training sessions planned (%).
  - Number of individuals who successfully complete a planned PSM training session on the first try/total number of individual PSM training sessions with completion assessment planned for that time period (%).
  - Number of safety critical tasks observed where all steps of the relevant safe working procedure were not followed/total number of safety critical tasks observed (%).
- Challenges to the safety system:
  - Activations of safety systems and relief valves.
  - Deviations outside of operating limits.

CCPS also recommends that the effectiveness of process safety culture be assessed, by - for example - use of a safety culture survey as presented in the Baker Panel Report (2007).

There is no specific discussion of human factors in the document although some examples of human error are considered under management system failures.

D.2.4 *Process safety performance indicators for the refining and petrochemical industries* (API, 2010)

This guidance sets out to integrate elements of other guidance, including HSE (2006a) and CCPS (2008). The document classifies process safety indicators into four 'tiers' of leading and lagging indicators. Tiers 1 and 2 are intended for public reporting and Tiers 3 and 4 are intended for internal use at individual sites. Guidance on methods for development and use of PIs is provided in the document.

A number of guiding principles are adopted:

- Indicators should drive process safety performance improvement and learning.
- Indicators should be relatively easy to implement and easily understood by all stakeholders (e.g. workers and the public).
- Indicators should be statistically valid.
- Indicators should be appropriate for benchmarking.

In the context of human factors PIs, it is the API Tier 3 and 4 indicators that are of particular interest. Tier 3 events typically represent a challenge to the barrier system that progressed along the path to harm, but stopped short of a loss of primary containment (LOPC), that is a Tier 1 or 2 event. API suggests that indicators at this level provide the opportunity to identify and correct weaknesses within the barrier system. Tier 3 indicators are intended for internal company use and can be used for local public reporting. API advances the following list of possible indicators:

- safe operating limit excursions;
- primary containment inspection or testing results outside acceptable limits;
- demands on safety systems, and
- other LOPCs.

Tier 4 indicators typically represent performance of individual components of the barrier (Swiss cheese) system and are comprised of operating discipline and management system performance. API suggests that indicators at this level provide an opportunity to identify and correct isolated system weaknesses. Tier 4 indicators are indicative of process safety system weaknesses that may contribute to future Tier 1 or Tier 2 PSEs and so may indicate opportunities for learning and systems improvement. Tier 4 indicators are intended for internal company use and for local reporting.

API indicates that the choice of Tier 4 PIs should be limited to a small number that are representative of the barrier systems in place at a plant. The indicators should be those with the highest predictive ability and those that provide actionable information. API advances the following list of operating discipline and management system PIs:

- Process hazard evaluations completion: schedule of process area retrospective and revalidation hazard evaluations completed on time by fully qualified teams.
- Process safety action item closure: percentage and/or number of past-due process safety actions. This may include items from incident investigations, hazard evaluations or compliance audits.
- Training completed on schedule: percentage of process safety required training sessions completed with skills verification.
- Procedures current and accurate: percentage of process safety required operations and maintenance procedures reviewed or revised as scheduled.
- Work permit compliance: percentage of sampled work permits that met all requirements. This may include permit to enter, hot work, general work, lockout/tagout, etc.
- Safety critical equipment inspection: percentage of inspections of safety critical equipment completed on time. This may include pressure vessels, storage tanks, piping systems, pressure relief devices, pumps, instruments, control systems, interlocks and emergency shutdown systems, mitigation systems, and emergency response equipment.
- Safety critical equipment deficiency management: response to safety critical inspection findings. This may include proper approvals for continued safe operations, sufficient interim safeguards, and timeliness of repairs, replacement, or rerate.
- MoC and pre start-up safety review (PSSR) compliance: percentage of sampled MoCs and PSSRs that met all requirements and quality standards.
- Completion of emergency response drills: percentage of emergency response drills completed as scheduled.
- Fatigue risk management: key measures of fatigue risk management systems may include: percentage of overtime, number of open shifts, number of extended shifts, number of consecutive shifts worked, number of exceptions, etc.

API proposes that indicators are identified by:

– Using process hazard evaluation and risk assessment findings to identify potential high impact events and the process safety barriers intended to prevent such incidents. This will include considering which are the most critical barriers and how vulnerable are the barriers to rapid deterioration?
– Using incident investigation findings to identify process safety barrier failures that contributed to incidents.
– Using shared external learnings to determine what others have successfully used.

API recommends that the involvement of employees and employee representatives, process safety professionals, and engineers in the process can help build a more complete picture of process safety performance that will help in indicator selection.

D.3 CRITICAL SUCCESS FACTORS FOR IMPLEMENTATION

Management scientists identify the following requirements for successful implementation of performance indicators:

– To have defined the business process we want to measure.
– To have defined the purpose of that process (inputs and outputs).
– To have quantitative or qualitative measures of the results of that process, and some set goals.
– To have a means of investigating variances, and a means of influencing the outcome of the process.

To which EI (2010) adds:

– There is a direct relationship between the indicator and performance.
– The indicators are clear, easy to understand and unambiguous.
– Good performance against an indicator is not easy to fake.
– They are sufficient in number and type to give a spread of measurements of performance.
– Actions clearly follow from the findings generated.

API 754 (API, 2010) identifies that credible and useful indicators will be:

– Appropriate for the intended audience; the data and indicators reported will vary depending upon the needs of a given audience. Information for senior management and public reporting usually contains aggregated or normalised data and trends, and is provided on a periodic basis (e.g. quarterly or annually). Information for employees and employee representatives is usually more detailed and is reported more frequently.
– Auditable: indicators should be auditable to ensure they meet the above expectations.

EI also notes that indicators are not permanent but may need to change as the organisation changes. INSAG emphasises this "the use of a fixed set of indicators that do not reflect the evolution of the organization and its requirements should be avoided".

In addition to these technical criteria, additional cultural criteria should be considered, for example:

- Are the source data sufficiently reliable (and available) for use in an indicator system?
- Can the organisation accept that its performance falls below stated requirements, and what are the consequences for the person providing that information?
- Can the information be acted upon?

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. Implementation of a suitable process for collecting, monitoring, and acting upon information derived from the indicators.

All of which should incorporate consideration of cultural maturity within the organisation.

ANNEX E
THE HUMAN FACTORS KEY TOPICS

E.1 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 (Step Change, 2010).

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 (Step Change, 2010).

E.2 PROCEDURES

Procedures include method statements, work instructions, PTW etc. Incomplete, incorrect, unclear or outdated procedures can lead to short cuts and errors. Procedures should be managed and use a format, style and level of detail appropriate to the user, task and consequences of failure (Step Change, 2010).

E.3 TRAINING AND COMPETENCE

Training gives people new knowledge and skills, but people need to apply and practise these to become competent. Training and competence can reduce errors caused by lack of knowledge and teach people behaviours that will keep them safe. This is not a universal safeguard though. Even the most experienced and competent individuals can make mistakes (Step Change, 2010).

E.4 STAFFING

Changes in staffing levels and increase/decrease of workload often occur as part of organisational change. It is important to consider the impact of this change on the control of hazards (Step Change, 2010).

Effective supervision has a significant positive impact on a range of human factors such as compliance with procedures, training and competence, safety critical communication, staffing levels and workload, fatigue and risk assessment (Step Change, 2010).

Contractors (including suppliers and third parties) face the same human factors issues as their clients. Some of these issues are critical at the client-contractor interface, e.g. communication, supervision, organisational culture, competence (Step Change, 2010).

E.5 ORGANISATIONAL CHANGE

Organisational change covers a range of issues e.g. staffing levels, use of contractors or outsourcing, combining departments, changes to roles and responsibilities etc. Similar to plan or process change, organisational change can have direct and indirect effects on the control of hazards. Organisational change needs to be planned and assessed (Step Change, 2010).

E.6 SAFETY CRITICAL COMMUNICATIONS

Frequent and clear two-way communication (spoken and written) is essential for safety in any task. The method of communication, language, timing and content are all important factors in effective communication. Checking understanding is also critical (Step Change, 2010).

Permits are effectively a means of communication between site management, plant supervisors and operators, and those who carry out the work. The goal of shift handover is the accurate reliable communication of task-relevant information across shift changes or between teams thereby ensuring continuity of safe and effective working (HSE, **http://www.hse.gov.uk/humanfactors/topics/hci.htm**).

E.7 HUMAN FACTORS IN DESIGN (HUMAN FACTORS ENGINEERING)

The design of control rooms, alarm systems, plant and equipment can have a huge impact on human performance. The work environment (lighting, thermal comfort, working space, noise and vibration) also impacts human performance in unexpected ways. Designing tasks, equipment, processes and the work environment to suit the user can reduce human error, accidents and ill-health (Step Change, 2010).

Human-system interactions have frequently been identified as major contributors to poor operator performance (HSE, **http://www.hse.gov.uk/humanfactors/topics/hci.htm**).

E.8 FATIGUE AND SHIFTWORK

Fatigue refers to the issues that arise from excessive working time or poorly designed shift patterns. It can lead to errors, slower reaction times, and reduced ability to process information, memory lapses, absent-mindedness, and losing attention (Step Change, 2010).

E.9 ORGANISATIONAL CULTURE

Organisational culture has been defined (Uttal, 1983) as consisting of shared values (what is important) and beliefs (how things work) that interact with an organisation's structure and control system to produce behavioural norms (the way we do things around here).

Organisational culture influences human behaviour and performance at work, with positive or negative impacts on safety. Success normally comes from good leadership, good worker involvement and good communications (**www.hse.gov.uk/humanfactors/topics/culture.htm**, HSE, 2010). HSE also identifies the importance of the learning organisation, and cautions against reliance on behavioural safety approaches which tend to ignore low probability, high consequence risks (and that can fail to address management behaviour).

HSE identifies behavioural safety and the learning organisation as two critical aspects of safety culture, and Step Change has added leadership to these. The Step Change definitions are provided below:

Setting of expectations, leading by example and decision making that takes safety into consideration are essential in creating a strong safety culture. This means taking personal responsibility for safety (Step Change, 2010).

A learning organisation values and encourages learning from its own and other organisations' experiences. Learning is linked to corporate memory, which must withstand organisational changes. Learning organisations are characterised by constant vigilance and seek out bad news as well as good. Understanding human factors can turn organisational learning into preventative solutions (Step Change, 2010).

Behavioural safety is an approach which tries to promote safe behaviours and eliminate unsafe behaviours. Behavioural safety programmes typically involve observation of workplace practices followed-up by individual feedback and reinforcement of good practices (Step Change, 2010).

E.10 MAINTENANCE, INSPECTION AND TESTING

Maintenance is heavily reliant on human activity. The actions and decisions of maintenance personnel should not leave equipment or systems in an unsafe state. Even experienced, highly-trained, well-motivated technicians can make simple errors that can cause an incident. Human error in maintenance is largely predictable and therefore can be identified and managed (Step Change, 2010).

Intelligent customer capability can be defined as "the capability of the organisation to have a clear understanding and knowledge of the product or service being supplied" (HSE, **http://www.hse.gov.uk/humanfactors/topics/hci.htm**).

ANNEX F
CULTURAL MATURITY

There are many models of cultural maturity available and further information is provided in, for example, IOSH Direction 04.2, *Promoting a positive culture* (IOSH[23], 2004) and HSE Offshore Technology Report 2000/049 (HSE, 2001b).

The organisational maturity model set out in Tables F.1 and F.2 is derived from (Miles, 2010). The model includes typical responses to the issues of reporting bad news, time pressure, workforce involvement and sophistication, understanding, accuracy and focus for front line staff and management respectively.

Table F.1 For front line staff

		Reporting bad news	Time pressure	Workforce involvement
More mature ↓	5	I know that management will be thankful for my honesty and welcome what I have to say.	I have all the resources I need to report accurately and I am involved in determining how the data are collected.	We were fully consulted on the PIs that affect us. We know where we fit into the performance picture and how we can improve things.
	4	I can report my concerns to management and they will listen what I have to say.	Reporting is part of my job plan and so I have the resources I need.	We were consulted on the PIs and we get periodic performance figures.
	3	I can report my concerns to management.	I have time to report the PIs I am responsible for.	The PIs were explained to us and we get periodic reports.
	2	There is no process for me to report my concerns to management.	I don't have time to report all the measures I'm asked for.	There are PIs but we don't know what they are and we don't see them.
Less mature	1	It is not advisable to report problems to management.	We don't bother.	Management do that, it's not our business.

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Table F.2 For management

		Sophistication	Understanding	Accuracy and focus
More mature	**5**	There's always the danger that the PIs drive unintended behaviours, we review continuously and do front line checks to make sure the PIs are working. We balance the PIs with other information.	We are confident we understand what the PIs are measuring. We only measure PIs that we can act upon. We have a suite of interventions ready to implement when we see PI trends emerging. We continue to develop our analytical approach.	We reviewed our business processes and linked the PIs to them. We take a view across a range of PIs and look at the profile and trends as well as the absolute numbers. We use leading and lagging PIs and review the utility to make sure we are measuring what we intend to.
↓	**4**	PIs can cause problems and so we are careful in their use.	We are confident we understand what the PIs are measuring and how to improve performance.	We reviewed our business processes and linked the PIs to them. We take a view across a range of PIs and look at the profile and trends as well as the absolute numbers.
↓	**3**	We use industry recognised PIs.	We discuss the PIs at management meetings and determine what actions to take.	We use a suite of standard industry practice PIs.
↓	**2**	We have PIs.	We discuss the PIs at management meetings.	We record lost time incidents (LTIs) as PIs.
Less mature	**1**	We do not use PIs.	We do not discuss the PIs at management meetings.	We have no plans to use PIs.