USING PROCESS SAFETY PERFORMANCE INDICATORS (PSPI) TO FACILITATE PROCESS SAFETY LEADERSHIP

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PSPIs seek to detect at an early stage that the performance of critical risk controls is deteriorating. This then provides time to take remedial action before a catastrophic event occurs. This paper reviews the experience gained at the BASF UK 'Top Tier' COMAH sites in using PSPIs at senior management level to support process safety leadership. The main aims of PSPI programs are described highlighting the need to view PSPIs as a management system that is dependent on people to make sure that it works effectively. Senior management reporting needs are described supported by site experience. The different approaches used in some large organisations are then assessed based on experience shared at the JRC workshop in 2010[7]. The main problems and weaknesses encountered with PSPI programs are then described. The paper concludes by considering the different ways in which PSPIs can be used positively in organisations to improve process safety performance.

KEYWORDS: Process safety performance indicators, COMAH

INTRODUCTION

Many different management system practices, human factors techniques and technical safety methodologies have been developed and successfully implemented in a wide range of industries in the last few decades. Some are more suitable to particular applications than others and there is no universally acknowledged 'silver bullet' which can guarantee that hazards will always be identified, people will always be competent, resources will always be in place and systems will always be followed correctly.

Most large organisations now use a management system based on a 'plan – do – check – act' model as illustrated in Figure 1. Formal EHS (Environment, Health and Safety) management systems are indeed a legal requirement for most high hazard industries. The 'check' function within the management system model can be implemented in a number of different ways, including structures based around KPIs (Key Performance Indicators). These are widely used for general management performance monitoring when key parameters can be quantified. The PSPI approach seeks to extend the KPI systems into the world of process safety. This paper explores how PSPIs can be used at a senior rather than line management level.

AIMS OF PSPI PROGRAMS

Major accidents in the process industries are relatively rare and process safety monitoring arrangements cannot be based purely on measuring such rare events, which, by their nature, are often catastrophic. A more sophisticated measure is therefore needed to detect at an early stage that the performance of critical risk controls is deteriorating, so that there is time to take remedial action before a catastrophic event occurs. The PSPI program seeks to achieve this requirement and tends to have aims such as:

- Effectively and clearly identifying trends at different levels in the organisation.
- Focusing on leading (measuring the health of critical risk controls before incidents have occurred) as well as lagging indicators (measuring system failures, such as incidents and accidents).
- Providing a platform for experience sharing involving the whole workforce in performance monitoring and continuous improvement.
- Challenging current performance and providing objective evidence of the real state of process safety within the organisation.

Some programs are also linked to internal benchmarking activities to facilitate reporting, performance ranking and continuous improvement either at a site level, a corporate level or an industry sector level.

PSPI AS A SYSTEM

One of the key conclusions from the 2010 JRC workshop on safety leadership, safety culture and safety performance indicators[7] was that successful PSPI programs require a systems based approach. They should not be constructed simply as a data collection system. PSPIs must be integrated into the organisation's management systems.

PLAN – DO – CHECK – ACT

Planning has to be effective both in terms of how the organisation conducts its daily business and in how it designs the PSPI system. Organisational discipline is required to ensure that the plans are implemented correctly. This requires quality people resources to make the correct process safety decisions, to know when to use systematic approaches and when to use judgement and to allocate the required resources for each key activity. Management leadership then provides clear process safety objectives and expectations, ensuring that there is a wide and deep application of good process safety within the organisation.

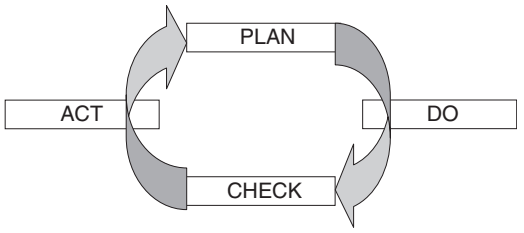

Figure 1. Plan – Do – Check – act model

They must also demonstrate their commitment to process safety through involvement and following up issues. Checking involves more than simple data collection and measurement using the PSPI program. It requires the active involvement of individuals at every level of the company, challenging and interpreting the data and looking for areas where improvements are needed. All of this effort needs to then deliver change by implementing the required corrective actions.

INVOLVING PEOPLE

Making the PSPI system effective requires the commitment and involvement of people. They must be involved at all stages of the system design if the system is to be robust and sustainable. Process safety specialists need to work closely with senior managers to define the PSPI system requirements, reporting arrangements and review mechanisms.

LINKS WITH OTHER RISK CONTROL SYSTEMS

PSPIs supplement rather than replace existing safety management system elements. Examples include:

- **EHS audits**: checking that audits are being carrying out and that audit actions have been closed out, identifying areas where additional audits are required and providing evidence of process safety performance for external audits.
- **Incidents and incident reporting**: analysing trends, detecting weak controls based on real performance data, identifying problem areas and measuring how successful the organisation is at completing incident investigations and their required corrective actions.
- **Management of change (MOC)**: checking that the MOC system is being implemented correctly and that actions are being closed out. The MOC system should also identify the need to review and change the measured PSPIs where required, for example if a new critical risk was created as a result of a plant upgrade project or changes were made to existing risk control systems.
- **Risk assessments**: identifying which critical parameters need to be measured based on risk assessment studies, good practice guidance and practices and specialist techniques such as 'Bowtie Analysis' which provide a very clear and visual representation of the importance of each risk control in preventing and mitigating major accident scenarios.
- **Communication**: involving the overall workforce, harnessing ideas from front line staff, reporting performance to front line line staff, safety committees, line managers and senior managers.
- **Safety Reports**: providing a demonstration that the EHS management system is effective and that mechanisms for achieving continuous improvement in process safety are in place. The Safety Report should also be a useful summary document, allowing key risks to be identified so that the critical risk controls that need to be measured in the PSPI program are selected.

SENIOR MANAGEMENT NEEDS

Senior managers have specific PSPI needs which reflect the wide nature of their responsibilities covering a broad span of different disciplines and issues. Process safety is a key issue for them but it is also only one of many issues that they manage. Experience gained from the BASF UK sites suggests that the key requirement for the PSPI system is to identify performance degradation before catastrophic failures occur so that a rapid senior management response can be put in place for any identified degradation in key risk control systems.

This has to be achieved in a way that shows the big picture of site/organisational issues and not just the detail. About 20 KPIs were already in place to measure issues across the broad span of business activities and it was felt that about three PSPIs should be reporting at site leadership team level (SLT), supported by detail which could be interpreted as required. This would provide a sensible level of reporting without overloading the SLT. By integrating the PSPIs into the overall site KPIs, process safety is integrated into the wider business issues rather than being treated in isolation. A PSPI dashboard consisting of so few PSPIs will, however, not present management with a reliable enough 'radar' to detect when complex process safety systems start to go wrong.

The EHS Manager is a member of the SLT and one of his roles is to present the PSPI data for the site. This provides the SLT with a focused summary of PSPI issues, backed up with hierarchical detailed reports which can be accessed as required. A key focus of the reporting is bringing adverse trends in performance to the general SLT, providing a list of areas which need improvement where the local plant manager is happy that adequate plans and resources are in place for addressing the problem and highlighting those problems which the local plant managers cannot currently address without further help. The latter category includes issues such as (1) the problem has been identified but a solution cannot be found, (2) inadequate resources are currently in place to remedy the problem, (3) the solutions have not worked and the problem still exists and (4) the problem appears to be complex and sitewide in nature.

A number of reporting tools have been developed to cascade the detailed plant PSPI information (as described by Beale[1]) to SLT level and the hierarchy of these reporting tools is shown in Figure 2. One important slide deliberately

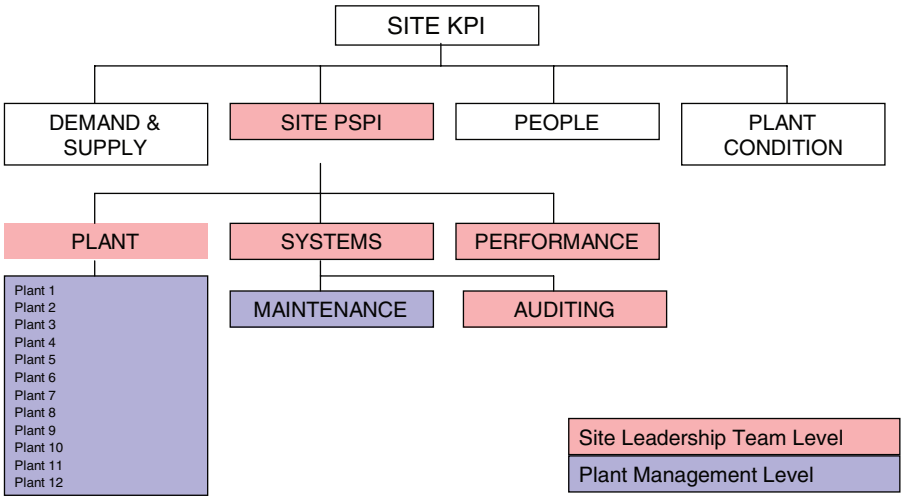

Figure 2. Hierarchy Of PSPI reporting

summarises a large amount of detailed information but in a graphical format. The idea for this method of presentation came from the HSE KP3 study of the state of the UK's offshore oil and gas platforms[6]. About 15 plants are listed on one axis and up to 12 plant specific PSPIs are listed on the other axis. The plant specific PSPIs are all different and reflect the specific risks and key risk controls for each of the technically diverse plant areas. Each specific PSPI is coloured red (outside tolerance level), yellow (outside desired level), green (in compliance), black (not measured) or grey (a continuous improvement target where no tolerances have been set). It is then possible to get an overview of the overall compliance status for the site, any plants which are operating outside their tolerance level and any plants which are not reporting data. The detailed management of individual plant PSPIs is the responsibility of the relevant Plant Manager and local Safety Committee. These reporting and system management arrangements are still in their infancy and changes will be made over the coming months as more experience is gained with the system.

Early indications suggest that the new reporting systems meet the SLT requirements for:

- Complementing existing management systems, site initiatives and SLT meeting structures.
- Fitting into day to day business, ensuring that process safety considerations form a feature of key business decisions.
- Having the right degree of focus on key process safety issues.
- Integrated at different site levels – front line operators, supervisers, managers and the SLT.
- Drawing SLT attention to the health of the most critical site risk control systems.

These PSPI structures should now deliver clear communication about the status of process safety with visibility up to SLT level. The reports are based on a mixture of real data collected by people, instruments, control systems and IT systems and are not just paper trails.

PSPI MATURITY

The CIA 'Process safety leadership in the chemicals industry best practice guide'[3] requires senior managers to have a good understanding of process safety if PSPI programs are to be effective at the highest levels within organisations. This is achieved in a number of ways in different organisations:

- Only appointing staff for senior technical roles who have demonstrated that they are able to manage front line operations successfully before they can be promoted. This approach works well for technical positions but is not appropriate for finance, sales and administration roles.
- Appointing board members with specific responsibilities for process safety who will then advise the other board members.
- Requiring senior managers to obtain externally validated training qualifications.
- Setting up formal corporate process safety programs specifically targeted at senior managers.

Organisations therefore need to ensure that senior managers are appropriately educated in the field of process safety so that they understand and pay attention to key risks and risk controls and ensure that process safety is at the heart of the business decision making process.

Bellamy[2] identified the three senior management attitudes which can exist to process safety which are summarized in Table 1.

Hailwood[5] also identified that from a regulatory perspective, there are a wide range of organisations of different sizes within the process industries and individual companies

Table 1. Three senior management attitudes to process safety

Attitude	Management formula	Behaviours
Probabilistic	$R = P \times C$	Operation has hazard potential. Appropriate risk controls need to be in place and working.
Deterministic	$R = C$	Operation has hazard potential. When will event happen? Can we mitigate the event?
Blinkered	$R = 0$	Complacency. Hazard will not be realised here.

have very different process safety cultures and levels of internal expertise. In Germany, there are a large number of smaller companies (the so called 'Mittelstand') who tend to rely on trade organisations such as VCI (the German chemical industry trade association) and external specialist consultants. Germany is also home to some of the world's largest process industry companies which have deep technical knowledge and sophisticated safety cultures. Overall, organisations could be categorized into the three groups shown in Figure 3.

DIFFERENT APPROACHES TO PSPIS

There are many different approaches which can be used for designing a PSPI program. Some are high level approaches which aim to produce a high level generic approach for use in benchmarking performance against targets, between companies and across industries. Others are tailored to the specific and varied risks that individual plant operations face. The following six main approaches have been identified based on real work that organisations have implemented:

- The **insurance model** focusing on the Top 10 risk controls that are of concern to insurance underwriters based on their historic experience of minimising claims associated with large industrial accidents. Generic PSPIs are then set to measure the effectiveness of these key controls which means that they will often be program indicators (measuring percentage compliance with a planned activity) rather than operational PSPIs. This approach clearly has uses for measuring site performance at a corporate or industry sector level but suffers from the disadvantages that it is not based on specific site risks and it is likely to have a focus on preventing business impacts losses, which will be similar but not identical to process safety risks. Table 2 provides an example of the 'Top 10' risk controls which might be specified. The insurance model could be used as part of a hierarchical approach with a small number of top level generic PSPIs managed at a corporate level and much more detail at a plant level based on an alternative approach, for example, the plant specific model.
- The **analytical model** developed by Taylor[10] in which a detailed analysis of the causes of historic high consequence accidents across all industries is made to identify families of causes of organisational vulnerability which are most commonly implicated in these events. This identifies those critical organisational factors which must be right and which cannot be allowed to degrade and is clearly more suitable for use at a higher level in an organisation rather than at an individual plant level. PSPI measures are then used to measure the performance of the organisation against each critical factor. The critical factors would typically be organised into the following eight groups:
  - Leadership.
  - Operational attitudes and behaviours.
  - Business environment.
  - Competence.

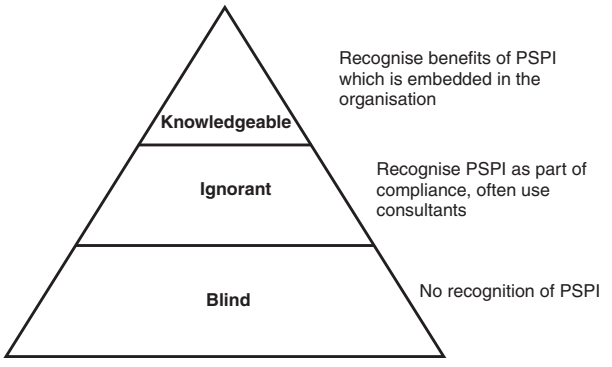

Figure 3. Safety culture/PSPI maturity classification

Table 2. Example list of 'top 10' risk controls

1	Planned maintenance – mechanical integrity inspections.
2	Management of change, permit to work, safety bypass system.
3	PSPI measurement system integrated into overall management system.
4	Design – equipment layout.
5	EHS management system.
6	Process hazards analysis (PHA).
7	Maintenance program.
8	Firewater delivery system and fixed fire protection systems.
9	Emergency shutdown system (ESD) capability.
10	Training and competence.

  - Risk assessment and management.
  - Oversight and scrutiny.
  - Organisational learning.
  - External regulation.
- The **industry sector model** in which a trade body or group of companies who have similar operations collaborate to produce a PSPI template for their particular industry sector. This works well when there is little variability between the operations of the individual companies but would not be suitable for a varied industry such as speciality chemicals manufacturing. A good example is the work completed by Sugden et al.[9] in the UK explosives industry. A template has been produced with PSPIs defined for different stages of the supply chain and unit operations. The PSPIs are designed to cover both leading and lagging metrics. They will not be appropriate for all operators but it is intended that individual companies select those PSPIs which are most useful for their particular operations. This means that individual companies spend less time in specifying which PSPIs should be measured and can, instead, make use of the work completed by the expert group. As such, it is particularly useful for industries which contain a large number of companies employing relatively low numbers of people and where technical resources are limited.
- The **accident rate model** which uses a similar approach to that traditionally used for occupational safety and lost time accidents. A normalised metric can then be defined and measured as the frequency of defined types of process safety accident per standardised number of working hours. This is, however, difficult in practice because a definition is required for a process safety accident. There is a large variability in the types of accident which can occur and the scale of possible consequences of an accident as process safety accidents often have the potential to cause catastrophic damage. One way forward would be to define a damage scale ranging from the more minor impacts, such as failure of a protective device, through accidents which can only cause localised impacts to accidents with offsite hazard potential and then the potential for multiple fatalities. The accident rate for all of these damage potentials is then measured as a lagging PSPI. This means that unlike occupational safety PSPIs where a single indicator can be defined relatively easily, process safety PSPIs would require multiple indicators such as the frequency of Scale 3 accidents per million hours worked. If common definitions were then implemented across different industries, it would be possible to use this measure for benchmarking approaches at an industry or sector level.
- The **plant specific model** tailored to specific plant risks and operations. An example is the HSG254 approach[4] which has been developed in the UK. Beale[1] explains how this can be implemented in the chemical manufacturing industry. It's major advantage is that it focuses the PSPI program on the actual plant risks and key risk controls. The disadvantages are that a certain amount of resources and technical expertise are required to define the PSPIs and care has to be taken to focus on the most important PSPIs not every possible PSPI. As each operation is likely to develop different PSPIs, benchmarking is unlikely to be meaningful. It can, however, be linked with one of the other models to measure generic program indicators.
- The **loss of primary containment (LOPC) model**. This is commonly used in northern Europe and is based on a rigorous collection of defined lagging PSPI data. Most of this data will involve events at the lower scale of severity, often with no significant impact on people, the environment or assets. It does, however, measure that risk controls have failed. Data sets can then be collected with this failure rate data and trends and root causes can be determined to identify areas of weakness where improvements are required. The data can also be benchmarked across sites, business units and even between companies. Although the PSPI data would be classified as lagging PSPI data in the UK, it is viewed as leading PSPI data because it is based on mainly smaller events with no significant impact rather than catastrophic events. In common with most of the German chemical industry, BASF use this approach. In BASF, two PSPI families are used:
  1. FER (Fire, Explosion, Release of chemicals) as defined by quantitative measures for different classes of chemical.
  2. AFPD (Activation or Failure of a Protective Device) based on those devices which are rated as critical in plant risk assessments (such as bursting discs and safety relief valves and SIL (Safety Integrity Level) rated interlocks).

At one extreme, process safety can be viewed as a series of well planned activities which all have to be performed correctly every time. Theoretically, PSPIs could be defined as:

$$\text{PSPI} = (\text{Total Number of Tasks Performed Correctly})/\text{Number of Tasks}$$

This can clearly not be measured, so PSPI programs tend to only focus on those most critical tasks required to deliver process safety. This will involve variability and detail at a plant level but there will be some commonality in generic systems such as completion of maintenance activities against plans, audit close out, management of change effectiveness etc. This suggests that the best approach for larger and more complex organisations is to have a two tier approach to PSPIs based on a small number of generic corporate PSPIs at board level using standardised definitions and local PSPIs for use at plant level as a tool for local plant managers.

DIFFICULT AREAS

ARE PSPIs MEASURING THE RIGHT THINGS?

Some process safety controls cannot easily be quantified for use in a PSPI program. Indeed, it can be argued that

the most critical process safety categories often fall into this category. Many plants operate continuously and historical accident data suggests that the highest risks are associated with abnormal events such as start up and shut down. PSPIs are useful for measuring data over a long period of time when data is collected regularly rather than in intense one-off events. Equally, history tells us that many accidents are caused by human factors. Human factors issues tend to be qualitative as they are linked to complex people issues such as behaviors and culture. They are not easy to measure numerically. It is therefore clear that PSPIs can be a useful tool for measuring and improving process safety performance but they can only form part of the overall management system and won't even include many of the critical rarer and softer parameters.

NOT EVERYONE IS ABLE TO DRIVE CHANGE

One of the main aims of PSPI programs is to detect any deteriorations in the health of critical risk controls so that action can be taken to correct any problems. The programs are likely to involve many different parts of the workforce and different layers of management and it is inevitable that conflicts will arise between:

- What people want to do
- What people are able to do and
- What people are enabled to do.

PSPI DATA IS NOT ALWAYS ACTED UPON

Some problems are clearly defined and easy to fix. Other problems are deep rooted and complex, where the solutions are not always obvious. For this reason, the time required to complete the 'Plan – Do – Check – Act' cycle can range from hours to months or years. With the current rate of corporate change, it can be difficult to complete all of the required changes before major organisational change occurs or major changes are made to key risk controls. This can lead to work that is started but does not get finished. It is also important to provide feedback as to the status of PSPI improvements to maintain commitment within the workforce and influence workforce behaviour positively.

PSPIs NEED TO CHALLENGE AND SHOULD NOT BREED COMPLACENCY

At their heart, PSPI programs need to challenge current behaviours and standards to achieve continuous improvement. The achievement of 'good' performance should not reduce the motivation to improve within an organisation or part of an organisation.

CONCLUSIONS

PSPIs can form a useful pillar of an organisation's safety management system, amplifying weak signals showing the onset of organisational drift and risk control system degradation. Problems can be brought to the attention of senior managers, allowing them to be fixed before catastrophic events occur. This helps to prevent so called 'unconscious management incompetence' and should strengthen feelings of chronic unease within the organisation mitigating against any tendency to become complacent about major hazard risks.

It is important that PSPIs are not used wrongly to bolster a good news culture and rather are used to 'frequently rock the boat', questioning the current situation and making people check that things really are right. PSPIs need to be challenging so they do not foster a culture of senior management overconfidence to promote real operational continuous improvement.

Organisation wide PSPI programs need to balance system generics and plant specifics in a way that is meaningful and clear to senior managers. This is a challenging problem and requires the direct involvement of the senior management team when designing the overall PSPI system, particularly the reporting arrangements. Experience within the BASF UK sites suggests that this process is likely to involve multiple iterations and practical benefits will flow by starting simple and getting more complex over time as people become more familiar with the PSPI programs.

PSPI programs need to be designed and managed as a system if they are to deliver real continuous improvement benefits. There are many ways of designing PSPI programs to suit the needs and cultures of individual organisations. These range from detailed plant specific approaches such as HSG254 in the UK[4] to generic industry approaches such as those developed for the UK explosives industry[9] to the OECD guidelines[8]. Whichever system is used, it is, however, essential to remember that the system will only be effective as a result of the efforts and competencies of the people who use it.

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