

## **Topical Issue Paper No. 5**

### **SAFETY PERFORMANCE INDICATORS**

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# 1. RATIONALE

## 1.1. BACKGROUND

Since its creation the nuclear industry has been struggling with the question of how safe is safe enough. Safety is a common goal to all involved in the design, operation and regulation of a nuclear installation. As a concept safety is not easy to define. However, there is a general understanding of what attributes a nuclear power plant should have in order to operate safely. The challenge lies in measuring the attributes.

The new competitive open electricity market, in many countries throughout the world, is increasing the economic pressure on operators to lower operating costs without jeopardizing safety. There is also a driving force to let regulations and regulatory decisions be influenced by risk insights and licensee performance to sharpen the safety focus on the real safety issues.

Challenges are occurring at a rate that is unprecedented in the nuclear industry: competitiveness; downsizing; ageing; policy changes; reorganization; restructuring; mergers; globalization; and takeovers demand increasing attention to the management of safety.

If safety is not easy to define it is even more difficult to define and assess a high level of safety. A high level of safety is the result of the complex interaction of engineered safety and operational safety. Experience has shown that focusing on any single aspect of performance is ineffective, and can be misleading. What is more valid is the broader picture presented by a set of indicators designed to monitor key aspects of operational safety performance.

There are various means to measure safety performance, some of which are more qualitative in nature and others which through quantitative measures provide the means by which to evaluate performance trends with clear ties to safety.

According to their use, indicators are generally considered in two groups: leading or proactive and lagging or reactive indicators. Leading indicators are most useful as a precursor to safety degradation for early management reaction. Lagging indicators are most commonly used to drive plant performance, to monitor and for benchmarking against similar plants.

The actual values of the indicators are not intended to be direct measures of safety, although safety performance can be inferred from the results achieved. The numerical value of any individual indicator may be of no significance if treated in an isolated manner, but can be made significant when considered in the context of the performance of other indicators.

On the other hand, specific indicator trends over a period of time can provide an early warning to plant management to investigate the causes behind the observed changes. In addition to monitoring the changes and trends, it may also be necessary to compare the indicators against identified targets and goals to evaluate performance strengths and weaknesses.

Each plant needs to determine which indicators best serve its needs. Selected indicators should not be static, but should be adapted to the conditions and performance of the plant, considering the cost-benefit of maintaining each individual indicator.

The operating experience from the past thirty years has led the industry to understand that plants with excellent safety records also tend to be good performers. Therefore, a complete set of parameters to monitor nuclear power plant performance should include both safety and economic performance indicators. Safety and reliable operational performance are not mutually exclusive.

It should be recognized that while indicators provide valuable information in the effective management of plant safety performance, they are just one of a larger set of tools including probabilistic safety assessment (PSA), regulatory inspection, quality assurance, external reviews and self-assessment needed to assess operational safety performance. The integration of information compiled from such evaluation tools yields the best results.

Two areas of increasingly common interest are 'risk based' indicators, and 'safety culture' indicators.

Industrial experience and research findings have shown that major concerns regarding the safety of nuclear power plants and other complex industrial systems are not so much about the breakdown of hardware components or isolated operator errors. Most important are the insidious and accumulated failures occurring within the organization and management domains. Common to many plants that have had to shut down because of safety problems have been the fact that senior utility management failed to recognize, within the suite of the performance indicators used, the symptoms and significance of shortcomings and progressive degradation in the safety management processes and safety culture and hence failed to take corrective action at an early stage. In their early operation many of them belonged in the league of the best performing plants as measured by the means available at the time.

The key to managing the nuclear business today is to establish a high quality safety management system as well as developing a strong safety culture within the entire organization. Such organizations will also be committed to continuous improvement and have an integrated set of performance measures and programmes created to act upon that information at all levels of the organization. Included in these measures are indicators that allow for early detection of failures in the management of safety and safety culture.

*“The safety management system comprises those arrangements made by the organization for the management of safety in order to promote a strong safety culture and achieve good safety performance”* [1]. This definition, presented in INSAG-13, illustrates the close connection between “safety management systems” and “safety culture” and that they are in fact inseparable. To manage safety effectively you need a systematic approach and at the same time be aware of the effects of the approach on individual and collective human behaviour.

The risk based indicator system is another safety information tool. Generally, this tool can be used to monitor safety performance, both during nuclear power plant operation and shutdown modes, and to alert the user if parameters exceed certain levels or follow undesired trends. Different kinds of information can be derived from the PSA as indicators for long term or short term applications. The long term risk based indicators focus on monitoring plant behaviour in order to obtain insights on the past history of nuclear power plant safety and to update the calculated average core damage frequency. Risk based indicators for short term use require instantaneous evaluation of risk.

## 1.2. DEVELOPMENT OF SAFETY PERFORMANCE INDICATORS.

After accumulating more than forty years of experience, through learning and safety backfitting, the nuclear industry and regulators are ready to use that operating experience and risk analysis to focus on most significant aspects of plant safety.

Nuclear power plants are developing human performance, self-assessment and corrective action programmes to improve safety and production. Operating experience is shared throughout the nuclear industry and incorporated into these programmes. Probabilistic safety assessment techniques have also improved and expanded so that risk insights are being increasingly used.

In the regulatory field there is a clear tendency to combine the traditional deterministic and the risk informed, performance based ways of looking at what is important to ensure public health and safety.

The risk informed, performance based regulation needs a comprehensive set of safety indicators as an important oversight tool. At the same time it is necessary to preserve the current regulatory requirements and criteria especially in safety areas, which are not covered by the set of indicators.

A new approach should be designed to fulfill the needs of nuclear power plants while maintaining an effective regulatory oversight programme.

### **1.2.1. Objectives of safety performance indicators**

The following objectives are suggested:

- Provide an objective measure of the safety performance of nuclear power plants with regard to public health and safety. It can be combined with other inputs such as inspections, evaluation of findings and audits to assess more completely plant safety performance. The way such insights are combined depends on the purpose of each particular use.
- Provide understandable safety performance information to technical and non-technical persons.
- Provide indicators to assess behaviour and trends in key areas of safety performance so as to allocate resources in an effective and efficient manner.
- Facilitate communication between regulators and licensees. In combination with other information, this enables indication of early signs of degradation.
- Facilitate efforts of licensees to improve their safety performance through an appropriate national and international comparison and inform the public of nuclear power plant safety . It should be measurable and quantifiable to the maximum possible extent.

### **1.2.2. Benefits of safety performance indicators**

The potential benefits of such a comprehensive set of safety performance indicators (SPIs) are:

- To identify an objective, auditable and non-disputable set of safety parameters;
- To provide insights, when used as a set, regarding what is important to safety;
- To provide information that is understandable to all stakeholders;
- To provide an additional basis for self-assessment and to take corrective actions;
- To provide an additional basis for investigations by regulators;
- To Enable comparisons to be made, especially in the framework of a small set of internationally agreed safety indicators;
- To encourage licensees to monitor performance using specific indicators;
- To promote the licensees' own improvement of processes.

### **1.2.3. Precautions in using safety indicators**

The following are some warnings:

- Indicators cannot be used alone to draw conclusions for one safety performance area;
- Some indicators are difficult to be defined without ambiguity;
- Results may be misleading if seen as a measurement of safety level instead of an indication of a particular aspect of an area of performance;
- Indicators can be subject to misuse or manipulation;
- When using composite indicators a good trend in one specific indicator can mask a bad trend in another;

- An indicator trend is not necessarily indicative of the trend in safety performance;
- Data collected by the plant personnel must be verified to ensure its accuracy'
- Lagging indicators may not provide timely indication of declining performance;
- Some safety performance indicators can only be effectively used as part of a full set of indicators that provide information regarding a spectrum of safety attributes;
- It is difficult to develop quantifiable indicators for some safety performance areas;
- When indicators are plant specific they are not appropriate for comparing plants, particularly if the definition and criteria are different from plant to plant and country to country;
- Indicators cannot replace qualitative engineering judgement.

### 1.3. INDICATOR SELECTION AND USE.

The development of traditional nuclear safety indicators has been concentrated in two major parameters: event occurrences and safety system performance. There are clear limitations in this set of indicators. In the case of event occurrences they are lagging indicators and the thresholds are often too high to allow for early problem identification and intervention. In the case of safety system performance, they are geared toward operating systems, focused on hardware. However, a decline in safety system performance can be an indication of poor human performance in maintenance and operation. On the other hand, good equipment performance may contribute to organizational complacency.

Managing safety performance requires identification of declining trends at incipient stages. Nuclear power plant indicators need to look broadly to technical and organizational issues, be sensitive to the kind of issues important for the plant and have thresholds low enough to allow for early identification of problems and rapid intervention.

Key safety performance indicators should provide the earliest possible warning that an organization has declining performance and it could be increasing the operational risk. It is therefore essential to use a broad set of key indicators to cover plant general performance: nuclear safety, environmental safety, industrial safety, and aspects of safety culture and management.

The selection and use of PIs require previous consideration of specific criteria and characteristics for their effective use to monitor operational safety performance, among which are the following:

- There is a direct relationship between the indicator and safety,
- The necessary data are available or capable of being generated,
- Indicators can be expressed in quantitative terms,
- Indicators are unambiguous,
- Their significance is understood,
- They are not susceptible to manipulation,

- They are a manageable set,
- They are meaningful,
- They can be integrated into normal operational activities,
- They can be validated,
- They can be linked to the cause of a malfunction,
- The accuracy of the data at each level can be subjected to quality control and verification,
- Local actions can be taken on the basis of indicators.

Criteria should be used by management to be alert to indicators containing subjective input or that are subject to manipulations so that abuses do not occur.

## **2. STATUS OF THE TOPICAL ISSUE**

There are two main driving forces to use safety performance indicators. The first requiring nuclear power plants to collect data and process a set of indicators prescribed by the regulatory body, or recommended by national or international organizations. The second is a voluntary approach which depends on individual initiatives of nuclear power plants for their internal use or for comparisons against the international situation.

### **2.1. ISSUES ON WHICH THERE IS GENERAL AGREEMENT**

It is generally agreed that a comprehensive set of safety performance indicators must be used in combination with other insights such as safety culture and human performance evaluations, inspections and audits, risk analysis, feedback of experience and other external review and self-assessment tools in order to have a complete safety management system.

In an increasingly competitive environment both an international set of a few principal performance indicators and a plant specific set of safety performance indicators can be valuable tools to enhance performance. They provide a standard to strive for, help determine what requires attention, and maintain or even improve the level of quality and safety, thereby avoiding complacency.

Safety indicators have always been used informally by regulators to trigger investigations or initiate regulatory actions. There is a recognized need to consider the licensee's performance in the regulatory decision-making process because of the current challenges facing the operating organizations and the nuclear industry. Safety performance indicators are one of the available tools.

## 2.2. PRESCRIBED OR RECOMMENDED INDICATORS

### 2.2.1. Safety performance indicators prescribed by national Regulatory Bodies

These safety performance indicators (SPIs) are used to guide the regulatory activities and to identify the needs for changes in the regulatory inspection, and other regulatory actions based on the safety performance of the licensee.

A good example for this approach is the approach of the US Nuclear Regulatory Commission (NRC). In the USA, the NRC has recently announced the ‘New NRC Reactor Inspection and Oversight Program’, introducing a new approach to the regulation of the nuclear industry. The new approach is the risk informed, performance based approach to regulation, that has been discussed in several forums over the last years. One key area in this approach is the regular measurement of the safety performance of the nuclear power plants; the consequent regulatory actions are based on the actual safety performance. The basis for monitoring the safety performance was the identification of “cornerstones” of the safe nuclear plant operation being characterized by a set of SPIs. Each PI is categorized to determine the appropriate regulatory response. The PIs are monitored by the NRC staff and reported quarterly by the utilities, and they are also publicly available .

The new indicators used by the NRC for regulatory oversight are defined in considerable detail in a Nuclear Energy Institute (NEI) publication [(NEI 99-02) [2] and on the NRC web site at [www.nrc.gov/OPA/assessment.htm](http://www.nrc.gov/OPA/assessment.htm). Two points about the NRC program must be emphasized. First, it is in its infancy. The definitions for some of the indicators are undergoing revision and pilot testing based on early recognition that some of the first indicators as described in NEI 99-02 could have unintended consequences.

The second point is that the indicators themselves tend to define operating “safety” parameters, but they do not of themselves describe risk. The connection to risk is achieved through the establishment of threshold levels. Understanding this leads to the concept of performance bands.

Practices in several countries are to use a set of safety indicators, mostly the indicators of the World Association of Nuclear Operators (WANO), complemented by some others for day-to-day inspection purposes. In countries with large number of plants, the Regulatory Body needs consistent tools to define policies to compare the safety performance of the nuclear power plants. In countries with a smaller number of plants, the Regulatory Body needs more specific means to evaluate plant operational safety performance. The general trend is to come up with a consensual approach to safety performance indicators at a high level.

### **2.2.2. Safety performance indicators recommended by national and international organizations to their members**

Indicators recommended by national and international organizations are used mainly to monitor the overall plant safety performance, to make comparisons between plants, to encourage emulation of ‘best performance’ and to promote exchange of ‘good practices’ among plants. Such indicators are the indicators of the Institute of Nuclear Power Operators (INPO) and WANO that are produced by the nuclear power plants affiliated to these organizations. These indicators are high level “backward-looking” indicators reported periodically, although much later than the actual period of time that they refer to. Therefore these indicators are of little use for managing real time plant safety. On the other hand, the WANO indicators are the most ‘successful’, having remained almost the same since their introduction, and are reported by all utilities worldwide.

### **2.3. INDICATORS COLLECTED FROM NUCLEAR POWER PLANT INITIATIVES**

The current set of WANO’s indicators is considered to be partial if an overall plant safety performance has to be looked at. With this in mind, the managers of some nuclear power plants decided to develop a more complete set of SPIs at both the department/division level and the upper management level. These plants spent time and effort to convince section leaders and supervisors so as to have their active participation in the selection, definition and deployment of meaningful indicators for key plant processes and activities, to evaluate them periodically and take corrective actions if necessary. Despite the large number of indicators selected, this endeavour is an important self-assessment tool which provides valuable safety insights both at the operational and plant management levels.

The many projects and individual pilot studies presented at international technical meetings confirm the great interest of nuclear power plants in using PIs to manage safety. Successful applications are reported, especially in countries where centralized efforts have been made, and most of those are intended to supplement the WANO indicator system in order to satisfy specific needs. Or they contain the WANO indicators as a subset of the plant specific indicator system.

### **2.4. IAEA PROPOSED FRAMEWORK FOR DEVELOPING PLANT SPECIFIC SPIs**

Since December 1995, the IAEA activities in this area have focused on the development of a *framework for the establishment of nuclear power plant operational SPIs*. The work was completed in 2000 and a report was published [3] that includes the results of pilot studies conducted at four nuclear power plants.

The objectives of these pilot studies were: (1) to validate the applicability, usefulness and viability of the approach; and (2) to obtain feedback regarding the difficulties found when implementing the programme. Each plant utilized the proposed indicator framework as a starting point; however, individual plant programmes were adapted to meet plant specific needs. Despite changes in the selection of indicators, all the plants involved chose to maintain the basic indicator organization, thus providing validation for the concept. The participating plants concluded that the proposed framework provides a good approach for establishing a comprehensive operational SPI programme.

In the proposed IAEA framework three important aspects were addressed — *nuclear power plant normal operation*, *nuclear power plant emergency operation*, and the *attitude of nuclear power plant personnel towards safety*. On this basis three key attributes were chosen that are associated with plants that operate safely:

- a) Plants *operate smoothly*,
- b) Plants *operate with low risk*,
- c) Plants *operate with a positive safety attitude*.

Because these attributes cannot be directly measured, the “indicator structure” was expanded further until a level of easily quantifiable or directly measurable indicators was identified.

Using the attributes as a starting point for indicator development, a set of *operational SPIs* were identified. Below each attribute, *overall indicators* were established. Associated with each overall indicator was a level of *strategic indicators*. Finally, each strategic indicator was supported by a set of *specific indicators*, most of which are already in use in the industry. Indicators were developed one level at a time to ensure that all relevant safety aspects of each attribute were covered.

The *overall or key indicators* were envisioned as providing an overall evaluation of relevant aspects of safety performance. *Strategic indicators* were intended to provide a bridge from overall to specific indicators. *Specific or plant specific indicators* represented quantifiable measures of performance. Specific indicators were chosen for their ability to identify declining performance trends or problem areas quickly so that after proper investigation, management could take corrective actions to prevent further performance degradation.

The IAEA started a Co-ordinated Research Project (CRP) on development and application of operational SPIs in December 1999. Eleven nuclear power plant/utility organizations from nine countries are participating in this project. The general aim of the CRP is to assist nuclear power plants worldwide to develop and implement their own plant specific operational SPI programmes. The CRP participants are exchanging information and discussing topics such as general principles for the establishment and use of SPI programmes, selection of specific indicators, principles for indicator definition (purpose, objective, description and formula), goals and thresholds for low level (specific) and high level (strategic and overall) indicators, how to use indicator systems, computerized systems to support indicator programmes, data needs and problems, benchmarking, credibility of the indicators, and use of SPIs for communication with regulatory authorities and the public.

### **3. PROBLEMS IDENTIFIED AND ISSUES TO BE RESOLVED**

So far, there has been a lack of indicators that can be more closely tied to the safety culture of an organization. Usually, the strength of the safety culture is inferred from the results shown in operational SPIs. In order to get a better understanding of the influence of attitudinal and other cultural factors on safety performance, there is a need for additional safety culture indicators.

At the same time, it must be recognized that safety culture is a complex concept and there is no simple indicator that measures its state. The multi-level nature of culture, and the tacit nature of some of the levels (basic assumptions), increases the difficulty of measurement. This means that a broad range of indicators, some of which may be more subjective in form than others, is necessary to gain useful information about the state of safety culture in an organization. The only practical way forward is to identify a portfolio of indicators that measure the important characteristics of a positive safety culture. It is also important to recognize the close connection between the management of safety and safety culture.

#### **3.1. MANAGEMENT OF SAFETY AND SAFETY CULTURE**

The essential components of an effective safety management system can be described in various ways. Some of the desirable attributes of an effective safety management system are described in INSAG-13 [1]. Through a set of questions covering the observable features of an effective safety management system, a basis is provided for judging the effectiveness of the system. The areas covered through these types of assessments can be further developed into more quantitative indicators.

To oversee safety culture, difficulties should not to be underestimated, since so many of the required characteristics lie below the surface. It is believed that in order to properly assess safety culture, it is necessary to consider various means of evaluation. Therefore, comprehensive questionnaires, structured interviews and checks on management and people doing safety related work, plant documentation and procedures could reveal strengths or weaknesses in an organization.

The key elements often covered in questionnaires and interviews to assess safety culture could also be developed further into indicators. Considering that the safety culture of an organization reveals itself at various levels (visible products and behaviours, stated values and basic assumptions, beliefs and perceptions), it may be more or less difficult to establish indicators. What is typically assessed through questionnaires and interviews is the employee perceptions of various safety management practices. A full assessment in this way usually covers a number of key elements. Examples of these elements, which can be further developed into indicators, are: top management commitment to safety, visible leadership, high priority of safety, openness and communication, systematic approach to safety, sufficient and competent staff, compliance with regulations and procedures, etc.

In recent years, several nuclear organizations have experienced degradations and shortcomings in their safety management processes. Based on a review of these experiences [4–6], some common symptoms and causes have emerged. There is often a delay between the development of weaknesses and the occurrence of an event involving a significant safety consequence. By being alert to the early warning signs, corrective action can be taken in sufficient time to avoid adverse safety consequences. Both the management and regulators must pay attention to signs of potential weakness. The management of an organization should pay particular attention to monitoring for these symptoms of a weakening safety culture in their self-assessment process. For some of the symptoms it may be possible to develop SPIs that will be of practical value in detecting adverse trends from both a utility and regulatory perspective [7].

Finally, regulators themselves should be technically competent, have high safety culture and standards for auditing their own work, deal with operators in a professional manner and show good judgement in evaluations and enforcement actions. Possible indicators are: organizational commitment to priority of safety matters, clear lines of responsibility within, staff competence, good internal communication, clear guidance for inspections and evaluations of safety cases, well established and known system for acceptance criteria, timely regulatory decisions, enforcement actions in accordance with the real importance of events and circumstances, and use of risk analysis and performance data in decision making. An extensive list of potential indicators of regulatory effectiveness has been developed through the IAEA peer discussions on regulatory practices [8].

## 3.2. GENERAL ISSUES

### 3.2.1. Need and feasibility of an international system

The possibility, feasibility and usefulness of a comprehensive set of SPIs agreed internationally is often discussed at forums where issues related to nuclear power plant operational safety and nuclear regulation are discussed.

Before such a significant effort is undertaken, there are issues to be clarified and questions that need answer. Some examples are listed below:

- Would the establishment of a set of SPIs agreed at an international level be feasible?
- Would this set be useful (e.g. would it be useful for use by regulatory authorities)? Would it be useful as a means to report to the Nuclear Safety Convention? Would it be useful to do benchmarking among nuclear power plants?
- Would not the difficulties of getting worldwide agreement on a set of indicators and establishing an efficient system for reporting and evaluation be far more significant than the benefit obtained from such an effort?
- Who would be the counterparts in this effort, i.e. nuclear power plants or regulatory organizations?
- Which international organization would be responsible for compiling, analysing and comparing all the information received from the counterparts in the countries?
- Would this information be made public?

Over the past two years, WANO has conducted a review of its set of Pis in order to see if there is any need to make any change. As a result of this review, WANO decided that it will no longer use either the Thermal Performance Indicator or the Volume of Radioactive Waste. Additionally, some clarifications to definitions were developed. The review groups also examined the development of a risk-based indicator for safety systems, as well as an event-based indicator. Although satisfactory indicators were not developed for these two areas, they remain of interest for future improvements to the set of WANO Pis.

An international system of SPIs could also be developed for use by regulatory bodies. It would be necessary to reach consensus on a small set of SPIs in the areas of plants performance stability, reliability of safety systems, integrity of barriers and radiological impact. The IAEA could provide a forum for regulators and operators to compare safety performance and identify strengths and weaknesses. Besides, regulators and operators will have a tool to provide information to the public and help to increase trust.

### **3.2.2. Plant management needs**

The plant management needs to have a complete picture of the safety performance of the plant in order to detect early symptoms of deterioration and be able to divert resources where they are most required. Therefore, there is a need for a comprehensive set of safety performance indicators, encompassing indicators in all the areas that directly or indirectly affect safety, to be used by the plant for self-assessment. These indicators would be used at the plant management level. Thus, this set would be, in principle, absolutely plant specific and would evolve with time to reflect the need to focus in great depth on specific topics for a period in order to improve safety performance in specific areas.

In this regard, it is necessary to understand why there are still nuclear power plants that have not implemented indicators to monitor performance in all areas that can impact safety.

Further thought needs to be given to the impact of the corporate organization on plant safety. Safety performance indicators applied to the corporate organization can be important for monitoring key aspects where its policies and decisions impact at plant level. Also the corporate level should monitor a set of Pis from each of its nuclear power plants to check for signs of deteriorating performance, progress towards agreed goals, etc.

### **3.2.3. Regulatory use of SPIs**

Although individual regulators use various approaches to SPIs, it is believed that a small set of indicators covering the key cornerstones could be agreed upon. The issue is related to what would be those key cornerstones and the complete set of indicators required by regulatory bodies. Should this be a subset of a wider scope set being collected by the plants? Are there any requirements for special indicators? Should a set of indicators for regulatory use be defined only after the plants have gained sufficient experience with the collection and evaluation of safety indicators, or should they be defined upfront to guide the formulation of plant indicator programmes?

The importance of baseline regulatory and management inspection programmes should be recognized. Indicators cannot do the job alone in any context. There is no substitute for sound inspection involvement. The indicators can help direct inspection efforts and possible supplements to a sound baseline programme, but indicators can never totally replace these efforts. Some countries have established working groups of regulators, nuclear power plants and R&D institutions to pursue these developments, looking for consensus among licensees and regulators.

#### **3.2.4. Public communication**

It is a function of both the operating organization and the Regulatory Body to provide timely and accurate public information on the safety performance and on safety issues of nuclear power plants. Therefore, either the same set of SPIs developed by the Regulatory Body or a subset of these indicators, carefully chosen in order to clearly transmit the correct messages to the public, should be used. The information may be communicated through public information centres and also through periodic written reports to be presented to the government and public institutions. The following are some pertinent issues:

- Selection and use of SPIs to communicate nuclear safety effectively outside the nuclear community;
- Should only easily understandable indicators be used for communication with the public in order to avoid misunderstanding and misinterpretation?
- Should only long term indicator trends rather than absolute values be used?

### **3.3. SPECIFIC ISSUES**

The following are specific issues that have been identified in the pilot studies conducted in the frame of IAEA activities and are discussed in greater detail in Ref. [3]:

- *Selection of indicators:* Depending upon their use, for regulatory purposes, operating organization and plant management purposes or plant department supervisor purposes, the number of SPIs is going to be different. Most important is that the selection of indicators be done after a complete and thoughtful revision of the key processes and activities by those who have responsibilities and therefore are involved in the processes. It should be taken into account that a reasonable and manageable set of indicators needs to be developed covering the important aspects of the safety management system and following a hierarchical structure. Depending upon their use for decision making they need to be at the appropriate organizational and institutional level.
- *Definition of indicators:* A clear and simple definition of each indicator has to be established as a key part of the programme. The future owners of the data collected, tracking and trend analysis of each indicator, should also be involved in the definition of procedures and methods of calculation of indicators. In the case of developing international indicators, an even more careful definition and clear and detailed explanation, including examples and data collection requirements should be provided, such that anyone can understand how to calculate and compare meaningful results among nuclear power plants.

- *Identification of goals, thresholds and performance bands:* Goals represent the standards or levels the plant wants to follow, maintain, or achieve. Indicators can provide useful information on a continuous improvement programme or an early warning of declining performance. The process again requires discussion and negotiation with the participation of the responsible owners of the indicators and management intervention to identify what constitutes a reasonable expectation for the performance of each indicator.
- *Data display and interpretation:* Usually data covering a five year period are sufficient for the purpose of evaluating the indicators. Some indicators provide valuable information when viewed separately, but when viewed together they can provide additional insights. Therefore it is recommended that methods be developed to enhance the value of the model by aggregating the performance across a number of indicators in relevant groups so that a 'big picture' at the higher level can emerge regarding the organization's strategic and overall safety performance. Although the value of the composite rating is not significant, it allows for visualization and trending of overall performance over time. Each specific indicator should be evaluated against the established goal and the results may be presented through graphic displays of individual indicators, colour window displays or trend display.
- *Logistics and other resources required to support programme development:* Depending on the starting point of each plant the effort to implement an operational safety indicators programme may be more or less significant. However, because plants already have some kind of data collection and performance monitoring system, it is believed that only small additional resources are required. However, the implementation process implies an additional effort by the plant above all to select and define the indicators and establish the goals.

In the frame of the IAEA CRP referred to in Section 2.4, the concept of a model for SPI evaluation is being developed based on two regions for the indicator values. These are satisfactory (acceptable) and unsatisfactory (unacceptable). The acceptability region is further divided into excellence, operating and warning zones.

The unsatisfactory/unacceptability region is where indicator values are considered by the management as unsatisfactory performance. If the indicator is governed by Technical Specifications or regulatory requirements, the zone is termed unacceptable; otherwise it is termed unsatisfactory.

In order to keep performance level in the acceptable region, it is required that a warning be generated before the limit is reached. This warning zone is defined by the unsatisfactory limit and a working goal that the management expects to achieve in a given year. It is therefore short-term goal.

The company's vision for an individual indicator is the long-term goal, also called the 'strategic goal'. The band between the working (annual) goal and the vision defines the operating zone. The zone beyond the vision represents the excellent results.

It is noted that the working goal may change from year to year as the performance improves. The intention is to have an achievable short term working goal which moves closer to the vision. The vision, on the other hand, represents a strategic goal which remains stable and is open to change only in the long term (for instance after five years).

There are several ways to determine the threshold values. It is up to the nuclear power plant to determine the most suitable ones for its plant specific use.

The scheme for the selection of the band thresholds considers two cases, depending on whether or not the unacceptable region is identified by regulatory requirements or by the safety case.

In the first case the unacceptable limit (between warning and unacceptable zones) should be set by the required limit set by the regulator or plant safety case documentation. The annual plan (between warning and operating zone) should be the value set in the annual plan by the plant management. A possible warning limit (working goal) could be 80% or 120% of the unacceptable limit, depending on whether low or high is good. This has to be discussed with the owner of the indicator and accepted by the management. The vision or strategic goal (between the operating and excellent zones) should be the value set by the company vision or strategy.

In the latter case, when the unacceptable region is not identified by regulatory requirements or by the safety case parameters, an analysis of historical data should be performed to obtain percentile information. The unsatisfactory limit (between warning and unsatisfactory zones) could be set by the 50<sup>th</sup> percentile. The annual plan (between the warning and operating zones) could be the value set by 40<sup>th</sup> percentile (if low is good). The vision or strategic goal (between the operating and excellent zones) could be the value set by the 20<sup>th</sup> percentile. In the event enough data is not available, expert judgement would have to be used to select the various limits once the company vision (strategy goal) has been set by the management.

An alternative option is to set the unsatisfactory region in the same way but set the vision or strategy goal (between the operating zone and the excellent zone) as the short term one year strategy. This would mean that the colour indicator would provide a more positive position. The annual plan (between the warning and operating zones) should be the value set as an initial warning level.

It needs to be recognized that when comparisons between previous years and the current year are performed, colour indications may indicate deterioration. The indicator value may in fact have improved or have been stable, but the colour code may have been brought down as a result of changing annual plan targets. This is deemed acceptable because the indication colour is established by the relevant company values set in that year. When a comparison is required that utilizes the colour indicator, previous years should be re-evaluated against current thresholds. This will provide a common base for comparison.

#### 4. RECOMMENDATIONS FOR STRATEGIC ACTIONS/PRIORITIES FOR FUTURE WORK

The following recommendations are proposed for strategic actions within four domains:

##### *Nuclear Power Plants*

Nuclear power plants and corporate organizations need to have a complete 'picture' of a safety management system and its monitoring performance so as to manage what can be qualitatively and quantitatively measured. Therefore:

1. The management of nuclear power plants is encouraged to use the attributes and overall and strategic indicators of the IAEA proposed framework in their safety management decision making process. The attribute corresponding to a positive safety attitude should be complemented by a periodic qualitative evaluation of the organization safety culture. The management also needs to overview SPIs at the nuclear power plant level.
2. For plant specific operational safety indicators, nuclear power plant management should consider committing plant department/section leaders to seek a selection of indicators, within the umbrella of the IAEA proposed framework.

##### *Regulators*

3. The set of SPIs to be used by the Regulatory Bodies can be derived as a subset from the indicators of the IAEA proposed framework. The subset should cover, at a minimum, the key cornerstones of operational safety performance.
4. Regulator and licensee representatives should convene in an international forum so as to agree upon this set of SPIs. The set has to be clearly defined, as well should the methods for gathering plant data and calculating the indicators.

##### *IAEA*

The Agency has been working for many years and has devoted significant resources to the development and improvement of operational safety management systems, safety culture and SPIs, and it should continue in this endeavour, by:

5. Continuing CRPs in different regions of the world to help nuclear power plant management in the development of plant operational safety indicators according to the IAEA proposed framework.
6. The IAEA can serve as a forum for nuclear power plant regulators and operators to achieve the goal stated in item 4. The work by the Agency should be initiated, as soon as possible and be completed in 2003, to accomplish this goal. Procedures should be developed to be used by both the operators and the regulators to collect and analyse data for SPIs.

### *International*

The well known set of WANO PIs has been used internationally for many years. While these indicators are well defined, they do not address the issue of operational safety performance. Therefore it is recommended that:

7. The set of safety indicators to be developed under the auspices of the IAEA be 'institutionalized' as a more complete set, to be used not only by regulatory bodies, but also used for public information purposes and for inclusion in publicly available reports periodically issued by regulators to inform the Government and public institutions. Consideration should be given to the IAEA collecting and making the indicators internationally available on an annual basis.

A basis for constructing a set of safety performance indicators for international use is proposed in the Annex.

### 5. QUESTIONS TO THE CONFERENCE

1. Can a threshold be established to compare safety data to risk relevance?
2. Can an international system or 'menu' of SPIs be used in the framework of the national reports prepared for the Convention on Nuclear Safety?
3. Should the set of internationally agreed SPIs be used for public information?

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## Annex

### A BASIS FOR CONSTRUCTING A SET OF SAFETY PERFORMANCE INDICATORS BASED ON THE THREE IAEA ATTRIBUTES

Threshold considerations for the indicators related to the three IAEA attributes should be keyed to worldwide performance statistics. Nominal performance might be defined as greater than 90% of the mean worldwide. A heightened awareness performance band might be established between 75 and 90% of the worldwide median, and performance at less than 75% could be considered in the safety concern range. Therefore, bands of nominal, heightened awareness and safety concern could be established for the various safety performance indicators.

#### A. PLANT OPERATES SMOOTHLY

- *Unplanned Power Transients (>20%)*. This factor would include all scrams, both manual and automatic, and power transients >20% that are initiated by urgent maintenance needs less than 72 hours after discovery. Management or dispatch directed transients not associated with urgent maintenance would not be included.
- *Reactor coolant system (RCS) integrity*. RCS identified or total leakage.

#### B. PLANT OPERATES WITH LOW RISK

- *Challenges to safety systems*.– The number of demands to the reactor protection system, emergency core cooling system, residual heat removal system and electric power supply system.
- *Safety system performance*.– The number of hours and times a safety system is unavailable. Availability may be a preferred measure to maintain a positive safety viewpoint.

#### C. PLANT OPERATES WITH A POSITIVE SAFETY ATTITUDE

- *Industrial safety accident rate*. This is used as an indicator of safety attitudes. It is easily measured and internationally understood. Performance values under this indicator should be very low and should be a small fraction of the accident rates evident for all industrialized activities in a national context. It is a WANO indicator but it is not reported by all sites.
- *Occupational radiation safety*. NEI 99-02 contains more detailed information on this indicator, which sums occurrences of non-conformance events in high radiation areas, very high radiation areas and unintended exposures.
- *Public radiation safety*. This indicator counts occurrences of radiological effluents, both gaseous and liquid, in excess of prescribed values. It is explained fully in NEI 99-02.

- *Self-identification fraction.* Problems are often identified at nuclear power plants by persons external to the facility such as regulators, peer reviews or assistance teams. In addition, problems may be identified by internal teams whose primary responsibility is inspection rather than operation. It is a sign of a good safety culture if the majority of problems identified at the facility are 'self identified' by internal staff with primary responsibility for operations and maintenance. Problems identified without the benefit of 'self-revealing' events are particularly beneficial. This indicator is highly dependent on the maturity of the nuclear power plants self-assessment and corrective action programmes, as well as the robust nature of external and internal dedicated inspection forces. However, where they exist a ratio of self-identified problems to all identified problems greater than 0.5 is an indication of a safety oriented culture.
  
- *Safety culture indicators*
  - Activity indicators. A set of indicators was developed and is in use in the Forum of Nuclear Co-operation in Asia. Indicators deal with: communication between management and employees on safety culture; activities on safety culture involving regulators and contractors; systematic analysis of incidents to determine human factors and lessons; safety culture training activities; surveys to determine employee's attitudes and adequacy of resources allocated to promote safety culture.
  
  - Weakening safety culture. A list of symptoms from both organization's and regulator's perspective is suggested in Ref [7]. The symptoms are related to a model which considers stages of organizational decline, each of increasing severe consequence. For some of the symptoms it may be possible to develop indicators. Examples are: procedures not properly served; incidents not analysed in-depth and lessons not learned; increasing number of violations; increasing backlog of corrections actions; and failure to deal with findings of external safety reviews.