How to Design Effective EH&S Management Systems for Continual Improvement of Risk Reduction Performance

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Introduction

Organizations continuously face the challenge of improving performance within the constraints of economics, technology, regulations and organizational issues. At the same time, responsible organizations recognize the need to manage their risks. The aim of such risk management is to safeguard public and occupational safety and health, and to protect the environment and other property. To this end, we employ formal environmental, health and safety (EH&S) management systems to proactively identify hazards, and evaluate and control the risks associated with work activities and resources, as well as those risks associated with products and services. Ultimately, comprehensive EH&S management systems represent an holistic approach to preventing the occurrence, or minimizing the consequences, of incidents involving the accidental release of, or exposure to, hazardous forms of energy that could cause losses to people, property or the environment.

The Need for Management System Design

Why should we bother with a formal design process when developing a EH&S management system? Simply, because there is evidence of a need that's been demonstrated throughout industry repeatedly during audits and incident investigations, where deficiencies were found that have, or could have, resulted in an incident. That is, management system failures, or inadequacies, are often the root causes of process deficiencies leading to hazards and their realization as incidents. Further analysis shows that such inadequacies also result in inefficiencies and poor cost performance of the management system.

The author's personal experience with audits and incident investigations from a wide spectrum of industries and processes, has revealed both successes and shortcomings of various EH&S management systems. The degree to which such management systems have been established and implemented ranges between having no system in place to implementation of best industry practices for continual improvement.

In most cases, EH&S management systems are partially developed and inconsistently implemented. Upon review of the audit or investigation findings, we commonly observe the following causes for management system inadequacies or deficiencies:

- A lack of understanding of the intent of the requirements;
- A lack of appreciation that existing performance-based regulations and industry standards represent only a partial set of requirements for an effective EH&S management system.
- A practice of jumping into "doing" activities and "developing" documentation without designing a management system for proper implementation and control;
- Managing the EH&S efforts for each element autonomously, without coordination or integration with other elements;

Each of the above situations can be remedied through a better understanding and application of a design process for the management system. In the past decade or so, we have seen proactive organizations which have begun to take a less reactive approach to controlling quality, and are now focusing on designing or "building in" quality from the beginning, i.e. before the product is produced. This applies not only to products, but also to the design of management systems which are responsible for ensuring the product's performance.

To accomplish our EH&S performance objectives, we need a well-designed EH&S management system to plan, organize, implement and control the quality of all the necessary activities and resources of the industrial process. The key to the effectiveness of an EH&S management system is its ***design***. All too often, we give little or no attention to designing an EH&S management system before we spend valuable resources on its development and implementation. It is not surprising then that incidents continue to occur primarily as the result of failures attributed to inadequately designed management systems.

Unless an EH&S management system is properly designed, we can have no assurance that EH&S performance objectives will be met. Proper design addresses the requirements for and interrelationships of all work activities and resources required to accomplish desired performance objectives. Once implemented, a well-designed EH&S management system provides the mechanism for measuring and continually improving risk reduction performance.

Processes

Process and System Approaches

During the past few decades, the world has experienced a dramatic shift in the way business is managed. Advances in quality management principles and their application have risen to the challenge of meeting the demands for global competition. Quality management standards have built upon the practical application of engineering systems principles to business management, begun during the early space and computer ages of the 1960s, 1970s, and 1980s. In his "Fourteen Points", Dr. W. Edwards Deming pointed out that it is management's responsibility to work continually on improving every process in both the engineering system and the management system [MacDonald].

Eight total quality management principles are described in the recently revised ISO 9000 family of standards [ISO 9000]:

1. Customer focus
2. Leadership
3. Involvement of people

4. Process approach
5. System approach to management
6. Continual improvement
7. Factual approach to decision making
8. Mutually beneficial supplier relationships

Although each of these have application to EH&S management systems, we will focus on the following two for this paper [ISO 9000]:

- Process Approach – A desired result is achieved more efficiently when activities and related resources are managed as a process.
- System Approach to Management – Identifying, understanding and managing interrelated processes as a system contributes to the organization's effectiveness and efficiency in achieving its objectives.

The following three terms will also help us in our discussions of management system design [ISO 9000]:

- process - set of interrelated or interacting activities which transforms input into output.
  note 1: inputs to a process are generally outputs of other processes.
  note 2: processes in an organization are generally planned and carried out under controlled conditions to add value.
- system - set of interrelated or interfacing elements.
- management system - system to establish policy and objectives and to achieve those objectives.

The process approach requires an organization to identify, implement, manage and continually improve the effectiveness of the processes that are necessary for the management system, and to manage the interactions of these processes in order to achieve the organization's objectives. This includes process activities for planning, allocation of resources, management review, product design and development, monitoring, training, maintenance, etc.

Recent guidelines, specifications and international standards have applied the same process/ system approach to management systems for both occupational health and safety (OH&S) and environmental:

- OSH management system - a set of interrelated or interacting elements to establish OSH policy and objectives, and to achieve those objectives [ILO/OSH 2001].
- OH&S management system - part of the overall management system that facilitates the management of the OH&S risks associated with the business of the organization. This includes the organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the organization's OH&S policy [BSI/OHSAS 18001].
- environmental management system - part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy [ISO 14001].

Implicit in the process/system approach for quality and EH&S management systems is the concept of the "Plan-Do-Check-Act" (PDCA) cycle for continual improvement, popularized by Deming. The four PDCA steps include:

- Plan - establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies;
- Do - implement the processes;
- Check - monitor and measure processes and product against policies, objectives and requirements for the product and report the results;
- Act - take actions to continually improve process performance.

The PDCA cycle can be applied at a high level of the management system for strategic processes, as well as at deeper levels of each individual process and their components. We'll look at these PDCA cycles later, where we'll see that designing a management system is actually the process of identifying and understanding how all the processes interrelate and how they interface with all levels of the organization.

The Generic Process

Returning to quality management terminology, a *process* is a set of interrelated resources and activities which transform inputs into outputs (see Exhibit 1). From this definition, all value-adding processes can be described, although some processes may involve a transaction or transportation rather than a transformation. Any industrial process, business process, or management process involves defined work activities which utilize resources to produce an output or result, whether as a product or service, external or internal to the organization.

Work activities in the process include: *managing* the work, *performing* the work, and *verifying* the work. Resources in the process include: *human* resources (including employees, contractors, suppliers), *information* resources (information/data, methodology, technology); and *physical* resources (facilities, equipment, materials, energy).

Industrial Processes

For much of industry, the concept of the process is the core business, with outputs in the form of processed materials or products. Some industrial processes involve traditional manufacturing (e.g. engineered systems, equipment), while others may include the production and processing of natural resources (e.g. oil and gas). For example, in the chemical process industry, we refer to various unit operations as *the process*. Typically, process inputs as raw materials are transformed or processed into finished products, or chemicals. The resources include: process operators, process technology and process equipment based on a process design, process information and data for process control, and so on. The general activities included in the chemical process are broadly described by the U.S. Occupational Safety and Health Administration's definition of *process* in its Process Safety Management Standard: "any activity involving a highly hazardous chemical including any use, storage, manufacturing, handling, or the on-site movement of such chemicals, or combination of these activities" [OSHA]. In addition, various auxiliary processes are required to support the chemical process. These typically include: quality assurance, inspection and testing, maintenance, and technical services.

We've learned from experience that the sources of risks in an industrial process include not only the hazards from inputs and outputs, as raw materials and products, but also the hazards associated with many of the resources and work activities within the process [Jones]. To manage the risks of the process, we must manage the risks associated with each resource and activity. Managing these risks becomes a matter of managing the quality of these resources and work activities [Jones]. Thus, we see the need for *management processes* to support the industrial process in order to achieve EH&S performance objectives for risk reduction.

Management Processes

Like any other process, the *management process* involves the transformation of inputs into outputs, using a set of interrelated resources and activities. Here, the work activities include the four fundamental management functions of planning, organizing, implementing and controlling. The resources required depend on the type of process, but typically include the same three categories previously discussed: human, information, physical. In most cases, some of these resources, such as management tools, management information, and management methods, are themselves products or services, which in turn are the output of other processes which generated them. While the development of some of these resources can be achieved through one-time projects, others are more critical and their quality deserve to be managed in a more formal manner and on a continual basis.

Next, we'll see that the *management system*, incorporating various interrelated management processes, is in fact a comprehensive and complex product itself (resulting from a design process), which must be properly designed and maintained in order to ensure its effective implementation.

MANAGEMENT SYSTEMS

Lets' describe what a *management system* is and what it is intended to do. Then we'll address the application of management systems to managing the EH&S risks to people, property and the environment.

Design Function

Borrowing from the definitions presented earlier, a management system can considered as an organized arrangement of the organizational structure, responsibilities, resources and activities comprising a complex set of interrelated management processes for developing, implementing, achieving, reviewing and maintaining the organization's policy in order to achieve certain performance objectives; whether for product quality, EH&S performance, or other business performance measures.

An organized arrangement implies *design* through a particular structure, pattern and order. Without an organized system for managing all of the resources and activities of an industrial process, its operation could not be carried out effectively, nor safely. Thus, a management system is intended to be used as a comprehensive management tool to assist in the planned execution of work through utilization of resources to achieve process objectives. Management systems should therefore be designed to set policy, to provide direction, to facilitate communication, to coordinate work activities, to serve as a depository for relevant documents and records, and to measure and control performance.

To this end, a developed management system itself must raise and answer the following questions for each individual management process: Who performs what activities with what resources? When or how often? Where? How? and Why? Documenting these answers results in an integrated set of policies, strategies, plans, programs, standards, specifications, procedures, work instructions, and other management system components, entities [Jones].

Key Design Features

Now let's turn our attention to managing the risks associated with the hazards of industrial processes. Formal EH&S management systems are employed to manage to a tolerable level, the risks associated with the hazards of each resource and work activity within a process, as well as the inputs and outputs (products) from the process. For example, the Center for Chemical Process Safety (CCPS) defines process safety management (PSM) as "the application of management systems to the identification, understanding, and control of process hazards to prevent process-related incidents and injuries" [CCPS]. Furthermore, "process safety management systems are comprehensive sets of policies, procedures, and practices *designed* [emphasis added] to ensure that barriers to episodic incidents are in place, in use, and effective" [CCPS].

What are some of the key design features of an effective EH&S management system? Well-designed EH&S management systems are characteristically: *holistic* in form; *integrated* in function; *formally documented* in content.

With stated requirements defined by various regulations and industry standards, EH&S management systems represent a *holistic* approach for preventing the occurrence, or minimizing the consequences, of incidents involving the accidental release of, or exposure to, hazardous forms of energy that cause losses to people, property or the environment. That is, they are comprehensive in addressing all the hazards (i.e. the sources of risks) and the means for controlling them, including the quality of resources and the work activities. Unfortunately, the requirements stated by performance-based regulations and standards do not provide answers to all the questions needed to define and document the design for such management systems. Therefore, before such EH&S management systems can be effectively implemented, all of the stated and implied requirements for must be defined and incorporated into the management system as a design objective.

Another feature is that management system elements should be *integrated*. That is, each management process in some way interrelates to others. Even if the work is carried out autonomously in a particular process, it will undoubtedly have the potential to impact other processes. Thus, properly integrating these processes is another design objective.

Finally, as previously discussed, a well-design management system is most often *formally documented*. That is, the format, function, and control of policies, procedures, and work instructions tend to be more standardized and are more often based on sound quality management principles (e.g. ISO 9001). For this reason, many organizations have seen the benefits of integrating their management systems for quality and EH&S.

Key Design Elements

Previous in-depth analysis of EH&S management systems shows that comprehensive performance-based standards address the following key elements [Jones]:

- Resources of the industrial process (e.g. training of personnel, development of process information);
- Activities of the process (e.g. operation of equipment, maintenance of equipment);
- Risk management activities (e.g. hazard identification, emergency response, incident investigation);
- EH&S management system support activities (e.g. management of change, auditing).

More recently, the International Labor Organization (ILO) has published its Guidelines on Occupational Safety and Health Management Systems (ILO-OSH 2001) based on identifying common key elements from an extensive review of several existing international guidance documents for the establishment and implementation of effective occupational safety and health management systems [ILO/OSH 2001].

Using the Deming PDCA cycle model, a comparison of the key elements for selected EH&S management system models is presented in Table 1. How these elements are organized and the terms used for such elements differs slightly between models. Combining the best of several industry models, we have chosen a hybrid model for this paper.

Cycle Step	ILO-OSH 2001	OHSAS 18001	ISO 14001	Hybrid Model
Plan	Policy, Organizing	OH&S Policy, Planning	Environmental Planning	Planning & Organizing
Do	Planning & Implementation	Implementation & Operation	Implementation & Operation	Implementing & Performing
Check	Evaluation	Checking & Corrective Action	Checking & Corrective Action	Measuring & Evaluating
Act	Action for Improvement	Management Review	Management Review	Reviewing & Improving

Table 1. Key elements for selected EH&S management system models are compared.

At a high level, the four key elements are processes of the PDCA cycle, each having their own products, or results, that are interrelated; namely: plans for improvement, changes to processes, performance results, and actions for further change (see Exhibit 2). Within each of these four key processes of the PDCA cycle lies another set of PDCA processes for managing EH&S performance, as we will address in a later section.

Design Basis

What is the basis then for the quality design of EH&S management systems? While several standards, as well as some regulations, define certain requirements for EH&S management system activities and components, they do not give detailed specifications for their design, leaving organizations to determine how best to meet such requirements.

For example, OHSAS 18001 states that it "…gives requirements for an occupational health and safety (OH&S) management system…" but goes to say that it "…does not state specific

OH&S performance criteria, nor does it give detailed specifications for the design of a management system" [BSI/OHSAS 18001]. At a more detailed level, OHSAS 18002 does "… describe the intent, typical inputs, processes and typical outputs, against each requirement of OHSAS 18001 [BSI/OHSAS 18002].

This is understandable, since organizations and their needs vary widely, and there is can be no "one-model-fits-all" approach. Therefore, to assist EH&S professionals in this effort, a methodology is presented below to describe the process for planning and developing the design of an EH&S management system.

DESIGN PROCESS

Referring again to the process/system approach, the proposed design methodology addresses identifying customers (i.e. all stakeholders) and their stated and implied needs, and translating these needs into a set of requirements for developing the management system as a work product in its own right.

Life Cycle Concept

As previously discussed, every industrial process is comprised of various components or entities, as inputs, outputs, resources and activities. Examples include: people, products, programs, plans, systems, reports, records, information, materials, equipment. Each of these have certain quality characteristics and to some degree each contributes to the total risk of operating the industrial process. In most cases, these entities have their own life cycle, during which their quality may vary, thereby contributing to more or less risk. During its life cycle, an entity may progress through some, if not all, of the following phases: conception, design, development, implementation (operation), maintenance, and demise. Proactively managing the quality of these entities, especially as process resources, throughout their life cycles allows us to either eliminate or minimize risks entering into or created within the process [Jones].

Supporting the industrial process are all the management processes that comprise the EH&S management system. The EH&S management system as a quality product has its own life cycle that follows the PDCA model in ISO 9001:

- Plan - Resource Management
- Do - Product Realization
- Check - Measurement, Analysis and Improvement
- Act - Management Responsibility

In this paper, we will focus on the design and development aspects of the product realization process for the EH&S management system.

Design Benefits

Now let's turn our attention to some of the specific benefits of carrying out the design function. A properly designed management system provides a documented:

- Basis for ensuring that performance objectives are translated into a set of requirements, or a design specification.

- Reference for critically reviewing the design of the management system (e.g. functionality, compliance, effectiveness). Such verification and validation reviews can be carried out during various phases of the management system's life cycle: before it is developed, after it is developed, and once it has been implemented.
- Means for communicating and training for understanding answers to the questions of who, what, when or how often, where, and why, during its implementation.
- Mechanism for controlling changes to the management system itself, either as a result of corrective action resulting from management system failures, or from continually improving its effectiveness as a preventive means. As changes occur (e.g. in objectives, regulatory or other requirements, methodologies, technologies, organization, equipment), the management system must adapt to the changes in a controlled manner.
- Template for future management systems in other locations or applications.

A well-designed management system provides a documented record of knowledge and experience for continual reference. With this background, let's proceed with how to develop the design of a management system.

Design Approach

What is interesting to note is that *designing* is actually a process itself. Let's walk through the steps of designing a management system:

1. Identify Output - what do I produce?
2. Identify Customers - for whom do I produce it?
3. Identify Customer Requirements - what are the requirements: needs, wants, expectations?
4. Translate Requirements into Specifications - what do the requirements mean to me?
5. Identify Steps in Process - how will I make it?
6. Select Measurements - how will I know I am succeeding?
7. Determine Process Capability - will this work process enable me to produce an output that fulfills requirements?
8. Evaluate Results - are changes required in the process and where are additional opportunities for quality improvement?
9. Recycle - how could this output be produced more efficiently?

To demonstrate the application of this design process to EH&S management systems, let's use the some of the requirements of OHSAS 18001 as a basis.

Step 1 - Identify Output

Ultimately, the EH&S management system can be considered a product. Practically, it is made up of various processes, each of which are work products to be integrated into the overall system. Therefore, the design task is both to design individual work processes, then integrate them into an overall system through their inputs and outputs.

Returning again to the PDCA cycle of Exhibit 2, we can see that managing EH&S risks at a high level involves managing process changes to continually improve EH&S performance. In fact, this PDCA cycle has three dimensions, since we typically focus on EH&S performance at three critical stages of incidents. First, we manage EH&S performance *before* incidents occur using a hazard identification and risk assessment process in order to prevent incidents. Second,

we manage EH&S performance *during* incidents using an emergency response process with the objective of minimizing the consequences of the event. Third, we manage EH&S performance *after* incidents using an incident investigation process to prevent recurrence. Thus, hazards and risks, emergencies, and incidents are three key entities (or process outputs) that we must manage through three life cycle processes within the EH&S management system.

The PDCA cycle represents the continual improvement life cycle for any entity. Let's look at the *design intents* for each of the four processes within the PDCA cycle. Depending on the nature of the entity, the process activities may take on different terms that are familiar to EH&S practitioners.

- Plan - Realization (of entity) - to study and understand changes needed to improve any entity, then to develop plans and organize resources and activities to carry out actions involving such changes for improving the quality of processes, and hence performance results. Typical work activities may include the terms: allocating, acquiring, defining, developing, encouraging, establishing, gaining, identifying, planning, preparing, selecting, etc.
- Do - Utilization (of entity) - to implement plans for carrying out process improvement changes by utilizing the plans (or other entities) and organized resources and activities. Typical work activities may include the terms: accessing, controlling, demonstrating, deploying, effecting, employing, implementing, investigating, obtaining, responding to, utilizing, etc.
- Check - Evaluation (of entity) - to measure the effects of process changes on performance results, and to evaluate these results against defined criteria (e.g. policy, objectives, plans). Typical work activities may include the terms: analyzing, assessing, evaluating, measuring, monitoring, verifying, validating, etc.
- Act - Improvement (of entity) - to review performance results and determine the corrective and preventive actions (e.g. adopt, alter, or abort plans) involving changes to improve processes and hence performance results. Typical work activities may include the terms: reviewing, improving, etc.

From OHSAS 18001, ISO 14001, ILO-OSH 2001, and similar standards and guidelines, we see a myriad of additional process entities (i.e. inputs, outputs, resources and activities) involved in managing EH&S performance. Typical EH&S entities include: management commitment, employee participation, hazards, risks, emergencies, incidents, plans, changes, performance results, corrective and preventive actions, policies, objectives, legal and other requirements, organizational structure, documents, programs, procedures, work instructions, communications, information, data, reports, records, methodologies, technologies, facilities, equipment, materials, energy, etc. In all cases, the aim of the EH&S management system is to manage the quality improvement of the various entities by identifying and correcting associated nonconformities.

Let's look at the three higher level PDCA life cycles mentioned earlier for managing EH&S performance before, during and after an incident:

- Managing EH&S Hazards and Risks (see Exhibit 3);
- Managing EH&S Emergencies (see Exhibit 4);
- Managing EH&S Incidents (see Exhibit 5).

In each of these life cycles, we see the same design structure and logical order of the four PDCA processes (with inputs and outputs) for the entity: realization, utilization, evaluation and improvement. At the next level of detail, we can take each of these four processes and expand them to their own PDCA life cycles to manage specific process outputs (i.e. products or results).

For example, the "Do" Process (Implementing & Performing) for EH&S Emergencies (see Exhibit 4) addresses the process of "responding to EH&S emergencies", with the process input defined as "anticipated emergencies" and the process output defined as "managed EH&S emergencies". Associated with this one process are several specific entities that must be managed; for example: an emergency response plan, an emergency response team, emergency response equipment, etc. These are all familiar and through experience, we know that the key to an effective response capability is the quality of the emergency response plan, the availability of qualified emergency personnel, the reliability of emergency equipment, the effectiveness of emergency communications, etc.

Again, each of these entities must not only be identified during the design of the EH&S management system, but they themselves must be realized through some process and their quality requirements defined and managed. To achieve the quality required, we can apply the same quality management principles of the PDCA cycle for each and every entity.

Let's take the emergency response plan for example. This entity, or work product, must be developed before it can be utilized, or put into effect for real (or simulated) emergencies. Examining the "Plan" step above for "realization", we see that the emergency response plan requires a certain amount of planning (e.g. what types of emergencies are anticipated? what regulatory requirements exist?); organizing (e.g. who's responsible for developing the plan? who will approve the plan? when must the plan be completed?); developing (how will the plan be written? what will be the format for the plan?); checking (how will the plan be verified for accuracy? how will it be validated for use?).

At first glance, the various levels of PDCA cycles may appear to be complex. However, this approach provides a logical, orderly, and systematic design for how all the various entities, or components, of the EH&S management system fit together. Without such structure, the task of defining all interrelated processes and other entities would be (an in practice is typically) very cumbersome. The degree to which these nested PDCA cycles are utilized depends of course on the criticality of the entity involved. Clearly, the level of depth for a simple record (e.g. training attendance sheet) does not warrant the same attention to its quality management as does critical safety equipment (e.g. emergency shutdown system).

Therefore, the management system designer must apply judgment to the PDCA life cycle methodology. Nevertheless, as a design tool for understanding how one goes about creating an EH&S management system, the PDCA approach to defining the interrelationships of processes and managing its entities has proven to be a valid best industry practice.

Keep in mind that whether or not you accept the formal PDCA approach as a design methodology, each of the hundreds of entities or work products (e.g. emergency response plan) still have a life cycle; and that life cycle must somehow be managed if we intend to attain, maintain, and improve on EH&S performance results.

The remainder of the steps in the design process are addressed for completeness, but in less detail, since the primary focus of this paper is on the first step – Identify Output.

Step 2 - Identify Customers

Next, we need to determine who the customer is for each of the products (or services) that are derived from the various EH&S management system processes. In a broader sense, we need to determine who all the stakeholders are. They may include: the organization's customers, employees, subcontractors and suppliers, as well government authorities, and the public. Determining the stakeholders will depend on several factors affecting the scope of the EH&S management system; in particular, the extent to which the organization's hazards may pose risks to such stakeholders.

Typically, each of the EH&S products and services has an ultimate customer, who establishes the requirements. Most often, this is the organization's management, a customer, or a regulator. Then, there is the end user of the product or service. These may be operators or maintenance personnel (who must use procedures and safe work practices), managers or supervisors (who must act on recommendations), contractors (who must adhere to safe work practices), and other departments such as purchasing, receiving, warehousing (who must follow quality assurance procedures for equipment, spare parts, materials).

From OHSAS 18001/18002, we can see some of the customers who either establish requirements, or will use the products. For example, regulators and management may be the ultimate customers for developing emergency response plans, while emergency responders are the und users of these plans. Some of the elements, such as "Legal and Other Requirements", has multiple end users, since this information is to be used as an information source for various EH&S activities.

Step 3 - Identify Customer Requirements

As mentioned above, we are trying to meet the needs of two types of customers: the ultimate customer who is placing requirements on the product or service, and the end user who must use the product to meet specific EH&S objectives.

Before we examine some of these requirements, let's consider two types of requirements:

- *Stated requirements* are explicitly written and address either the requirement for a particular product, or they address one or more of the following questions: Who? What? When or how often? Where? How? and Why? An example would be the requirement to develop written operating procedures that address safe work practices such as confined space entry. In this case, the requirements address both the product itself and specific content.
- *Implied requirements* are derived from the need implied by a stated requirement. For example, the stated requirement to provide operator training implies the need for some type of training program or process that may utilize training instructors, training materials, and training facilities. These implied requirements are in fact representative of performance-based regulations and industry standards. That is, while they state, for example, that training must be provided, they do not state how to accomplish it, either in terms of the resources or the activities.

Another example of an implied requirement is that which addresses commonly accepted quality characteristics such as: correctness, timeliness, suitability, etc. Because such requirements are often implied, they are not always recognized or acknowledged as being part of the design of a management system. In fact, because many requirements are implied, they are often overlooked or neglected; or often ignored because to some they appear to be obvious, or to others they appear to go "beyond" the minimum stated requirements. However, we must recognize that requirements from such performance-based regulations or standards are not intended to be prescriptive. Nevertheless, to fulfill the stated requirements (and to achieve the overall intent or desired performance result once the management system is implemented), implied requirements must be identified up front and translated into part of the design specification.

Now let's examine some of the requirements for both the ultimate customer and the end user. For hazard identification, various regulations and standards state that all hazards are to be identified, evaluated and controlled. As for implicit requirements, we know that we must somehow manage other resources for this process, such as the human resources for performing the analysis. Who should perform these, and what qualifications should they have in order to perform the work in a competent manner? Answers to the above questions are themselves requirements that must be determined and built into the design of the EH&S management system.

In other cases, implicit requirements are derived from wording such as "assure that … is suitable …". Assurance (of suitability) however is not a product or a tangible service; it is a quality characteristic. Yet what is implied is that some activity must be performed "in order that assurance is achieved". This implied activity then is some form of verification (whether a review, inspection, test or audit) so that the suitability can be verified. Thus, we've shown that another example of where a regulation or a standard may not stipulate that you even have to perform an activity, let alone specify how to perform it. But what is clearly a stated requirement is that all of the procedures and practices developed under the standard (stated and implied) are adequate and are being followed. That is, they must be developed and effectively implemented. Their adequacy can only be achieved through proper design (including defining all requirements) and determining what else (implied) must also be developed or accomplished for implementation.

This leads us into the next step, which is to translate these needs and requirements into specifications for all the management system components or entities (i.e. the processes, products and services, and their associated resources and activities).

Step 4 - Translate Requirements into Specifications

Requirements address stated and implied needs for a product (e.g. audit report); a process, program or system (e.g. management of change); resources (e.g. personnel, information, equipment); or activity (e.g. training). Each requirement can be used to specify key quality characteristics and performance criteria, as part of documented specifications for policies, procedures, and work instructions.

Step 5 - Identify Steps in Work Process

By mapping out how the processes interrelate and how their work products interface, we establish a work flow at a system level. The design for the system can be expressed as a flowchart or matrix. Further, steps within each work process should be defined and documented in procedures and more detailed work instructions.

Step 6 - Select Measurements

Certain processes and their products, resources or activities, have certain requirements placed on them that require measurement and monitoring of quality characteristics and performance. For example, certifications of critical equipment, EH&S performance targets, and qualifications of personnel all have criteria that must be established to determine a variety of quality measures (e.g. effectiveness, timeliness, compliance, competence, technical integrity). Each of these criterion affect EH&S performance and must be defined within the specifications.

Step 7 - Determine Process Capability

Having defined the management processes and all the requirements for each component or entity, the capability of the process must be determined. For example, given the design of the auditing process, an organization must determine whether it is capable of fulfilling its expectations in terms of qualified personnel, frequency of audits, or workload from the findings of the audits. If not, resource allocation becomes an important consideration. Then too, awareness, training and competence of personnel must be considered to make a process function. Each of these considerations in turn should have their own processes defined so that the overall system will operate effectively. At any point in the management system, inadequacy of a single process may degrade the whole EH&S risk management system, possibly resulting in an incident.

Step 8 - Evaluate Results

Measuring results of each individual management process is key to achieving overall effectiveness of the management system and therefore achievement of EH&S performance objectives. Much has been written about using proactive measures or leading indicators, rather than relying on reactive measures and lagging indicators. Processes to measure, monitor and evaluate the quality of entities and all aspects of performance using defined criteria must be designed into the management system itself to ensure their success and continual improvement.

Step 9 - Recycle

Once you have defined all the requirements and have a management system in place for fulfilling these requirements, then you are managing the quality of all entities – quality of the management system overall, quality of the inputs and outputs, quality of the resources and activities. And since you are managing the quality of all aspects of the EH&S management, you are actually managing EH&S performance, since controlling all hazards and their risks is a matter of controlling the quality of all processes that create the risks and those that control the risks. The use of the PDCA cycle model provides for a built-in recycle loop to continually improve through corrective and preventive actions.

SUMMARY

This paper has:

1. Discussed the concept of a process and demonstrated its broad use in industrial processes, and their supporting management processes;
2. Described what a management system is and what it is intended to do;
3. Explained the importance of the design process in developing a management system and the benefits of documenting the design;

4. Presented a management system design approach based on quality management principles of the "process approach" and Plan-Do-Check-Act life cycle for continual improvement;
5. Demonstrated the application of the design approach to EH&S management systems; and
6. Presented examples of the higher level designs for three key processes for managing EH&S performance, namely: hazard identification and risk assessment, emergency response, and incident investigation.

CONCLUSIONS

1. You can expect that performance-based regulations and standards will not to tell you how to do everything, because they are purposely intended to define "what" must be done, but not necessarily "how" it should be done.
2. You can expect to achieve your EH&S performance objectives (i.e. reducing risks) once you define, and then meet, the requirements for all resources and activities of all the interrelated processes within the EH&S management system.
3. You can define every entity of the EH&S management system that is produced or accomplished in terms of a process.
4. You can consider realization, utilization, evaluation and improvement as the processes for managing the continual improvement life cycles of all entities, where their output, product, or result is performance.
5. You can consider the EH&S management system as a product, in its own right, subject to quality management throughout its own life cycle. It must be designed, developed, implemented, maintained, and continually improved. Design is the key to an effective EH&S management system. A systematic approach, or design process, is required to ensure that stated and implied requirements are defined and satisfied. Conversely, inadequately designed management systems are subject to failures that will eventually lead to incidents.

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Illustrations

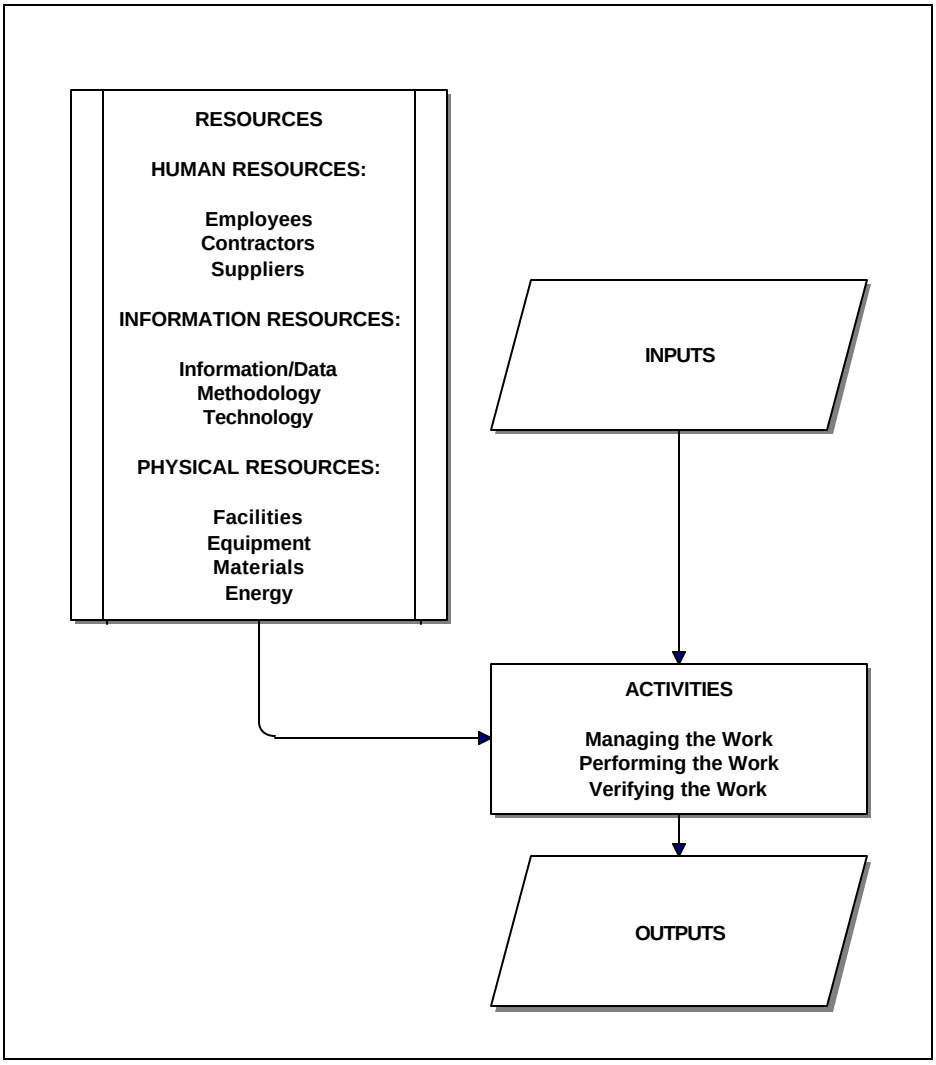

Exhibit 1. A process is a set of interrelated resources and activities which transforms inputs into outputs.

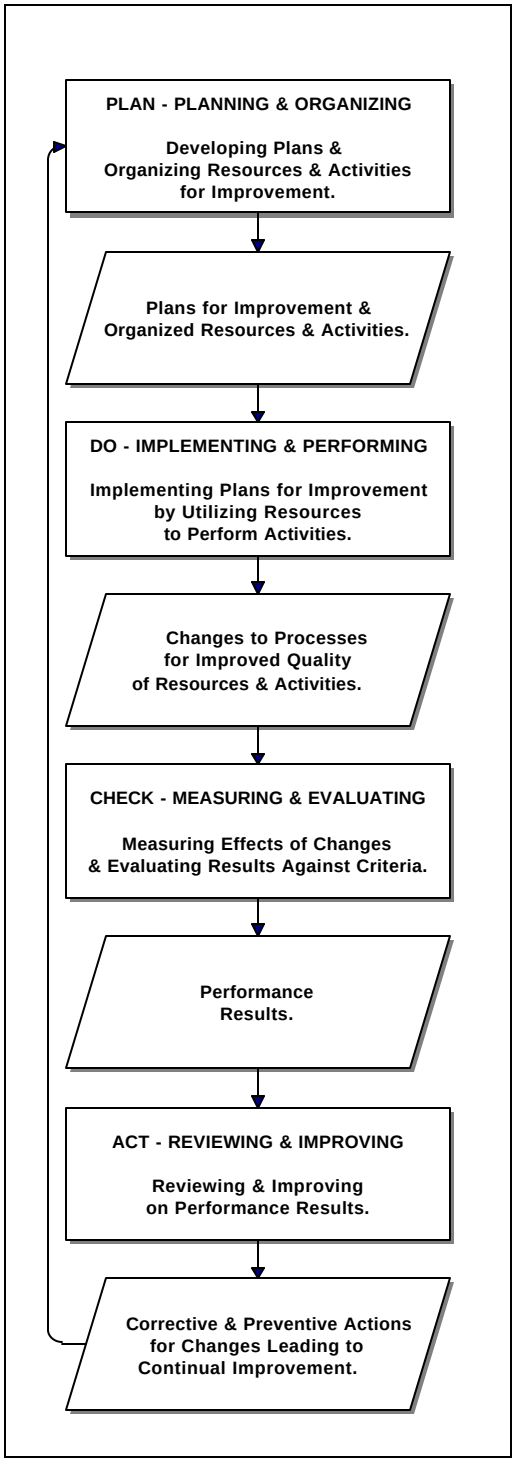

Exhibit 2. The Plan-Do-Check-Act life cycle includes four processes and their outputs.

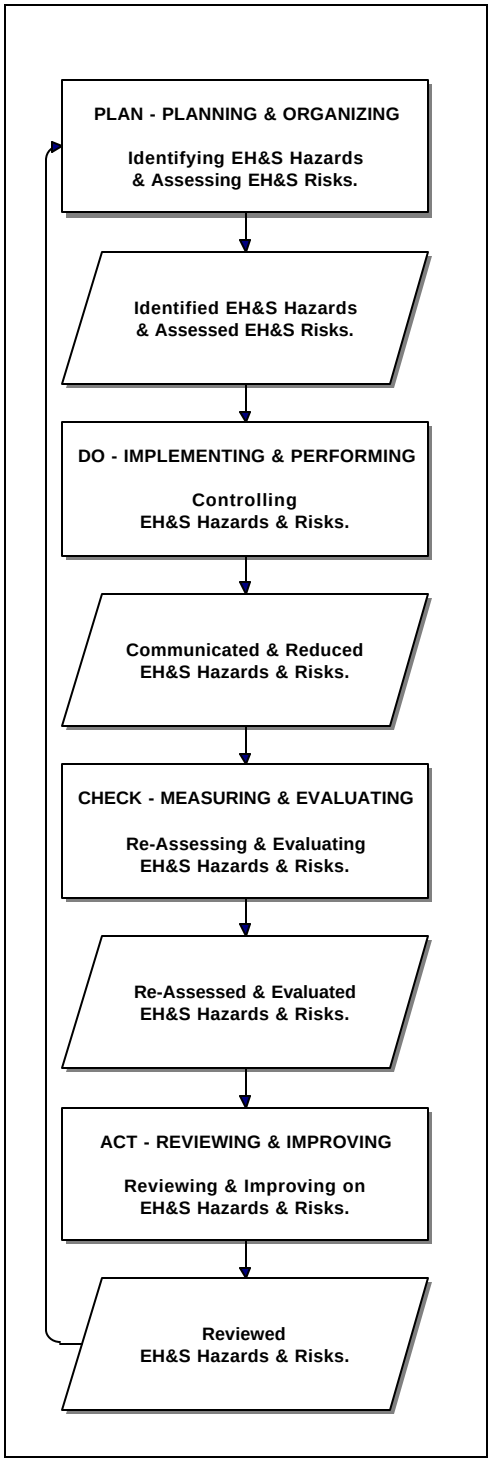

Exhibit 3. EH&S hazards and risks are identified and assessed *before* an incident.

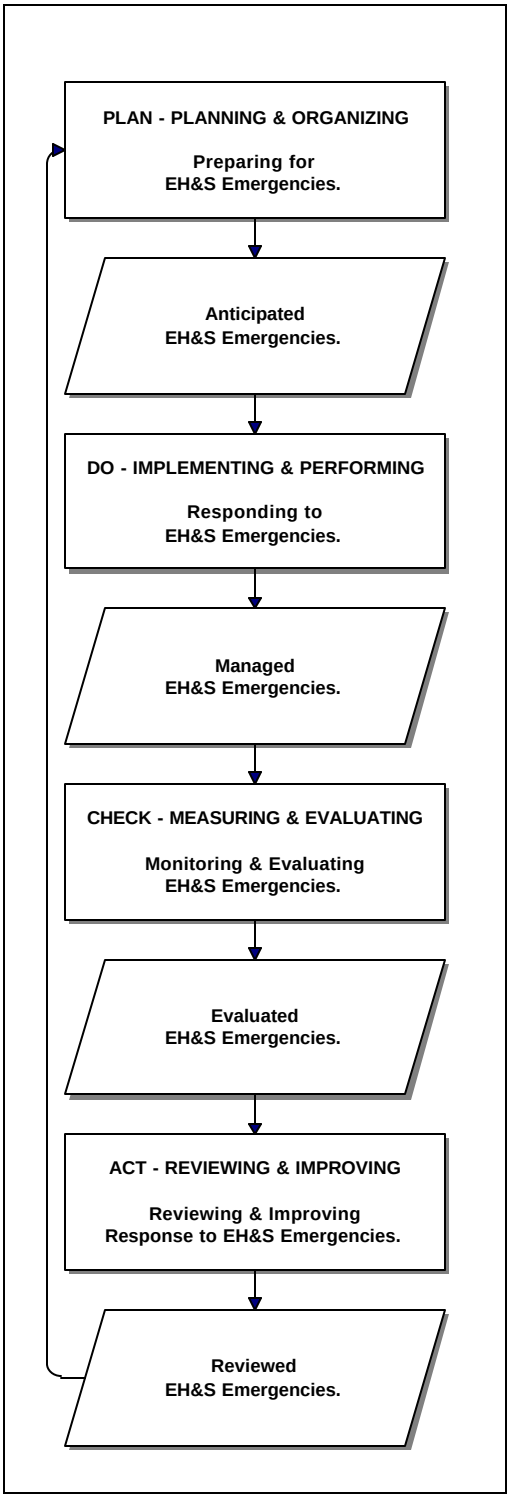

Exhibit 4. EH&S emergencies are responded to *during* an incident.

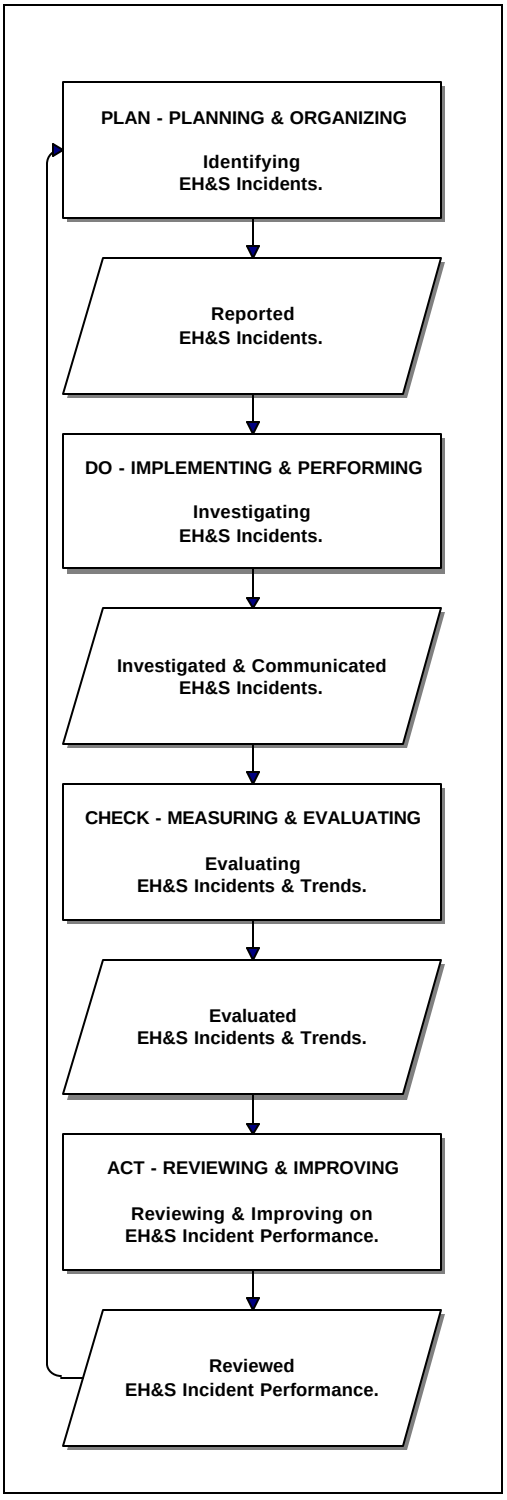

Exhibit 5. EH&S incidents are investigated *after* an incident.