8

Implementing an Integrated Error and Process Safety Management System at the Plant

8.1. INTRODUCTION

The purpose of this chapter is to set out in concrete terms the ways in which the techniques described in the previous sections can be implemented in the chemical process plant environment. The integration of error and process safety management systems is also described.

Three main opportunities for applying the techniques to minimize error and maximize performance can be identified:

Optimization

This is the situation where the company has decided to implement a specific program to reduce error. There are two main opportunities for optimization activities:

- During the design of a new process plant, in order to ensure that when the plant is operational its systems (hardware, procedures, training, etc.) will provide the maximum support for error-free operation
- Where it has been decided (possibly because of an unacceptable level of human error leading to safety and production problems) to implement a comprehensive error management program at an existing plant

Evaluation

This is a situation where a plant appears to be operating successfully, without a major human error problem. However, management are interested in assessing the systems in the plant from the point of view of minimizing the error potential. This type of exercise is particularly relevant for plants dealing with substances or processes with high hazard potential, for example, in terms of the toxicity and energy of the materials. In such plants, errors, although rare, may have severe consequences for individuals or the environment if they do occur. Management may therefore wish to evaluate or audit the factors that can directly affect error potential, and take appropriate action if these factors are found to be less than adequate.

The areas that may be considered as part of such an evaluation are the performance-influencing factors (PIFs) described in Chapter 3. The human factors assessment methodology (HFAM) method described in Chapter 2, provides a systematic framework for the evaluation process.

Problem Solving

Where a specific incident leading to safety, quality or production problems has occurred, the plant management may wish to perform a very focused intervention. This will be directed at identifying the direct and underlying causes of the problem, and developing an appropriate remedial strategy. The process for performing an analysis of this type is described in the incident analysis section of Chapter 6.

Risk Assessment

This application is similar to evaluation except that it may be performed as part of an overall qualitative or quantitative risk assessment. In the latter case, quantitative assessment techniques such as those described in Chapter 5 may be applied.

In subsequent sections the specific procedures for implementing a program to optimize human performance and minimize human error will be described.

8.2. MANAGING HUMAN ERROR BY DESIGN

The following sections describe a design process based on the CCPS approach to human factors in chemical process safety management, which addresses a wide variety of issues relevant to reducing error potential. Many of these issues can be considered both during the process of designing a new plant and also for an existing operation. The design process addresses both management level factors (e.g., objectives and goals) and also operational level factors (e.g., training and procedures).

The CCPS approach to chemical process safety management has been described in a number of documents:

- *A Challenge to Commitment* (CCPS, 1989a)
- *Guidelines for Technical Management of Chemical Process Safety* (CCPS, 1989c)
- *Plant Guidelines for Technical Management of Chemical Process Safety* (CCPS, 1992a)

- *Guidelines for Auditing Process Safety Management* (CCPS, 1993)
- *Guidelines for Investigating Chemical Process Incidents* (CCPS, 1992d)

These publications contain information on twelve key elements of chemical process safety management. In this section, seven of those elements that can be significantly impacted by paying careful attention to human factors principles are addressed. These are:

- Accountability, Objectives, and Goals
- Capital Project Review and Design Procedures
- Process Risk Management
- Management of Change
- Process and Equipment Integrity
- Training and Performance
- Incident Investigation

8.2.1. Accountability, Objectives, and Goals

Accountability is the obligation to answer for one's performance with respect to expectations, goals, and objectives. It is an important element of an effective process safety management system. To improve safety, the risk associated with human errors must be reduced. The work situation is the predominant cause of human errors and management has control over the work situation.

For reduction of human errors to be a top priority, management must convey this priority throughout the organization by administering policies that

- Demonstrate commitment
- Establish a blame-free atmosphere
- Provide resources
- Promote understanding
- Eliminate error-likely situations

Demonstrate Commitment

The likelihood of success of any endeavor is largely dependent on the commitment to that success. This is especially true with improving process safety and reducing human errors. That commitment must start at the very top and flow strongly through all levels of the organization.

Establish a Blame-free Atmosphere

The people most knowledgeable about a particular task are the people who perform it every day. Their help is essential for reducing the associated risks. Continuous feedback from the worker will provide the framework for improvements to the job. This feedback can only be fostered in an atmosphere of trust. If an incident occurs in which human error is a suspected cause, management response is critical. If management realizes that it is really the work situation that is at fault and that eventually a similar incident would have occurred no matter who the worker was, then a blame-free atmosphere exists. If instead, management lashes out and seeks to blame individuals for the incident, then trust will vanish. In such a negative environment, meaningful communication cannot take place.

Provide Resources

It is readily acknowledged that resources such as manpower, equipment, and training are generally provided by management. What may not be recognized is that a human factors science exists which is capable of improving the power of these resources. Managers need to make use of this science by incorporating human factors expertise into their organizations to improve their process design, operation, and maintenance.

Promote Understanding

Promoting understanding throughout the organization is an essential part of management's human error communication. By having persons in the organization well versed in human factors principles, management can greatly enhance the understanding of these principles by everyone in the organization. This allows incorporation of these ideas into all aspects of process design, operation, and maintenance.

Eliminate Error-Likely Situations

The final element in management's communication of a desire to reduce human error is the identification and elimination of error-likely situations. Every task is an opportunity for a human error, but some situations represent greater risks than others. Identifying these high-risk situations is not easy and an expertise in applying human factors principles to the workplace is an essential prerequisite for this identification. Eliminating these hazardous situations is often relatively simple once they have been identified. In some cases it may be appropriate to provide error-tolerant systems, which are those that facilitate identification of and recovery from the errors.

8.2.2. Process Safety Review Procedures for Capital Projects

The "Capital Projects Design Review Procedures" element of process safety management assures that the design, the equipment and the construction are properly reviewed for all new projects. Process safety review procedures should be involved with the project from its inception. One method of illustrating the various phases of a project is shown in Figure 8.1 (Figure 5-1 from CCPS, 1989a).

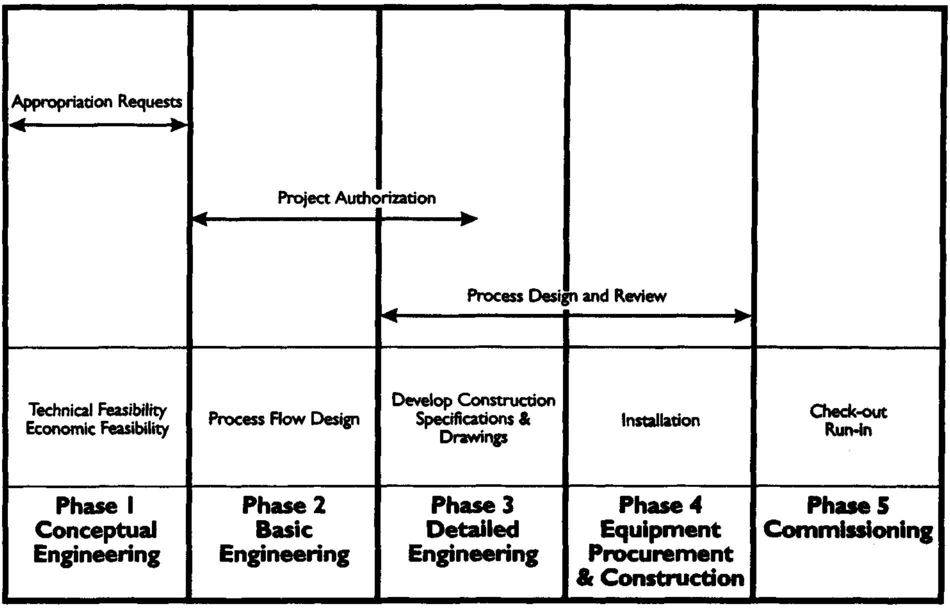

FIGURE 8.1. **The Phases of a Capital Project.**

While this process implies an ordered, structured process, it should be noted that the various stages overlap and it is frequently necessary to return to an earlier step in the process to modify or clarify information or decisions made in an earlier phase. The influence of the human factors aspects on design needs to be similarly integrated into the process design procedure. The particular human factors elements to be addressed at each phase are discussed below. These phases can be directly related to the human factors engineering and ergonomics (HFE/E) design approach described in Section 2.2.

Phase I—Conceptual Engineering

During this phase the objectives of the system as well as the system performance specifications are identified. In addition, the technical and economic feasibility of the project is evaluated.

Human factors considerations include determining the characteristics of the population in the area where the facility will draw its labor force. Factors such as educational levels, languages, norms, and environmental conditions should be considered because they can have a significant impact on later stages of the design process.

Phase II—Basic Engineering

This phase is where the basic design work, such as process flow design, is performed. Piping and instrumentation diagrams (P&IDs) and equipment data sheets used for design are some of the products of this phase. The human factors issues include the allocation of functions between human and machine, what is best to automate and let a machine (computer) perform and what should be assigned to the human. This process needs to be given considerable thought and effort, and should include normal as well as unusual plant conditions. The strategy of simply automating what can easily and cheaply be automated and relegating the remainder to the human should be avoided. The intent should be to maximize system performance by the logical and proper distribution of functions.

Knowing what functions or tasks are to be performed by humans permits the development of initial staffing strategies. Consideration should also be given to work load. It is also necessary to begin to examine the information and response requirements needed to operate the system.

The system requirements will influence such human factors issues as

- Personnel skill requirements
- Physical demands placed on the operator (e.g., temperature, noise, vibration)
- Mental demands (e.g., the number and complexity of demands and the response time for decision making)

Since most systems are based on existing systems it is wise to begin to evaluate the existing systems to gain insight into potential problems and improvement opportunities. While these insights can be gained through observations, interviews or questionnaires, the most effective method is the participation of operators, mechanics, engineers, and supervisors on design review teams. This is an excellent technique to get the user involved in the design process and to tap into the resources that will not only identify potential problem areas but often will provide good methods for determining cost effective ways to address these problems. Those participating also develop a sense of ownership with the design and become stake holders in the process. They also develop a good basic understanding of the system and how it works before they receive formal training on its operation and maintenance.

Phase III—Detailed Engineering

In this phase the specifications and drawings for construction are being developed and issued. Attention should be given to human–machine and human–computer interface which includes such issues as software design, general work space design, controls, displays (including computer displays), communication and information requirements, maintainability, labeling, and handling tasks. The intent should be to incorporate good human factors principles into the design in an effort to eliminate error-likely or accident prone situations. Once again reviewing past incidents may prove to be beneficial at identifying areas to address. It may be appropriate to analyze specific human interface designs utilizing mock-ups or other simulations. The application of information from reference guidelines, mock-ups and simulations should be used to assist in the development of the detailed design. Depending on the performance results, it may be necessary to alter the allocation of the function or task.

Phase IV—Equipment Procurement and Installation

This phase involves the purchasing of fabricated and bulk materials and installations on site. As equipment is fabricated it is necessary to review its design to ensure that the design has not been modified and to detect any unforeseen problems that might negatively impact human and therefore system performance. Further evaluations and testing may be necessary on simulators. Planning should begin for preparing operating procedures and training manuals and devices (see Section 8.2.5). The need for additional performance aids such as computer-assisted decision making tools should be considered. The implications of the layout of plant equipment such as valves and pumps should be reviewed from a human factors standpoint to ensure that issues such as accessibility are addressed.

Quality of installation and the adherence to design specifications of the equipment should be evaluated to ensure that errors during shipping and installation were not made. Often overlooked at this phase are human factors considerations for the construction crew, such as selection of the contractor, training of the crew, lighting, shift work, procedures, and supervision.

Phase V—Commissioning

This phase involves the performance of check-out and run-in activities to ensure that equipment and piping are mechanically integrated, functionally located and free of obstructions It is also necessary to ensure that instruments and controls are functioning properly and that all previously identified problems have been addressed. All maintenance and operating procedures need to be verified as correct.

The impact of the system design on human performance should be examined during this phase. The designer should consider whether or not the operator will be able to keep the system operating correctly under normal conditions and is he or she able to effectively handle unusual conditions, returning them to normal operating conditions. Observation of personnel and discussions with them are effective ways that should be employed in this phase. Where necessary, appropriate modifications should be made to the system to ensure proper performance.

8.2.3. Process Risk Management

Hazard identification is the first step in process risk management. In order for this procedure to be adequately utilized, the hazard identification team must know what to look for. This requires that participants be trained in the capabilities of people. This training should include biomechanical information for tasks such as lifting; display and control design factors such as colors, directions, and order; and man–machine interface issues such as feedback skill level, complexity, and environment. Operating Input from operating personnel through a blame-free culture must be sought for effective hazard identification. The operators must be encouraged to point out problems that have occurred. Upon raising the human factors issues, the recommendations for change must be addressed by the design engineer.

Management must modify the culture and develop human factors awareness in the hazard identification teams so that they will be capable of identifying the potential for human error. A good practice is to involve operators in the hazard identification team.

In order to do a risk analysis properly, the analyst must understand human capabilities, including the capability to recover from errors. Human error data may be available from generic sources or from in-plant studies done previously.

Effective process management during emergencies requires that emergencies must be visualized before they occur and that the capabilities of the human be taken into account when designing response mechanisms. Procedures should be developed to assist the operators and the emergency response team. Simulation exercises designed to test and evaluate emergency response capability should be conducted, critiques held, and corrections made. These will provide insight into the effectiveness of the humans' role.

8.2.4. Management of Change

Management of change procedures must be simple yet effective in capturing changes. Human nature being what it is, many changes will be deemed too trivial to qualify as a change to avoid the extra effort of following the management of change procedures (documentation, approval reviews, etc.)

Many changes that are not normally recognized as such, can significantly affect people's performance. Examples are changes in:

- Management style or philosophy
- Organizational structure or reporting relationships
- Company and union relationship
- Shift regimes
- Staffing (at either the worker or supervisor level)
- Work environment (lighting, noise level, temperature, etc.)
- Educational level of employees (either higher or lower)
- Work organization
- Work flow
- Authority and/or responsibilities of first-line supervisors or operators

- Production rate
- Skill level required to perform tasks
- Information feedback
- Process control philosophy (e.g., computerization that removes supervisory control from the operator and may lead to inability of the operator to respond effectively to an abnormal situation)
- Stress level (e.g., more complicated or less complicated processes, layoffs)

8.2.5. Process and Equipment Integrity

Equipment integrity is primarily achieved by good design and installation and the proper consideration of human factors should be an integral part of the design phases (see Section 8.2.2 on Capital Project Review and Design Procedures and the earlier sections of this chapter.

Maintenance, Inspection, and Testing
Maintaining equipment integrity throughout its lifetime is achieved by continual inspection, testing, and maintenance; equipment therefore should be designed and installed to provide a good working location for operation and maintenance. This requires considering lighting, shelter, humidity, noise, temperature, access, personnel working position, availability of correct tools, and the like. Clear responsibilities for isolating, verifying, and sign off are necessary. Labeling exactly what must be worked on, and explicit, accurate, unambiguous communications on what must be done are essential. Frequent reviews of work permitting systems are required to ensure that specified procedures continue to be followed.

Stress from working against a deadline, working in danger, long working hours and hot conditions, must be considered. Workshops should be designed with human factors principles in mind. The environment, both physical and managerial, working positions, and tools should be designed to facilitate good error-free maintenance.

Procedures
Correct procedures for maintenance, inspection, and testing will be needed and should be written with human factors ideas in mind. Some considerations for good procedures are:

- The operators should be intimately involved in writing procedures. This will both make use of their extensive knowledge of the process and help to ensure their commitment to following those procedures.
- Procedures should specify the process "windows" for safe operation.
- The procedure should show how to do the task and not be confused with a training manual. The latter, but not the former, should include

the reasons for the task and explanations of the results or objectives of each step.
- They must be kept up-to-date and be easy to revise. A system needs to exist so that all outdated copies are immediately replaced with current editions.
- Diagrams and examples should supplement text for clarity and understanding.
- The best presentation will have considered text font, color, columns, relationship of text to diagrams, single-sided printing, etc.
- The text should be written at the appropriate reading level. The active tense should be used and complex sentences avoided.
- Procedures should be easy to use on the job, portable, and resistant to abuse.
- Steps that include some feedback to verify their completion are desirable.
- The whole procedure should be validated to ensure that it is practicable and is indeed followed in practice.
- It should be easier to obtain and follow the correct procedure than to improvise.
- Procedures should follow a standard format, facility-wide. The objective is to avoid errors by ensuring consistency and ease of use.

8.2.6. Training and Performance

Training

Training requires much more than simply following and practicing the procedures. It requires understanding the reasons for the procedures, the consequences of deviations from these procedures and recognition and accommodation for the fact that actual performance will differ from that observed in training sessions. The training should, as far as is possible, reduce there differences, or at least the significance of such differences. It is essential that operating procedures and training be closely integrated.

Training should in no way be considered as a substitute or remedy for poor design. Although poor training is frequently given as the reason for people making mistakes, we must emphasize that working in an error-likely situation is probably a more valid reason. Good training will have considered the relevant human factors elements.

Training can be considered to take place at two levels:

- The general (appreciation, overview, awareness), education level
- The detailed level of being able to perform tasks, functions or acquire skills

While it is impractical to provide all employees with detailed human factors training, process safety, and management training should provide an overview of the subject. The detailed training in operations, maintenance, inspections, and tests, must include reference to specific and readily applicable human factors issues. An integral part of training is the existence of quality procedures to follow. Writing quality procedures is not a casual skill, it requires proper consideration of all the ways the user interacts with the procedure. Discussion of the human factors aspects of preparing procedures is given in Section 8.2.5, Process and Equipment Integrity. A more detailed case study of procedure development is provided in Chapter 7.

In all training programs, the importance of identifying, reporting, and eliminating error-likely situations, reporting mistakes and near misses and looking for ways to prevent errors should be emphasized. Once again this requires a blame-free environment.

The following are some human factors aspects relevant to training but they are meant only as a stimulus to further study and consideration and not as an authoritative and exhaustive checklist.

- The trainer must understand human factors principles.
- The training environment should be noise-free, with proper lighting and a comfortable temperature provided. Good audio-visual aids should be used.
- Lines of communication should be kept short. Transfer of information is probably least accurate by word of mouth. Avoid superfluous information. Show is better than tell.
- Understanding the objectives of a procedure and the consequences of deviation are a vital part of learning how to perform the procedure. Knowing process limitations and tolerances is also important.
- Choosing the tasks best suited to equipment and allowing people to do the task they are best suited to, is better than training people to do jobs for which they are ill-suited. Practice needs to be carried using training situations similar to the active tasks and the differences between the real and artificial situations need to be appreciated.
- All activities are based on various levels of ability. Skill based actions are virtually automatic and may fail due to distractions and change. Rule based actions require good procedures and adequate time. Knowledge based actions require technical knowledge and organized thinking. Different types and levels of training and practice are required for these different abilities. Full discussions of these concepts and their implications for training are provided in Chapter 3.
- Recognize the effects of stress in case of emergencies. The actual emergency probably will differ considerably from those practiced. The reluctance to acknowledge that the emergency exists is a well-known cause of delayed response. Complex decisions are doomed to failure

under stress; anticipate as many decisions as possible and make them simple by providing decision aids such as those described in Chapter 4.

- People develop bad habits and take things for granted; processes, equipment, and technology change, so retraining is essential at appropriate intervals.
- Develop realistic evaluation exercises to verify that effective learning of skills has occurred.

Performance

In addition to proper training and quality procedures, good performance requires a supportive culture and working environment. The procedures provide the "how to," the training reinforces this with the background, the understanding, and the practice to develop the necessary skills; the environment must support their quality execution.

An encouraging, motivational environment is likely to evoke better performance than a threatening one. It is generally accepted that results are better where employees are empowered to contribute and participate rather than just follow instructions.

8.2.7. Incident Investigation

The most important thing that must be in place to have a successful incident investigation program is a blame-free culture. Unless this is in place, the only incidents that will be reported are those with outcomes that are difficult to cover-up such as serious injuries and large spills. Even first-aid cases will go unreported, if there is a penalty for having an injury (or a prize for not having one). Once the culture is at least partially in place, *all incidents must be reported, including near misses. It is important to have all these incidents in your data base for a complete analysis of your program needs.*

Investigating these reports then becomes paramount. However investigation takes know-how. A training program that focuses on finding the root, secondary, underlying, or hidden causes is required. Superficial investigations that stop when unsafe acts and conditions are identified and only blame the person add nothing to incident investigation. The objective is to discover the real causes of the incident, so that they can be corrected. After investigations are started, a data bank for the information extracted from the exercise should be initiated. The data can be used for risk analysis (see Section 8.2.3 on Process Risk Management and Chapter 5), giving direction to your training programs (see Section 8.2.6 on Training and Performance), and providing design feedback for future plant changes and new plant designs (see Section 8.2.2 on Process Safety Review Procedures).

Sometimes special expertise may be needed when incidents are investigated. Human factors professionals may be needed to do a Task Analysis to determine if a task exceeds the capabilities of the human. Assessments of the factors in a situation that would have affected the likelihood of the error (performance-influencing factors—see Chapter 3) may also need to be made by the investigator.

In order to accurately describe the actual sequence of events that make up the accident techniques such as STEP (sequential timed event plotting—see Chapter 6 and the case study in Chapter 7) can be used by the investigator.

8.3. SETTING UP AN ERROR MANAGEMENT SYSTEM IN AN EXISTING PLANT

Some of the elements of an error management system were described in the Section 8.2. In this section, the process of setting up an error management program in an existing plant will be described. The components of the error management program have been discussed in previous chapters and are summarized in Figure 8.2.

This indicates that error management comprises two strategies: proactive methods are applied to prevent errors occurring, and reactive strategies are used to learn lessons from incidents that have occurred and to apply these lessons to the development of preventive measures. Both proactive and reactive methods rely on an understanding of the courses of human error based on the theories and perspectives presented in this book. The tools and tech-

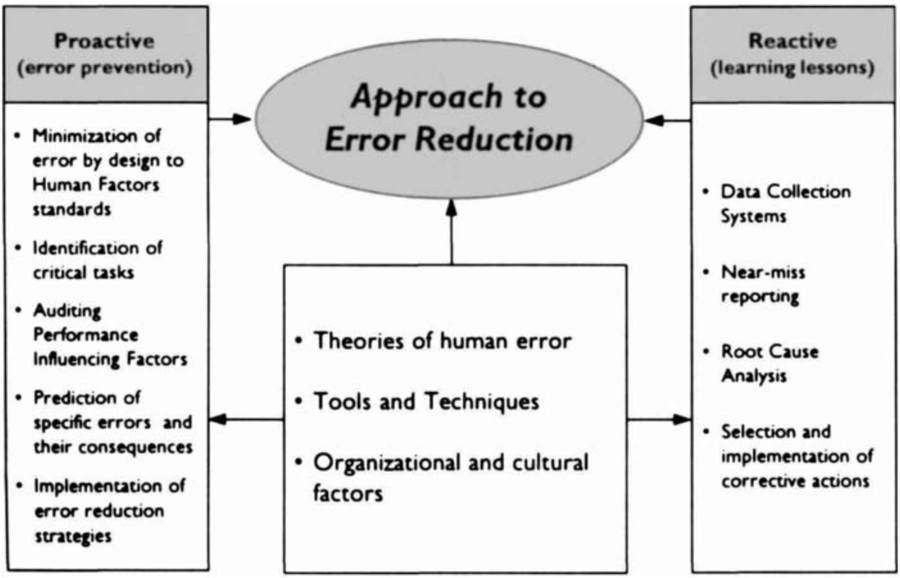

FIGURE 8.2. **General Error Management Structure.**

niques that need to be applied, such as task and error analysis, have been described and illustrated in Chapters 4 and 7. The PIFs that need to be evaluated and controlled are described in Chapter 3. In setting up a successful error management program, it is vital to address organizational and cultural issues as well as technical methods. The overall structure of the error management program is illustrated in Figure 8.3.

8.3.1. Stage 1: Obtain Senior Management Commitment to Support the Program

Since senior management will ultimately control the resources required to implement a program, they need to be convinced that the benefits which are likely to arise will provide a reasonable return on their investment. Evidence presented in Chapter 1 of this book and from other sources can be used to provide a convincing argument that investment in improving human performance and reducing error will produce a rate of return which is at least equal to and will probably exceed that obtained from the same investment in hardware. It should be emphasized, however, that any program which requires a change of attitudes and culture, particularly in a sensitive area such as human error, will required time for its effects to be felt. Management commitment must therefore be reasonably long term.

The decision to initiate a human error management program will normally be taken by senior plant management or at a corporate level. The reasons for setting up a program may be the occurrence of significant losses that are clearly attributable to human error, or from regulatory pressures to produce improvements in this area.

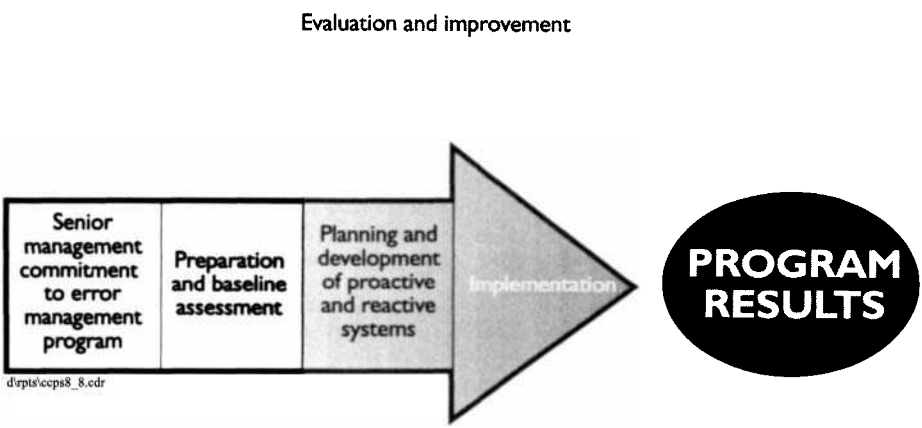

FIGURE 8.3. **Stages in Setting Up an Error Management Program.**

8.3.2. Stage 2: Evaluate the Current Situation

An evaluation of the nature and magnitude of the current human error problem in the organization is an essential step in the program. This assessment identifies the existing concerns and perceived problem areas and sets the initial agenda for the error reduction program. Typical information sources that will be utilized are plant incident records, problem reports and near miss reports if such a system exists. Structured interviews will also provide an important source of data concerning problem areas. The initial baseline evaluation will normally be carried out by a human reliability specialist appointed by senior management.

The main output from this stage is a detailed assessment of the human error problem areas. If possible this should include quantitative data on the incidence of errors and the significance of their consequences. This will provide a valuable baseline against which to evaluate the success of the error management program.

In addition to these assessments of the causes and consequences of errors, the baseline assessment should also include an evaluation of the systems that are currently in place to control errors. This will include an evaluation of the current state of a representative set of the PIFs discussed in Chapter 3. Typical factors would include

- Training policies
- Procedures
- Work organization (e.g., shift work)
- Design of human–machine interfaces (e.g., process information displays, alarm systems, plant labeling)
- Communications systems
- Work control systems (e.g., work permits)

8.3.3. Stage 3: Set Up a Program Development and Coordination Committee

The purpose of this stage is to set up a group of plant personnel who will be responsible for initiating and sustaining the effectiveness of the error management program. The composition of this group should include individuals from all areas of the plant (e.g., operations, line management, engineering) who may be affected by the error management process when it is implemented. It is also desirable that a human factors professional is on the committee in order to provide specialist knowledge as required. However, the most important requirement of the committee is that it is enthusiastic and strongly committed to the systems approach to error reduction.

In order to obtain this commitment, training in the systems view will be necessary, preferably using examples from the plant that the group can readily relate to. It will normally be the responsibility of the human factors specialists who have conducted the baseline analysis to provide this training.

8.3.4. Stage 4: Program Strategy Development

The committee will formulate an error management strategy to address the specific needs of the plant based on the information collected during the baseline exercise. The strategy will address the following areas:

- Specific interventions to address the problem areas identified during the baseline study
- Setting up proactive error management systems
- Development of reactive programs including data collection and root cause analysis systems
- Development of programs to create an appropriate culture to support the error management system
- Assessment of policy needs to support these programs

The objective of initially focusing on the problem areas identified during the baseline assessment is to enable the error management program to demonstrate its capability to solve problems as quickly as possible. By providing solutions to perceived problem areas, the program will gain credibility which will considerably enhance its acceptance and support. The results of the initial interventions can also be used as case studies as part of the consciousness raising process that will be necessary in order to successfully implement the program in the plant. It is recommended that the problem solving exercise is performed for one or two of the problem areas identified during the baseline study **before** the program is launched. This will enable tangible benefits to be described during the launch of the program.

8.3.5. Stage 5: Program Launch

The launch should ensure that it is perceived to be an important and significant innovation. Major factors that will enhance the success of the launch are listed below.

Publicity
The program launch should be prominently featured and explained in company communication channels such as newsletters and in-house magazines.

Senior Management Support
Senior management should attend the launch and endorse its importance.

Demonstrated Credibility
The case studies obtained from the pre-launch error reduction interventions should be used to demonstrate the practical value of the program.

8.3.6. Stage 6: Implementation

The program plans for the five areas addressed during the program strategy development phase are implemented at this stage.

Specific Interventions
The error reduction activities that were begun in the pre-launch phase should be completed at this stage.

Setting Up the Proactive Error Management System
This system will include the following topics:

- Identification of critical tasks. This is an important initial step as it identifies the areas where application of proactive error reduction approaches will produce the greatest benefits (see Chapter 5)
- Prediction of specific errors and their consequences by using task analysis and error prediction techniques (Chapters 4 and 5)
- Auditing PIFs (Chapter 3)
- Implementation of error reduction measures

Setting Up Reactive Error Management Systems
This involves the development of data collection and root cause analysis systems as described in Chapter 6.

Development of a Plant Culture to Support the Error Management Program
This aspect of the program may be difficult to achieve quickly, especially in an environment where a blame culture has predominated. A supportive culture can only be achieved in a situation where there is a clear policy direction from senior management, and this policy is implemented in a day to day basis by line managers and supervisors. In addition, a continuing program of education is necessary to overcome skepticism and to reinforce the practical benefits of the program. In order to gain acceptance from the workforce the program has to demonstrate that active participation produces tangible benefits in terms of enhanced safety and a reduced burden of blame from errors that are due to causes outside the workers' control.

Development of Policies to Provide Long-Term Support for the Program

The various elements of the error management program such as the development of high quality procedures and training and effective feedback and communications systems need to be supported by policies and standards to implement these policies. The development of these policies is an important strategic aspect of the implementation process.

8.3.7. Stage 7: Evaluation and Improvement

Following the implementation of the error management program, evaluations of its effectiveness must be made on a continuing basis. Measures of effectiveness can be gained partly by direct discussions with individuals at all levels of the plant, using a predesigned evaluation checklist to ensure that all the evaluation dimensions are assessed in a systematic way. Examples of evaluation questions follow.

- Since the program began are people generally more willing to admit that they have made errors?
- Has the program made it easier to understand the causes of errors?
- Are people still blamed or punished if they admit to making errors?
- Have you noticed any changes in the conditions that may have caused you to make errors in the past (e.g., improved procedures, better plant labeling, more effective sharing of experience)?
- Have changes been made that are likely to reduce the incidence of errors?

In addition to these types of evaluations, the incident reporting and near miss systems should be monitored for improvements in performance that can be attributed to the program. On the basis of feedback from these and other sources such as changes in quality levels or efficiency, modifications should be made to the program to enhance and sustain its effectiveness. Concrete evidence regarding the benefits arising from the program should be communicated to those involved.

8.3.8. Stage 8: Maintenance and Ownership

The key to maintaining the long-term effectiveness of the program lies in ensuring that it provides tangible benefits for its stake-holders. These include the plant management as well as the various levels of the workforce. Because the plant worker will have the greatest day-to-day contact with the factors that impact directly on the likelihood of errors, it is vital that they eventually come to own and operate the error management system.

However, this will only occur if their efforts in identifying the factors that give rise to errors is matched by evidence that their contributions lead to tangible changes being made that improve their jobs. If this is achieved then the error management program will in the long run become self-sustaining, and self-financing through reductions in accident rates, and improved quality and efficiency.

8.4. SUMMARY

The general approach that has been advocated in this chapter is that it is the responsibility of an organization, through its safety management policies, to create the systems, environment, and culture that will minimize human error and thereby maximize safety.

The potential benefits to be gained are considerable. In addition to reducing the burden of death, injury, and ill health that arises from human caused accidents, enhancing safety through the reduction of error has the potential for direct financial payback. A recent U.K. study (HSE, 1994) indicated the annual cost of accidents to employers was equal to between 5% and 10% of all U.K. companies gross trading profits (between $6 and $12.5 billion). Even if human error is conservatively estimated at being the direct cause of only 50% of industrial accidents, the savings in reducing human error by 50% could be estimated as being of the order of $15 billion if these results were translated to the U.S. economy. The benefits of investing in human error prevention programs are therefore difficult to challenge. It is hoped that the contents of this book will provide the chemical process industry with the knowledge and tools it needs to begin to achieve these benefits.