# HUMAN FACTORS IN PROCESS SAFETY AND RISK MANAGEMENT: NEEDS FOR MODELS, TOOLS AND TECHNIQUES

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## ABSTRACT

This paper reviews the need to perform human factors studies for onshore and offshore processes. A general assessment is provided of the current state of development of the human factors discipline and the extent to which it is currently meeting the needs of the process industries.

Scant attention has been paid to human factors by the process industries and the reasons for this are discussed. Areas within human factors are identified where we believe more work is needed to facilitate the consideration of this subject by the process industries. We provide a new conceptual model that can be used as a framework for identifying important human factors considerations in processes and we advocate an approach that we recommend both to satisfy current regulatory requirements and to provide a reasonable assessment of human factors considerations for processes.

## 1. INTRODUCTION

Recent government regulations and industry recommended practices have focused interest in the process industries on human factors. Pertinent regulations and recommended practices are:

- The Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) standard, CFR 1910.119

- The Environmental Protection Administration's (EPA) Risk Management Plan (RMP) rule, 40 CFR Part 68

- The American Petroleum Institute's (API) Safety Environmental Management Program (SEMP), RP75

These regulations and recommended practices cover both onshore and offshore facilities. Covered facilities generally process, handle or store materials that pose risks of toxic releases, fires or explosions.

These regulations and recommended practices require human factors be considered as part of conducting a process hazards analysis (PHA) for covered facilities. However, no explanation is provided of what is meant by human factors. OSHA, EPA and the Minerals Management Service (MMS) have provided some clarifying comments but have not yet provided any definitive guidance on what should be done. This is because the regulations and recommended practices are performance-based and there is a lack of understanding in the process industries on what constitutes human factors or how the subject should be handled.

Historically, the field of human factors has developed in somewhat separate areas. First, the discipline of human factors engineering has evolved and its principles have been applied in several industries such as automobiles, but with the notable exception of the process industries. There are many texts on this subject and they are typified by the classic work of Sanders and McCormick (1). Second, a number of workers have focused on theoretical considerations of human error and the human cognition process. These are typified by such researchers as Rasmussen (2,3) and Reason (4). A third group of workers has focused on the formal consideration of human errors in risk analyses using human reliability analysis. Much of this work has been performed in the nuclear industry and is typified by the work of Swain (5). Kirwan has provided a more recent description of work in this field (6). A fourth perspective has been provided by Kletz who advocates a pragmatic engineer's view for considering human error in safety studies (7). More recently behavior-based approaches to improving safety have been advocated by such authors as Krause (8) and McSween (9). The Center for Chemical Process Safety has also published a book that attempts to summarize much of what is known about preventing human error in the process industries under the authorship of Embrey (10).

Given the amount of work that has been performed and published in the area of human factors it is pertinent to inquire why the subject has received such scant attention in the process industries. We believe there are various reasons:

- Lack of awareness. The process industries is heavily focused on hardware. Most process engineers see equipment when they think of a process and do not see the people who are an integral part of designing, building, operating or maintaining the equipment.

- Lack of understanding. To the uninitiated the field of human factors appears confusing and poorly structured with apparently no definitive analysis approach that can be followed. There is no conceptual model that process engineers can use as a frame of reference to understand how human factors applies to their processes. It is difficult for process engineers to know where to start, or, for that matter, when they are done.

- Lack of need. Most engineers in the process industries are unaware of the benefits that can be obtained by attention to human factors in their processes.

- Misunderstanding of human factors. Process engineers and managers may feel threatened at the prospect of a human factors study. They may feel their job performance or personality is to be evaluated. Managers may feel that their effectiveness will be judged.

- Fear of the effort involved. Few in the process industries relish the thought of more studies that must be performed in order to operate their processes. The work force is already stretched thin after re-engineering and downsizing and few people are available to handle this work.

- Fear of opening Pandora's box. Many companies in the process industries have performed PHAs over the past few years that have resulted in many recommendations for process improvements that companies are now often obligated to implement with their associated costs. There is a fear that human factors studies may have the same result.

- Lack of integration. Various approaches to treating human factors are available but little work has been done on their integration. Human error analysts, human factors specialists, and behavioral scientists usually work independently.

- Lack of approaches to remediation of some human factors issues. When problems are identified with displays and controls, corrective actions can usually be devised without difficulty. However, when organizational or socio-technical problems arise their solution is often less obvious.

- Lack of qualified analysts. There are few practitioners who combine the required knowledge of human factors engineering, human error analysis, process engineering, safety and risk analysis and who have the requisite personal skills to work with process engineers and operators to perform these studies. Few companies have such individuals on staff.

- Lack of motivation. Until the advent of process safety and risk management regulations in the early 1990's, there was no need to consider human factors.

Given these issues, we may inquire as to the prospects for human factors studies in the process industries. Companies certainly are now motivated by regulations to do something and there is a developing awareness that this is indeed an important topic. However, many companies are still trying to decide what to do.

## 2. HUMAN FACTORS NEEDS OF THE PROCESS INDUSTRIES

In order for human factors studies to become a way of life for the process industries we believe various tools and information are needed including:

- A better understanding of the benefits of human factors studies. This can best come from publicizing case studies where the benefits are apparent, especially with regard to the investment required
- A simple classification of the types of human factors studies that can be performed.
- A conceptual model that defines the scope of human factors for processes and that facilitates understanding of the role of human factors in the process industries
- A classification of human errors that is both theoretically sound and practical for use in identifying human errors
- A compilation of human factors design guidelines
- Specific guidance on how process engineers can perform simple but meaningful human factors and human error studies that meet regulatory requirements

Other actions will also be needed but if the above items are provided we believe significant progress will be possible in the adoption of human factors studies by the process industries. Each of these issues is now addressed in the remaining sections of this paper.

## 3. THE NEED FOR AND BENEFITS OF HUMAN FACTORS STUDIES

People are key components of processes. They are involved in process design, operation, maintenance, etc. No step in the process life cycle is without some human involvement. Based on human nature, human error is a given and will arise in all parts of the process life cycle. Also, processes are generally not well-protected from human errors since many safeguards are focused on equipment failure. Consequently, it is likely that human error will be an important contributor to risk for most processes. This is evidenced by the number of major accidents that have been attributed to this cause including such well-known accidents as Piper Alpha, Feyzin and Flixborough.

It is generally believed that 50 - 90% of industrial incidents can be attributed to human error. Consequently, if human errors are not considered in process safety and risk studies, then at most only about half the risk is likely to be analyzed and perhaps as little as 10%.

Most processes have been designed with little, if any, consideration given to human factors. Consequently, many obvious changes are often identified in human factors studies to improve the process. Frequently, these changes are inexpensive. In today's competitive world, this source of relatively low cost process improvements should not be ignored.

While regulatory considerations are causing a number of companies to focus attention on human factors in their processes, there is a variety of other reasons that justify their consideration. Improving the human factors design of a process can produce not only improvements in safety and health but also gains in quality, productivity and employee job satisfaction.

A few process companies have begun to perform human factors studies for their processes with positive results. As word spreads and other companies become familiar with the benefits of human factors studies then we will see more of this work performed. Thus there is a real need for these early studies to be well publicized.

## 4. TYPES OF HUMAN FACTORS STUDIES

The term human factors is now used with a variety of meanings. Historically, it has meant the study of the human-machine interface. More recently, it is being used in a broader sense. Ideally human factors considerations should be incorporated in the design of a process by the design engineers. However, at the present time this is rarely done in the process industries. The greatest present need is for tools that can be used to assess existing processes and develop recommendations for changes in their human factors design that will improve the process. We believe it is convenient to consider three types of studies that relate to human factors:

- Human error analysis
  - the systematic identification and evaluation of the possible errors that may be made by operators, maintenance engineers, technicians, and other personnel in the plant
- Human factors engineering
  - the analysis of the interface of people with the process and its impact on system operation

- Human reliability analysis
  - the assessment of the impact of humans on the reliability of process plants

For each of these general types of studies there are several specific technical approaches available.

For example, for human error analysis the following approaches can be used:

- Checklists
  - review of a facility to identify possible human errors using a prepared checklist. This may be accomplished during the performance of a PHA
- Task safety analysis
  - a formal analysis of actions performed by people to identify potential for problems
- Task error analysis
  - a formal analysis of the steps performed to accomplish a task and the identification and analysis of possible errors and their probabilities

For human factors engineering the following approaches can be used:

- Human factors engineering review
  - use of a prepared checklist to evaluate a proposed design or an existing facility
- Human factors engineering evaluation
  - detailed review of a proposed design or an on-site inspection and review of an existing facility by human factors specialists

Human reliability analysis usually involves task analysis plus quantification using event and fault trees. Various approaches are available (6, 10).

## 5. MODEL OF HUMAN FACTORS IN PROCESSES

Many process engineers are confused by human factors because textbooks on the subject rarely explain how topics such as displays and controls, workplace design, environmental conditions, etc. arise as important issues and result in the consideration of all relevant human factors issues. What is needed is a process model that allows the complete scope of human factors issues to be defined and understood.

Classically, human factors often deals with the man-machine interface (Figure 1). While this model captures many important human factors a more complete model is required to capture all those of importance in processes. We must fully analyze the person-process interface and its impact on system operation. Consequently, in order to model human factors in processes we must define completely the person-process interface. This requires that we define a person and a process in terms meaningful for performing human factors studies. Humans can be defined by their attributes (Figure 2 and Table 1). Processes or facilities may be defined by their components (Figure 3).

The issues that need to be explored in a human factors study of a process may then be identified by examining how humans with their attributes interact with facility components and their attributes. This provides both a framework for organizing human factors issues as well as a practical model for identifying and analyzing human factors issues.

The model of a facility shows that people in the facility interact with one another as well as with the facility hardware (equipment and computers) and software (written and unwritten procedures and rules as well as computer software). These interactions occur in the accomplishment of various jobs and tasks by the people. They may be operators, maintenance engineers, etc. The jobs and tasks are performed in a particular workplace and each workplace has an environment associated with it. This all occurs within the organizational structure set up to run the process. These components of the facility may interact with one another individually or in combination to accomplish the purpose of the process. A matrix model can be envisioned to represent these interactions of facility components (Figure 4). Only two dimensions have been shown in the figure but additional dimensions can easily be envisioned in order to capture higher-order interactions. While this model is capable of representing the entire operation of the facility we are interested in the human factors issues so we must focus on interactions of people with the rest of the facility components. Thus, in order to define the scope of the human factors issues that need to be considered we consider first two-way interactions of people in the process with other process components such as:

people with other people

people with equipment

people with computers

people with procedures

people with tasks

people with the workplace

people with the environment

people with the organization

Higher-order interactions may also be important. For example, multiple people working on one piece of equipment or a person working on a specific task in a particular environment.

All people involved with the process should be considered (Table 2). This procedure allows us to identify numerous human factors issues by investigating the match of the attributes of the people with the attributes of the process components.
This model is important for several reasons. It provides:

- a theoretical framework for organizing human factors issues
- the means to completely define all human factors issues for a process
- a way to prepare detailed checklists of questions on human factors issues for use in conducting human factors studies (see example in Table 3)

## 6. CLASSIFICATION OF HUMAN ERRORS

Human error classifications facilitate the identification and analysis of human errors. In order to classify human error it must first be defined. A human error is any human action that exceeds some limit of acceptability or performance for a process or system in which the human is a component. It is an out-of-tolerance action such as an operator closing the wrong valve. The limits of performance are defined by requirements for successful operation of the system or process.

Alternatively, by analogy with hardware reliability, the probability of human error can be defined as the likelihood that a human fails to provide a required system function when called upon to do so, within a required time period. For example, an operator may not stop a pump within the time period specified in the procedures when a specific alarm condition arises.

The identification of errors requires an understanding of the range of error types and their causes/mechanisms (Figure 5). A knowledge of error mechanisms and causes is needed in order to decide how errors can be prevented or minimized. It is impossible to predict every possible, potentially negative, human impact on a process since there are many ways in which people can interact with processes and an infinite variety of possible human responses. Human error studies are best seen as ways of locating vulnerabilities of processes to human errors or performance problems.

There are various ways of classifying human errors. The simplest is classification by mode or action:

- Omission error - action is not performed
- Commission error - action is performed incorrectly
- Extraneous act - non-required action is performed instead of or in addition to required act

There is a variety of commission errors that are possible (Table 4).

This classification does not address the cause or mechanism of the error. While human error studies often deal with modes, a consideration of mechanism can provide guidance on suitable corrective action. A mechanistic classification is possible by combining Rasmussen's skill, rule, and knowledge-based model with more recent phenomenological work on human error (Figure 6). These error mechanisms are defined below.

Slips - errors in skill-based actions (require virtually no conscious thought). The intention is correct but a failure occurs when carrying out the required action, e.g. operator fails to close valve due to spatial confusion with another valve.

Mistakes due to failure of expertise - errors in rule-based information processing. The intention is incorrect, e.g. operator assumes reactor is OK based on one temperature indication that proves faulty.

Mistakes due to lack of expertise - errors in knowledge-based information processing. (requires conscious thought). The intention is incorrect, e.g. the operator fails to diagnose causes of a severe process abnormality under time-pressure.

Violations - deliberate acts that are prohibited or different from those prescribed and carried out intentionally.

Sociotechnical errors - originate in biases or behavior patterns of people. They are often related to problem-solving, emergency and team situations, e.g. decreased willingness to take decisions in the face of an emergency.

Management and organizational errors - errors attributable to decisions and actions (or inactions) by managers. They depend on the culture of the organization, e.g. unwillingness to communicate required performance goals.

Sociotechnical and management/organizational errors have been recognized relatively recently. Undoubtedly, more work is needed to fully define them and to develop ways in which their potential can be identified.

These classifications of human error are used when human error studies are performed, for example, using the Task Error Analysis technique described below.

## 7. HUMAN FACTORS DESIGN GUIDELINES

Human factors issues have been largely ignored in the design of process facilities yet this is the best time to apply human factors principles. This lack of application in design is due in part to a lack of awareness of the discipline of human factors but is also due to the lack of a complete set of human factors design guidelines and procedures for process facilities. While there are human factors handbooks available and some design guidelines exist, they are not well known in the process industries nor do we have a complete set. This is an area where effort to compile a handbook for the process industries would be well worthwhile.

## 8. RECOMMENDED APPROACHES FOR HUMAN FACTORS STUDIES

We believe that process safety and risk studies of human factors should cover:

- the consideration of human errors of all types as causes of accidents and process upsets
- the impact of all aspects of the design of a process on human error rates

This will enable recommendations to be developed for improvements in the human factors design of processes in order to improve safety and reduce risk. We also believe studies that address these two items will meet the requirements of regulators.

Some regulators have implied that both these aspects of human factors can be treated within a process hazards analysis. However, we believe a preferred approach is to perform a separate human factors study and follow it with the consideration of human errors in a PHA (Figure 7). This allows the human factors that influence human error rates to be better understood and the risks posed by human errors to be better managed. It can also be useful to perform a separate human error study prior to the PHA (Figure 7). This can be important when human errors are believed to be particularly important for a process or when there is high human involvement with a process.

A useful approach to performing an initial human factors review of an existing process is to perform a human factors engineering review (HFER). An HFER involves the use of a prepared checklist to evaluate a proposed design or an existing facility. This can usually be accomplished by a small team of analysts or even a single individual. A worksheet format is usually employed to guide the analysis and record the results (Figure 8). Typically a facility is divided into separate systems and all the relevant checklist questions applied to each system.
If a separate human error analysis is to be performed we recommend the use of task error analysis (TEA). This technique is used to identify the human elements in tasks and the potential for human error. It is a combination of task analysis and human error analysis.

Various forms of task analysis exist but we are using the term here to mean the detailed definition of the actions required of humans in the process, such as operators. Human error analysis is used to identify the types of errors that may be associated with the actions required of humans in a process. Often this includes the identification of any performance influencing factors and possible error causes.

A task is an activity that the operator sees as a separate, complete activity, e.g., transferring material from storage to a hold tank. Task error analysis involves breaking down each task into steps and individual units of behavior, e.g., set valves in transfer lines is a step; open valve A is a unit of behavior. This breakdown is normally accomplished by tabulating information about each specific human action in a worksheet (Figure 9). Specific potential errors are identified for each unit of behavior, e.g., "open valve A" may have errors of omission (valve A not opened) or commission (wrong valve opened). This is where the classification of error types by mode is used. As is seen in the example, there may be multiple possible errors for each unit of action.

There may be factors that influence human performance such as adverse environmental conditions. A checklist is usually employed to assist in their identification and they are entered in the TEA worksheet. Underlying causes of errors are optionally identified. This can assist in formulating recommendations to reduce the error likelihood or eliminate its possibility.

TEA worksheets often provide additional information beyond the simple example given in Figure 9. For example, columns may appear identifying equipment involved in the action, the location where the action is performed, numerical probabilities of individual errors, the means by which error may be detected, the consequences of errors, etc.

When these initial studies of human factors and human errors have been performed it is much easier to address these items in a PHA. We view the initial HFER as a very important precursor to PHA since human factors can be difficult to handle within a PHA. The initial TEA is desirable but not always necessary. Human errors can usually be treated adequately within a PHA. Techniques for treating human errors and human factors in a PHA have been described elsewhere (12).

## 9. CONCLUSIONS

Regulatory requirements for the consideration of human factors in process safety and risk management are motivating companies to address this subject and the importance of considering human factors in the process life cycle is beginning to be recognized by the process industries, both onshore and offshore. However, a number of issues must be addressed for the consideration of human factors to become standard. In particular, human factors needs to be more widely understood and tools need to be provided so that studies can be performed more routinely.

An opportunity exists for companies to explore the many benefits afforded by human factors studies of their processes. In particular, since this subject has been neglected for a long time, numerous opportunities exist for process improvements.

Figure 1. CLASSICAL MODEL OF MAN-MACHINE INTERFACE

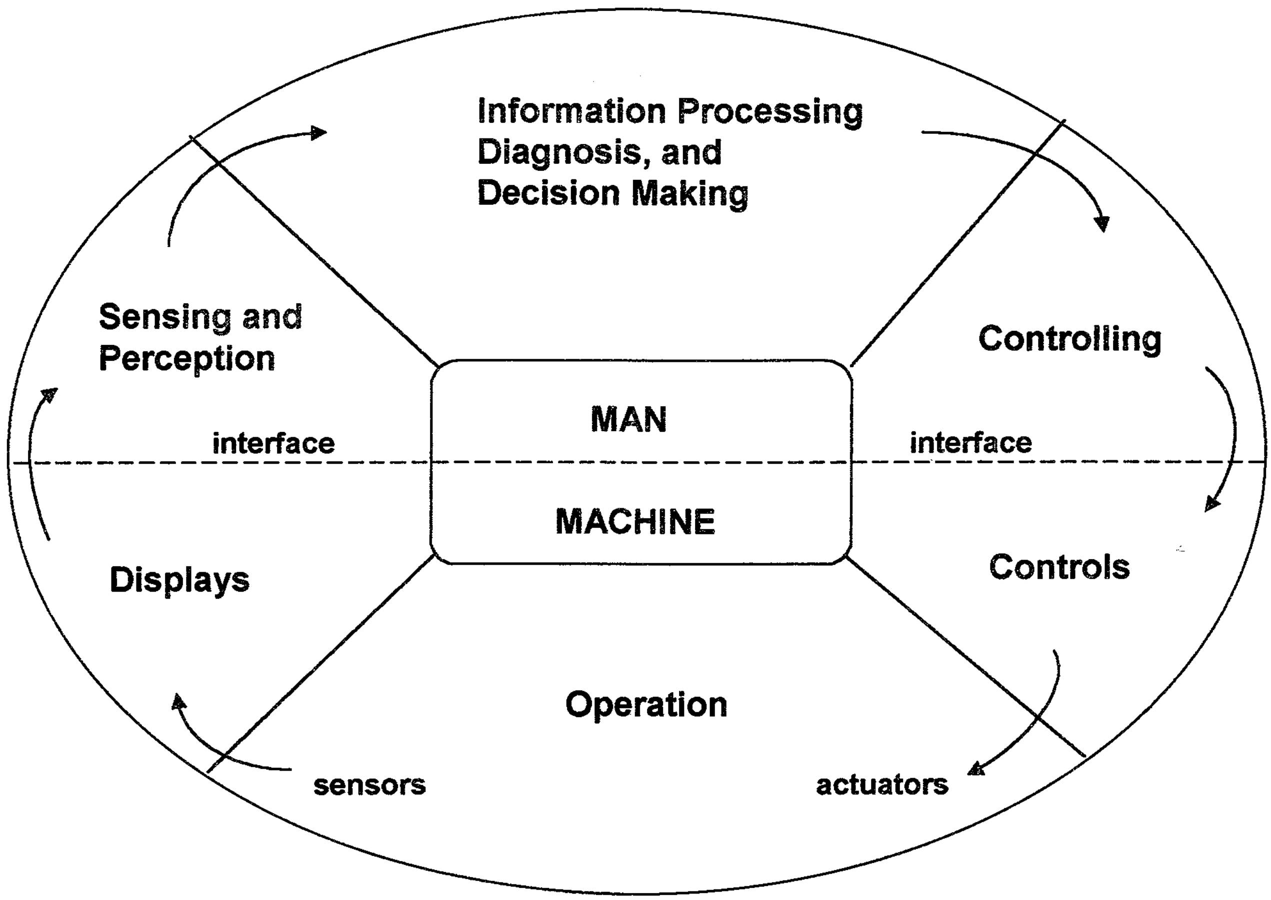


FIGURE 2. MODEL OF A HUMAN

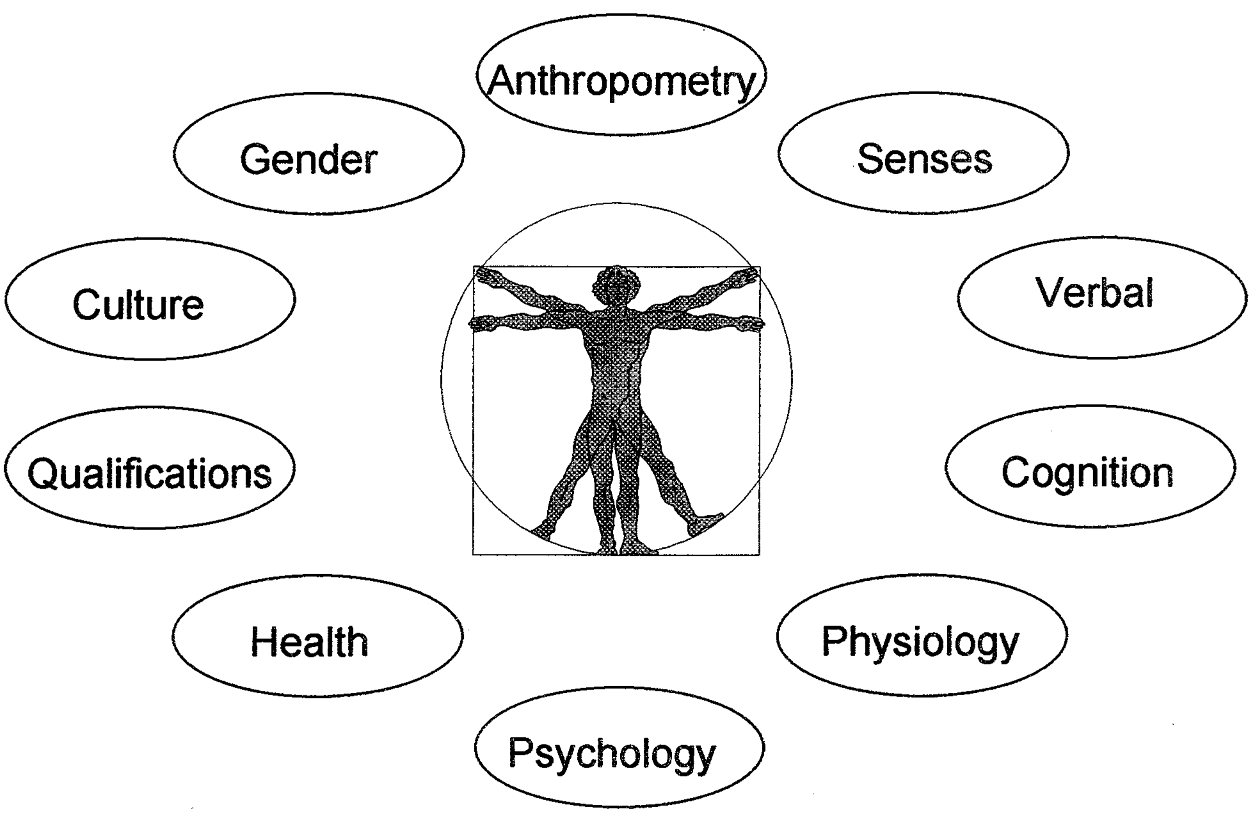

FIGURE 3. MODEL OF A FACILITY

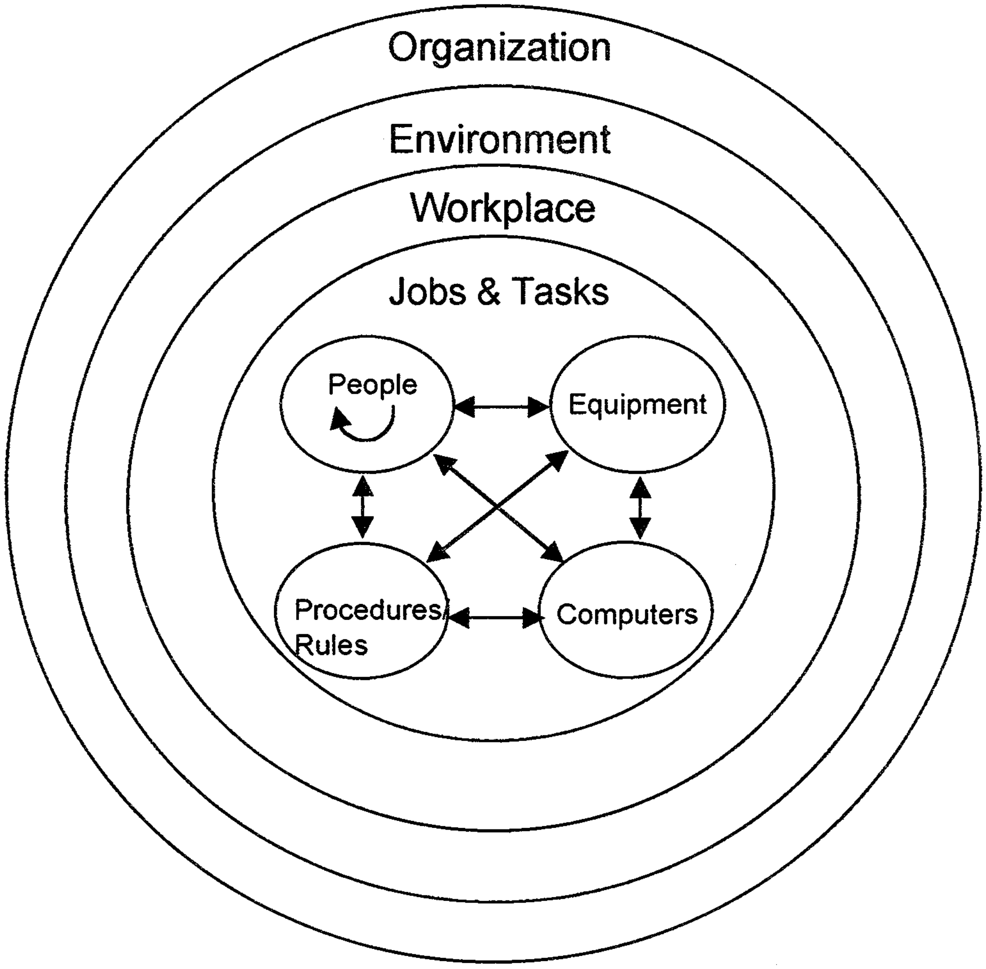


FIGURE 4. MATRIX MODEL OF PROCESS

| | People | Equipment | Procedures | Computers | Jobs/Tasks | Etc. |
|---|---|---|---|---|---|---|
| People | | | | | | |
| Equipment | | | | | | |
| Procedures | | Process | Interactions | | | |
| Computers | | | | | | |
| Jobs/Tasks | | | | | | |
| Etc. | | | | | | |

FIGURE 5. MODEL OF HUMAN ERROR

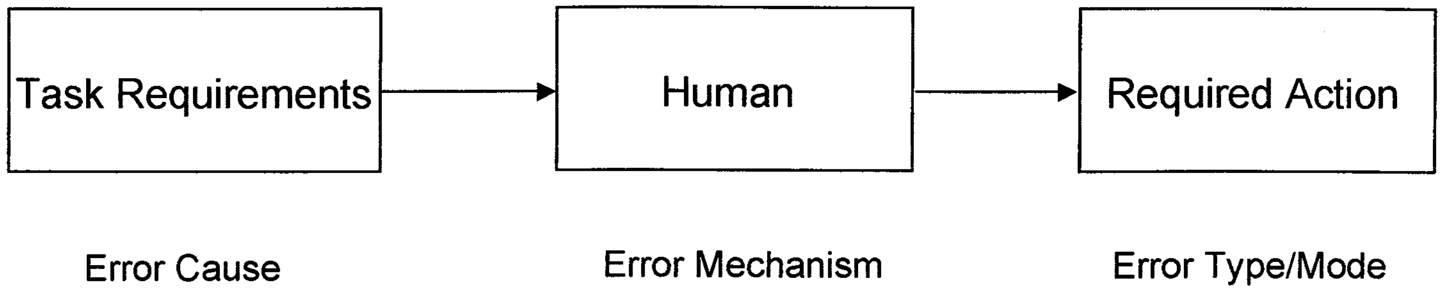


FIGURE 6. MECHANISTIC CLASSIFICATION OF HUMAN ERRORS

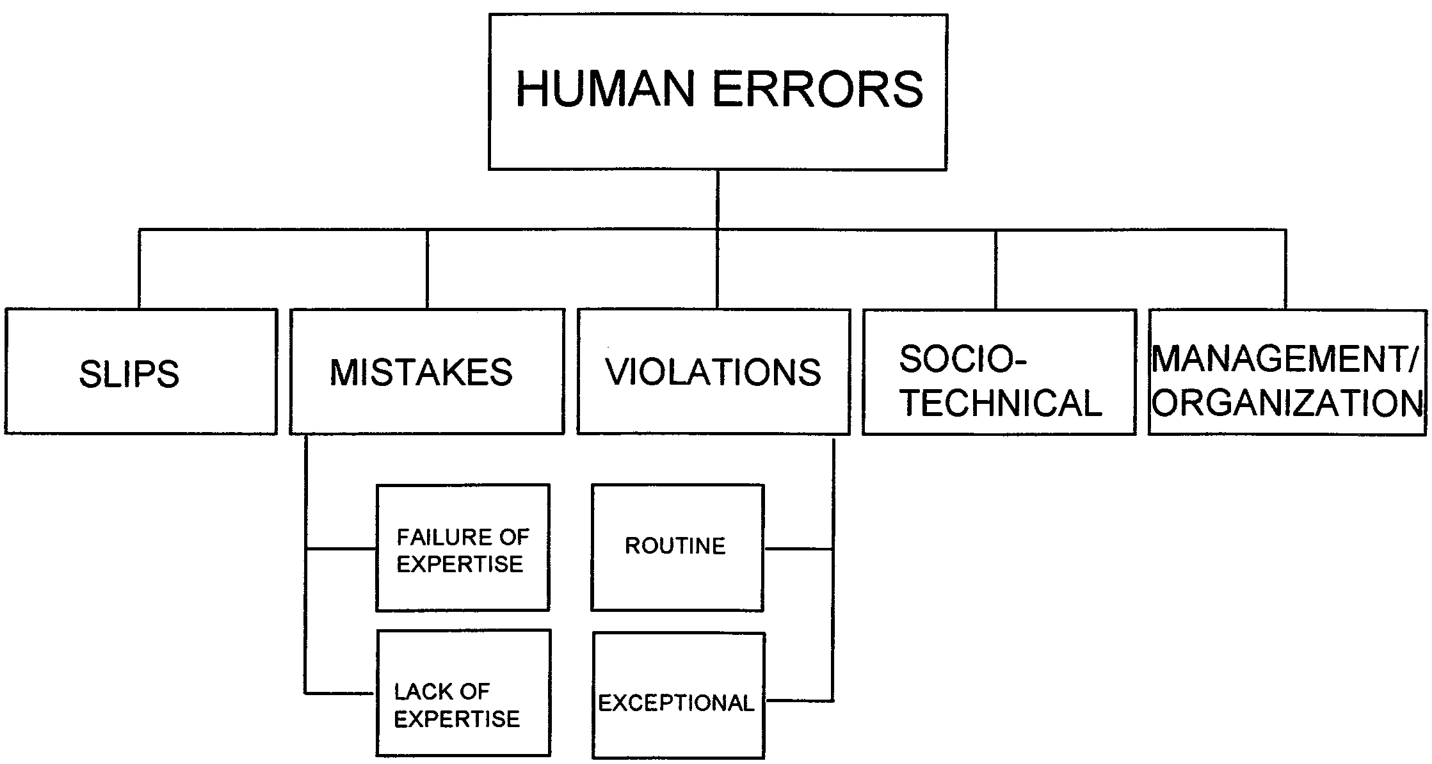

FIGURE 7. APPROACH FOR TREATING HUMAN FACTORS IN PROCESS SAFETY MANAGEMENT

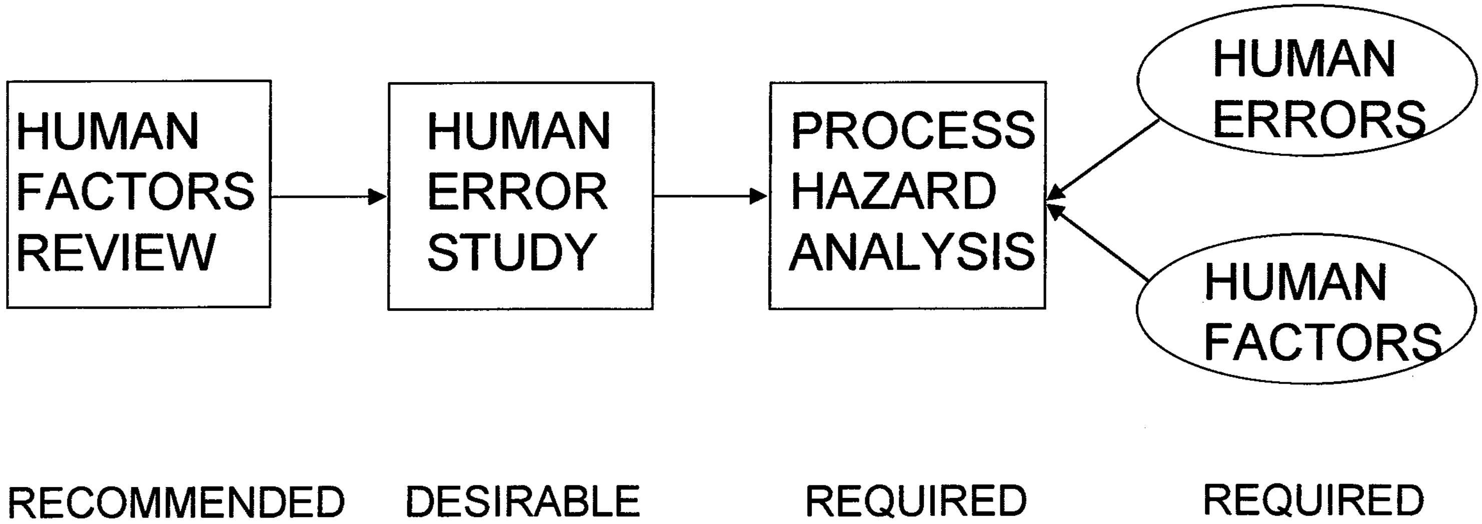


FIGURE 8. A HUMAN FACTORS ENGINEERING REVIEW WORKSHEET

**HUMAN FACTORS ENGINEERING REVIEW**

Facility: Bulk Chemicals Plant
Analyst: John Major    Date: 1/23/95
System: Chlorination Reactor    Category: Controls

| QUESTION | A | REMARKS | RECOMMENDATIONS | BY |
|---|---|---|---|---|
| 1. Are all required controls readily accessible? | N | 1. ESD is located away from reactor operator's normal work area. | 1. Relocate ESD to location adjacent to reactor building exit | ENG |
| 2. Are non-authorized personnel prevented from changing set points? | Y | 2. Password is required for change of set points in DCS | | |
| 3. Are controls grouped so as not to be confusing? | Y | | | |
| 4. Are there enough controls available to adequately place the plant in a safe and stable state in the case of an emergency? | I | 3. Control room air supply is not isolable from that of the reactor building | 2. Relocate air intakes for control room | ENG |

\=menu    F6=zoom    F8=functions    F10=pop-up

FIGURE 9. A TASK ERROR ANALYSIS WORKSHEET

| TEA WORKSHEET | | | | | |
|---|---|---|---|---|---|
| FACILITY: Resin Production Plant | | | | | |
| ANALYST: John Smith | | | | DATE: 1/14/92 | |
| TASK: Pump Solvent | | | | | |
| STEP: Reset System | | | | | |
| UNIT | PIF's | ERRORS | CAUSES | RECOMMENDATIONS | BY |
| 1. Reset blender valve | Hot environment | 1.1 Omission<br>1.2 Selection<br>1.3 Incomplete | | Consider labeling valves | SAF |
| 2. Close pipeline valve on vessel bank | None | 2.1 Omission<br>2.2 Selection | | Consider providing indication that valve is closed. | ENG |
| 3. Ensure all pipeline valves are closed | Requires use of PPE | 3.1 Incomplete | | Consider upgrading training program | TRN |
| 4. Disconnect hose from vessel bank | High noise | 4.1 Omission | | None Identified | |
| 5. Place hose in drain | Distractions | 5.1 Omission | | Consider requiring use of a checklist | OPNS |
| 6. Disconnect hose from pump | None | 6.1 Selection | | None Identified | |

**TABLE 1. IMPORTANT ATTRIBUTES OF PEOPLE**

Anthropometry
- Height
- Weight
- Reach
- Hand size

Senses
- Vision
- Color-blindness
- Hearing
- Kinesthetics

Verbal skills

Cognition
- Attention
- Decision making
- Diagnosis
- Information processing
  - Quality
  - Speed
- Judgement
- Language skills
- Memory
- Mental workload capacity
- Perception
- Problem solving
- Reading ability
- Reasoning
- Recognition
- Thinking

Physiology
- Motor skills
  - Reaction time
  - Speed of movement
  - Regulation of movement
- Strength (static and dynamic)

**TABLE 1. IMPORTANT ATTRIBUTES OF PEOPLE (contd.)**

- Dexterity
- Stamina
- Physical workload capacity
- Physical conditioning

Psychology
- Aptitude
- Attitudes
- Beliefs
- Biases
- Emotions
- Feelings
- Habits
- Moods
- Motivation
- Perception
- Personality
- Stress

Medical and health
- Side effects from prescription drugs
- Drug or alcohol abuse
- Ill health or stress
- Handicaps
- Aging factors

Qualifications
- Education
- Experience
- Knowledge
- Skills
- Training

Culture

Gender

**TABLE 2. PEOPLE TYPICALLY INVOLVED WITH A PROCESS**

Design engineers

Construction engineers

Process Engineers

Operators

Maintenance engineers

Supervisors

Managers

## TABLE 3. EXAMPLE OF HUMAN FACTORS CHECKLIST - CONTROLS

Are controls accessible?
Are controls easy to reach?
Can important and frequently used controls be reached and operated without strain from the normal working position?
Can controls always be reached when needed?
Can controls be reached and activated in the time available?
Are controls easy to use?
Can controls be manipulated easily?
Can controls be used without discomfort?
Are controls easy to distinguish?
Are controls subject to substitution errors (confusion of controls)?
Are controls subject to adjustment errors (inappropriate movement)?
Can the required use of controls be forgotten?
Can controls be moved in the wrong direction?
Does the movement of the control, either forward, to the right, upward or clockwise, result in increasing values or in a starting-up process?
Can controls easily be activated inadvertently or by mistake?
    Are controls located so that they cannot be inadvertently or accidentally activated?
Are safeguards used against mistaken or inadvertent activation of controls (e.g. guards, key interlock)?
    Is response time compromised?
If activation by a key is required for any of the controls, are the keys easily retrievable?
Are people provided with optimal amounts of information by the control system?
Are different controls distinguished by their shape?
Are controls that are critical to emergency operations clearly distinguishable?
Do labels explain control functions?
Are switches arrayed horizontally rather than vertically?
Is the range of movement of controls appropriate?
Are the resistance values of controls appropriate?
    Is the degree of force required to operate controls high enough to avoid inadvertent activation?
    Is the degree of force required to operate controls low enough to avoid muscular fatigue?
Are devices used by operators to increase leverage over manual controls?
Do controls provide adequate tactile feedback?
    Will gloves reduce tactile feedback from controls?
Is adequate control-response feedback provided?
Is the control/response rate adequate?
Will gloves or other clothing prevent the operation of controls?
Are control surfaces too hot or too cold to touch?

*Note: This is not a complete checklist. It is provided for illustrative purposes only.*

**TABLE 4. EXAMPLES OF COMMISSION ERRORS**

Action incorrect
Action inadequate
Action on wrong object
Action at wrong time
Action too long / too short
Action too great / too small
Action repeated
Action in wrong direction
Action in wrong sequence
Action in wrong place

## REFERENCES

1. M. S. Sanders and E. J. McCormick, Human Factors in Engineering and Design, McGraw-Hill, Seventh Edition (1993)

2. J. Rasmussen, K. Duncan, and J. Leplat (Eds.), New Technology and Human Error, Wiley (1987)

3. J. Rasmussen. A. M. Pejtersen and L. P. Goodstein, Cognitive Systems Engineering, Wiley (1994)

4. J. Reason, Human Error , Cambridge University Press(1990)

5. A. D. Swain and H. E. Guttmann, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278-F (1983)

6. B. Kirwan, A Guide to Practical Human Reliability Assessment, Taylor and Francis (1994)

7. An Engineer□s View of Human Error, The Institution of Chemical Engineers, 2nd Edition (1991)

8. T. R. Krause, J. H. Hidley, and S. J. Hodson, The Behavior-Based Safety Process, Van Nostrand Reinhold (1990)

9. T. E. McSween, The Values-Based Safety Process, Van Nostrand Reinhold (1995)

10. D. Embrey et al, Guidelines for Preventing Human Error in Process Safety, Center for Chemical Process Safety (1994)

11. B. Kirwan and L. K. Ainsworth (Eds.), A Guide to Task Analysis, Taylor and Francis (1992)

12. P. Baybutt, The Treatment of Human Factors and Human Errors in Process Safety and Risk Management, to be published (1996)